MONITOR BOARD TEST PLAN

Serial No……Mon269……
Test Engineer……Xen……
Date……...15/12/10……

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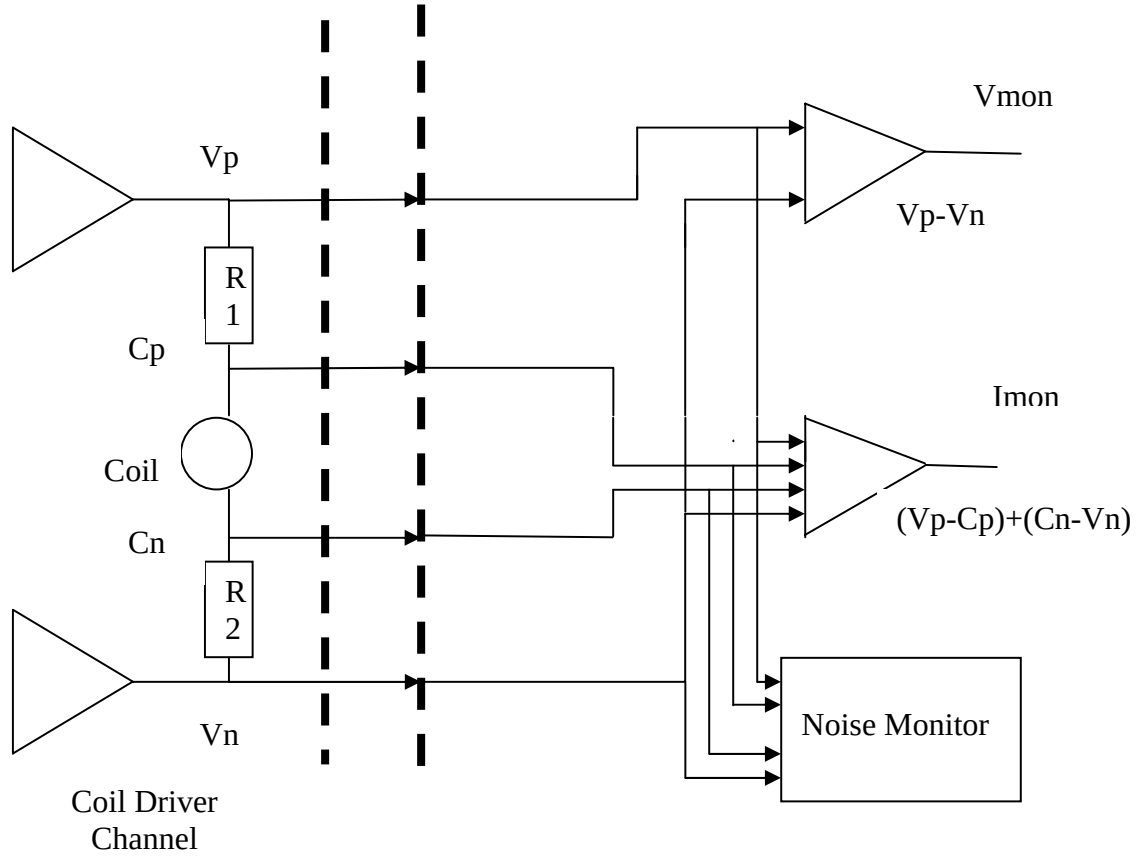
1. BLOCK DIAGRAM



1. Block diagram of one channel of the monitor board.
Each board houses four such channels.

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Replaced U2.

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.96	√
-15V (TP6)	-14.96	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	3mV	300mA
-15v (TP6)	√	5mV	250mA

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1		2.4	**2.4V to 2.6V**	√
Ch2		2.4	**2.4V to 2.6V**	√
Ch3		2.4	**2.4V to 2.6V**	√
Ch4		2.4	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1		2.4	**2.4V to 2.6V**	√
Ch2		2.4	**2.4V to 2.6V**	√
Ch3		2.4	**2.4V to 2.6V**	√
Ch4		2.4	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1		1.8	**1.6V to 1.9V**	√
Ch2		1.8	**1.6V to 1.9V**	√
Ch3		1.8	**1.6V to 1.9V**	√
Ch4		1.8	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1		1.75	**1.6V to 1.9V**	√
Ch2		1.75	**1.6V to 1.9V**	√
Ch3		1.80	**1.6V to 1.9V**	√
Ch4		1.75	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.95	**4.7V to 5.2V**	√
Ch2		4.95	**4.7V to 5.2V**	√
Ch3		4.95	**4.7V to 5.2V**	√
Ch4		4.95	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.5	1.5	1.5	1.5
TP6	4	4	4	4	2.3	2.3	2.3	2.3
TP7	8	8	8	8	3.4	3.4	3.4	3.4

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.5	1.5	1.5	1.5	√
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	√
TP7/TP6	2	2	2	2	1.5	1.5	1.5	1.5	√

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10	**9.7 to 10V**	√	4.95	**4 to 5.5V**	√
Ch2	**TP10**	10	**9.7 to 10V**	√	4.95	**4 to 5.5V**	√
Ch3	**TP10**	10	**9.7 to 10V**	√	4.95	**4 to 5.5V**	√
Ch4	**TP10**	10	**9.7 to 10V**	√	4.95	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		1.99	**1.9 to 2.1V**	√
Ch2		1.99	**1.9 to 2.1V**	√
Ch3		1.99	**1.9 to 2.1V**	√
Ch4		1.99	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0	0	0	0	√
(2) 3V in	**1V +/- 0.1V**	1	1	1	1	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5	1.5	1.5	1.5	√
(4) 6V in	**2V +/- 0.1V**	2	2	2	2	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.710	**0.707 (0.68 to 0.72V)**	√
Ch2	0.711	**0.707 (0.68 to 0.72V)**	√
Ch3	0.711	**0.707 (0.68 to 0.72V)**	√
Ch4	0.711	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.355	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.0	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.0	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.0	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.0	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.02	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.02	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.02	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No ……Mon21……..
Test Engineer ……Xen……
Date ……5/10/09……

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1. Block diagram

2. Test equipment

3. Description

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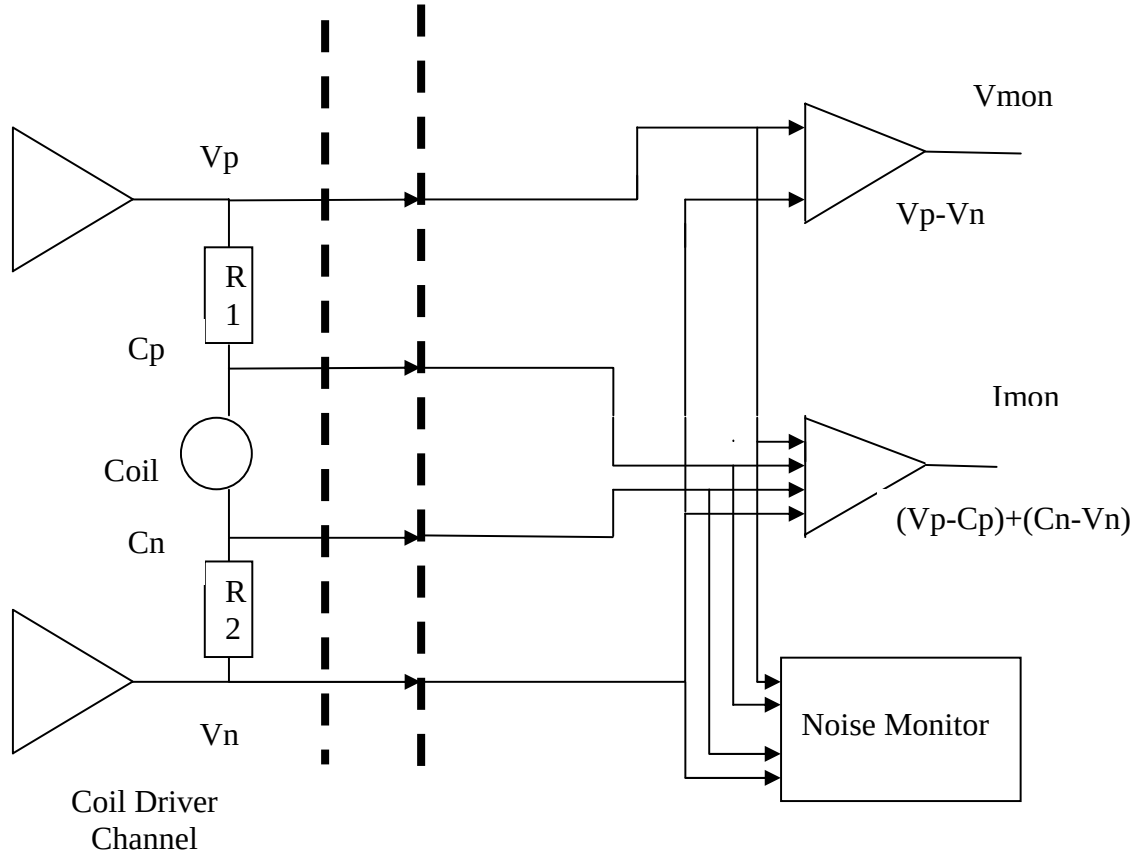
5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15v power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9K resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15v and -15v, the sum of which is 30v, would give an output of 30v/3 = 10v.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9K resistors for R1 and R2. The coil is simulated by two 3.9K resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15v in the output will be 5v.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

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NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3v.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5v)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5v)
+15v (TP4)	15.01	√
-15v (TP6)	-15.00	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the powe supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	300mA
-15v (TP6)	√	5mV	250mA

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20 Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0v

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/Fail
Ch1	100	2.6	**2.4V to 2.6V**	√
Ch2	100	2.6	**2.4V to 2.6V**	√
Ch3	100	2.6	**2.4V to 2.6V**	√
Ch4	100	2.6	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/Fail
Ch1	100	2.4	**2.4V to 2.6V**	√
Ch2	100	2.4	**2.4V to 2.6V**	√
Ch3	100	2.4	**2.4V to 2.6V**	√
Ch4	100	2.4	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5 Hz:
Amplitude= 100mV pk/pk
Ground reference = Power 0v

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/Fail
Ch1	100	1.9	**1.6v to 1.9v**	√
Ch2	100	1.9	**1.6v to 1.9v**	√
Ch3	100	1.9	**1.6v to 1.9v**	√
Ch4	100	1.9	**1.6v to 1.9v**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/Fail
Ch1	100	1.8	**1.6v to 1.9v**	√
Ch2	100	1.8	**1.6v to 1.9v**	√
Ch3	100	1.8	**1.6v to 1.9v**	√
Ch4	100	1.8	**1.6v to 1.9v**	√

6.1.1.3 Summing Amplifier

Pass band Gain

Set frequency to 20 Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/Fail
Ch1	100	4.9	**4.8v to 5.2v**	√
Ch2	100	4.9	**4.8v to 5.2v**	√
Ch3	100	4.9	**4.8v to 5.2v**	√
Ch4	100	4.9	**4.8v to 5.2v**	√

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Gains of Successive Stages:
Make measurements at 100 Hz, then at 5 Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.5	1.5	1.5	1.5
TP6	4	4	4	4	2.2	2.1	2.2	2.2
TP7	8	8	8	8	3.2	3	3.4	3.2

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5 Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.5	1.5	1.5	1.5	√
TP6/TP4	2	2	2	2	1.5	1.4	1.5	1.5	√
TP7/TP6	2	2	2	2	1.5	1.4	1.5	1.5	√

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5Khz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500hz	OK?	5 KHz (V peak)	Spec @ 5KHz	OK?
Ch1	TP10	10	9.7 to 10v	√	4.4	4 to 5.5v	√
Ch2	TP10	10	9.7 to 10v	√	4.6	4 to 5.5v	√
Ch3	TP10	10	9.7 to 10v	√	4.6	4 to 5.5v	√
Ch4	TP10	10	9.7 to 10v	√	4.8	4 to 5.5v	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30 Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/Fail
Ch1	3	2	**1.9 to 2.1v**	√
Ch2	3	2	**1.9 to 2.1v**	√
Ch3	3	2	**1.9 to 2.1v**	√
Ch4	3	2	**1.9 to 2.1v**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set
Frequency to 100Hz
The input voltage between TP8 and TP9 to 3v Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0v in	**0v +/- 0.1v**	0	0	0	0	√
(2) 3v in	**1v +/- 0.1v**	1	1	1	1	√
(3) 4.5vin	**1.5v +/- 0.1v**	1.5	1.5	1.5	1.5	√
(4) 6v in	**2v +/- 0.1v**	2	2	2	2	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30 Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s dc output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.712	**0.707 (0.68 to 0.72)**	√
Ch2	0.716	**0.707 (0.68 to 0.72)**	√
Ch3	0.711	**0.707 (0.68 to 0.72)**	√
Ch4	0.712	**0.707 (0.68 to 0.72)**	√
1.5V peak			
Ch1	0.357	**0.35v (0.33 to 0.37)**	√
Ch2	0.360	**0.35v (0.33 to 0.37)**	√
Ch3	0.357	**0.35v (0.33 to 0.37)**	√
Ch4	0.356	**0.35v (0.33 to 0.37)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3v peak and the frequency to 30 Hz.

3v peak Square Wave		Expected value (volts dc)	Pass/ Fail
Ch1, TP13	0.980	**1v (0.9 to 1.1v)**	√
Ch2, TP13	0.980	**1v (0.9 to 1.1v)**	√
Ch3, TP13	0.975	**1v (0.9 to 1.1v)**	√
Ch4, TP13	0.977	**1v (0.9 to 1.1v)**	√

DC input

Apply a 3v DC input between TP8 and TP9.

3v DC		Expected value (volts dc)	Pass/ Fail
Ch1, TP13	1.012	**1v (0.9 to 1.1v)**	√
Ch2, TP13	1.016	**1v (0.9 to 1.1v)**	√
Ch3, TP13	1.006	**1v (0.9 to 1.1v)**	√
Ch4, TP13	1.011	**1v (0.9 to 1.1v)**	√

MONITOR BOARD TEST PLAN

Serial No ……Mon22……...
Test Engineer ……Xen……
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Contents

1. Block diagram

2. Test equipment

3. Description

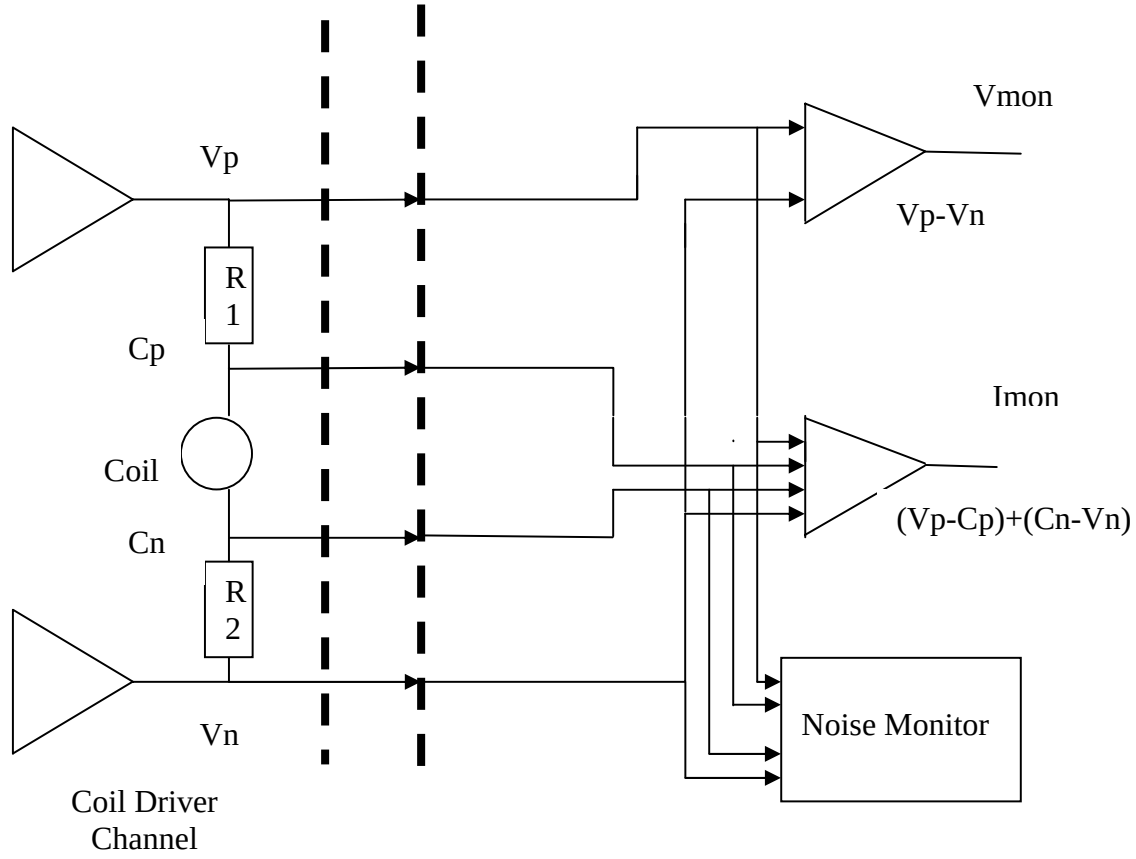
4. Inspection

5. Power

6. Circuit operation

- **6.1.1 Noise Amplifier**
- **6.1.2 Voltage Monitor**
- **6.1.3 Current Monitor**
- **6.1.4 RMS Circuit**

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15v power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9K resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15v and -15v, the sum of which is 30v, would give an output of 30v/3 = 10v.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9K resistors for R1 and R2. The coil is simulated by two 3.9K resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15v in the output will be 5v.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3v.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5v)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5v)
+15v (TP4)	14.97	√
-15v (TP6)	-15.03	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the powe supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	300mA
-15v (TP6)	√	5mV	250mA

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20 Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0v

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/Fail
Ch1	100	2.4	**2.4V to 2.6V**	√
Ch2	100	2.4	**2.4V to 2.6V**	√
Ch3	100	2.4	**2.4V to 2.6V**	√
Ch4	100	2.4	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/Fail
Ch1	100	2.4	**2.4V to 2.6V**	√
Ch2	100	2.4	**2.4V to 2.6V**	√
Ch3	100	2.4	**2.4V to 2.6V**	√
Ch4	100	2.4	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5 Hz:
Amplitude= 100mV pk/pk
Ground reference = Power 0v

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/Fail
Ch1	100	1.8	**1.6v to 1.9v**	√
Ch2	100	1.8	**1.6v to 1.9v**	√
Ch3	100	1.8	**1.6v to 1.9v**	√
Ch4	100	1.8	**1.6v to 1.9v**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/Fail
Ch1	100	1.8	**1.6v to 1.9v**	√
Ch2	100	1.8	**1.6v to 1.9v**	√
Ch3	100	1.8	**1.6v to 1.9v**	√
Ch4	100	1.8	**1.6v to 1.9v**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20 Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/Fail
Ch1	100	5	**4.8v to 5.2v**	√
Ch2	100	5	**4.8v to 5.2v**	√
Ch3	100	5	**4.8v to 5.2v**	√
Ch4	100	5	**4.8v to 5.2v**	√

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Gains of Successive Stages:
Make measurements at 100 Hz, then at 5 Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.5	1.5	1.5	1.5
TP6	4	4	4	4	2.2	2.2	2.2	2.2
TP7	8	8	8	8	3.2	3.2	3.4	3.2

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5 Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.5	1.5	1.5	1.5	√
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	√
TP7/TP6	2	2	2	2	1.5	1.5	1.5	1.5	√

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5Khz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500hz	OK?	5 kHz (V peak)	Spec @ 5KHz	OK?
Ch1	TP10	10	9.7 to 10v	√	4.8	4 to 5.5v	√
Ch2	TP10	10	9.7 to 10v	√	4.8	4 to 5.5v	√
Ch3	TP10	10	9.7 to 10v	√	4.6	4 to 5.5v	√
Ch4	TP10	10	9.7 to 10v	√	4.4	4 to 5.5v	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30 Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/Fail
Ch1	3	2	**1.9 to 2.1v**	√
Ch2	3	2	**1.9 to 2.1v**	√
Ch3	3	2	**1.9 to 2.1v**	√
Ch4	3	2	**1.9 to 2.1v**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set
Frequency to 100Hz
The input voltage between TP8 and TP9 to 3v Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0v in	**0v +/- 0.1v**	0	0	0	0	√
(2) 3v in	**1v +/- 0.1v**	1	1	1	1	√
(3) 4.5vin	**1.5v +/- 0.1v**	1.5	1.5	1.5	1.5	√
(4) 6v in	**2v +/- 0.1v**	2	2	2	2	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30 Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s dc output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.713	**0.707 (0.68 to 0.72)**	√
Ch2	0.715	**0.707 (0.68 to 0.72)**	√
Ch3	0.710	**0.707 (0.68 to 0.72)**	√
Ch4	0.716	**0.707 (0.68 to 0.72)**	√
1.5V peak			
Ch1	0.358	**0.35v (0.33 to 0.37)**	√
Ch2	0.359	**0.35v (0.33 to 0.37)**	√
Ch3	0.354	**0.35v (0.33 to 0.37)**	√
Ch4	0.360	**0.35v (0.33 to 0.37)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3v peak and the frequency to 30 Hz.

3v peak Square Wave		Expected value (volts dc)	Pass/ Fail
Ch1, TP13	0.981	**1v (0.9 to 1.1v)**	√
Ch2, TP13	0.984	**1v (0.9 to 1.1v)**	√
Ch3, TP13	0.979	**1v (0.9 to 1.1v)**	√
Ch4, TP13	0.984	**1v (0.9 to 1.1v)**	√

DC input

Apply a 3v DC input between TP8 and TP9.

3v DC		Expected value (volts dc)	Pass/ Fail
Ch1, TP13	1.010	**1v (0.9 to 1.1v)**	√
Ch2, TP13	1.015	**1v (0.9 to 1.1v)**	√
Ch3, TP13	1.029	**1v (0.9 to 1.1v)**	√
Ch4, TP13	1.012	**1v (0.9 to 1.1v)**	√

MONITOR BOARD TEST PLAN

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1. Block diagram

2. Test equipment

3. Description

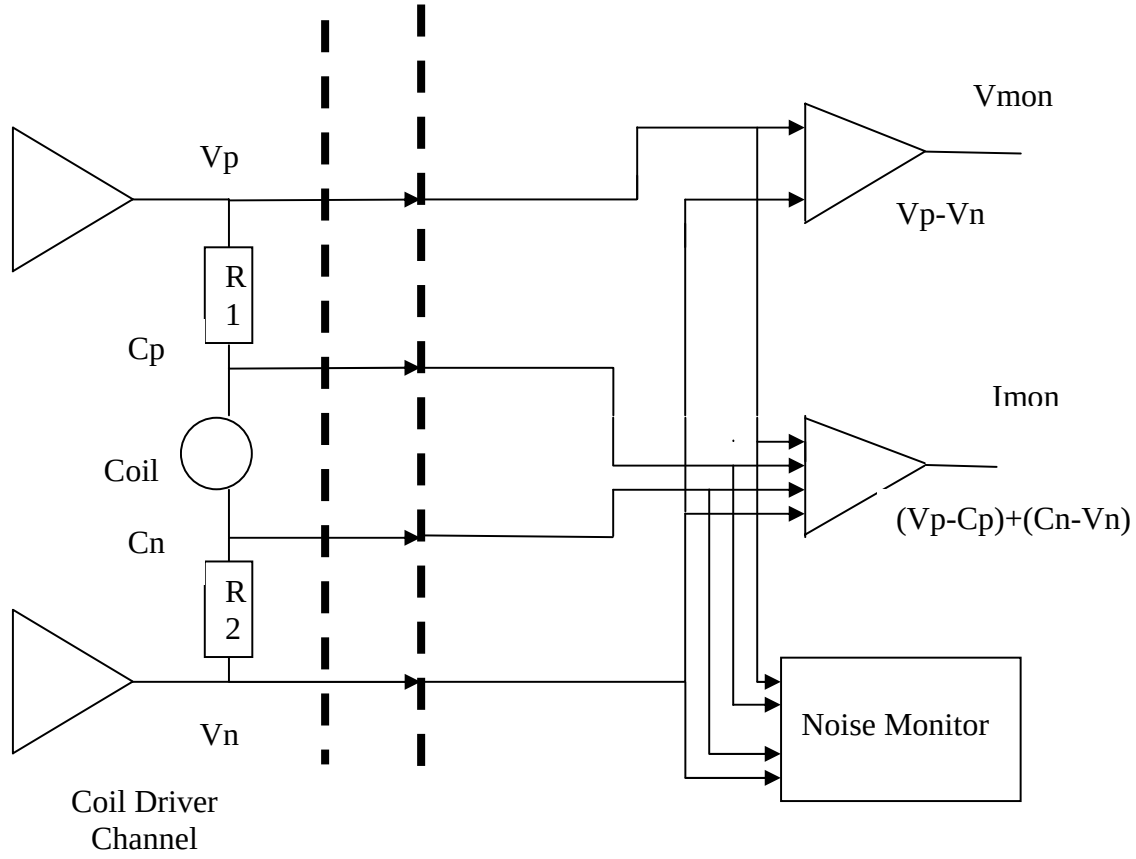
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



1. Block diagram of one channel of the monitor board.
Each board houses four such channels.

2. TEST EQUIPMENT

Variable +/- 15v power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9K resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15v and -15v, the sum of which is 30v, would give an output of 30v/3 = 10v.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9K resistors for R1 and R2. The coil is simulated by two 3.9K resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15v in the output will be 5v.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No ……Mon23……...
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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3v.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5v)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5v)
+15v (TP4)	14.83	√
-15v (TP6)	-15.01	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the powe supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	300mA
-15v (TP6)	√	5mV	250mA

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20 Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0v

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/Fail
Ch1	100	2.5	**2.4V to 2.6V**	√
Ch2	100	2.5	**2.4V to 2.6V**	√
Ch3	100	2.5	**2.4V to 2.6V**	√
Ch4	100	2.5	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/Fail
Ch1	100	2.4	**2.4V to 2.6V**	√
Ch2	100	2.4	**2.4V to 2.6V**	√
Ch3	100	2.4	**2.4V to 2.6V**	√
Ch4	100	2.4	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5 Hz:
Amplitude= 100mV pk/pk
Ground reference = Power 0v

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/Fail
Ch1	100	1.9	**1.6v to 1.9v**	√
Ch2	100	1.9	**1.6v to 1.9v**	√
Ch3	100	1.9	**1.6v to 1.9v**	√
Ch4	100	1.9	**1.6v to 1.9v**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/Fail
Ch1	100	1.8	**1.6v to 1.9v**	√
Ch2	100	1.8	**1.6v to 1.9v**	√
Ch3	100	1.8	**1.6v to 1.9v**	√
Ch4	100	1.8	**1.6v to 1.9v**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20 Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/Fail
Ch1	100	5	**4.8v to 5.2v**	√
Ch2	100	5	**4.8v to 5.2v**	√
Ch3	100	5	**4.8v to 5.2v**	√
Ch4	100	5	**4.8v to 5.2v**	√

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Gains of Successive Stages:
Make measurements at 100 Hz, then at 5 Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.5	1.5	1.5	1.5
TP6	4	4	4	4	2.2	2.2	2.2	2.2
TP7	8	8	8	8	3.4	3.4	3.3	3.3

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5 Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.5	1.5	1.5	1.5	√
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	√
TP7/TP6	2	2	2	2	1.5	1.5	1.5	1.5	√

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10	**9.7 to 10v**	√	4.4	**4 to 5.5v**	√
Ch2	**TP10**	10	**9.7 to 10v**	√	4.4	**4 to 5.5v**	√
Ch3	**TP10**	10	**9.7 to 10v**	√	4.4	**4 to 5.5v**	√
Ch4	**TP10**	10	**9.7 to 10v**	√	4.8	**4 to 5.5v**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/Fail
Ch1	3	2	**1.9 to 2.1v**	√
Ch2	3	2	**1.9 to 2.1v**	√
Ch3	3	2	**1.9 to 2.1v**	√
Ch4	3	2	**1.9 to 2.1v**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set
Frequency to 100Hz
The input voltage between TP8 and TP9 to 3v Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0v in	**0v +/- 0.1v**	0	0	0	0	√
(2) 3v in	**1v +/- 0.1v**	1	1	1	1	√
(3) 4.5vin	**1.5v +/- 0.1v**	1.5	1.5	1.5	1.5	√
(4) 6v in	**2v +/- 0.1v**	2	2	2	2	√

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Test Engineer ……Xen……
Date ……6/10/09……

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s dc output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.718	**0.707 (0.68 to 0.72)**	√
Ch2	0.714	**0.707 (0.68 to 0.72)**	√
Ch3	0.715	**0.707 (0.68 to 0.72)**	√
Ch4	0.712	**0.707 (0.68 to 0.72)**	√
1.5V peak			
Ch1	0.362	**0.35v (0.33 to 0.37)**	√
Ch2	0.357	**0.35v (0.33 to 0.37)**	√
Ch3	0.359	**0.35v (0.33 to 0.37)**	√
Ch4	0.356	**0.35v (0.33 to 0.37)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3v peak and the frequency to 30Hz.

3v peak Square Wave		Expected value (volts dc)	Pass/ Fail
Ch1, TP13	0.995	**1v (0.9 to 1.1v)**	√
Ch2, TP13	0.991	**1v (0.9 to 1.1v)**	√
Ch3, TP13	0.991	**1v (0.9 to 1.1v)**	√
Ch4, TP13	0.987	**1v (0.9 to 1.1v)**	√

DC input

Apply a 3v DC input between TP8 and TP9.

3v DC		Expected value (volts dc)	Pass/ Fail
Ch1, TP13	1.020	**1v (0.9 to 1.1v)**	√
Ch2, TP13	1.020	**1v (0.9 to 1.1v)**	√
Ch3, TP13	1.006	**1v (0.9 to 1.1v)**	√
Ch4, TP13	1.014	**1v (0.9 to 1.1v)**	√

MONITOR BOARD TEST PLAN

Serial No ……Mon24……...
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Contents

1. Block diagram

2. Test equipment

3. Description

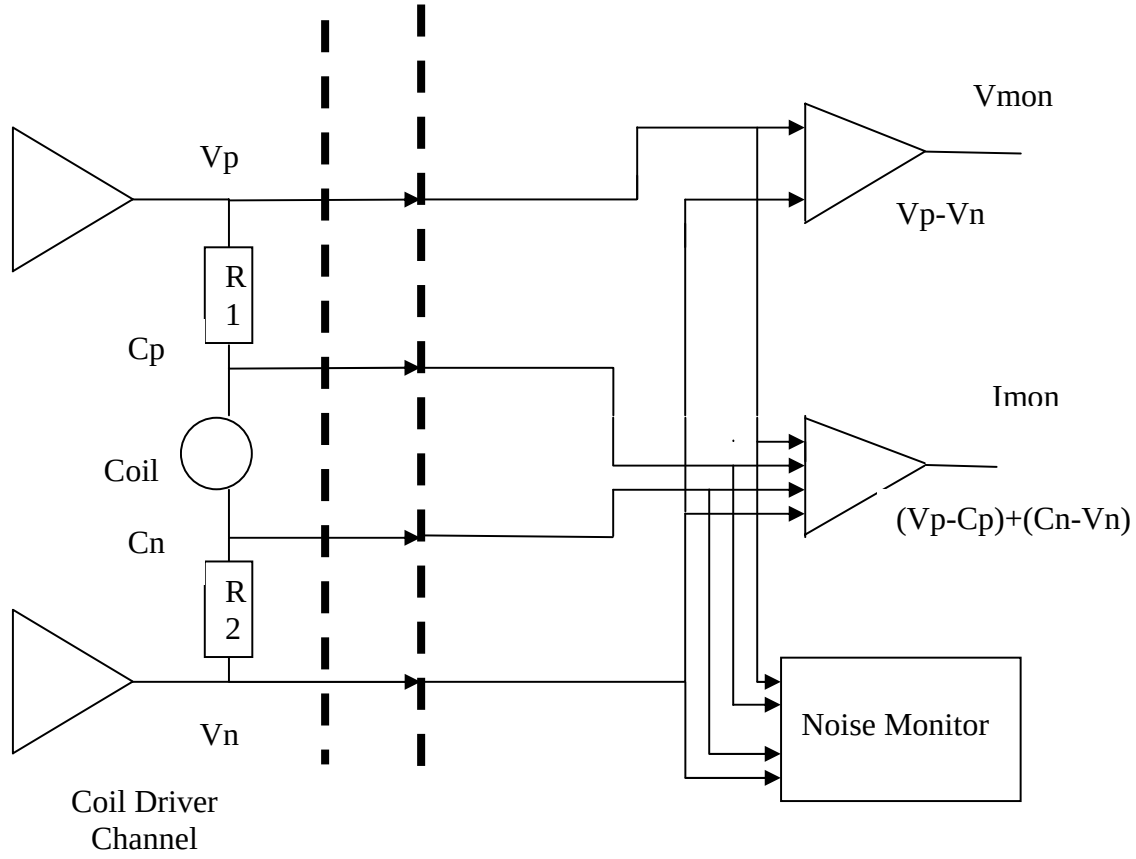
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15v power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9K resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15v and -15v, the sum of which is 30v, would give an output of 30v/3 = 10v.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9K resistors for R1 and R2. The coil is simulated by two 3.9K resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15v in the output will be 5v.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

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Test Engineer ……
Date ……

NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3v.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5v)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5v)
+15v (TP4)	14.94	√
-15v (TP6)	-15.06	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	300mA
-15v (TP6)	√	5mV	250mA

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.5	**2.4V to 2.6V**	√
Ch2	100	2.5	**2.4V to 2.6V**	√
Ch3	100	2.5	**2.4V to 2.6V**	√
Ch4	100	2.5	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.4	**2.4V to 2.6V**	√
Ch2	100	2.4	**2.4V to 2.6V**	√
Ch3	100	2.4	**2.4V to 2.6V**	√
Ch4	100	2.4	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100	1.9	**1.6V to 1.9V**	√
Ch2	100	1.9	**1.6V to 1.9V**	√
Ch3	100	1.9	**1.6V to 1.9V**	√
Ch4	100	1.9	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100	1.8	**1.6V to 1.9V**	√
Ch2	100	1.8	**1.6V to 1.9V**	√
Ch3	100	1.8	**1.6V to 1.9V**	√
Ch4	100	1.8	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1	100	5	**4.8V to 5.2V**	√
Ch2	100	5	**4.8V to 5.2V**	√
Ch3	100	5	**4.8V to 5.2V**	√
Ch4	100	5	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.5	1.5	1.5	1.5
TP6	4	4	4	4	2.3	2.3	2.3	2.3
TP7	8	8	8	8	3.4	3.4	3.3	3.3

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.5	1.5	1.5	1.5	√
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	√
TP7/TP6	2	2	2	2	1.5	1.5	1.5	1.5	√

Low Pass Output Stage:
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5 kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10	**9.7 to 10V**	√	4.8	**4 to 5.5V**	√
Ch2	**TP10**	10	**9.7 to 10V**	√	4.6	**4 to 5.5V**	√
Ch3	**TP10**	10	**9.7 to 10V**	√	4.6	**4 to 5.5V**	√
Ch4	**TP10**	10	**9.7 to 10V**	√	4.4	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1	3	2	**1.9 to 2.1V**	√
Ch2	3	2	**1.9 to 2.1V**	√
Ch3	3	2	**1.9 to 2.1V**	√
Ch4	3	2	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0v in	**0v +/- 0.1V**	0	0	0	0	√
(2) 3v in	**1v +/- 0.1V**	1	1	1	1	√
(3) 4.5vin	**1.5v +/- 0.1V**	1.5	1.5	1.5	1.5	√
(4) 6v in	**2v +/- 0.1V**	2	2	2	2	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s dc output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.712	**0.707 (0.68 to 0.72V)**	√
Ch2	0.711	**0.707 (0.68 to 0.72V)**	√
Ch3	0.715	**0.707 (0.68 to 0.72V)**	√
Ch4	0.713	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356	**0.35V (0.33 to 0.37V)**	√
Ch3	0.359	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.980	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.977	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.982	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.979	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.018	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.013	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.018	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.013	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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1. Block diagram

2. Test equipment

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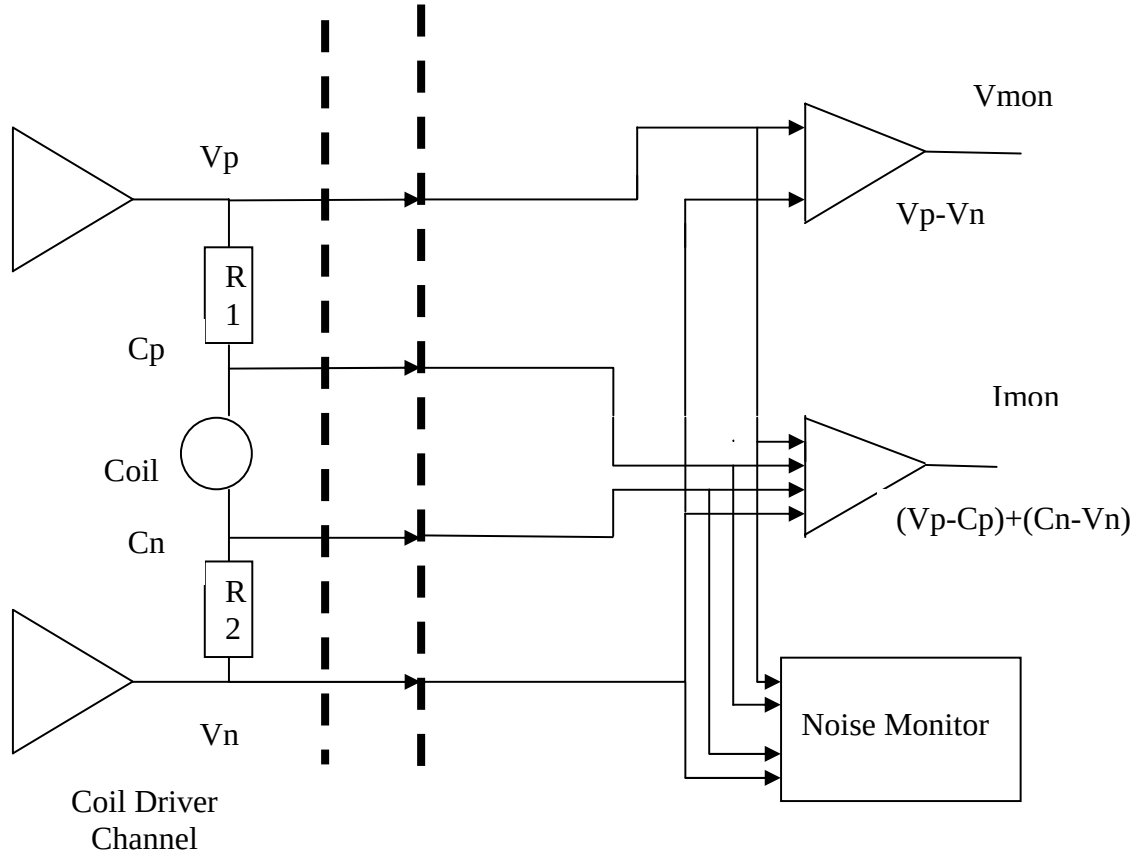
6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.94	√
-15V (TP6)	-15.07	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	300mA
-15v (TP6)	√	5mV	250mA

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.5	**2.4V to 2.6V**	√
Ch2	100	2.5	**2.4V to 2.6V**	√
Ch3	100	2.5	**2.4V to 2.6V**	√
Ch4	100	2.5	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.4	**2.4V to 2.6V**	√
Ch2	100	2.4	**2.4V to 2.6V**	√
Ch3	100	2.4	**2.4V to 2.6V**	√
Ch4	100	2.4	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude= 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100	1.8	**1.6V to 1.9V**	√
Ch2	100	1.8	**1.6V to 1.9V**	√
Ch3	100	1.8	**1.6V to 1.9V**	√
Ch4	100	1.8	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100	1.8	**1.6V to 1.9V**	√
Ch2	100	1.8	**1.6V to 1.9V**	√
Ch3	100	1.8	**1.6V to 1.9V**	√
Ch4	100	1.8	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain:
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1	100	5	**4.8V to 5.2V**	√
Ch2	100	5	**4.8V to 5.2V**	√
Ch3	100	5	**4.8V to 5.2V**	√
Ch4	100	5	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.5	1.5	1.5	1.5
TP6	4	4	4	4	2.2	2.2	2.3	2.3
TP7	8	8	8	8	3.4	3.4	3.4	3.3

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.5	1.5	1.5	1.5	√
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	√
TP7/TP6	2	2	2	2	1.5	1.5	1.5	1.5	√

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5 kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10	**9.7 to 10V**	√	4.4	**4 to 5.5V**	√
Ch2	**TP10**	10	**9.7 to 10V**	√	4.8	**4 to 5.5V**	√
Ch3	**TP10**	10	**9.7 to 10V**	√	4.6	**4 to 5.5V**	√
Ch4	**TP10**	10	**9.7 to 10V**	√	4.4	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1	3	2	**1.9 to 2.1V**	√
Ch2	3	2	**1.9 to 2.1V**	√
Ch3	3	2	**1.9 to 2.1V**	√
Ch4	3	2	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0	0	0	0	√
(2) 3V in	**1V +/- 0.1V**	1	1	1	1	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5	1.5	1.5	1.5	√
(4) 6V in	**2V +/- 0.1V**	2	2	2	2	√

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Test Engineer ……Xen……
Date ……6/10/09……

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.720	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713	**0.707 (0.68 to 0.72V)**	√
Ch3	0.715	**0.707 (0.68 to 0.72V)**	√
Ch4	0.717	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.364	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358	**0.35V (0.33 to 0.37V)**	√
Ch3	0.360	**0.35V (0.33 to 0.37V)**	√
Ch4	0.362	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.990	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.982	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.983	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.986	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.020	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.016	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.017	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.021	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No ……Mon26……...
Test Engineer ……Xen……
Date ……7/10/09……

Contents

1. Block diagram

2. Test equipment

3. Description

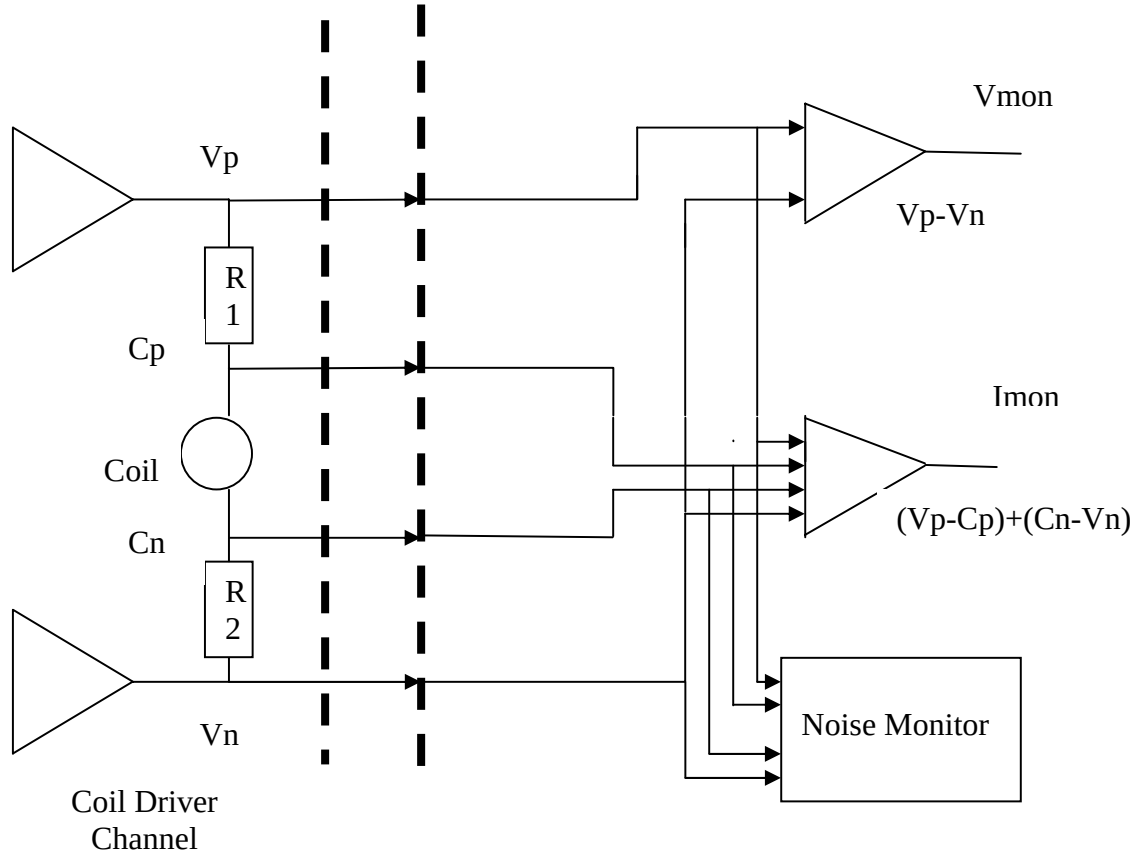
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

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Test Engineer ……Xen……
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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.97	√
-15V (TP6)	-15.01	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	300mA
-15v (TP6)	√	5mV	250mA

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.5	**2.4V to 2.6V**	√
Ch2	100	2.5	**2.4V to 2.6V**	√
Ch3	100	2.5	**2.4V to 2.6V**	√
Ch4	100	2.5	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.4	**2.4V to 2.6V**	√
Ch2	100	2.4	**2.4V to 2.6V**	√
Ch3	100	2.4	**2.4V to 2.6V**	√
Ch4	100	2.4	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude= 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100	1.8	**1.6V to 1.9V**	√
Ch2	100	1.8	**1.6V to 1.9V**	√
Ch3	100	1.8	**1.6V to 1.9V**	√
Ch4	100	1.8	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100	1.8	**1.6V to 1.9V**	√
Ch2	100	1.8	**1.6V to 1.9V**	√
Ch3	100	1.8	**1.6V to 1.9V**	√
Ch4	100	1.8	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1	100	5	**4.8V to 5.2V**	√
Ch2	100	5	**4.8V to 5.2V**	√
Ch3	100	5	**4.8V to 5.2V**	√
Ch4	100	5	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.5	1.5	1.5	1.5
TP6	4	4	4	4	2.2	2.2	2.2	2.2
TP7	8	8	8	8	3.3	3.3	3.2	3.2

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.5	1.5	1.5	1.5	√
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	√
TP7/TP6	2	2	2	2	1.5	1.5	1.5	1.5	√

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10	9.7 to 10V	√	4.8	4 to 5.5V	√
Ch2	TP10	10	9.7 to 10V	√	4.4	4 to 5.5V	√
Ch3	TP10	10	9.7 to 10V	√	4.4	4 to 5.5V	√
Ch4	TP10	10	9.7 to 10V	√	4.8	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1	3	2	**1.9 to 2.1V**	√
Ch2	3	2	**1.9 to 2.1V**	√
Ch3	3	2	**1.9 to 2.1V**	√
Ch4	3	2	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0	0	0	0	√
(2) 3V in	**1V +/- 0.1V**	1	1	1	1	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5	1.5	1.5	1.5	√
(4) 6V in	**2V +/- 0.1V**	2	2	2	2	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.717	**0.707 (0.68 to 0.72V)**	√
Ch2	0.716	**0.707 (0.68 to 0.72V)**	√
Ch3	0.716	**0.707 (0.68 to 0.72V)**	√
Ch4	0.714	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.360	**0.35V (0.33 to 0.37V)**	√
Ch2	0.359	**0.35V (0.33 to 0.37V)**	√
Ch3	0.360	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.981	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.980	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.979	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.977	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.015	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.020	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.015	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.013	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No ……Mon27……...
Test Engineer ……Xen……
Date ……7/10/09……

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1. Block diagram

2. Test equipment

3. Description

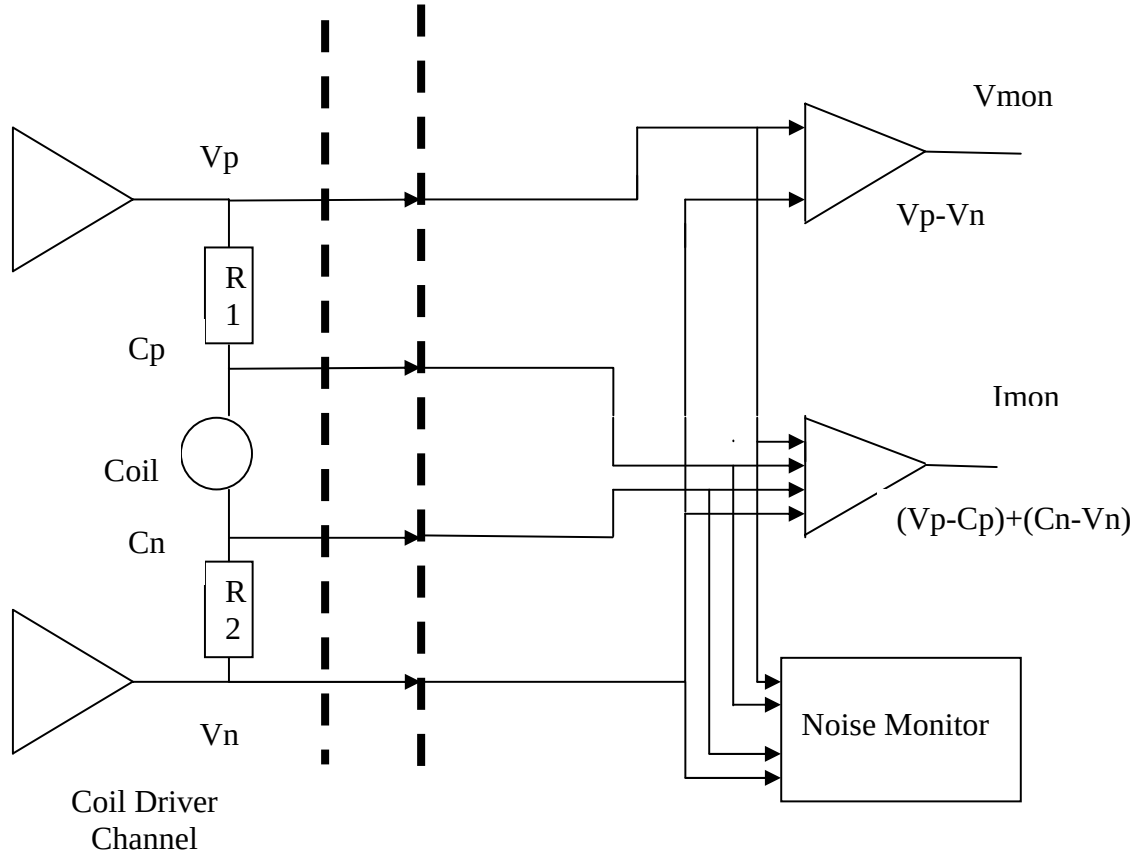
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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Test Engineer ……Xen……
Date ……7/10/09……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No ……Mon27……...
Test Engineer ……Xen……
Date ……7/10/09……

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.93	√
-15V (TP6)	-14.98	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	300mA
-15v (TP6)	√	5mV	250mA

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.5	**2.4V to 2.6V**	√
Ch2	100	2.5	**2.4V to 2.6V**	√
Ch3	100	2.5	**2.4V to 2.6V**	√
Ch4	100	2.5	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.4	**2.4V to 2.6V**	√
Ch2	100	2.4	**2.4V to 2.6V**	√
Ch3	100	2.4	**2.4V to 2.6V**	√
Ch4	100	2.4	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude= 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100	1.85	**1.6V to 1.9V**	√
Ch2	100	1.85	**1.6V to 1.9V**	√
Ch3	100	1.85	**1.6V to 1.9V**	√
Ch4	100	1.85	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100	1.8	**1.6V to 1.9V**	√
Ch2	100	1.8	**1.6V to 1.9V**	√
Ch3	100	1.8	**1.6V to 1.9V**	√
Ch4	100	1.8	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1	100	5	**4.8V to 5.2V**	√
Ch2	100	5	**4.8V to 5.2V**	√
Ch3	100	5	**4.8V to 5.2V**	√
Ch4	100	5	**4.8V to 5.2V**	√

Serial No ……Mon27……..
Test Engineer ……Xen……
Date ……7/10/09……

Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.5	1.5	1.5	1.5
TP6	4	4	4	4	2.2	2.2	2.2	2.2
TP7	8	8	8	8	3.2	3.2	3.2	3.2

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.5	1.5	1.5	1.5	√
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	√
TP7/TP6	2	2	2	2	1.5	1.5	1.5	1.5	√

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10	9.7 to 10V	√	4.6	4 to 5.5V	√
Ch2	TP10	10	9.7 to 10V	√	4.4	4 to 5.5V	√
Ch3	TP10	10	9.7 to 10V	√	4.4	4 to 5.5V	√
Ch4	TP10	10	9.7 to 10V	√	4.6	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1	3	2	**1.9 to 2.1V**	√
Ch2	3	2	**1.9 to 2.1V**	√
Ch3	3	2	**1.9 to 2.1V**	√
Ch4	3	2	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0	0	0	0	√
(2) 3V in	**1V +/- 0.1V**	1	1	1	1	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5	1.5	1.5	1.5	√
(4) 6V in	**2V +/- 0.1V**	2	2	2	2	√

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Test Engineer ……Xen……
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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.717	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713	**0.707 (0.68 to 0.72V)**	√
Ch3	0.708	**0.707 (0.68 to 0.72V)**	√
Ch4	0.712	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.360	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358	**0.35V (0.33 to 0.37V)**	√
Ch3	0.354	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.993	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.986	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.980	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.984	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.023	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.014	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.007	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.009	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No ……Mon28……...
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Contents

1. Block diagram

2. Test equipment

3. Description

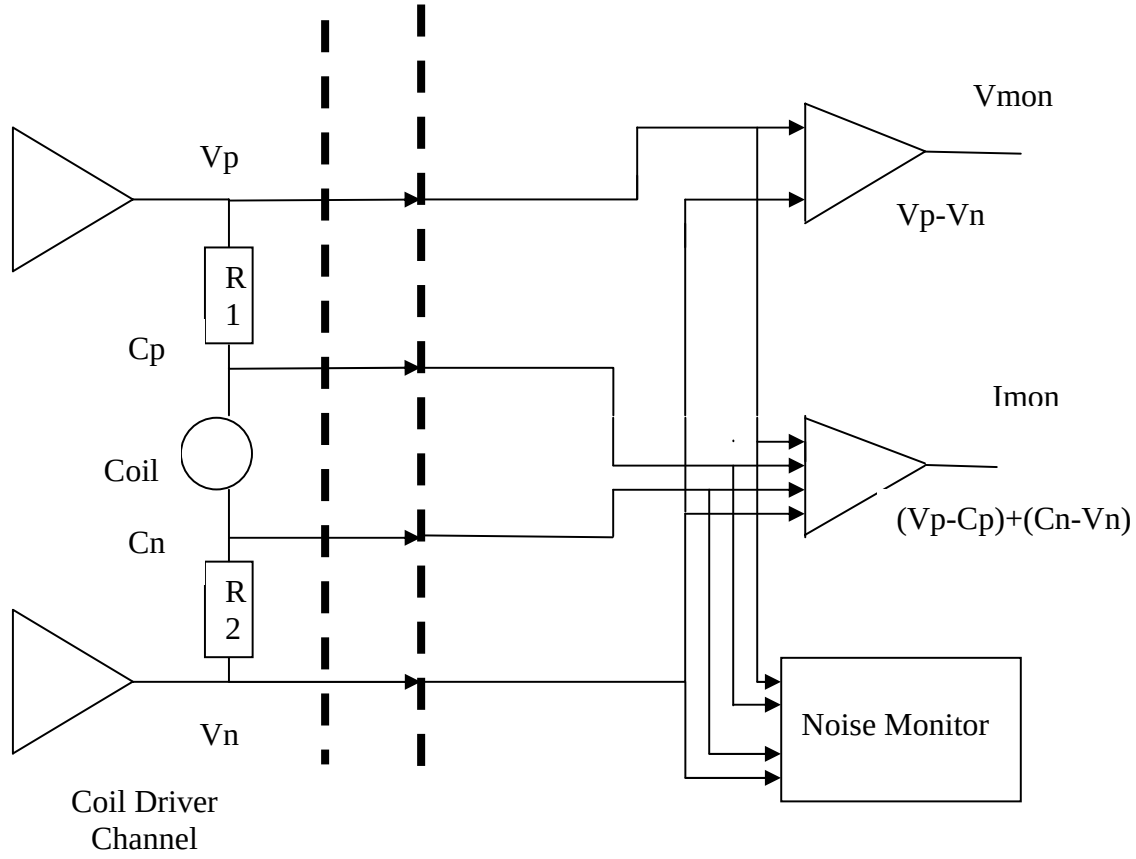
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	15.00	√
-15V (TP6)	-14.87	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	300mA
-15v (TP6)	√	5mV	250mA

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.5	**2.4V to 2.6V**	√
Ch2	100	2.5	**2.4V to 2.6V**	√
Ch3	100	2.5	**2.4V to 2.6V**	√
Ch4	100	2.5	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.4	**2.4V to 2.6V**	√
Ch2	100	2.4	**2.4V to 2.6V**	√
Ch3	100	2.4	**2.4V to 2.6V**	√
Ch4	100	2.4	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude= 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100	1.8	**1.6V to 1.9V**	√
Ch2	100	1.8	**1.6V to 1.9V**	√
Ch3	100	1.8	**1.6V to 1.9V**	√
Ch4	100	1.8	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100	1.8	**1.6V to 1.9V**	√
Ch2	100	1.8	**1.6V to 1.9V**	√
Ch3	100	1.8	**1.6V to 1.9V**	√
Ch4	100	1.8	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1	100	5	**4.8V to 5.2V**	√
Ch2	100	5	**4.8V to 5.2V**	√
Ch3	100	5	**4.8V to 5.2V**	√
Ch4	100	5	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.5	1.5	1.5	1.5
TP6	4	4	4	4	2.2	2.2	2.2	2.2
TP7	8	8	8	8	3.3	3.3	3.3	3.3

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.5	1.5	1.5	1.5	√
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	√
TP7/TP6	2	2	2	2	1.5	1.5	1.5	1.5	√

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10	9.7 to 10V	√	4.6	4 to 5.5V	√
Ch2	TP10	10	9.7 to 10V	√	4.4	4 to 5.5V	√
Ch3	TP10	10	9.7 to 10V	√	4.4	4 to 5.5V	√
Ch4	TP10	10	9.7 to 10V	√	4.6	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1	3	2	**1.9 to 2.1V**	√
Ch2	3	2	**1.9 to 2.1V**	√
Ch3	3	2	**1.9 to 2.1V**	√
Ch4	3	2	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0	0	0	0	√
(2) 3V in	**1V +/- 0.1V**	1	1	1	1	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5	1.5	1.5	1.5	√
(4) 6V in	**2V +/- 0.1V**	2	2	2	2	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.715	**0.707 (0.68 to 0.72V)**	√
Ch2	0.707	**0.707 (0.68 to 0.72V)**	√
Ch3	0.715	**0.707 (0.68 to 0.72V)**	√
Ch4	0.712	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.361	**0.35V (0.33 to 0.37V)**	√
Ch2	0.355	**0.35V (0.33 to 0.37V)**	√
Ch3	0.359	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.991	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.980	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.989	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.984	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.001	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.009	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.021	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.014	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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2. Test equipment

3. Description

4. Inspection

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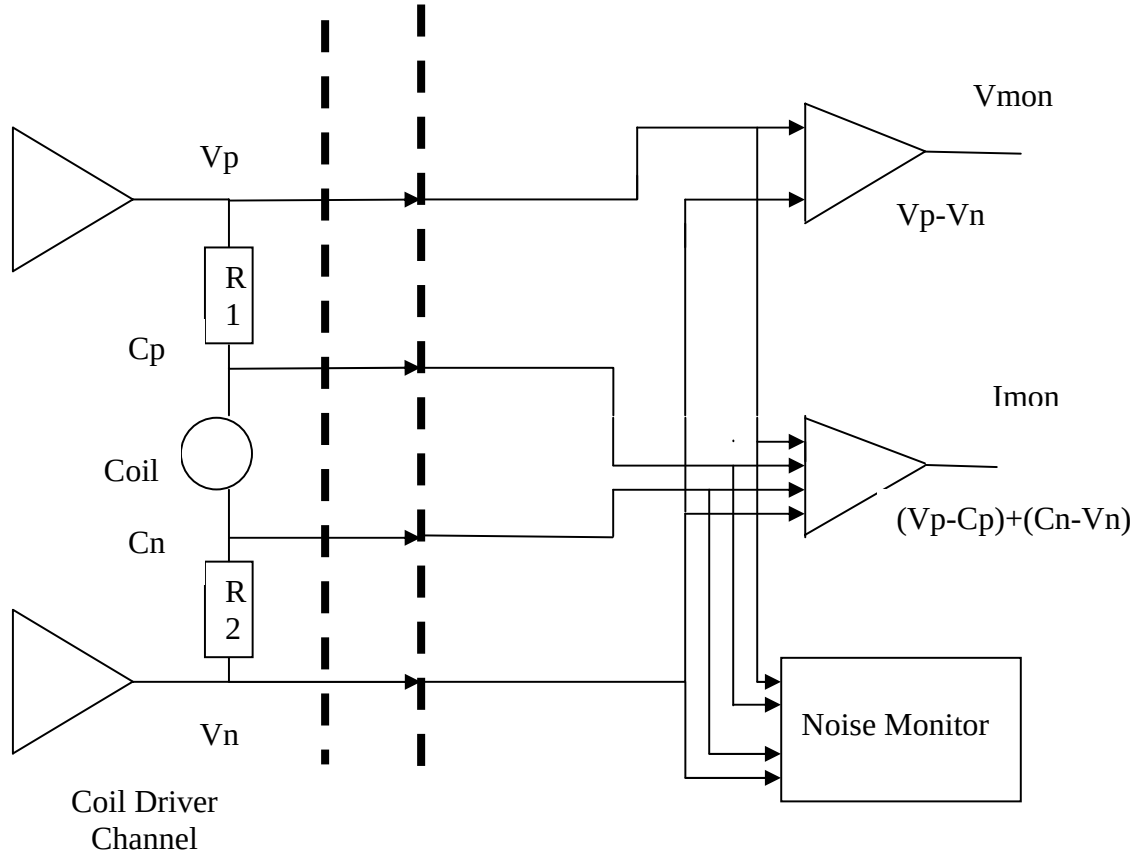
6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No ……Mon29……...
Test Engineer ……Xen……
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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.93	√
-15V (TP6)	-14.93	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	300mA
-15v (TP6)	√	5mV	250mA

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.5	**2.4V to 2.6V**	√
Ch2	100	2.5	**2.4V to 2.6V**	√
Ch3	100	2.5	**2.4V to 2.6V**	√
Ch4	100	2.5	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.4	**2.4V to 2.6V**	√
Ch2	100	2.4	**2.4V to 2.6V**	√
Ch3	100	2.4	**2.4V to 2.6V**	√
Ch4	100	2.4	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude= 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100	1.8	**1.6V to 1.9V**	√
Ch2	100	1.8	**1.6V to 1.9V**	√
Ch3	100	1.8	**1.6V to 1.9V**	√
Ch4	100	1.8	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100	1.8	**1.6V to 1.9V**	√
Ch2	100	1.8	**1.6V to 1.9V**	√
Ch3	100	1.8	**1.6V to 1.9V**	√
Ch4	100	1.8	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1	100	5	**4.8V to 5.2V**	√
Ch2	100	5	**4.8V to 5.2V**	√
Ch3	100	5	**4.8V to 5.2V**	√
Ch4	100	5	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.5	1.5	1.5	1.5
TP6	4	4	4	4	2.2	2.2	2.2	2.2
TP7	8	8	8	8	3.1	3.1	3.1	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.5	1.5	1.5	1.5	√
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	√
TP7/TP6	2	2	2	2	1.4	1.4	1.4	1.4	√

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10	9.7 to 10V	√	4.6	4 to 5.5V	√
Ch2	TP10	10	9.7 to 10V	√	4.6	4 to 5.5V	√
Ch3	TP10	10	9.7 to 10V	√	4.6	4 to 5.5V	√
Ch4	TP10	10	9.7 to 10V	√	4.6	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1	3	2	**1.9 to 2.1V**	√
Ch2	3	2	**1.9 to 2.1V**	√
Ch3	3	2	**1.9 to 2.1V**	√
Ch4	3	2	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0	0	0	0	√
(2) 3V in	**1V +/- 0.1V**	1	1	1	1	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5	1.5	1.5	1.5	√
(4) 6V in	**2V +/- 0.1V**	2	2	2	2	√

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Test Engineer ……Xen……
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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.712	**0.707 (0.68 to 0.72V)**	√
Ch2	0.717	**0.707 (0.68 to 0.72V)**	√
Ch3	0.713	**0.707 (0.68 to 0.72V)**	√
Ch4	0.714	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357	**0.35V (0.33 to 0.37V)**	√
Ch2	0.362	**0.35V (0.33 to 0.37V)**	√
Ch3	0.359	**0.35V (0.33 to 0.37V)**	√
Ch4	0.359	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.983	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.989	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.983	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.984	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.013	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.020	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.999	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.018	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No ……Mon30……...
Test Engineer ……Xen……
Date ……8/10/09……

Contents

1. Block diagram

2. Test equipment

3. Description

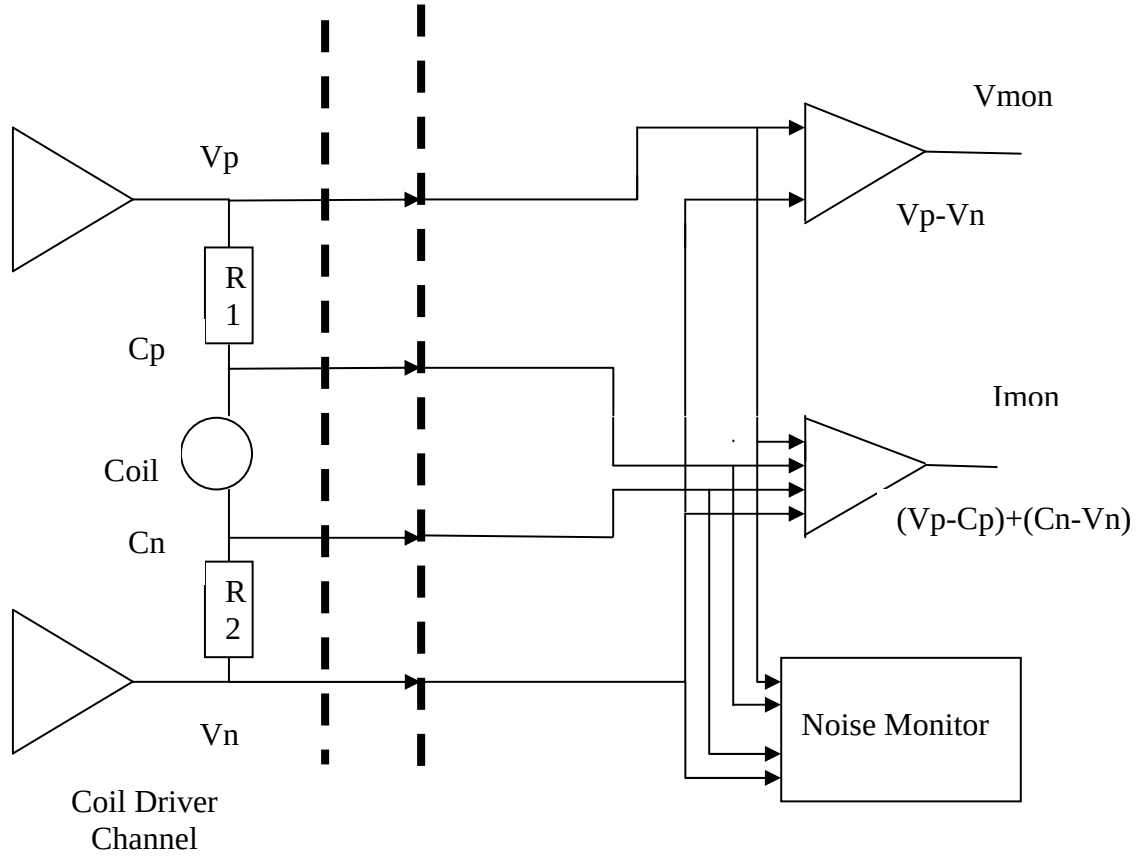
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
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Date ……

NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	15.02	√
-15V (TP6)	-14.89	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	300mA
-15v (TP6)	√	5mV	250mA

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.5	**2.4V to 2.6V**	√
Ch2	100	2.5	**2.4V to 2.6V**	√
Ch3	100	2.5	**2.4V to 2.6V**	√
Ch4	100	2.5	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.4	**2.4V to 2.6V**	√
Ch2	100	2.4	**2.4V to 2.6V**	√
Ch3	100	2.4	**2.4V to 2.6V**	√
Ch4	100	2.4	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude= 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100	1.8	**1.6V to 1.9V**	√
Ch2	100	1.8	**1.6V to 1.9V**	√
Ch3	100	1.8	**1.6V to 1.9V**	√
Ch4	100	1.8	**1.6V to 1.9V**	√

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Test Engineer ……Xen……
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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100	1.8	**1.6V to 1.9V**	√
Ch2	100	1.8	**1.6V to 1.9V**	√
Ch3	100	1.8	**1.6V to 1.9V**	√
Ch4	100	1.8	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1	100	5	**4.8V to 5.2V**	√
Ch2	100	5	**4.8V to 5.2V**	√
Ch3	100	5	**4.8V to 5.2V**	√
Ch4	100	5	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.5	1.5	1.5	1.5
TP6	4	4	4	4	2.2	2.2	2.2	2.2
TP7	8	8	8	8	3.3	3.3	3.2	3.2

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.5	1.5	1.5	1.5	√
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	√
TP7/TP6	2	2	2	2	1.5	1.5	1.5	1.5	√

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10	9.7 to 10V	√	4.6	4 to 5.5V	√
Ch2	TP10	10	9.7 to 10V	√	4.6	4 to 5.5V	√
Ch3	TP10	10	9.7 to 10V	√	4.4	4 to 5.5V	√
Ch4	TP10	10	9.7 to 10V	√	4.4	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1	3	2	**1.9 to 2.1V**	√
Ch2	3	2	**1.9 to 2.1V**	√
Ch3	3	2	**1.9 to 2.1V**	√
Ch4	3	2	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0	0	0	0	√
(2) 3V in	**1V +/- 0.1V**	1	1	1	1	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5	1.5	1.5	1.5	√
(4) 6V in	**2V +/- 0.1V**	2	2	2	2	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.719	**0.707 (0.68 to 0.72V)**	√
Ch2	0.719	**0.707 (0.68 to 0.72V)**	√
Ch3	0.714	**0.707 (0.68 to 0.72V)**	√
Ch4	0.717	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.363	**0.35V (0.33 to 0.37V)**	√
Ch2	0.362	**0.35V (0.33 to 0.37V)**	√
Ch3	0.359	**0.35V (0.33 to 0.37V)**	√
Ch4	0.361	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.996	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.996	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.989	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.993	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.018	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.019	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.014	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.021	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No ……Mon31……...
Test Engineer ……Xen……
Date ……8/10/09……

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1. Block diagram

2. Test equipment

3. Description

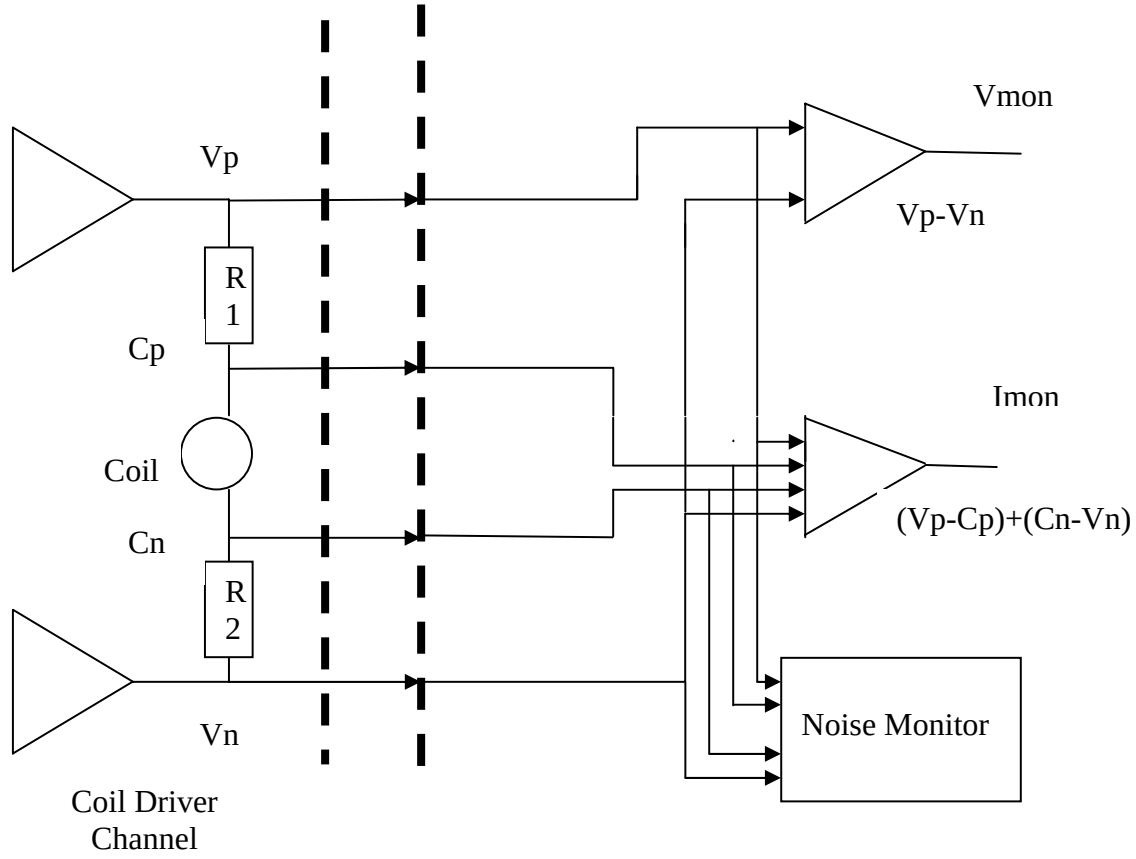
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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Test Engineer ……Xen……
Date ……8/10/09……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No ……Mon31……...
Test Engineer ……Xen……
Date ……8/10/09……

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.95	√
-15V (TP6)	-14.96	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	300mA
-15v (TP6)	√	5mV	250mA

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Test Engineer ……Xen……
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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.5	**2.4V to 2.6V**	√
Ch2	100	2.5	**2.4V to 2.6V**	√
Ch3	100	2.5	**2.4V to 2.6V**	√
Ch4	100	2.5	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.4	**2.4V to 2.6V**	√
Ch2	100	2.4	**2.4V to 2.6V**	√
Ch3	100	2.4	**2.4V to 2.6V**	√
Ch4	100	2.4	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude= 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100	1.8	**1.6V to 1.9V**	√
Ch2	100	1.8	**1.6V to 1.9V**	√
Ch3	100	1.8	**1.6V to 1.9V**	√
Ch4	100	1.8	**1.6V to 1.9V**	√

Serial No ……Mon31……...
Test Engineer ……Xen……
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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100	1.75	**1.6V to 1.9V**	√
Ch2	100	1.75	**1.6V to 1.9V**	√
Ch3	100	1.75	**1.6V to 1.9V**	√
Ch4	100	1.75	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1	100	5	**4.8V to 5.2V**	√
Ch2	100	5	**4.8V to 5.2V**	√
Ch3	100	5	**4.8V to 5.2V**	√
Ch4	100	5	**4.8V to 5.2V**	√

Serial No ……Mon31……...
Test Engineer ……Xen……
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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.49	1.49	1.49	1.49
TP6	4	4	4	4	2.2	2.1	2.1	2.1
TP7	8	8	8	8	3.1	3.1	3.1	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.49	1.49	1.49	1.49	√
TP6/TP4	2	2	2	2	1.5	1.4	1.4	1.4	√
TP7/TP6	2	2	2	2	1.4	1.5	1.5	1.5	√

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10	9.7 to 10V	√	4.4	4 to 5.5V	√
Ch2	TP10	10	9.7 to 10V	√	4.4	4 to 5.5V	√
Ch3	TP10	10	9.7 to 10V	√	4.6	4 to 5.5V	√
Ch4	TP10	10	9.7 to 10V	√	4.6	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1	3	2	**1.9 to 2.1V**	√
Ch2	3	2	**1.9 to 2.1V**	√
Ch3	3	2	**1.9 to 2.1V**	√
Ch4	3	2	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0	0	0	0	√
(2) 3V in	**1V +/- 0.1V**	1	1	1	1	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5	1.5	1.5	1.5	√
(4) 6V in	**2V +/- 0.1V**	2	2	2	2	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.712	**0.707 (0.68 to 0.72V)**	√
Ch2	0.710	**0.707 (0.68 to 0.72V)**	√
Ch3	0.713	**0.707 (0.68 to 0.72V)**	√
Ch4	0.711	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357	**0.35V (0.33 to 0.37V)**	√
Ch2	0.355	**0.35V (0.33 to 0.37V)**	√
Ch3	0.359	**0.35V (0.33 to 0.37V)**	√
Ch4	0.355	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.982	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.980	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.982	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.980	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.024	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.018	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.016	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.017	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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1. Block diagram

2. Test equipment

3. Description

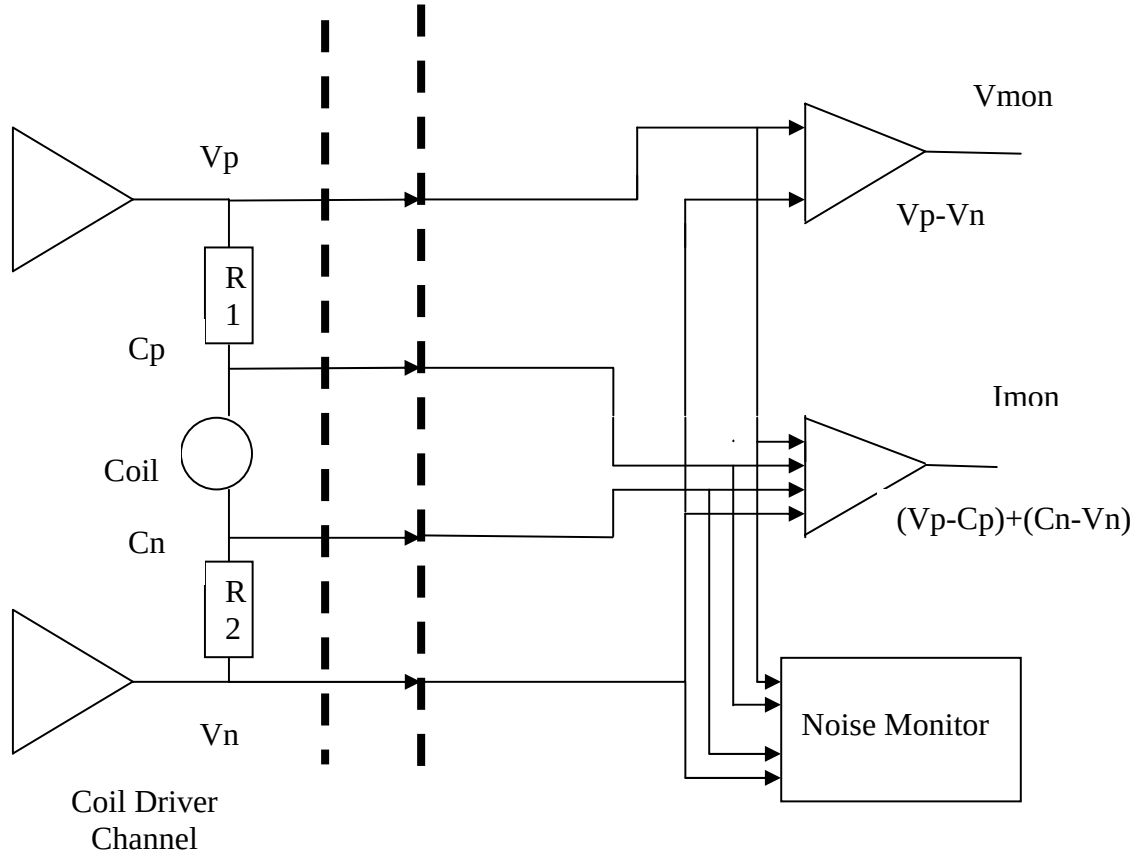
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

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NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.91	√
-15V (TP6)	-15.02	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	300mA
-15v (TP6)	√	5mV	250mA

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.5	**2.4V to 2.6V**	√
Ch2	100	2.5	**2.4V to 2.6V**	√
Ch3	100	2.5	**2.4V to 2.6V**	√
Ch4	100	2.5	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.4	**2.4V to 2.6V**	√
Ch2	100	2.4	**2.4V to 2.6V**	√
Ch3	100	2.4	**2.4V to 2.6V**	√
Ch4	100	2.4	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100	1.8	**1.6V to 1.9V**	√
Ch2	100	1.8	**1.6V to 1.9V**	√
Ch3	100	1.8	**1.6V to 1.9V**	√
Ch4	100	1.8	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100	1.8	**1.6V to 1.9V**	√
Ch2	100	1.8	**1.6V to 1.9V**	√
Ch3	100	1.8	**1.6V to 1.9V**	√
Ch4	100	1.8	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1	100	5	**4.8V to 5.2V**	√
Ch2	100	5	**4.8V to 5.2V**	√
Ch3	100	5	**4.8V to 5.2V**	√
Ch4	100	5	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.5	1.5	1.5	1.5
TP6	4	4	4	4	2.3	2.3	2.3	2.3
TP7	8	8	8	8	3.5	3.5	3.5	3.5

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.5	1.5	1.5	1.5	√
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	√
TP7/TP6	2	2	2	2	1.5	1.5	1.5	1.5	√

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10	9.7 to 10V	√	4.4	4 to 5.5V	√
Ch2	TP10	10	9.7 to 10V	√	4.4	4 to 5.5V	√
Ch3	TP10	10	9.7 to 10V	√	4.4	4 to 5.5V	√
Ch4	TP10	10	9.7 to 10V	√	4.5	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1	3	2	**1.9 to 2.1V**	√
Ch2	3	2	**1.9 to 2.1V**	√
Ch3	3	2	**1.9 to 2.1V**	√
Ch4	3.	2	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0	0	0	0	√
(2) 3V in	**1V +/- 0.1V**	1	1	1	1	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5	1.5	1.5	1.5	√
(4) 6V in	**2V +/- 0.1V**	2	2	2	2	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.714	**0.707 (0.68 to 0.72V)**	√
Ch2	0.720	**0.707 (0.68 to 0.72V)**	√
Ch3	0.709	**0.707 (0.68 to 0.72V)**	√
Ch4	0.715	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.360	**0.35V (0.33 to 0.37V)**	√
Ch2	0.361	**0.35V (0.33 to 0.37V)**	√
Ch3	0.355	**0.35V (0.33 to 0.37V)**	√
Ch4	0.359	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.988	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.997	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.983	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.981	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.009	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.026	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.009	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.015	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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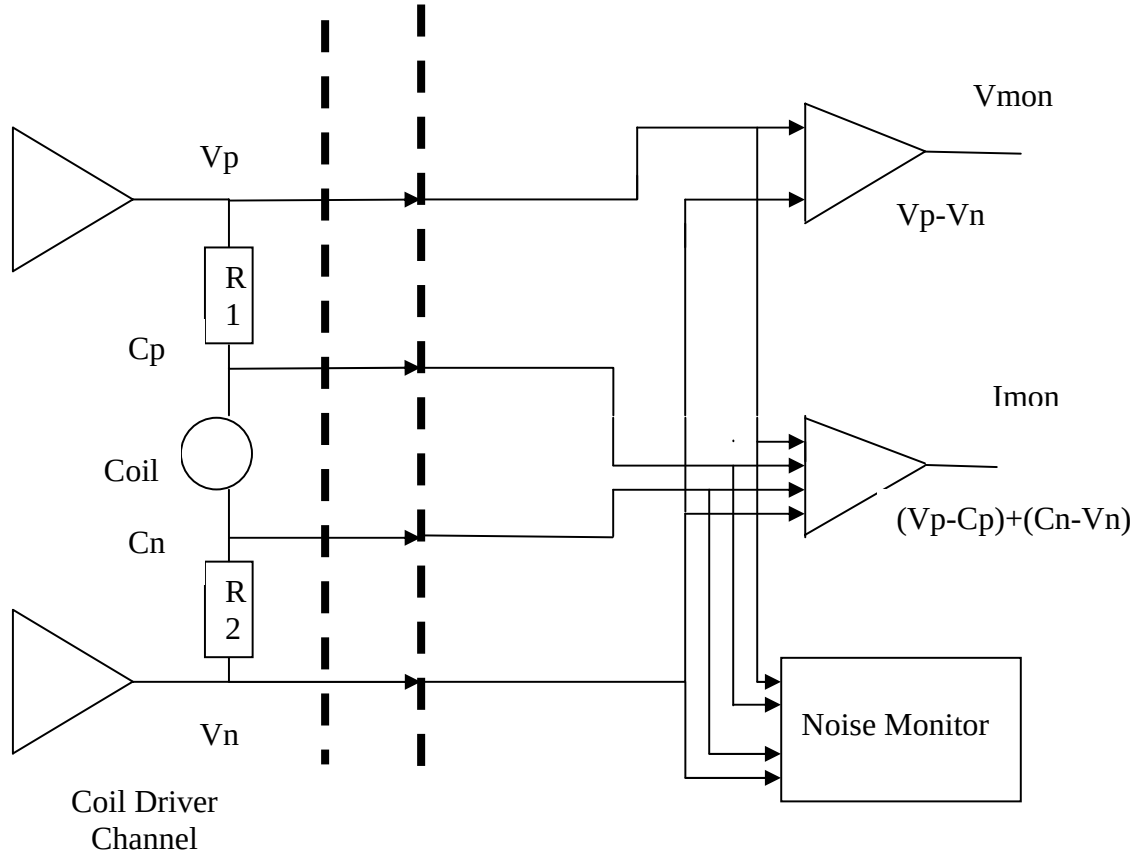
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No ……Mon33……...
Test Engineer ……Xen……
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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.98	√
-15V (TP6)	-14.88	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	300mA
-15v (TP6)	√	5mV	250mA

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.5	**2.4V to 2.6V**	√
Ch2	100	2.5	**2.4V to 2.6V**	√
Ch3	100	2.5	**2.4V to 2.6V**	√
Ch4	100	2.5	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.4	**2.4V to 2.6V**	√
Ch2	100	2.4	**2.4V to 2.6V**	√
Ch3	100	2.4	**2.4V to 2.6V**	√
Ch4	100	2.4	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude= 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100	1.8	**1.6V to 1.9V**	√
Ch2	100	1.8	**1.6V to 1.9V**	√
Ch3	100	1.8	**1.6V to 1.9V**	√
Ch4	100	1.8	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100	1.8	**1.6V to 1.9V**	√
Ch2	100	1.8	**1.6V to 1.9V**	√
Ch3	100	1.8	**1.6V to 1.9V**	√
Ch4	100	1.8	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1	100	5	**4.8V to 5.2V**	√
Ch2	100	5	**4.8V to 5.2V**	√
Ch3	100	5	**4.8V to 5.2V**	√
Ch4	100	5	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.5	1.5	1.5	1.5
TP6	4	4	4	4	2.2	2.2	2.2	2.2
TP7	8	8	8	8	3.4	3.4	3.4	3.4

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.5	1.5	1.5	1.5	√
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	√
TP7/TP6	2	2	2	2	1.5	1.5	1.5	1.5	√

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10	9.7 to 10V	√	4.8	4 to 5.5V	√
Ch2	TP10	10	9.7 to 10V	√	4.6	4 to 5.5V	√
Ch3	TP10	10	9.7 to 10V	√	4.8	4 to 5.5V	√
Ch4	TP10	10	9.7 to 10V	√	4.6	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1	3	2	**1.9 to 2.1V**	√
Ch2	3	2	**1.9 to 2.1V**	√
Ch3	3	2	**1.9 to 2.1V**	√
Ch4	3	2	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0	0	0	0	√
(2) 3V in	**1V +/- 0.1V**	1	1	1	1	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5	1.5	1.5	1.5	√
(4) 6V in	**2V +/- 0.1V**	2	2	2	2	√

Serial No ……Mon33……...
Test Engineer ……Xen……
Date ……8/10/09……

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.711	**0.707 (0.68 to 0.72V)**	√
Ch2	0.714	**0.707 (0.68 to 0.72V)**	√
Ch3	0.714	**0.707 (0.68 to 0.72V)**	√
Ch4	0.715	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357	**0.35V (0.33 to 0.37V)**	√
Ch2	0.359	**0.35V (0.33 to 0.37V)**	√
Ch3	0.360	**0.35V (0.33 to 0.37V)**	√
Ch4	0.353	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.984	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.984	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.987	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.978	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.009	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.017	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.009	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.002	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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Contents

1. Block diagram

2. Test equipment

3. Description

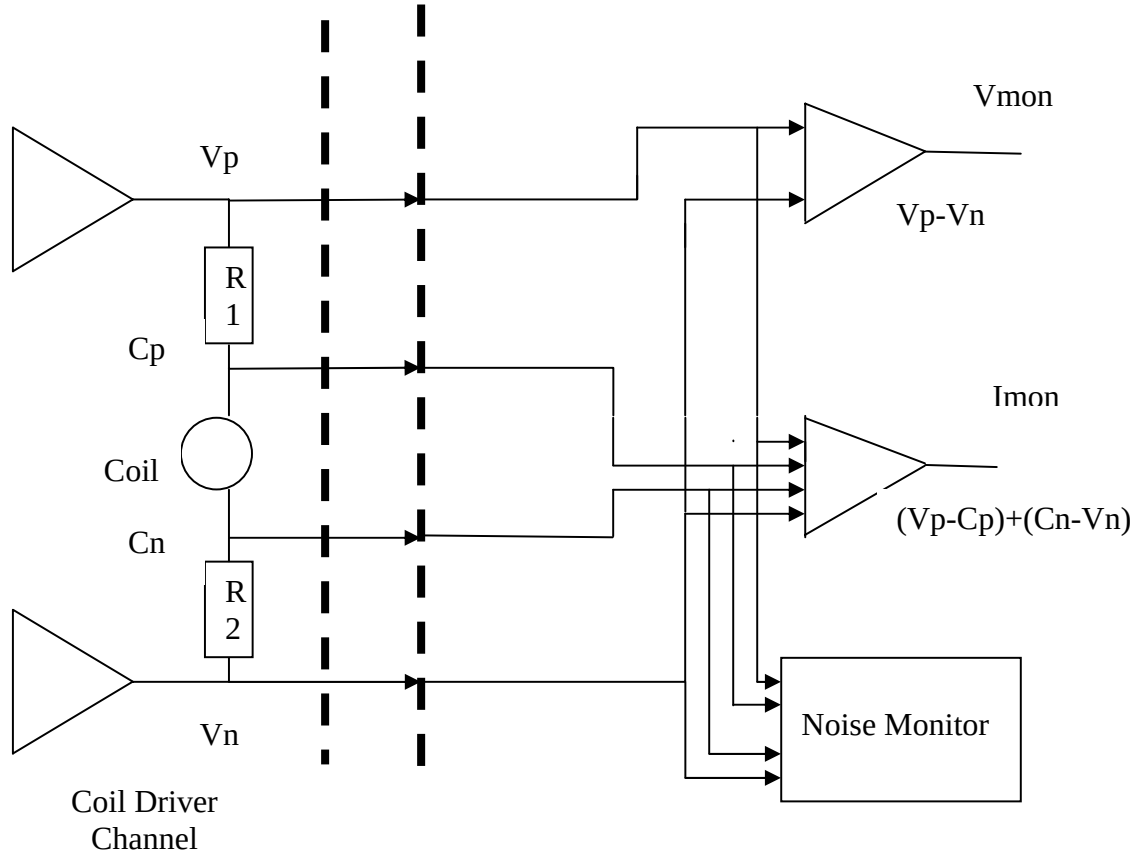
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

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NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.81	√
-15V (TP6)	-14.90	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	300mA
-15v (TP6)	√	5mV	250mA

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.5	**2.4V to 2.6V**	√
Ch2	100	2.5	**2.4V to 2.6V**	√
Ch3	100	2.5	**2.4V to 2.6V**	√
Ch4	100	2.5	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.4	**2.4V to 2.6V**	√
Ch2	100	2.4	**2.4V to 2.6V**	√
Ch3	100	2.4	**2.4V to 2.6V**	√
Ch4	100	2.4	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude= 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100	1.9	**1.6V to 1.9V**	√
Ch2	100	1.9	**1.6V to 1.9V**	√
Ch3	100	1.9	**1.6V to 1.9V**	√
Ch4	100	1.9	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100	1.8	**1.6V to 1.9V**	√
Ch2	100	1.8	**1.6V to 1.9V**	√
Ch3	100	1.8	**1.6V to 1.9V**	√
Ch4	100	1.8	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1	100	5	**4.8V to 5.2V**	√
Ch2	100	5	**4.8V to 5.2V**	√
Ch3	100	5	**4.8V to 5.2V**	√
Ch4	100	5	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.50	1.50	1.55	1.50
TP6	4	4	4	4	2.3	2.3	2.4	2.3
TP7	8	8	8	8	3.4	3.4	3.6	3.5

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.5	1.5	1.5	1.5	√
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	√
TP7/TP6	2	2	2	2	1.5	1.5	1.5	1.5	√

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10	9.7 to 10V	√	4.5	4 to 5.5V	√
Ch2	TP10	10	9.7 to 10V	√	4.4	4 to 5.5V	√
Ch3	TP10	10	9.7 to 10V	√	4.5	4 to 5.5V	√
Ch4	TP10	10	9.7 to 10V	√	4.6	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1	3	2	**1.9 to 2.1V**	√
Ch2	3	2	**1.9 to 2.1V**	√
Ch3	3	2	**1.9 to 2.1V**	√
Ch4	3	2	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0	0	0	0	√
(2) 3V in	**1V +/- 0.1V**	1	1	1	1	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5	1.5	1.5	1.5	√
(4) 6V in	**2V +/- 0.1V**	2	2	2	2	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.715	**0.707 (0.68 to 0.72V)**	√
Ch2	0.715	**0.707 (0.68 to 0.72V)**	√
Ch3	0.711	**0.707 (0.68 to 0.72V)**	√
Ch4	0.717	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.360	**0.35V (0.33 to 0.37V)**	√
Ch2	0.360	**0.35V (0.33 to 0.37V)**	√
Ch3	0.356	**0.35V (0.33 to 0.37V)**	√
Ch4	0.360	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.986	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.985	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.982	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.988	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.012	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.019	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.011	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.017	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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2. Test equipment

3. Description

4. Inspection

5. Power

6. Circuit operation

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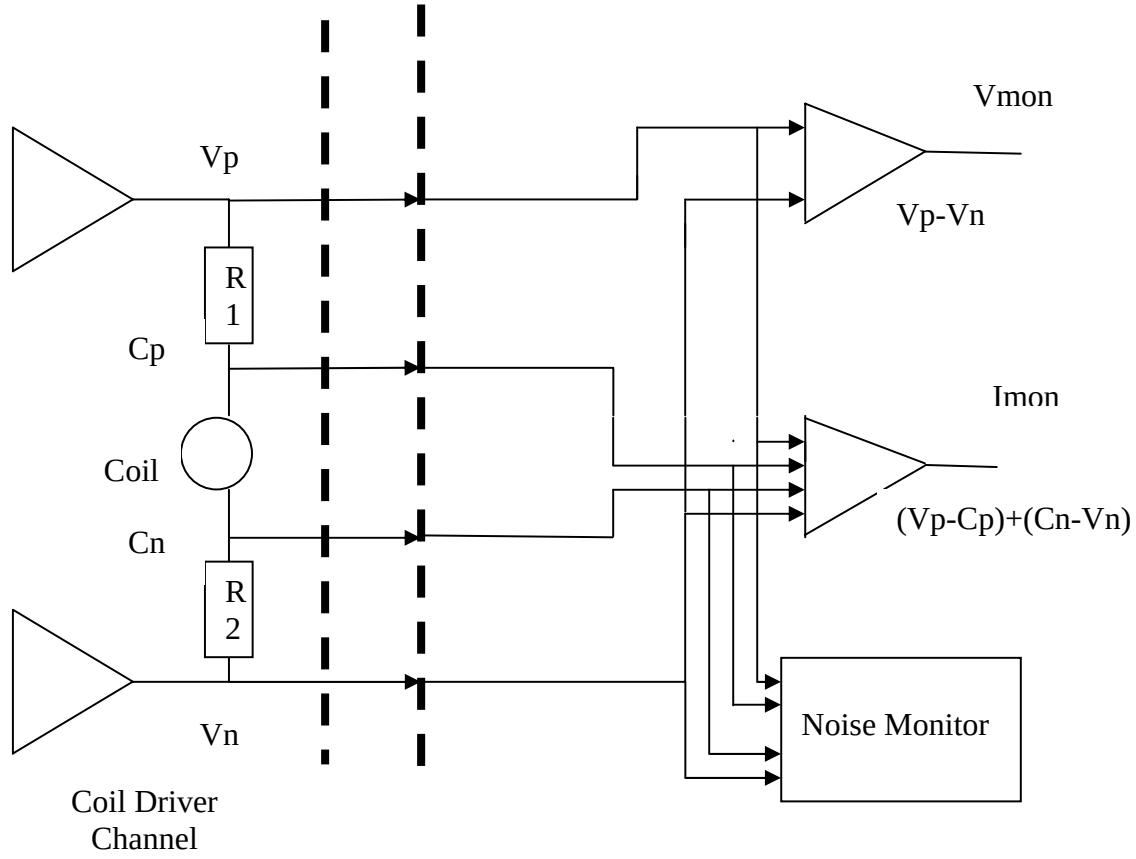
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No ……Mon35……...
Test Engineer ……Xen……
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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.93	√
-15V (TP6)	-15.02	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	300mA
-15v (TP6)	√	5mV	250mA

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Date ……9/10/09……

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.5	**2.4V to 2.6V**	√
Ch2	100	2.5	**2.4V to 2.6V**	√
Ch3	100	2.5	**2.4V to 2.6V**	√
Ch4	100	2.5	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.4	**2.4V to 2.6V**	√
Ch2	100	2.4	**2.4V to 2.6V**	√
Ch3	100	2.4	**2.4V to 2.6V**	√
Ch4	100	2.4	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude= 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100	1.8	**1.6V to 1.9V**	√
Ch2	100	1.8	**1.6V to 1.9V**	√
Ch3	100	1.8	**1.6V to 1.9V**	√
Ch4	100	1.9	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100	1.8	**1.6V to 1.9V**	√
Ch2	100	1.8	**1.6V to 1.9V**	√
Ch3	100	1.7	**1.6V to 1.9V**	√
Ch4	100	1.7	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1	100	5	**4.8V to 5.2V**	√
Ch2	100	5	**4.8V to 5.2V**	√
Ch3	100	5	**4.8V to 5.2V**	√
Ch4	100	5	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.5	1.5	1.5	1.5
TP6	4	4	4	4	2.3	2.3	2.3	2.2
TP7	8	8	8	8	3.4	3.4	3.4	3.3

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.5	1.5	1.5	1.5	√
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	√
TP7/TP6	2	2	2	2	1.5	1.5	1.5	1.5	√

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10	9.7 to 10V	√	4.6	4 to 5.5V	√
Ch2	TP10	10	9.7 to 10V	√	4.6	4 to 5.5V	√
Ch3	TP10	10	9.7 to 10V	√	4.5	4 to 5.5V	√
Ch4	TP10	10	9.7 to 10V	√	4.6	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1	3	2	**1.9 to 2.1V**	√
Ch2	3	2	**1.9 to 2.1V**	√
Ch3	3	2	**1.9 to 2.1V**	√
Ch4	3	2	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0	0	0	0	√
(2) 3V in	**1V +/- 0.1V**	1	1	1	1	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5	1.5	1.5	1.5	√
(4) 6V in	**2V +/- 0.1V**	2	2	2	2	√

Serial No ……Mon35……...
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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.713	**0.707 (0.68 to 0.72V)**	√
Ch2	0.714	**0.707 (0.68 to 0.72V)**	√
Ch3	0.718	**0.707 (0.68 to 0.72V)**	√
Ch4	0.714	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358	**0.35V (0.33 to 0.37V)**	√
Ch2	0.359	**0.35V (0.33 to 0.37V)**	√
Ch3	0.360	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.988	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.989	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.994	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.989	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.014	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.013	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.023	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.015	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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Contents

1. Block diagram

2. Test equipment

3. Description

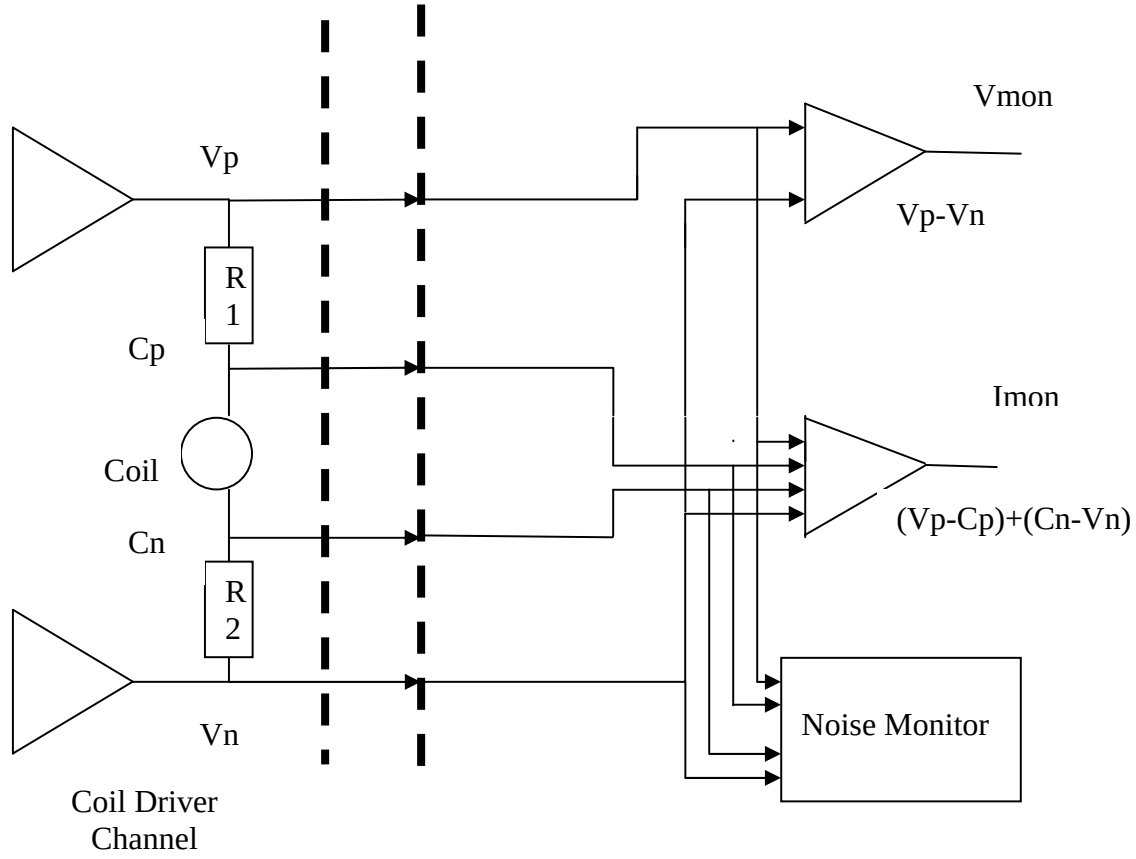
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
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Date ……

NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.99	√
-15V (TP6)	-14.94	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	300mA
-15v (TP6)	√	5mV	250mA

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.45	**2.4V to 2.6V**	√
Ch2	100	2.45	**2.4V to 2.6V**	√
Ch3	100	2.45	**2.4V to 2.6V**	√
Ch4	100	2.45	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.4	**2.4V to 2.6V**	√
Ch2	100	2.4	**2.4V to 2.6V**	√
Ch3	100	2.4	**2.4V to 2.6V**	√
Ch4	100	2.4	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude= 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100	1.8	**1.6V to 1.9V**	√
Ch2	100	1.8	**1.6V to 1.9V**	√
Ch3	100	1.8	**1.6V to 1.9V**	√
Ch4	100	1.8	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100	1.75	**1.6V to 1.9V**	√
Ch2	100	1.75	**1.6V to 1.9V**	√
Ch3	100	1.75	**1.6V to 1.9V**	√
Ch4	100	1.75	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1	100	5	**4.8V to 5.2V**	√
Ch2	100	5	**4.8V to 5.2V**	√
Ch3	100	5	**4.8V to 5.2V**	√
Ch4	100	5	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.5	1.5	1.5	1.5
TP6	4	4	4	4	2.1	2.1	2.2	2.2
TP7	8	8	8	8	3.2	3.1	3.2	3.2

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.5	1.5	1.5	1.5	√
TP6/TP4	2	2	2	2	1.4	1.4	1.5	1.5	√
TP7/TP6	2	2	2	2	1.5	1.5	1.5	1.5	√

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10	9.7 to 10V	√	4.4	4 to 5.5V	√
Ch2	TP10	10	9.7 to 10V	√	4.4	4 to 5.5V	√
Ch3	TP10	10	9.7 to 10V	√	4.6	4 to 5.5V	√
Ch4	TP10	10	9.7 to 10V	√	4.6	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1	3	2	**1.9 to 2.1V**	√
Ch2	3	2	**1.9 to 2.1V**	√
Ch3	3	2	**1.9 to 2.1V**	√
Ch4	3	2	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0	0	0	0	√
(2) 3V in	**1V +/- 0.1V**	1	1	1	1	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5	1.5	1.5	1.5	√
(4) 6V in	**2V +/- 0.1V**	2	2	2	2	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.708	**0.707 (0.68 to 0.72V)**	√
Ch2	0.707	**0.707 (0.68 to 0.72V)**	√
Ch3	0.714	**0.707 (0.68 to 0.72V)**	√
Ch4	0.717	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.356	**0.35V (0.33 to 0.37V)**	√
Ch2	0.354	**0.35V (0.33 to 0.37V)**	√
Ch3	0.359	**0.35V (0.33 to 0.37V)**	√
Ch4	0.362	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.975	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.974	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.981	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.984	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.013	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.007	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.018	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.022	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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6. Circuit operation

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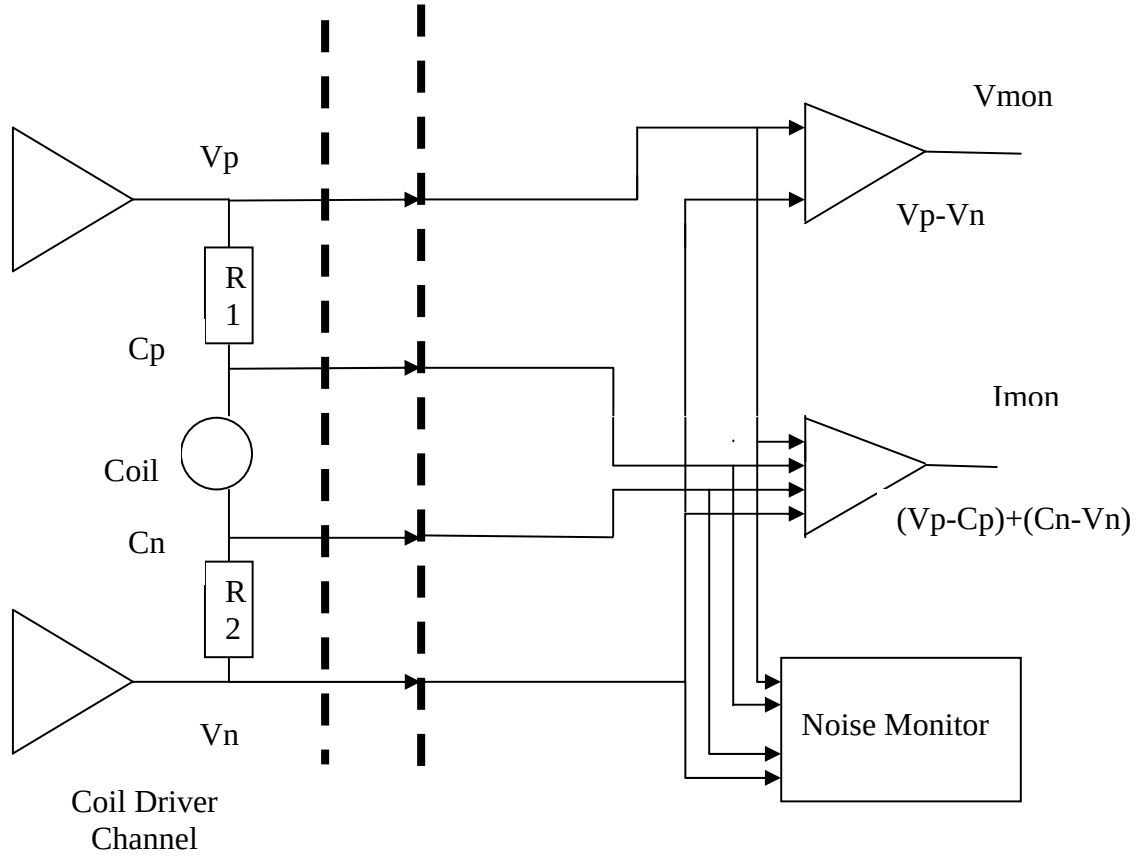
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No ……Mon37……...
Test Engineer ……Xen……
Date ……9/10/09……

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.99	√
-15V (TP6)	-15.01	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	300mA
-15v (TP6)	√	5mV	250mA

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.5	**2.4V to 2.6V**	√
Ch2	100	2.5	**2.4V to 2.6V**	√
Ch3	100	2.5	**2.4V to 2.6V**	√
Ch4	100	2.5	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.4	**2.4V to 2.6V**	√
Ch2	100	2.4	**2.4V to 2.6V**	√
Ch3	100	2.4	**2.4V to 2.6V**	√
Ch4	100	2.4	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude= 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100	1.85	**1.6V to 1.9V**	√
Ch2	100	1.85	**1.6V to 1.9V**	√
Ch3	100	1.85	**1.6V to 1.9V**	√
Ch4	100	1.85	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100	1.8	**1.6V to 1.9V**	√
Ch2	100	1.8	**1.6V to 1.9V**	√
Ch3	100	1.8	**1.6V to 1.9V**	√
Ch4	100	1.8	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1	100	5	**4.8V to 5.2V**	√
Ch2	100	5	**4.8V to 5.2V**	√
Ch3	100	5	**4.8V to 5.2V**	√
Ch4	100	5	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.5	1.48	1.48	1.48
TP6	4	4	4	4	2.2	2.1	2.2	2.2
TP7	8	8	8	8	3.2	3.1	3.1	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.5	1.48	1.48	1.48	√
TP6/TP4	2	2	2	2	1.5	1.4	1.5	1.5	√
TP7/TP6	2	2	2	2	1.5	1.5	1.4	1.4	√

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10	9.7 to 10V	√	4.4	4 to 5.5V	√
Ch2	TP10	10	9.7 to 10V	√	4.6	4 to 5.5V	√
Ch3	TP10	10	9.7 to 10V	√	4.4	4 to 5.5V	√
Ch4	TP10	10	9.7 to 10V	√	4.8	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1	3	2	**1.9 to 2.1V**	√
Ch2	3	2	**1.9 to 2.1V**	√
Ch3	3	2	**1.9 to 2.1V**	√
Ch4	3	2	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0	0	0	0	√
(2) 3V in	**1V +/- 0.1V**	1	1	1	1	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5	1.5	1.5	1.5	√
(4) 6V in	**2V +/- 0.1V**	2	2	2	2	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.713	**0.707 (0.68 to 0.72V)**	√
Ch2	0.712	**0.707 (0.68 to 0.72V)**	√
Ch3	0.714	**0.707 (0.68 to 0.72V)**	√
Ch4	0.713	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358	**0.35V (0.33 to 0.37V)**	√
Ch3	0.359	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.990	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.988	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.989	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.988	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.022	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.009	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.004	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.012	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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Contents

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2. Test equipment

3. Description

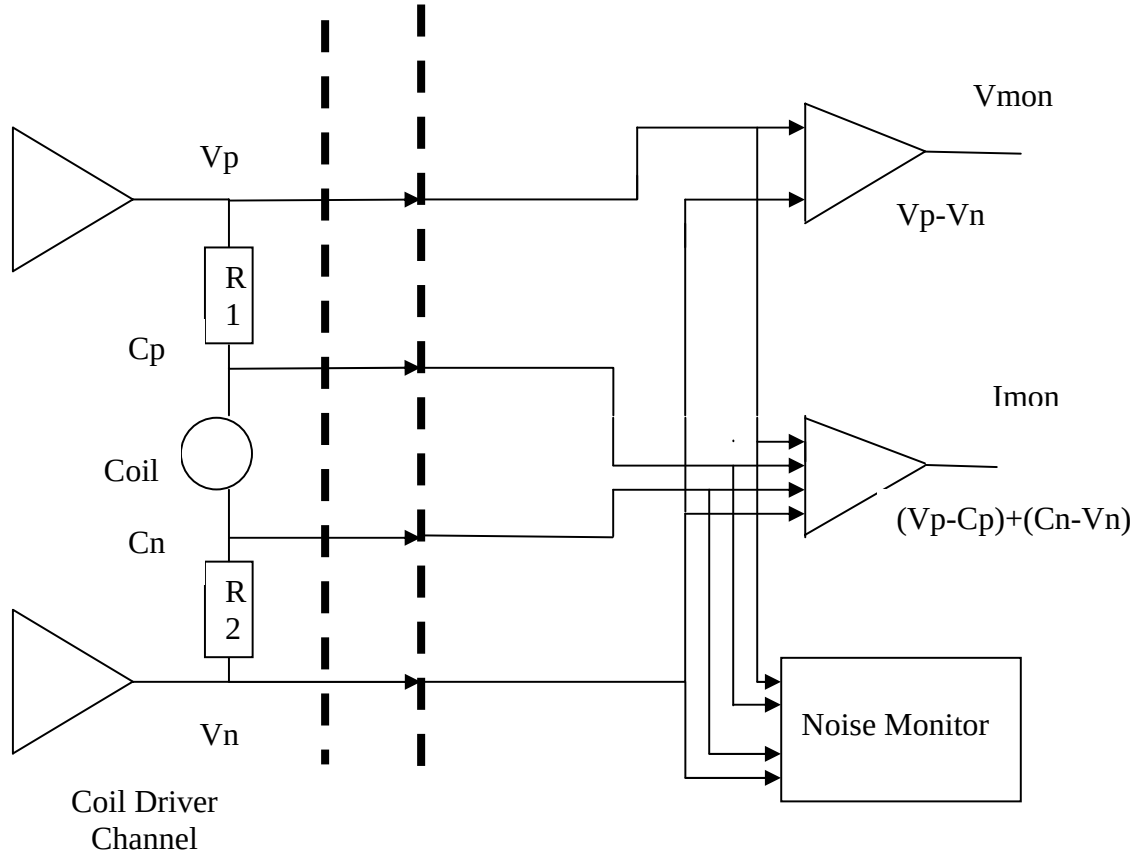
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

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Test Engineer ……
Date ……

NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.97	√
-15V (TP6)	-15.01	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	300mA
-15v (TP6)	√	5mV	250mA

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.5	**2.4V to 2.6V**	√
Ch2	100	2.5	**2.4V to 2.6V**	√
Ch3	100	2.5	**2.4V to 2.6V**	√
Ch4	100	2.5	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.4	**2.4V to 2.6V**	√
Ch2	100	2.4	**2.4V to 2.6V**	√
Ch3	100	2.4	**2.4V to 2.6V**	√
Ch4	100	2.4	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude= 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100	1.8	**1.6V to 1.9V**	√
Ch2	100	1.8	**1.6V to 1.9V**	√
Ch3	100	1.8	**1.6V to 1.9V**	√
Ch4	100	1.8	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100	1.8	**1.6V to 1.9V**	√
Ch2	100	1.8	**1.6V to 1.9V**	√
Ch3	100	1.8	**1.6V to 1.9V**	√
Ch4	100	1.8	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1	100	5	**4.8V to 5.2V**	√
Ch2	100	5	**4.8V to 5.2V**	√
Ch3	100	5	**4.8V to 5.2V**	√
Ch4	100	5	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.5	1.5	1.5	1.5
TP6	4	4	4	4	2.2	2.2	2.2	2.3
TP7	8	8	8	8	3.4	3.4	3.4	3.4

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.5	1.5	1.5	1.5	√
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	√
TP7/TP6	2	2	2	2	1.5	1.5	.5	1.5	√

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10	**9.7 to 10V**	√	4.4	**4 to 5.5V**	√
Ch2	**TP10**	10	**9.7 to 10V**	√	4.4	**4 to 5.5V**	√
Ch3	**TP10**	10	**9.7 to 10V**	√	4.4	**4 to 5.5V**	√
Ch4	**TP10**	10	**9.7 to 10V**	√	4.6	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1	3	2	**1.9 to 2.1V**	√
Ch2	3	2	**1.9 to 2.1V**	√
Ch3	3	2	**1.9 to 2.1V**	√
Ch4	3	2	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0	0	0	0	√
(2) 3V in	**1V +/- 0.1V**	1	1	1	1	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5	1.5	1.5	1.5	√
(4) 6V in	**2V +/- 0.1V**	2	2	2	2	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.716	**0.707 (0.68 to 0.72V)**	√
Ch2	0.718	**0.707 (0.68 to 0.72V)**	√
Ch3	0.715	**0.707 (0.68 to 0.72V)**	√
Ch4	0.712	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.361	**0.35V (0.33 to 0.37V)**	√
Ch2	0.362	**0.35V (0.33 to 0.37V)**	√
Ch3	0.359	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.986	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.988	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.984	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.979	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.016	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.020	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.011	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.011	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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1. Block diagram

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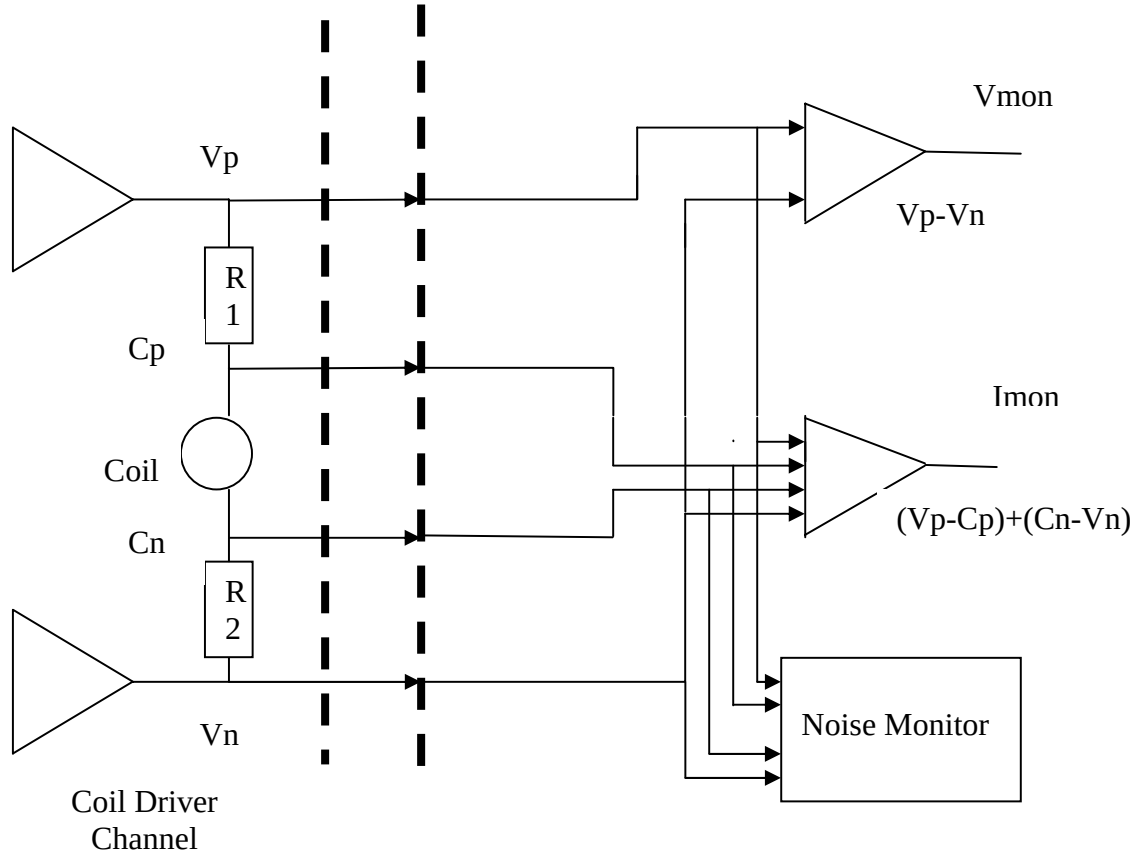
6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No ……Mon39……...
Test Engineer ……Xen……
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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	15.02	√
-15V (TP6)	-14.94	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	300mA
-15v (TP6)	√	5mV	250mA

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Test Engineer ……Xen……
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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.5	**2.4V to 2.6V**	√
Ch2	100	2.5	**2.4V to 2.6V**	√
Ch3	100	2.5	**2.4V to 2.6V**	√
Ch4	100	2.5	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.4	**2.4V to 2.6V**	√
Ch2	100	2.4	**2.4V to 2.6V**	√
Ch3	100	2.4	**2.4V to 2.6V**	√
Ch4	100	2.4	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude= 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100	1.9	**1.6V to 1.9V**	√
Ch2	100	1.9	**1.6V to 1.9V**	√
Ch3	100	1.9	**1.6V to 1.9V**	√
Ch4	100	1.9	**1.6V to 1.9V**	√

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Test Engineer ……Xen……
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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100	1.8	**1.6V to 1.9V**	√
Ch2	100	1.8	**1.6V to 1.9V**	√
Ch3	100	1.8	**1.6V to 1.9V**	√
Ch4	100	1.8	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1	100	5	**4.8V to 5.2V**	√
Ch2	100	5	**4.8V to 5.2V**	√
Ch3	100	5	**4.8V to 5.2V**	√
Ch4	100	5	**4.8V to 5.2V**	√

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Test Engineer ……Xen……
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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.5	1.5	1.5	1.5
TP6	4	4	4	4	2.3	2.35	2.3	2.35
TP7	8	8	8	8	3.4	3.6	3.5	3.6

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.5	1.5	1.5	1.5	√
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	√
TP7/TP6	2	2	2	2	1.5	1.5	1.5	1.5	√

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10	**9.7 to 10V**	√	4.6	**4 to 5.5V**	√
Ch2	**TP10**	10	**9.7 to 10V**	√	4.6	**4 to 5.5V**	√
Ch3	**TP10**	10	**9.7 to 10V**	√	4.4	**4 to 5.5V**	√
Ch4	**TP10**	10	**9.7 to 10V**	√	4.6	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1	3	2	**1.9 to 2.1V**	√
Ch2	3	2	**1.9 to 2.1V**	√
Ch3	3	2	**1.9 to 2.1V**	√
Ch4	3	2	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0	0	0	0	√
(2) 3V in	**1V +/- 0.1V**	1	1	1	1	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5	1.5	1.5	1.5	√
(4) 6V in	**2V +/- 0.1V**	2	2	2	2	√

Serial No ……Mon39……...
Test Engineer ……Xen……
Date ……12/10/09……

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box.

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.711	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713	**0.707 (0.68 to 0.72V)**	√
Ch3	0.713	**0.707 (0.68 to 0.72V)**	√
Ch4	0.714	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.356	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358	**0.35V (0.33 to 0.37V)**	√
Ch3	0.358	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.986	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.987	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.987	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.989	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.014	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.010	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.012	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.017	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No ……Mon40……...
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Contents

1. Block diagram

2. Test equipment

3. Description

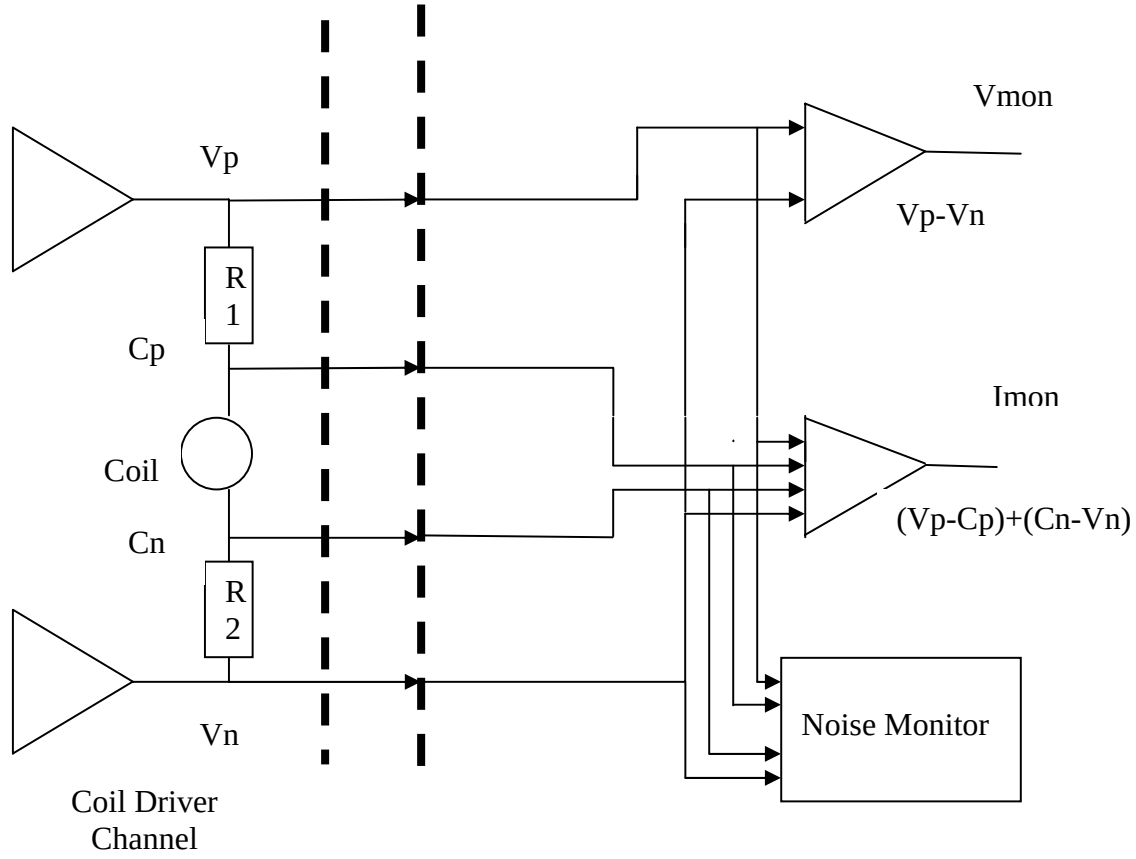
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No ……Mon40……...
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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.84	√
-15V (TP6)	-15.04	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	300mA
-15v (TP6)	√	5mV	250mA

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.5	**2.4V to 2.6V**	√
Ch2	100	2.5	**2.4V to 2.6V**	√
Ch3	100	2.5	**2.4V to 2.6V**	√
Ch4	100	2.5	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.4	**2.4V to 2.6V**	√
Ch2	100	2.4	**2.4V to 2.6V**	√
Ch3	100	2.4	**2.4V to 2.6V**	√
Ch4	100	2.4	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude= 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100	1.8	**1.6V to 1.9V**	√
Ch2	100	1.8	**1.6V to 1.9V**	√
Ch3	100	1.8	**1.6V to 1.9V**	√
Ch4	100	1.8	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100	1.8	**1.6V to 1.9V**	√
Ch2	100	1.8	**1.6V to 1.9V**	√
Ch3	100	1.8	**1.6V to 1.9V**	√
Ch4	100	1.8	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1	100	5	**4.8V to 5.2V**	√
Ch2	100	5	**4.8V to 5.2V**	√
Ch3	100	5	**4.8V to 5.2V**	√
Ch4	100	5	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.5	1.5	1.5	1.5
TP6	4	4	4	4	2.3	2.1	2.2	2.2
TP7	8	8	8	8	3.4	3.2	3.3	3.3

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.5	1.5	1.5	1.5	√
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	√
TP7/TP6	2	2	2	2	1.5	1.5	1.5	1.5	√

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10	9.7 to 10V	√	4.6	4 to 5.5V	√
Ch2	TP10	10	9.7 to 10V	√	4.6	4 to 5.5V	√
Ch3	TP10	10	9.7 to 10V	√	4.6	4 to 5.5V	√
Ch4	TP10	10	9.7 to 10V	√	4.6	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1	3	2	**1.9 to 2.1V**	√
Ch2	3	2	**1.9 to 2.1V**	√
Ch3	3	2	**1.9 to 2.1V**	√
Ch4	3	2	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0	0	0	0	√
(2) 3V in	**1V +/- 0.1V**	1	1	1	1	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5	1.5	1.5	1.5	√
(4) 6V in	**2V +/- 0.1V**	2	2	2	2	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.715	**0.707 (0.68 to 0.72V)**	√
Ch2	0.711	**0.707 (0.68 to 0.72V)**	√
Ch3	0.717	**0.707 (0.68 to 0.72V)**	√
Ch4	0.714	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.359	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356	**0.35V (0.33 to 0.37V)**	√
Ch3	0.361	**0.35V (0.33 to 0.37V)**	√
Ch4	0.359	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.983	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.977	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.984	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.980	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.021	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.012	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.018	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.017	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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1. Block diagram

2. Test equipment

3. Description

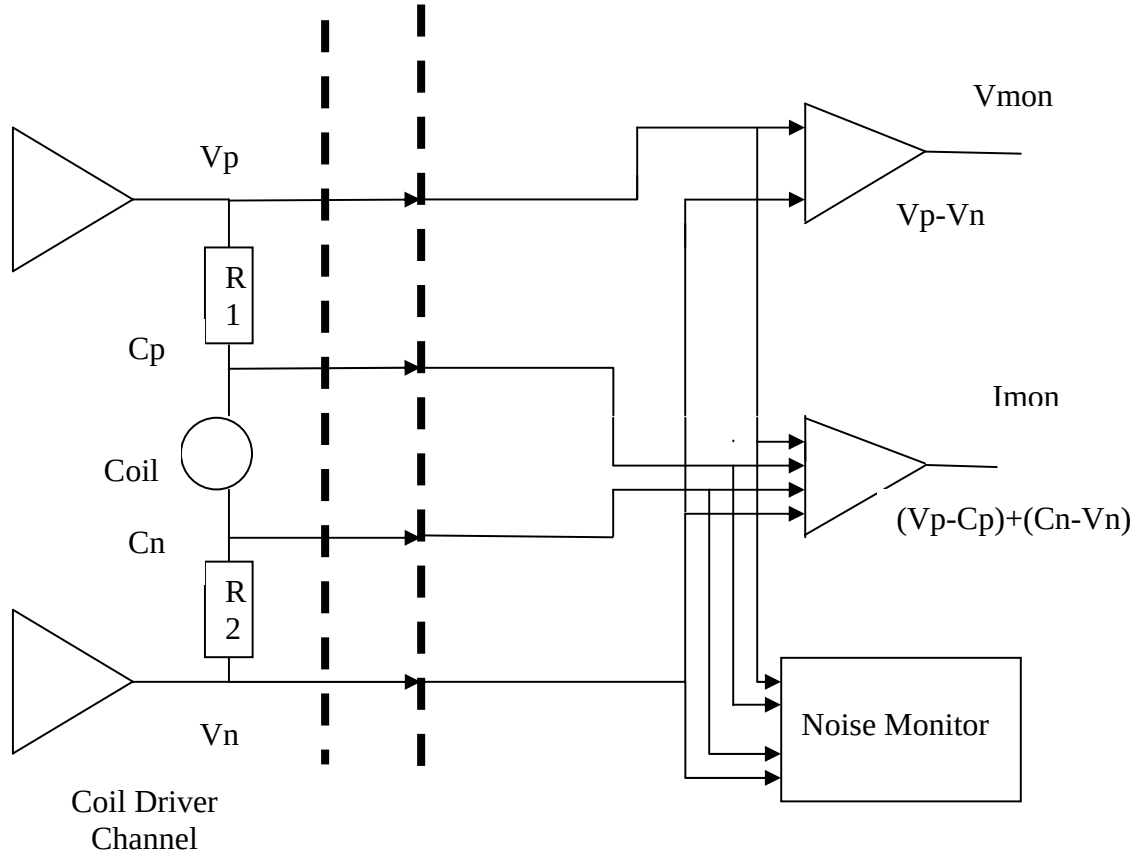
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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Date ……12/10/09……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No ……Mon41……...
Test Engineer ……Xen……
Date ……12/10/09……

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.99	√
-15V (TP6)	-15.04	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	300mA
-15v (TP6)	√	5mV	250mA

Serial No ……Mon41……...
Test Engineer ……Xen……
Date ……12/10/09……

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.5	**2.4V to 2.6V**	√
Ch2	100	2.5	**2.4V to 2.6V**	√
Ch3	100	2.5	**2.4V to 2.6V**	√
Ch4	100	2.5	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.4	**2.4V to 2.6V**	√
Ch2	100	2.4	**2.4V to 2.6V**	√
Ch3	100	2.4	**2.4V to 2.6V**	√
Ch4	100	2.4	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude= 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100	1.85	**1.6V to 1.9V**	√
Ch2	100	1.85	**1.6V to 1.9V**	√
Ch3	100	1.85	**1.6V to 1.9V**	√
Ch4	100	1.85	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100	1.8	**1.6V to 1.9V**	√
Ch2	100	1.8	**1.6V to 1.9V**	√
Ch3	100	1.8	**1.6V to 1.9V**	√
Ch4	100	1.8	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1	100	5	**4.8V to 5.2V**	√
Ch2	100	5	**4.8V to 5.2V**	√
Ch3	100	5	**4.8V to 5.2V**	√
Ch4	100	5	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	15	1.5	1.5	1.5
TP6	4	4	4	4	2.2	2.3	2.2	2.3
TP7	8	8	8	8	3.4	3.4	3.4	3.4

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.5	1.5	1.5	1.5	√
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	√
TP7/TP6	2	2	2	2	1.5	1.5	1.5	1.5	√

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	**TP10**	10	**9.7 to 10V**	√	4.6	**4 to 5.5V**	√
Ch2	**TP10**	10	**9.7 to 10V**	√	4.8	**4 to 5.5V**	√
Ch3	**TP10**	10	**9.7 to 10V**	√	4.6	**4 to 5.5V**	√
Ch4	**TP10**	10	**9.7 to 10V**	√	4.8	**4 to 5.5V**	√

Serial No ……Mon41……...
Test Engineer ……Xen……
Date ……12/10/09……

6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1	3	2	**1.9 to 2.1V**	√
Ch2	3	2	**1.9 to 2.1V**	√
Ch3	3	2	**1.9 to 2.1V**	√
Ch4	3	2	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0	0	0	0	√
(2) 3V in	**1V +/- 0.1V**	1	1	1	1	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5	1.5	1.5	1.5	√
(4) 6V in	**2V +/- 0.1V**	2	2	2	2	√

Serial No ……Mon41……...
Test Engineer ……Xen……
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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.716	**0.707 (0.68 to 0.72V)**	√
Ch2	0.709	**0.707 (0.68 to 0.72V)**	√
Ch3	0.711	**0.707 (0.68 to 0.72V)**	√
Ch4	0.712	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.362	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356	**0.35V (0.33 to 0.37V)**	√
Ch3	0.356	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.987	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.977	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.980	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.981	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.019	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.016	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.013	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.014	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No ……Mon42……...
Test Engineer ……Xen……
Date ……12/10/09……

Contents

1. Block diagram

2. Test equipment

3. Description

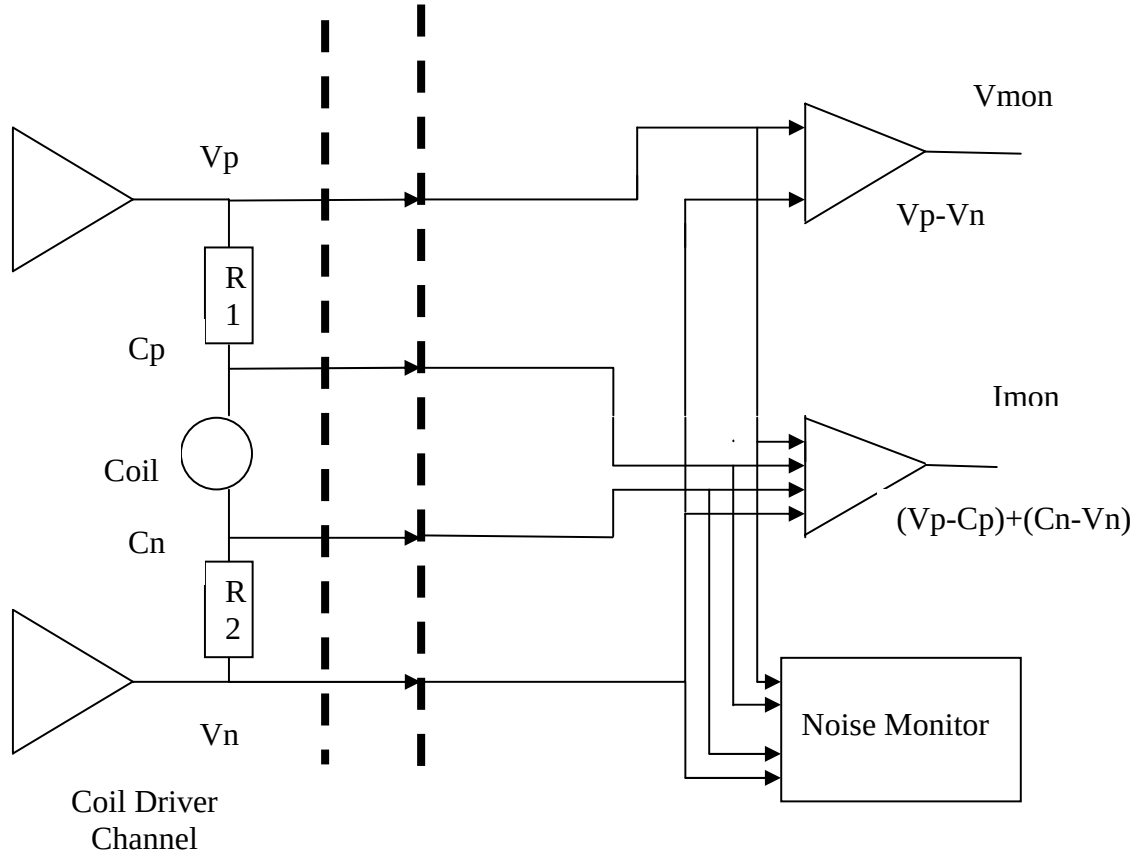
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No ……Mon42……...
Test Engineer ……Xen……
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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.80	√
-15V (TP6)	-15.01	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	300mA
-15v (TP6)	√	5mV	250mA

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.5	**2.4V to 2.6V**	√
Ch2	100	2.5	**2.4V to 2.6V**	√
Ch3	100	2.5	**2.4V to 2.6V**	√
Ch4	100	2.5	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.4	**2.4V to 2.6V**	√
Ch2	100	2.4	**2.4V to 2.6V**	√
Ch3	100	2.4	**2.4V to 2.6V**	√
Ch4	100	2.4	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude= 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100	1.9	**1.6V to 1.9V**	√
Ch2	100	1.9	**1.6V to 1.9V**	√
Ch3	100	1.9	**1.6V to 1.9V**	√
Ch4	100	1.9	**1.6V to 1.9V**	√

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Test Engineer ……Xen……
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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100	1.8	**1.6V to 1.9V**	√
Ch2	100	1.8	**1.6V to 1.9V**	√
Ch3	100	1.8	**1.6V to 1.9V**	√
Ch4	100	1.8	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1	100	5	**4.8V to 5.2V**	√
Ch2	100	5	**4.8V to 5.2V**	√
Ch3	100	5	**4.8V to 5.2V**	√
Ch4	100	5	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.5	1.5	1.5	1.5
TP6	4	4	4	4	2.3	2.2	2.3	2.2
TP7	8	8	8	8	3.4	3.3	3.3	3.3

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.5	1.5	1.5	1.5	√
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	√
TP7/TP6	2	2	2	2	1.5	1.5	1.4	1.5	√

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10	9.7 to 10V	√	4.4	4 to 5.5V	√
Ch2	TP10	10	9.7 to 10V	√	4.6	4 to 5.5V	√
Ch3	TP10	10	9.7 to 10V	√	4.6	4 to 5.5V	√
Ch4	TP10	10	9.7 to 10V	√	4.8	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1	3	2	**1.9 to 2.1V**	√
Ch2	3	2	**1.9 to 2.1V**	√
Ch3	3	2	**1.9 to 2.1V**	√
Ch4	3	2	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0	0	0	0	√
(2) 3V in	**1V +/- 0.1V**	1	1	1	1	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5	1.5	1.5	1.5	√
(4) 6V in	**2V +/- 0.1V**	2	2	2	2	√

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Test Engineer ……Xen……
Date ……12/10/09……

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.714	**0.707 (0.68 to 0.72V)**	√
Ch2	0.716	**0.707 (0.68 to 0.72V)**	√
Ch3	0.711	**0.707 (0.68 to 0.72V)**	√
Ch4	0.713	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358	**0.35V (0.33 to 0.37V)**	√
Ch2	0.359	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.984	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.986	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.978	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.982	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.016	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.018	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.008	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.015	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No ……Mon43……...
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Contents

1. Block diagram

2. Test equipment

3. Description

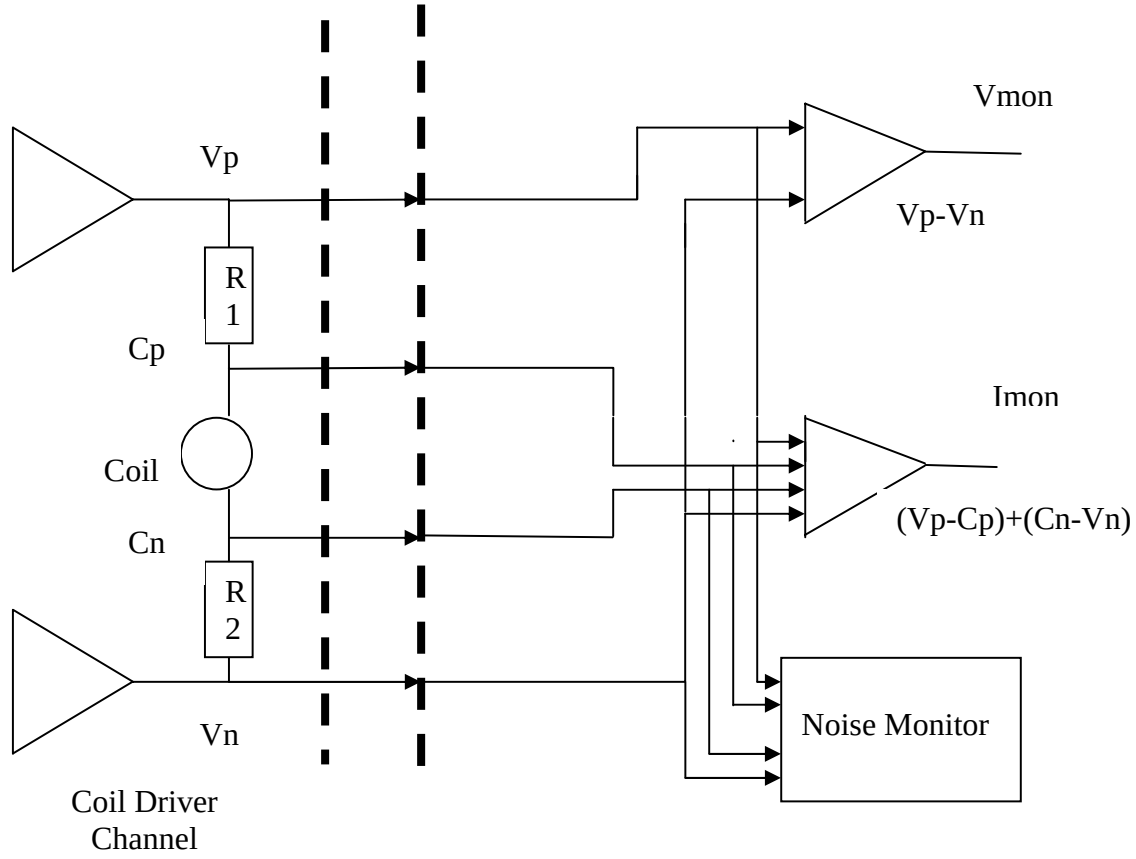
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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Test Engineer ……Xen……
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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No ……Mon43……...
Test Engineer ……Xen……
Date ……12/10/09……

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.94	√
-15V (TP6)	-14.98	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	300mA
-15v (TP6)	√	5mV	250mA

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.45	**2.4V to 2.6V**	√
Ch2	100	2.45	**2.4V to 2.6V**	√
Ch3	100	2.45	**2.4V to 2.6V**	√
Ch4	100	2.45	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.4	**2.4V to 2.6V**	√
Ch2	100	2.4	**2.4V to 2.6V**	√
Ch3	100	2.4	**2.4V to 2.6V**	√
Ch4	100	2.4	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100	1.9	**1.6V to 1.9V**	√
Ch2	100	1.9	**1.6V to 1.9V**	√
Ch3	100	1.9	**1.6V to 1.9V**	√
Ch4	100	1.9	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100	1.8	**1.6V to 1.9V**	√
Ch2	100	1.8	**1.6V to 1.9V**	√
Ch3	100	1.8	**1.6V to 1.9V**	√
Ch4	100	1.8	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1	100	5	**4.8V to 5.2V**	√
Ch2	100	5	**4.8V to 5.2V**	√
Ch3	100	5	**4.8V to 5.2V**	√
Ch4	100	5	**4.8V to 5.2V**	√

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Test Engineer ……Xen……
Date ……12/10/09……

Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.5	1.5	1.5	1.5
TP6	4	4	4	4	2.2	2.2	2.2	2.2
TP7	8	8	8	8	3.3	3.3	3.4	3.3

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.5	1.5	1.5	1.5	√
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	√
TP7/TP6	2	2	2	2	1.5	1.5	1.5	1.5	√

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10	**9.7 to 10V**	√	4.4	**4 to 5.5V**	√
Ch2	**TP10**	10	**9.7 to 10V**	√	4.8	**4 to 5.5V**	√
Ch3	**TP10**	10	**9.7 to 10V**	√	4.6	**4 to 5.5V**	√
Ch4	**TP10**	10	**9.7 to 10V**	√	4.4	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1	3	2	**1.9 to 2.1V**	√
Ch2	3	2	**1.9 to 2.1V**	√
Ch3	3	2	**1.9 to 2.1V**	√
Ch4	3	2	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0	0	0	0	√
(2) 3V in	**1V +/- 0.1V**	1	1	1	1	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5	1.5	1.5	1.5	√
(4) 6V in	**2V +/- 0.1V**	2	2	2	2	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.713	**0.707 (0.68 to 0.72V)**	√
Ch2	0.711	**0.707 (0.68 to 0.72V)**	√
Ch3	0.712	**0.707 (0.68 to 0.72V)**	√
Ch4	0.713	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.359	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.984	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.982	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.981	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.981	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.031	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.010	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.012	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.014	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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Contents

1. Block diagram

2. Test equipment

3. Description

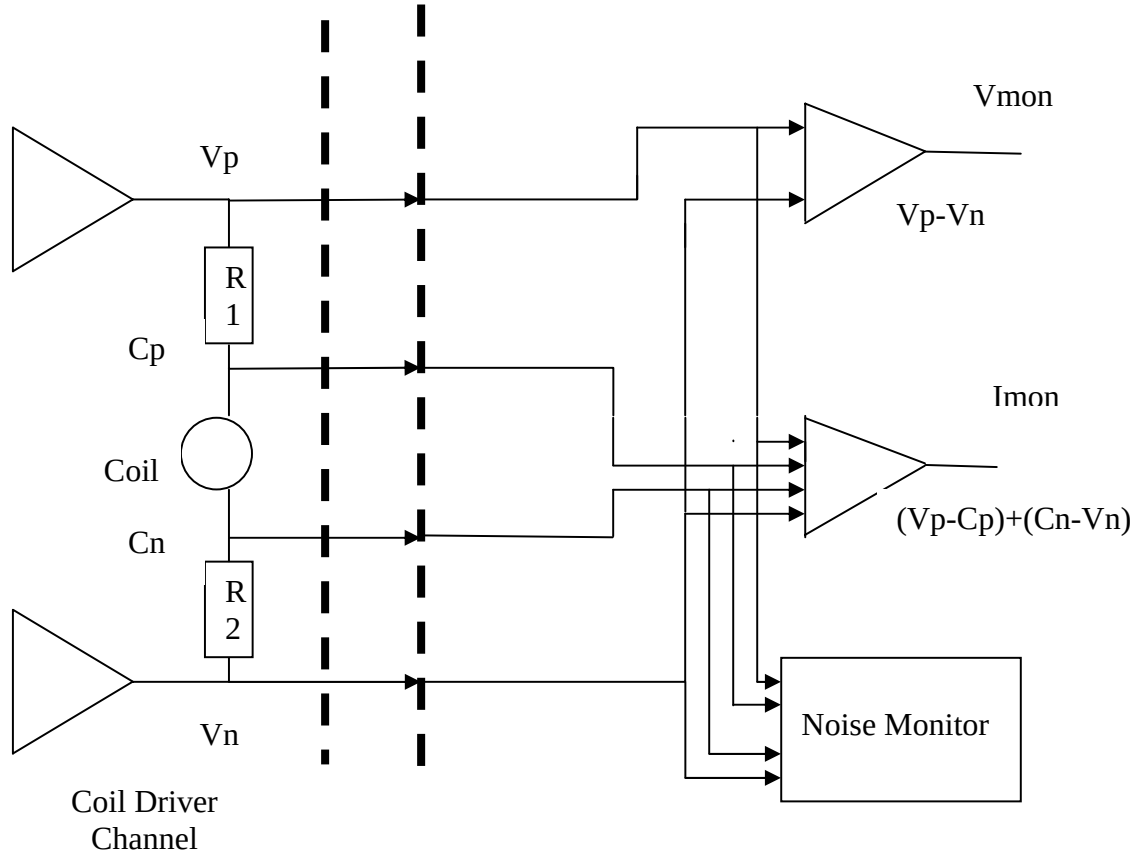
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

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NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.82	√
-15V (TP6)	-15.00	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	300mA
-15v (TP6)	√	5mV	250mA

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.45	**2.4V to 2.6V**	√
Ch2	100	2.45	**2.4V to 2.6V**	√
Ch3	100	2.45	**2.4V to 2.6V**	√
Ch4	100	2.45	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.4	**2.4V to 2.6V**	√
Ch2	100	2.4	**2.4V to 2.6V**	√
Ch3	100	2.4	**2.4V to 2.6V**	√
Ch4	100	2.4	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude= 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100	2.5	**1.6V to 1.9V**	√
Ch2	100	2.5	**1.6V to 1.9V**	√
Ch3	100	2.5	**1.6V to 1.9V**	√
Ch4	100	2.5	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100	1.75	**1.6V to 1.9V**	√
Ch2	100	1.75	**1.6V to 1.9V**	√
Ch3	100	1.75	**1.6V to 1.9V**	√
Ch4	100	1.75	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1	100	5	**4.8V to 5.2V**	√
Ch2	100	5	**4.8V to 5.2V**	√
Ch3	100	5	**4.8V to 5.2V**	√
Ch4	100	5	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.5	1.5	1.5	1.5
TP6	4	4	4	4	2.1	2.2	2.2	2.2
TP7	8	8	8	8	3.2	3.3	3.4	3.4

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.5	1.5	1.5	1.5	√
TP6/TP4	2	2	2	2	1.4	1.5	1.5	1.5	√
TP7/TP6	2	2	2	2	1.5	1.5	1.5	1.5	√

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10	**9.7 to 10V**	√	4.6	**4 to 5.5V**	√
Ch2	**TP10**	10	**9.7 to 10V**	√	4.4	**4 to 5.5V**	√
Ch3	**TP10**	10	**9.7 to 10V**	√	4.6	**4 to 5.5V**	√
Ch4	**TP10**	10	**9.7 to 10V**	√	4.4	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1	3	2	**1.9 to 2.1V**	√
Ch2	3	2	**1.9 to 2.1V**	√
Ch3	3	2	**1.9 to 2.1V**	√
Ch4	3	2	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0	0	0	0	√
(2) 3V in	**1V +/- 0.1V**	1	1	1	1	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5	1.5	1.5	1.5	√
(4) 6V in	**2V +/- 0.1V**	2	2	2	2	√

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Test Engineer ……Xen……
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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.716	**0.707 (0.68 to 0.72V)**	√
Ch2	0.719	**0.707 (0.68 to 0.72V)**	√
Ch3	0.713	**0.707 (0.68 to 0.72V)**	√
Ch4	0.714	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.361	**0.35V (0.33 to 0.37V)**	√
Ch2	0.363	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.984	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.988	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.981	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.981	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.016	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.020	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.010	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.014	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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Contents

1. Block diagram

2. Test equipment

3. Description

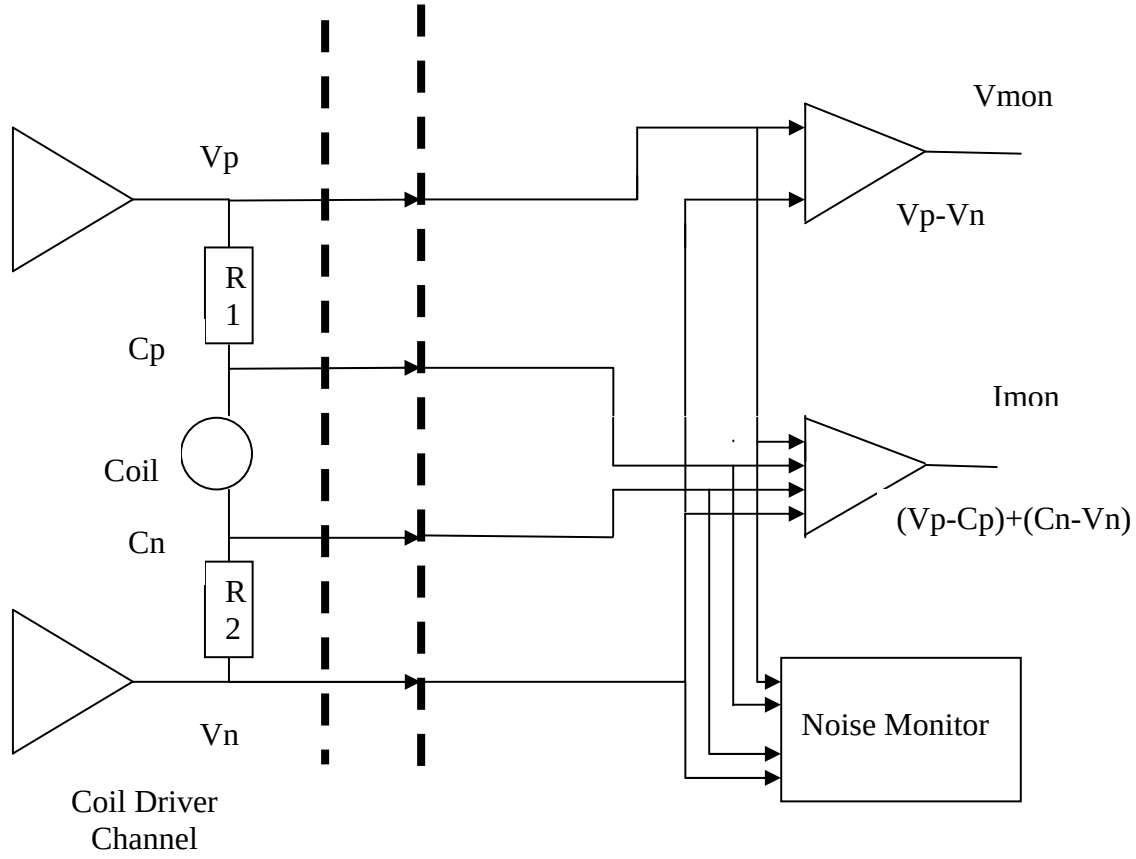
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

Serial No ……Mon45……...
Test Engineer ……Xen……
Date ……13/10/09……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No ……Mon45……...
Test Engineer ……Xen……
Date ……13/10/09……

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.98	√
-15V (TP6)	-15.02	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	300mA
-15v (TP6)	√	5mV	250mA

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.5	**2.4V to 2.6V**	√
Ch2	100	2.5	**2.4V to 2.6V**	√
Ch3	100	2.5	**2.4V to 2.6V**	√
Ch4	100	2.5	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.4	**2.4V to 2.6V**	√
Ch2	100	2.4	**2.4V to 2.6V**	√
Ch3	100	2.4	**2.4V to 2.6V**	√
Ch4	100	2.4	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude= 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100	1.8	**1.6V to 1.9V**	√
Ch2	100	1.8	**1.6V to 1.9V**	√
Ch3	100	1.8	**1.6V to 1.9V**	√
Ch4	100	1.8	**1.6V to 1.9V**	√

Serial No ……Mon45……...
Test Engineer ……Xen……
Date ……13/10/09……

Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100	1.8	**1.6V to 1.9V**	√
Ch2	100	1.8	**1.6V to 1.9V**	√
Ch3	100	1.8	**1.6V to 1.9V**	√
Ch4	100	1.8	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1	100	5	**4.8V to 5.2V**	√
Ch2	100	5	**4.8V to 5.2V**	√
Ch3	100	5	**4.8V to 5.2V**	√
Ch4	100	5	**4.8V to 5.2V**	√

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Test Engineer ……Xen……
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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.5	1.5	1.5	1.5
TP6	4	4	4	4	2.2	2.2	2.2	2.2
TP7	8	8	8	8	3.2	3.2	3.2	3.2

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.5	1.5	1.5	1.5	√
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	√
TP7/TP6	2	2	2	2	1.5	1.5	1.5	1.5	√

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10	**9.7 to 10V**	√	4.8	**4 to 5.5V**	√
Ch2	**TP10**	10	**9.7 to 10V**	√	4.6	**4 to 5.5V**	√
Ch3	**TP10**	10	**9.7 to 10V**	√	4.4	**4 to 5.5V**	√
Ch4	**TP10**	10	**9.7 to 10V**	√	4.6	**4 to 5.5V**	√

Serial No ……Mon45……...
Test Engineer ……Xen……
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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1	3	2	**1.9 to 2.1V**	√
Ch2	3	2	**1.9 to 2.1V**	√
Ch3	3	2	**1.9 to 2.1V**	√
Ch4	3	2	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0	0	0	0	√
(2) 3V in	**1V +/- 0.1V**	1	1	1	1	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5	1.5	1.5	1.5	√
(4) 6V in	**2V +/- 0.1V**	2	2	2	2	√

Serial No ……Mon45……...
Test Engineer ……Xen……
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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.718	**0.707 (0.68 to 0.72V)**	√
Ch2	0.714	**0.707 (0.68 to 0.72V)**	√
Ch3	0.714	**0.707 (0.68 to 0.72V)**	√
Ch4	0.710	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.361	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358	**0.35V (0.33 to 0.37V)**	√
Ch3	0.358	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.988	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.983	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.982	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.976	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.017	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.018	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.015	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.012	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No ……Mon46……...
Test Engineer ……Xen……
Date ……13/10/09……

Contents

1. Block diagram

2. Test equipment

3. Description

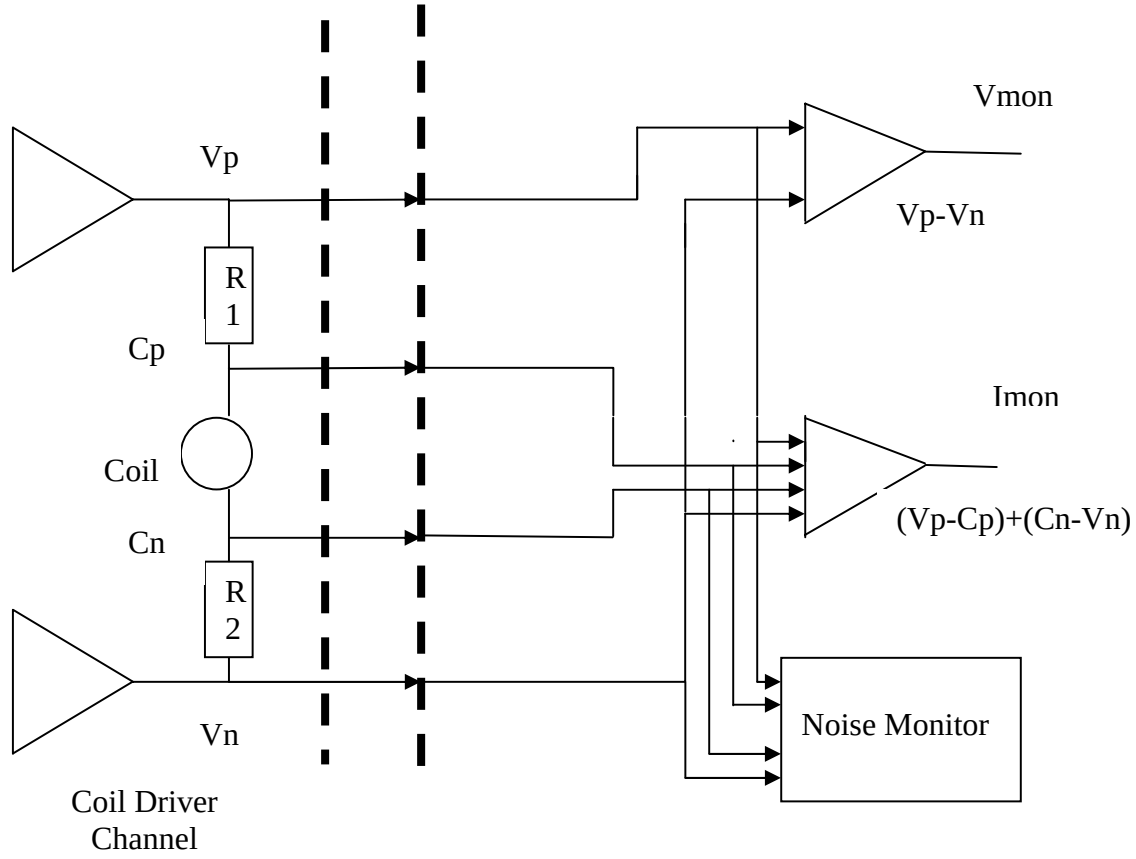
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No ……Mon46……...
Test Engineer ……Xen……
Date ……13/10/09……

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.94	√
-15V (TP6)	-15.01	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	300mA
-15v (TP6)	√	5mV	250mA

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Test Engineer ……Xen……
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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.5	**2.4V to 2.6V**	√
Ch2	100	2.5	**2.4V to 2.6V**	√
Ch3	100	2.5	**2.4V to 2.6V**	√
Ch4	100	2.5	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.4	**2.4V to 2.6V**	√
Ch2	100	2.4	**2.4V to 2.6V**	√
Ch3	100	2.4	**2.4V to 2.6V**	√
Ch4	100	2.4	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude= 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100	1.85	**1.6V to 1.9V**	√
Ch2	100	1.85	**1.6V to 1.9V**	√
Ch3	100	1.85	**1.6V to 1.9V**	√
Ch4	100	1.85	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100	1.8	**1.6V to 1.9V**	√
Ch2	100	1.8	**1.6V to 1.9V**	√
Ch3	100	1.8	**1.6V to 1.9V**	√
Ch4	100	1.8	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1	100	5	**4.8V to 5.2V**	√
Ch2	100	5	**4.8V to 5.2V**	√
Ch3	100	5	**4.8V to 5.2V**	√
Ch4	100	5	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.5	1.5	1.5	1.5
TP6	4	4	4	4	2.2	2.2	2.3	2.3
TP7	8	8	8	8	3.3	3.3	3.3	3.4

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.5	1.5	1.5	1.5	√
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	√
TP7/TP6	2	2	2	2	1.5	1.5	1.5	1.5	√

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10	9.7 to 10V	√	4.6	4 to 5.5V	√
Ch2	TP10	10	9.7 to 10V	√	4.5	4 to 5.5V	√
Ch3	TP10	10	9.7 to 10V	√	4.6	4 to 5.5V	√
Ch4	TP10	10	9.7 to 10V	√	4.4	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1	3	2	**1.9 to 2.1V**	√
Ch2	3	2	**1.9 to 2.1V**	√
Ch3	3	2	**1.9 to 2.1V**	√
Ch4	3	2	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0	0	0	0	√
(2) 3V in	**1V +/- 0.1V**	1	1	1	1	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5	1.5	1.5	1.5	√
(4) 6V in	**2V +/- 0.1V**	2	2	2	2	√

Serial No ……Mon46……...
Test Engineer ……Xen……
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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.713	**0.707 (0.68 to 0.72V)**	√
Ch2	0.714	**0.707 (0.68 to 0.72V)**	√
Ch3	0.711	**0.707 (0.68 to 0.72V)**	√
Ch4	0.712	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357	**0.35V (0.33 to 0.37V)**	√
Ch4	0.356	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.990	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.991	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.987	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.988	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.008	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.013	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.031	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.010	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No ……Mon47……...
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Date ……13/10/09……

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1. Block diagram

2. Test equipment

3. Description

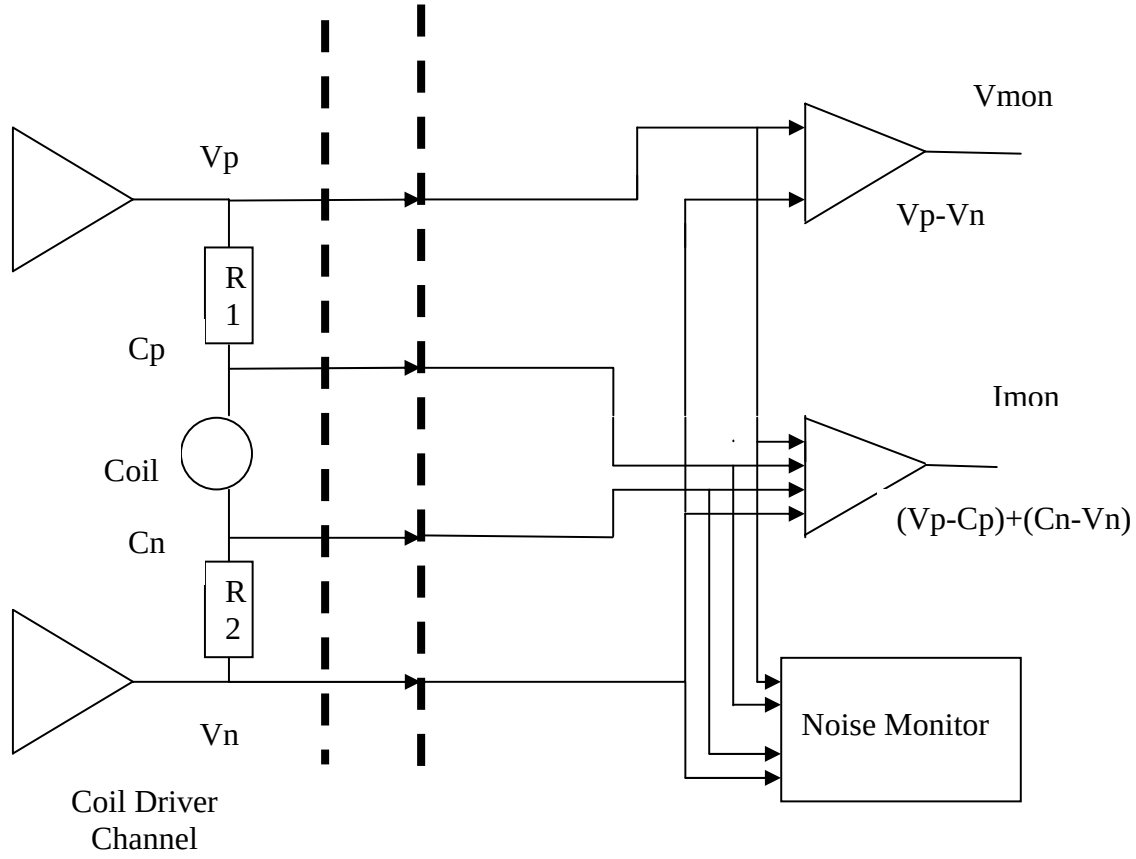
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

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Test Engineer ……Xen……
Date ……13/10/09……

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.99	√
-15V (TP6)	-14.94	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	300mA
-15v (TP6)	√	5mV	250mA

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.5	**2.4V to 2.6V**	√
Ch2	100	2.5	**2.4V to 2.6V**	√
Ch3	100	2.5	**2.4V to 2.6V**	√
Ch4	100	2.5	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.4	**2.4V to 2.6V**	√
Ch2	100	2.4	**2.4V to 2.6V**	√
Ch3	100	2.4	**2.4V to 2.6V**	√
Ch4	100	2.4	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100	1.9	**1.6V to 1.9V**	√
Ch2	100	1.9	**1.6V to 1.9V**	√
Ch3	100	1.9	**1.6V to 1.9V**	√
Ch4	100	1.9	**1.6V to 1.9V**	√

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Test Engineer ……Xen……
Date ……13/10/09……

Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100	1.8	**1.6V to 1.9V**	√
Ch2	100	1.8	**1.6V to 1.9V**	√
Ch3	100	1.8	**1.6V to 1.9V**	√
Ch4	100	1.8	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1	100	5	**4.8V to 5.2V**	√
Ch2	100	5	**4.8V to 5.2V**	√
Ch3	100	5	**4.8V to 5.2V**	√
Ch4	100	5	**4.8V to 5.2V**	√

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Test Engineer ……Xen……
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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.5	1.5	1.5	1.5
TP6	4	4	4	4	2.4	2.35	2.3	2.4
TP7	8	8	8	8	3.6	3.6	3.4	3.6

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.5	1.5	1.5	1.5	√
TP6/TP4	2	2	2	2	1.6	1.5	1.5	1.6	
TP7/TP6	2	2	2	2	1.5	1.5	1.5	1.5	√

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10	9.7 to 10V	√	4.8	4 to 5.5V	√
Ch2	TP10	10	9.7 to 10V	√	4.8	4 to 5.5V	√
Ch3	TP10	10	9.7 to 10V	√	4.6	4 to 5.5V	√
Ch4	TP10	10	9.7 to 10V	√	4.6	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1	3	2	**1.9 to 2.1V**	√
Ch2	3	2	**1.9 to 2.1V**	√
Ch3	3	2	**1.9 to 2.1V**	√
Ch4	3	2	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0	0	0	0	√
(2) 3V in	**1V +/- 0.1V**	1	1	1	1	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5	1.5	1.5	1.5	√
(4) 6V in	**2V +/- 0.1V**	2	2	2	2	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.713	**0.707 (0.68 to 0.72V)**	√
Ch2	0.711	**0.707 (0.68 to 0.72V)**	√
Ch3	0.716	**0.707 (0.68 to 0.72V)**	√
Ch4	0.715	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358	**0.35V (0.33 to 0.37V)**	√
Ch2	0.357	**0.35V (0.33 to 0.37V)**	√
Ch3	0.361	**0.35V (0.33 to 0.37V)**	√
Ch4	0.360	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.990	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.985	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.991	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.989	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.016	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.013	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.020	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.020	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No ……Mon48……...
Test Engineer ……Xen……
Date ……13/10/09……

Contents

1. Block diagram

2. Test equipment

3. Description

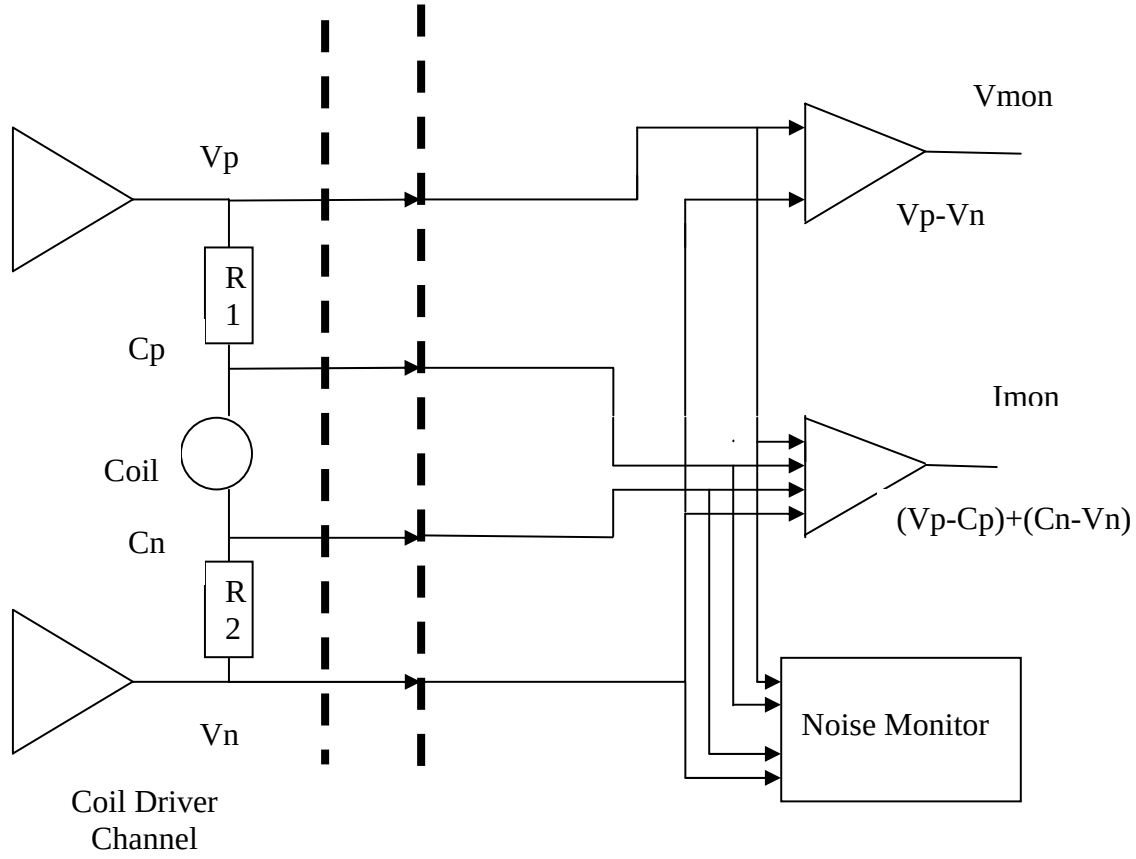
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No ……Mon48……...
Test Engineer ……Xen……
Date ……13/10/09……

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.86	√
-15V (TP6)	-15.01	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	300mA
-15v (TP6)	√	5mV	250mA

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.5	**2.4V to 2.6V**	√
Ch2	100	2.5	**2.4V to 2.6V**	√
Ch3	100	2.5	**2.4V to 2.6V**	√
Ch4	100	2.5	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.4	**2.4V to 2.6V**	√
Ch2	100	2.4	**2.4V to 2.6V**	√
Ch3	100	2.4	**2.4V to 2.6V**	√
Ch4	100	2.4	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude= 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100	1.85	**1.6V to 1.9V**	√
Ch2	100	1.85	**1.6V to 1.9V**	√
Ch3	100	1.85	**1.6V to 1.9V**	√
Ch4	100	1.85	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100	1.8	**1.6V to 1.9V**	√
Ch2	100	1.8	**1.6V to 1.9V**	√
Ch3	100	1.8	**1.6V to 1.9V**	√
Ch4	100	1.8	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1	100	5	**4.8V to 5.2V**	√
Ch2	100	5	**4.8V to 5.2V**	√
Ch3	100	5	**4.8V to 5.2V**	√
Ch4	100	5	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.5	1.5	1.5	1.5
TP6	4	4	4	4	2.3	2.3	2.3	2.3
TP7	8	8	8	8	3.4	3.4	3.5	3.4

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.5	1.5	1.5	1.5	√
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	√
TP7/TP6	2	2	2	2	1.5	1.5	1.5	1.5	√

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10	9.7 to 10V	√	4.8	4 to 5.5V	√
Ch2	TP10	10	9.7 to 10V	√	4.6	4 to 5.5V	√
Ch3	TP10	10	9.7 to 10V	√	4.6	4 to 5.5V	√
Ch4	TP10	10	9.7 to 10V	√	4.4	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1	3	2	**1.9 to 2.1V**	√
Ch2	3	2	**1.9 to 2.1V**	√
Ch3	3	2	**1.9 to 2.1V**	√
Ch4	3	2	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0	0	0	0	√
(2) 3V in	**1V +/- 0.1V**	1	1	1	1	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5	1.5	1.5	1.5	√
(4) 6V in	**2V +/- 0.1V**	2	2	2	2	√

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Date ……13/10/09……

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.719	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713	**0.707 (0.68 to 0.72V)**	√
Ch3	0.714	**0.707 (0.68 to 0.72V)**	√
Ch4	0.713	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.363	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358	**0.35V (0.33 to 0.37V)**	√
Ch3	0.359	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.983	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.976	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.977	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.976	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.023	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.014	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.014	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.020	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No ……Mon49……...
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1. Block diagram

2. Test equipment

3. Description

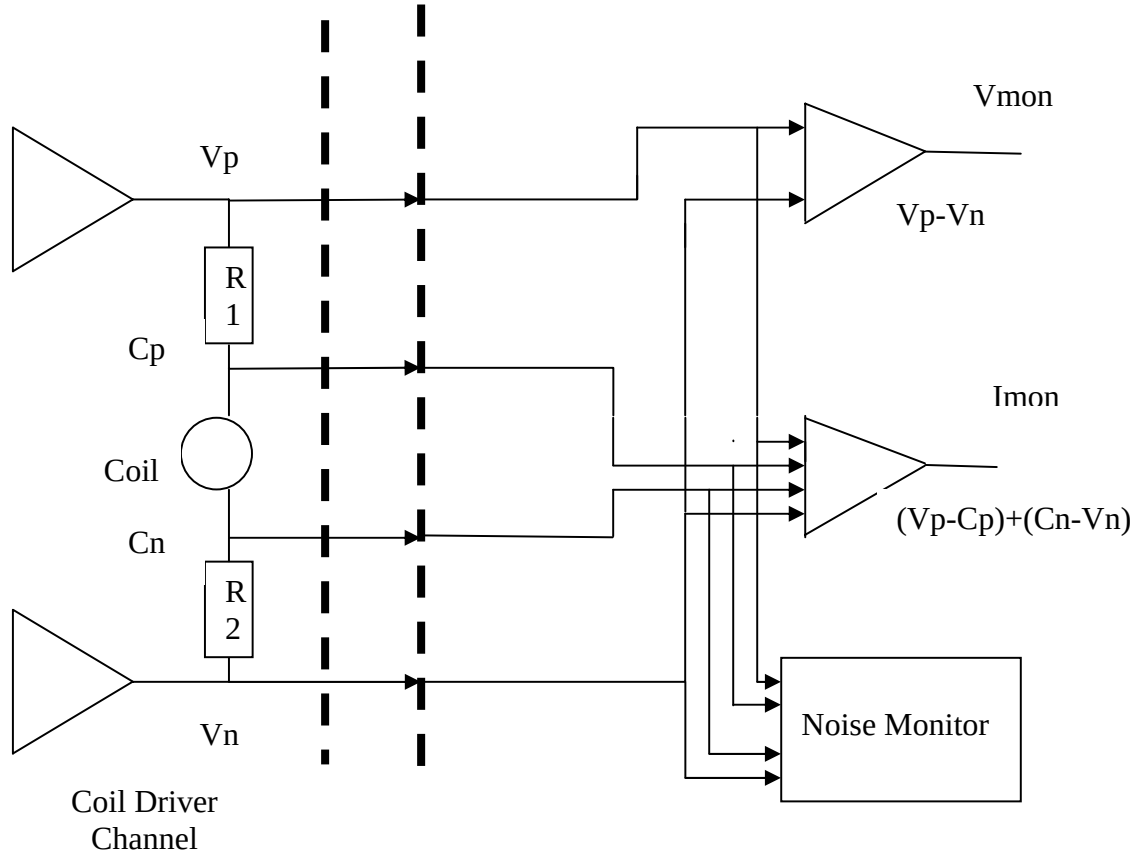
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No ……Mon49……...
Test Engineer ……Xen……
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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.94	√
-15V (TP6)	-14.94	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	300mA
-15v (TP6)	√	5mV	250mA

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.5	**2.4V to 2.6V**	√
Ch2	100	2.5	**2.4V to 2.6V**	√
Ch3	100	2.5	**2.4V to 2.6V**	√
Ch4	100	2.5	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.4	**2.4V to 2.6V**	√
Ch2	100	2.4	**2.4V to 2.6V**	√
Ch3	100	2.4	**2.4V to 2.6V**	√
Ch4	100	2.4	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100	1.8	**1.6V to 1.9V**	√
Ch2	100	1.8	**1.6V to 1.9V**	√
Ch3	100	1.8	**1.6V to 1.9V**	√
Ch4	100	1.9	**1.6V to 1.9V**	√

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Test Engineer ……Xen……
Date ……14/10/09……

Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100	1.8	**1.6V to 1.9V**	√
Ch2	100	1.8	**1.6V to 1.9V**	√
Ch3	100	1.8	**1.6V to 1.9V**	√
Ch4	100	1.8	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1	100	5	**4.8V to 5.2V**	√
Ch2	100	5	**4.8V to 5.2V**	√
Ch3	100	5	**4.8V to 5.2V**	√
Ch4	100	5	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.5	1.5	1.5	1.5
TP6	4	4	4	4	2.3	2.3	2.2	2.2
TP7	8	8	8	8	3.5	3.5	3.3	3.4

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.5	1.5	1.5	1.5	√
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	√
TP7/TP6	2	2	2	2	1.5	1.5	1.5	1.5	√

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10	9.7 to 10V	√	4.6	4 to 5.5V	√
Ch2	TP10	10	9.7 to 10V	√	4.4	4 to 5.5V	√
Ch3	TP10	10	9.7 to 10V	√	4.6	4 to 5.5V	√
Ch4	TP10	10	9.7 to 10V	√	4.8	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1	3	2	**1.9 to 2.1V**	√
Ch2	3	2	**1.9 to 2.1V**	√
Ch3	3	2	**1.9 to 2.1V**	√
Ch4	3	2	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0	0	0	0	√
(2) 3V in	**1V +/- 0.1V**	1	1	1	1	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5	1.5	1.5	1.5	√
(4) 6V in	**2V +/- 0.1V**	2	2	2	2	√

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Test Engineer ……Xen……
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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.713	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713	**0.707 (0.68 to 0.72V)**	√
Ch3	0.713	**0.707 (0.68 to 0.72V)**	√
Ch4	0.711	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358	**0.35V (0.33 to 0.37V)**	√
Ch2	0.357	**0.35V (0.33 to 0.37V)**	√
Ch3	0.358	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.988	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.987	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.988	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.983	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.013	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.007	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.015	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.017	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No ……Mon50…...
Test Engineer ……Xen…….
Date ……14/10/09…

Contents

1. Block diagram

2. Test equipment

3. Description

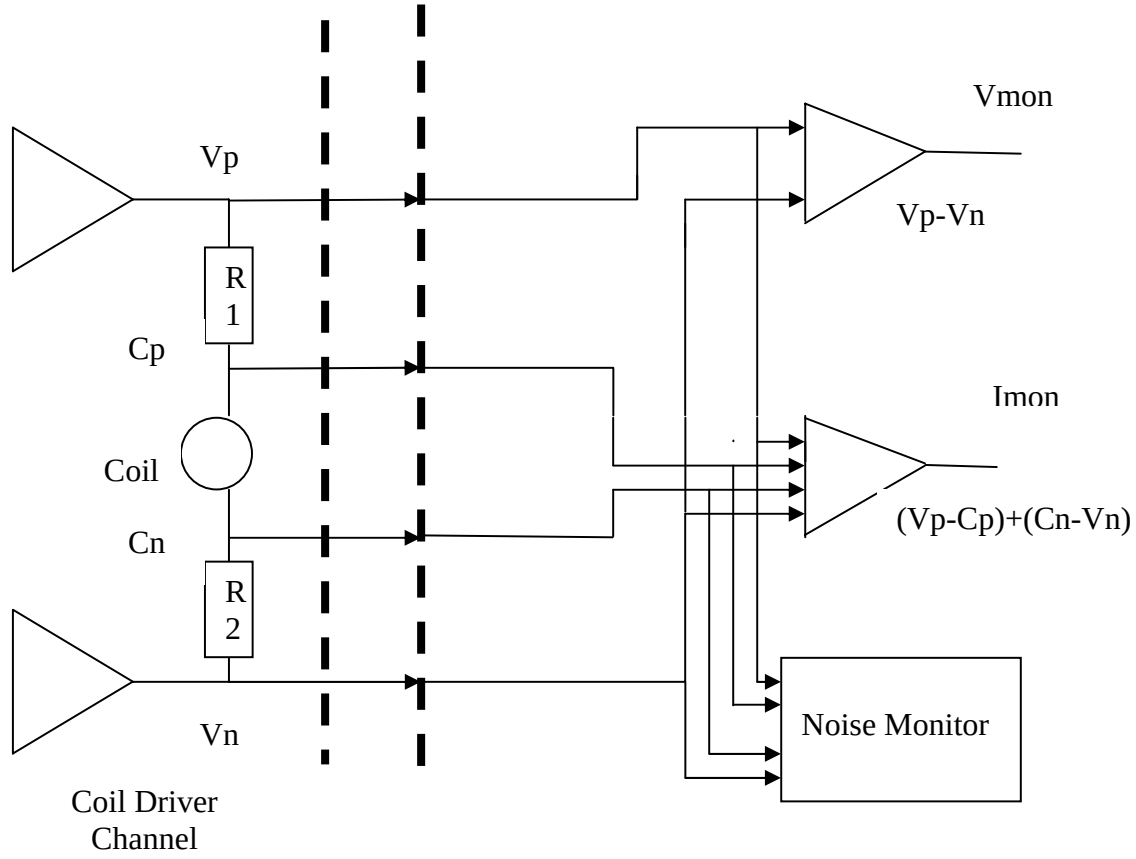
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No ……Mon50……...
Test Engineer ……Xen……
Date ……14/10/09……

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.92	√
-15V (TP6)	-15.06	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	300mA
-15v (TP6)	√	5mV	250mA

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Date ……14/10/09……

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.5	**2.4V to 2.6V**	√
Ch2	100	2.5	**2.4V to 2.6V**	√
Ch3	100	2.5	**2.4V to 2.6V**	√
Ch4	100	2.5	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.4	**2.4V to 2.6V**	√
Ch2	100	2.4	**2.4V to 2.6V**	√
Ch3	100	2.4	**2.4V to 2.6V**	√
Ch4	100	2.4	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100	1.9	**1.6V to 1.9V**	√
Ch2	100	1.9	**1.6V to 1.9V**	√
Ch3	100	1.9	**1.6V to 1.9V**	√
Ch4	100	1.9	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100	1.8	**1.6V to 1.9V**	√
Ch2	100	1.8	**1.6V to 1.9V**	√
Ch3	100	1.8	**1.6V to 1.9V**	√
Ch4	100	1.8	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1	100	5	**4.8V to 5.2V**	√
Ch2	100	5	**4.8V to 5.2V**	√
Ch3	100	5	**4.8V to 5.2V**	√
Ch4	100	5	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.5	1.5	1.5	1.5
TP6	4	4	4	4	2.2	2.3	2.3	2.2
TP7	8	8	8	8	3.4	3.4	3.4	3.4

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.5	1.5	1.5	1.5	√
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	√
TP7/TP6	2	2	2	2	1.5	1.5	1.5	1.5	√

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10	9.7 to 10V	√	4.6	4 to 5.5V	√
Ch2	TP10	10	9.7 to 10V	√	4.6	4 to 5.5V	√
Ch3	TP10	10	9.7 to 10V	√	4.4	4 to 5.5V	√
Ch4	TP10	10	9.7 to 10V	√	4.75	4 to 5.5V	√

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Test Engineer ……Xen……
Date ……14/10/09……

6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1	3	2	**1.9 to 2.1V**	√
Ch2	3	2	**1.9 to 2.1V**	√
Ch3	3	2	**1.9 to 2.1V**	√
Ch4	3	2	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0	0	0	0	√
(2) 3V in	**1V +/- 0.1V**	1	1	1	1	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5	1.5	1.5	1.5	√
(4) 6V in	**2V +/- 0.1V**	2	2	2	2	√

Serial No ……Mon50……...
Test Engineer ……Xen……
Date ……14/10/09……

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.712	**0.707 (0.68 to 0.72V)**	√
Ch2	0.714	**0.707 (0.68 to 0.72V)**	√
Ch3	0.716	**0.707 (0.68 to 0.72V)**	√
Ch4	0.712	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358	**0.35V (0.33 to 0.37V)**	√
Ch3	0.360	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.987	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.989	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.991	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.986	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.013	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.013	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.021	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.018	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No……Mon51……
Test Engineer……Xen……
Date……14/10/09……

Contents

1. Block diagram

2. Test equipment

3. Description

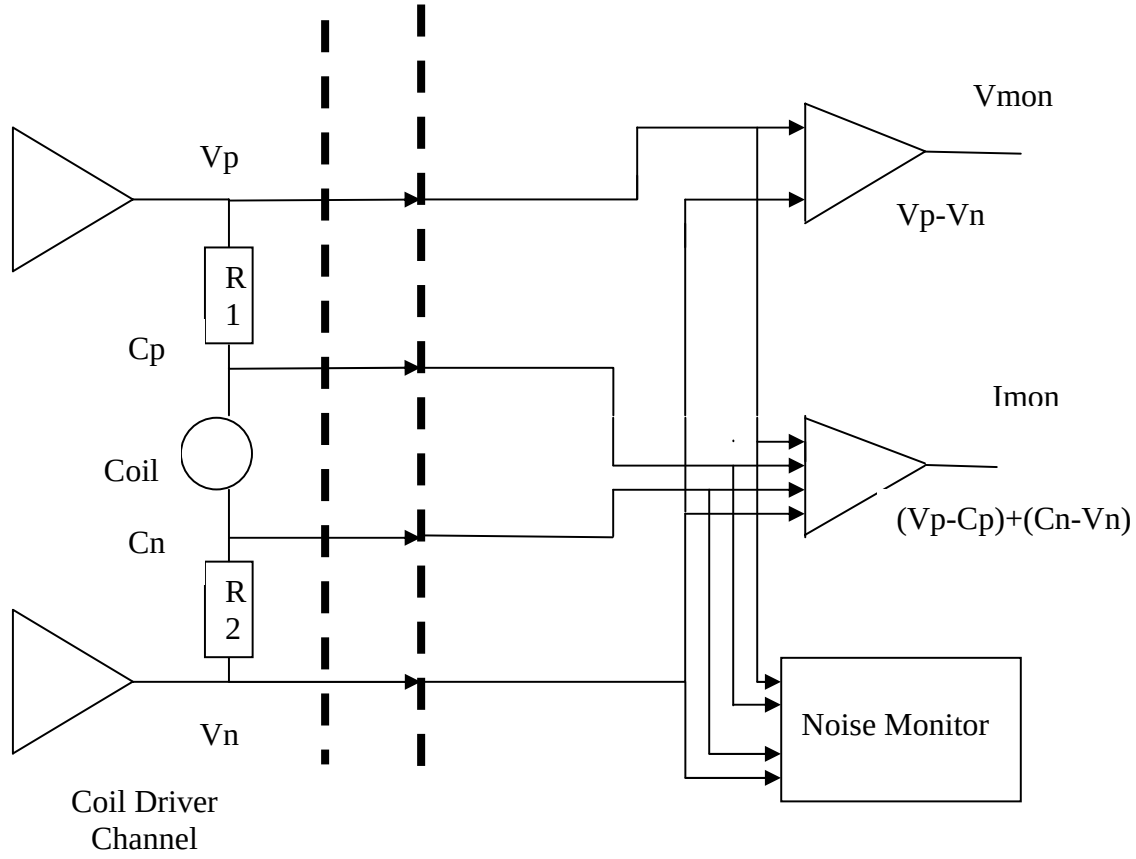
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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Test Engineer ……Xen……
Date ……14/10/09……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No ……Mon51……...
Test Engineer ……Xen……
Date ……14/10/09……

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.80	√
-15V (TP6)	-14.93	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	300mA
-15v (TP6)	√	5mV	250mA

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.5	**2.4V to 2.6V**	√
Ch2	100	2.5	**2.4V to 2.6V**	√
Ch3	100	2.5	**2.4V to 2.6V**	√
Ch4	100	2.5	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.4	**2.4V to 2.6V**	√
Ch2	100	2.4	**2.4V to 2.6V**	√
Ch3	100	2.4	**2.4V to 2.6V**	√
Ch4	100	2.4	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100	1.9	**1.6V to 1.9V**	√
Ch2	100	1.9	**1.6V to 1.9V**	√
Ch3	100	1.9	**1.6V to 1.9V**	√
Ch4	100	1.9	**1.6V to 1.9V**	√

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Test Engineer ……Xen……
Date ……14/10/09……

Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100	1.8	**1.6V to 1.9V**	√
Ch2	100	1.8	**1.6V to 1.9V**	√
Ch3	100	1.8	**1.6V to 1.9V**	√
Ch4	100	1.8	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1	100	4.8	**4.8V to 5.2V**	√
Ch2	100	4.8	**4.8V to 5.2V**	√
Ch3	100	4.8	**4.8V to 5.2V**	√
Ch4	100	4.8	**4.8V to 5.2V**	√

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Test Engineer ……Xen……
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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.5	1.5	1.5	1.5
TP6	4	4	4	4	2.2	2.2	2.2	2.2
TP7	8	8	8	8	3.4	3.4	3.4	3.4

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.5	1.5	1.5	1.5	√
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	√
TP7/TP6	2	2	2	2	1.5	1.5	1.5	1.5	√

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10	9.7 to 10V	√	4.7	4 to 5.5V	√
Ch2	TP10	10	9.7 to 10V	√	4.4	4 to 5.5V	√
Ch3	TP10	10	9.7 to 10V	√	4.6	4 to 5.5V	√
Ch4	TP10	10	9.7 to 10V	√	4.7	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1	3	2	**1.9 to 2.1V**	√
Ch2	3	2	**1.9 to 2.1V**	√
Ch3	3	2	**1.9 to 2.1V**	√
Ch4	3	2	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0	0	0	0	√
(2) 3V in	**1V +/- 0.1V**	1	1	1	1	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5	1.5	1.5	1.5	√
(4) 6V in	**2V +/- 0.1V**	2	2	2	2	√

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Test Engineer ……Xen……
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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.716	**0.707 (0.68 to 0.72V)**	√
Ch2	0.715	**0.707 (0.68 to 0.72V)**	√
Ch3	0.713	**0.707 (0.68 to 0.72V)**	√
Ch4	0.718	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.361	**0.35V (0.33 to 0.37V)**	√
Ch2	0.359	**0.35V (0.33 to 0.37V)**	√
Ch3	0.358	**0.35V (0.33 to 0.37V)**	√
Ch4	0.361	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.990	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.990	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.986	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.991	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.015	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.021	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.014	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.023	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No……Mon52…….
Test Engineer……Xen……
Date……14/10/09…….

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1. Block diagram

2. Test equipment

3. Description

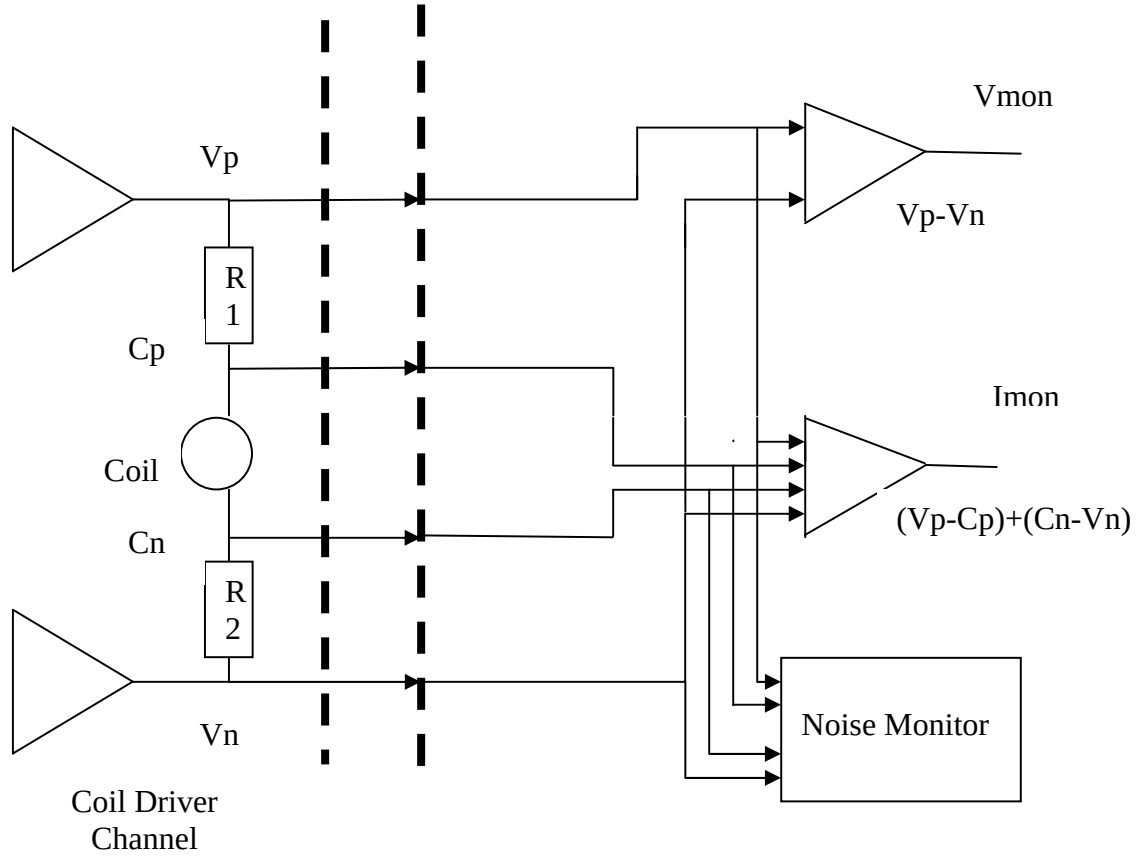
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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Date ……14/10/09……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No ……Mon52……...
Test Engineer ……Xen……
Date ……14/10/09……

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	15.04	√
-15V (TP6)	-14.99	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	300mA
-15v (TP6)	√	5mV	250mA

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Test Engineer ……Xen……
Date ……14/10/09……

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.5	**2.4V to 2.6V**	√
Ch2	100	2.5	**2.4V to 2.6V**	√
Ch3	100	2.5	**2.4V to 2.6V**	√
Ch4	100	2.5	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.4	**2.4V to 2.6V**	√
Ch2	100	2.4	**2.4V to 2.6V**	√
Ch3	100	2.4	**2.4V to 2.6V**	√
Ch4	100	2.4	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100	1.9	**1.6V to 1.9V**	√
Ch2	100	1.9	**1.6V to 1.9V**	√
Ch3	100	1.9	**1.6V to 1.9V**	√
Ch4	100	1.9	**1.6V to 1.9V**	√

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Test Engineer ……Xen……
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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100	1.8	**1.6V to 1.9V**	√
Ch2	100	1.8	**1.6V to 1.9V**	√
Ch3	100	1.8	**1.6V to 1.9V**	√
Ch4	100	1.8	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1	100	4.8	**4.8V to 5.2V**	√
Ch2	100	4.8	**4.8V to 5.2V**	√
Ch3	100	4.8	**4.8V to 5.2V**	√
Ch4	100	4.8	**4.8V to 5.2V**	√

Serial No ……Mon52……...
Test Engineer ……Xen……
Date ……14/10/09……

Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.5	1.5	1.5	1.5
TP6	4	4	4	4	2.3	2.3	2.3	2.2
TP7	8	8	8	8	3.4	3.4	3.4	3.4

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.5	1.5	1.5	1.5	√
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	√
TP7/TP6	2	2	2	2	1.5	1.5	1.5	1.5	√

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10	9.7 to 10V	√	4.5	4 to 5.5V	√
Ch2	TP10	10	9.7 to 10V	√	4.4	4 to 5.5V	√
Ch3	TP10	10	9.7 to 10V	√	4.8	4 to 5.5V	√
Ch4	TP10	10	9.7 to 10V	√	4.8	4 to 5.5V	√

Serial No ……Mon52……...
Test Engineer ……Xen……
Date ……14/10/09……

6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1	3	2	**1.9 to 2.1V**	√
Ch2	3	2	**1.9 to 2.1V**	√
Ch3	3	2	**1.9 to 2.1V**	√
Ch4	3	2	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0	0	0	0	√
(2) 3V in	**1V +/- 0.1V**	1	1	1	1	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5	1.5	1.5	1.5	√
(4) 6V in	**2V +/- 0.1V**	2	2	2	2	√

Serial No ……Mon52……...
Test Engineer ……Xen……
Date ……14/10/09……

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.710	**0.707 (0.68 to 0.72V)**	√
Ch2	0.714	**0.707 (0.68 to 0.72V)**	√
Ch3	0.714	**0.707 (0.68 to 0.72V)**	√
Ch4	0.713	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358	**0.35V (0.33 to 0.37V)**	√
Ch3	0.359	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.975	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.979	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.980	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.979	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.015	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.019	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.014	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.011	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No……Mon53……
Test Engineer……Xen……
Date……14/10/09……

Contents

1. Block diagram

2. Test equipment

3. Description

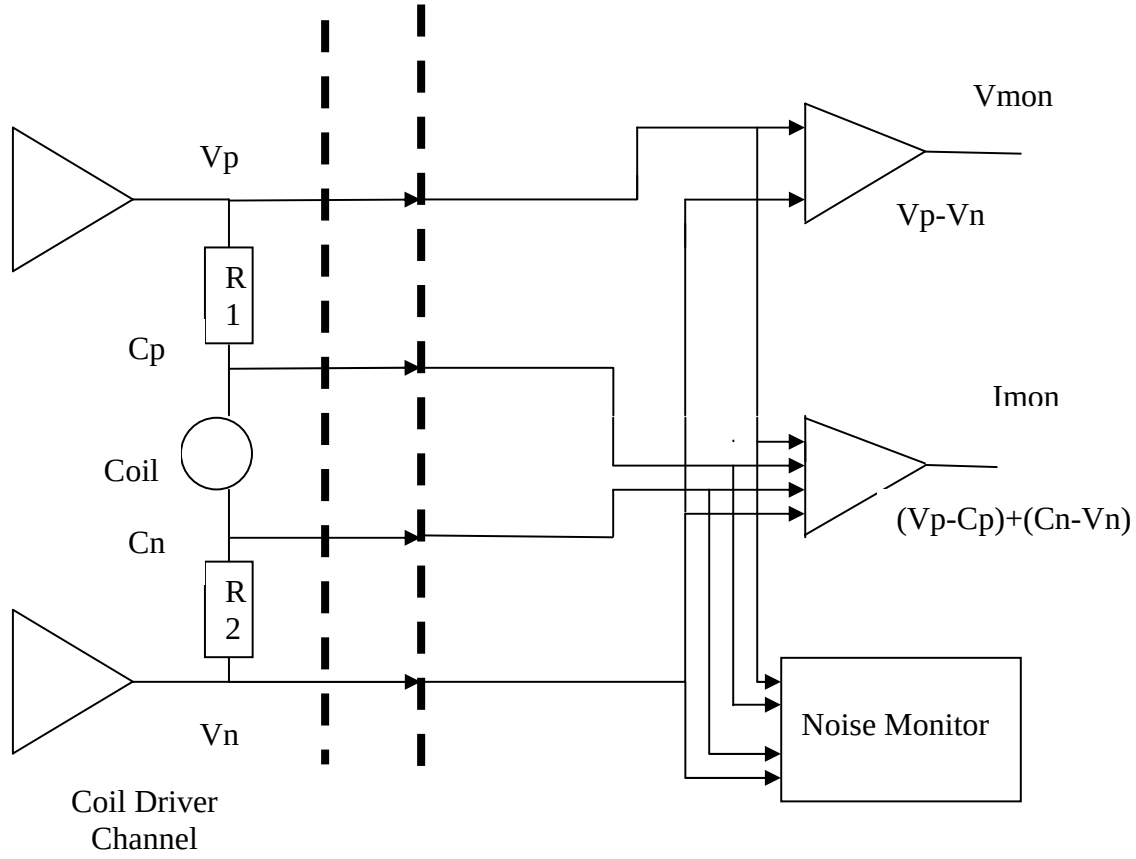
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

Serial No ……Mon53……...
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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No ……Mon53……...
Test Engineer ……Xen……
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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.86	√
-15V (TP6)	-14.95	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	300mA
-15v (TP6)	√	5mV	250mA

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.5	**2.4V to 2.6V**	√
Ch2	100	2.5	**2.4V to 2.6V**	√
Ch3	100	2.5	**2.4V to 2.6V**	√
Ch4	100	2.5	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.4	**2.4V to 2.6V**	√
Ch2	100	2.4	**2.4V to 2.6V**	√
Ch3	100	2.4	**2.4V to 2.6V**	√
Ch4	100	2.4	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100	1.9	**1.6V to 1.9V**	√
Ch2	100	1.9	**1.6V to 1.9V**	√
Ch3	100	1.9	**1.6V to 1.9V**	√
Ch4	100	1.9	**1.6V to 1.9V**	√

Serial No ……Mon53……...
Test Engineer ……Xen……
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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100	1.8	**1.6V to 1.9V**	√
Ch2	100	1.8	**1.6V to 1.9V**	√
Ch3	100	1.8	**1.6V to 1.9V**	√
Ch4	100	1.8	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1	100	4.8	**4.8V to 5.2V**	√
Ch2	100	4.8	**4.8V to 5.2V**	√
Ch3	100	4.8	**4.8V to 5.2V**	√
Ch4	100	4.8	**4.8V to 5.2V**	√

Serial No ……Mon53……...
Test Engineer ……Xen……
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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.5	1.5	1.5	1.5
TP6	4	4	4	4	2.2	2.3	2.2	2.3
TP7	8	8	8	8	3.3	3.4	3.3	3.3

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.5	1.5	1.5	1.5	√
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	√
TP7/TP6	2	2	2	2	1.5	1.5	1.5	1.4	√

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10	**9.7 to 10V**	√	4.8	**4 to 5.5V**	√
Ch2	**TP10**	10	**9.7 to 10V**	√	4.6	**4 to 5.5V**	√
Ch3	**TP10**	10	**9.7 to 10V**	√	4.6	**4 to 5.5V**	√
Ch4	**TP10**	10	**9.7 to 10V**	√	4.6	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1	3	2	**1.9 to 2.1V**	√
Ch2	3	2	**1.9 to 2.1V**	√
Ch3	3	2	**1.9 to 2.1V**	√
Ch4	3	2	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0	0	0	0	√
(2) 3V in	**1V +/- 0.1V**	1	1	1	1	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5	1.5	1.5	1.5	√
(4) 6V in	**2V +/- 0.1V**	2	2	2	2	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.714	**0.707 (0.68 to 0.72V)**	√
Ch2	0.716	**0.707 (0.68 to 0.72V)**	√
Ch3	0.715	**0.707 (0.68 to 0.72V)**	√
Ch4	0.712	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.359	**0.35V (0.33 to 0.37V)**	√
Ch2	0.360	**0.35V (0.33 to 0.37V)**	√
Ch3	0.359	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.983	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.985	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.984	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.981	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.014	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.020	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.025	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.015	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No……Mon54…….
Test Engineer……Xen……
Date……15/10/09…….

Contents

1. Block diagram

2. Test equipment

3. Description

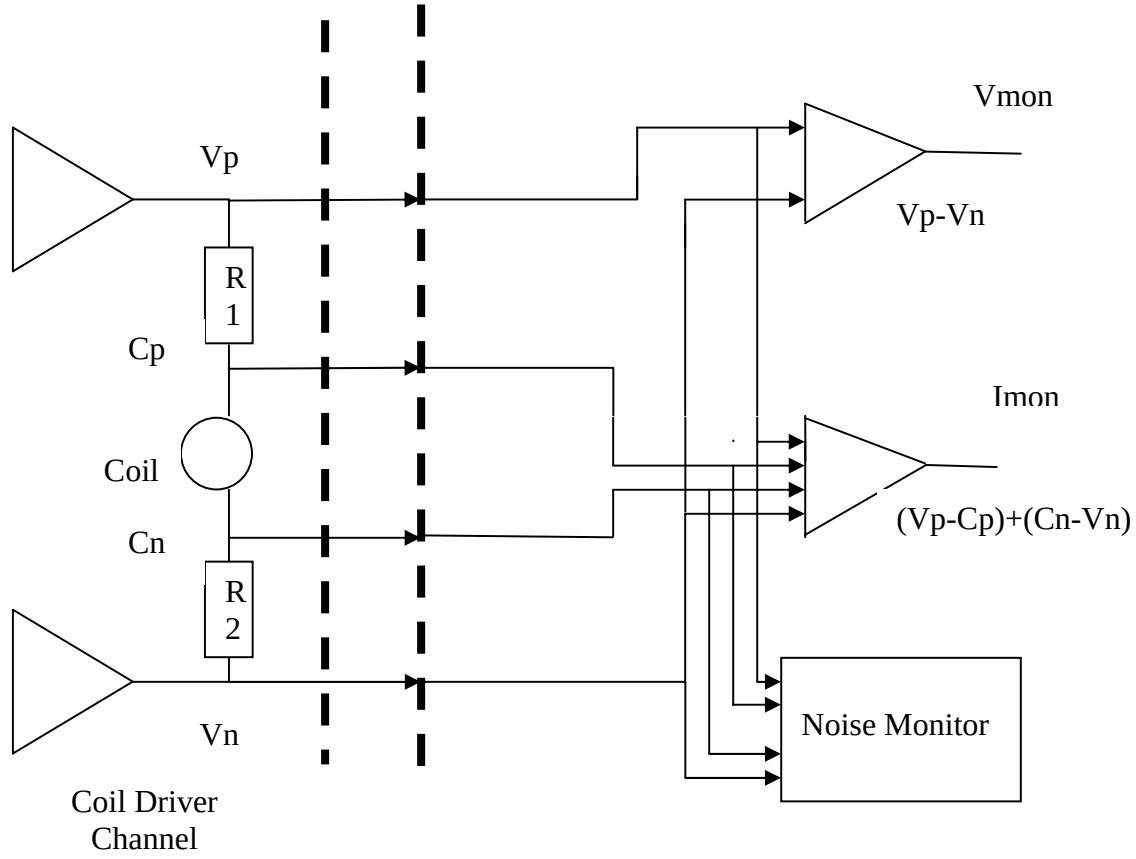
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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Test Engineer ……Xen……
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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No ……Mon54……...
Test Engineer ……Xen……
Date ……15/10/09……

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.83	√
-15V (TP6)	-14.91	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	300mA
-15v (TP6)	√	5mV	250mA

Serial No ……Mon54……...
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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.5	**2.4V to 2.6V**	√
Ch2	100	2.5	**2.4V to 2.6V**	√
Ch3	100	2.5	**2.4V to 2.6V**	√
Ch4	100	2.5	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.4	**2.4V to 2.6V**	√
Ch2	100	2.4	**2.4V to 2.6V**	√
Ch3	100	2.4	**2.4V to 2.6V**	√
Ch4	100	2.4	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100	1.9	**1.6V to 1.9V**	√
Ch2	100	1.8	**1.6V to 1.9V**	√
Ch3	100	1.8	**1.6V to 1.9V**	√
Ch4	100	1.9	**1.6V to 1.9V**	√

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Test Engineer ……Xen……
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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100	1.8	**1.6V to 1.9V**	√
Ch2	100	1.8	**1.6V to 1.9V**	√
Ch3	100	1.8	**1.6V to 1.9V**	√
Ch4	100	1.8	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1	100	4.8	**4.8V to 5.2V**	√
Ch2	100	4.8	**4.8V to 5.2V**	√
Ch3	100	4.8	**4.8V to 5.2V**	√
Ch4	100	4.8	**4.8V to 5.2V**	√

Serial No ……Mon54……...
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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.5	1.5	1.5	1.5
TP6	4	4	4	4	2.3	2.2	2.2	2.2
TP7	8	8	8	8	3.4	3.4	3.4	3.4

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.5	1.5	1.5	1.5	√
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	√
TP7/TP6	2	2	2	2	1.5	1.5	1.5	1.5	√

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10	9.7 to 10V	√	4.6	4 to 5.5V	√
Ch2	TP10	10	9.7 to 10V	√	4.4	4 to 5.5V	√
Ch3	TP10	10	9.7 to 10V	√	4.7	4 to 5.5V	√
Ch4	TP10	10	9.7 to 10V	√	4.7	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1	3	2	**1.9 to 2.1V**	√
Ch2	3	2	**1.9 to 2.1V**	√
Ch3	3	2	**1.9 to 2.1V**	√
Ch4	3	2	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0	0	0	0	√
(2) 3V in	**1V +/- 0.1V**	1	1	1	1	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5	1.5	1.5	1.5	√
(4) 6V in	**2V +/- 0.1V**	2	2	2	2	√

Serial No ……Mon54……...
Test Engineer ……Xen……
Date ……15/10/09……

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.716	**0.707 (0.68 to 0.72V)**	√
Ch2	0.709	**0.707 (0.68 to 0.72V)**	√
Ch3	0.715	**0.707 (0.68 to 0.72V)**	√
Ch4	0.710	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.360	**0.35V (0.33 to 0.37V)**	√
Ch2	0.355	**0.35V (0.33 to 0.37V)**	√
Ch3	0.359	**0.35V (0.33 to 0.37V)**	√
Ch4	0.355	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.997	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.989	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.995	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.995	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.020	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.005	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.018	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.007	**1V (0.9 to 1.1V)**	√

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MONITOR BOARD TEST PLAN

Serial No……Mon55…….
Test Engineer……Xen……
Date……15/10/09…….

Contents

1. Block diagram

2. Test equipment

3. Description

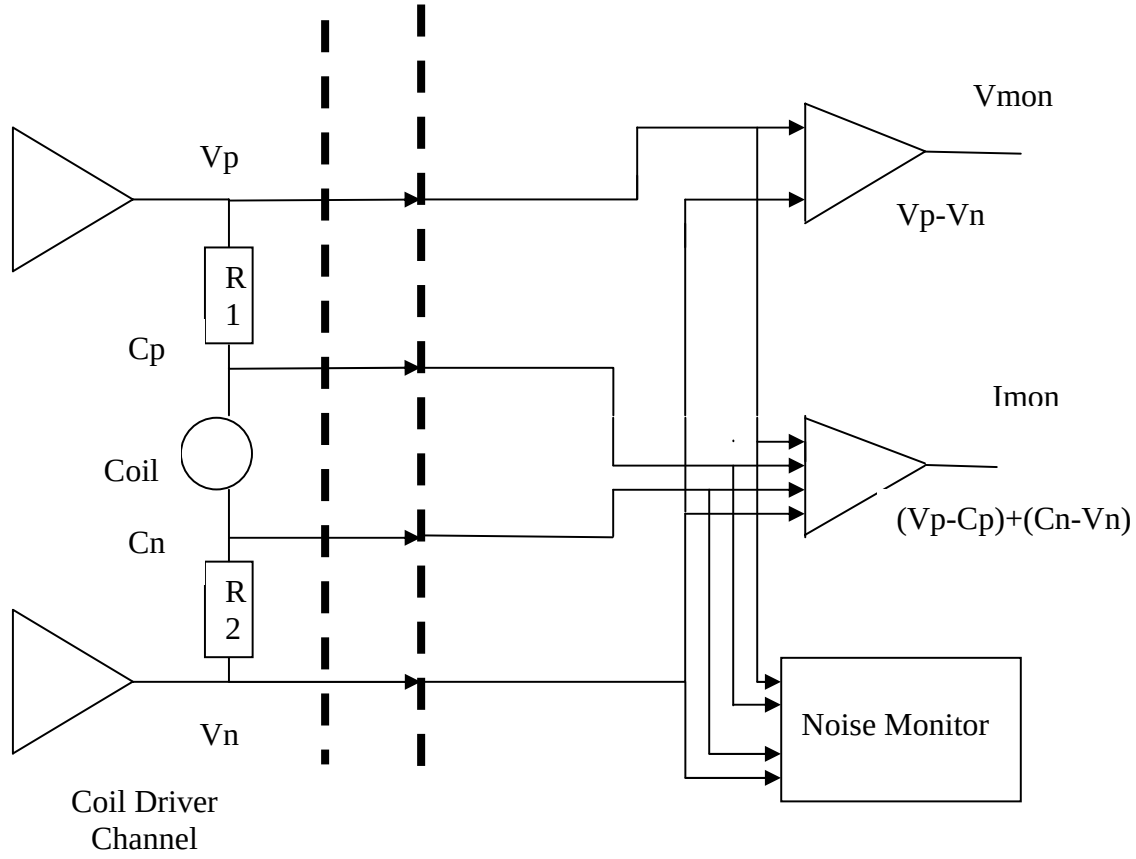
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No ……Mon55……...
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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	15.00	√
-15V (TP6)	-14.93	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	300mA
-15v (TP6)	√	5mV	250mA

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.5	**2.4V to 2.6V**	√
Ch2	100	2.5	**2.4V to 2.6V**	√
Ch3	100	2.5	**2.4V to 2.6V**	√
Ch4	100	2.5	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.4	**2.4V to 2.6V**	√
Ch2	100	2.4	**2.4V to 2.6V**	√
Ch3	100	2.4	**2.4V to 2.6V**	√
Ch4	100	2.4	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100	1.85	**1.6V to 1.9V**	√
Ch2	100	1.85	**1.6V to 1.9V**	√
Ch3	100	1.85	**1.6V to 1.9V**	√
Ch4	100	1.85	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100	1.8	**1.6V to 1.9V**	√
Ch2	100	1.8	**1.6V to 1.9V**	√
Ch3	100	1.8	**1.6V to 1.9V**	√
Ch4	100	1.8	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1	100	4.8	**4.8V to 5.2V**	√
Ch2	100	4.8	**4.8V to 5.2V**	√
Ch3	100	4.8	**4.8V to 5.2V**	√
Ch4	100	4.8	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.5	1.5	1.5	1.5
TP6	4	4	4	4	2.2	2.2	2.2	2.2
TP7	8	8	8	8	3.4	3.4	3.4	3.4

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.5	1.5	1.5	1.5	√
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	√
TP7/TP6	2	2	2	2	1.5	1.5	1.5	1.5	√

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10	9.7 to 10V	√	4.6	4 to 5.5V	√
Ch2	TP10	10	9.7 to 10V	√	4.8	4 to 5.5V	√
Ch3	TP10	10	9.7 to 10V	√	4.4	4 to 5.5V	√
Ch4	TP10	10	9.7 to 10V	√	4.8	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1	3	2	**1.9 to 2.1V**	√
Ch2	3	2	**1.9 to 2.1V**	√
Ch3	3	2	**1.9 to 2.1V**	√
Ch4	3	2	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0	0	0	0	√
(2) 3V in	**1V +/- 0.1V**	1	1	1	1	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5	1.5	1.5	1.5	√
(4) 6V in	**2V +/- 0.1V**	2	2	2	2	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.714	**0.707 (0.68 to 0.72V)**	√
Ch2	0.716	**0.707 (0.68 to 0.72V)**	√
Ch3	0.714	**0.707 (0.68 to 0.72V)**	√
Ch4	0.713	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.359	**0.35V (0.33 to 0.37V)**	√
Ch2	0.360	**0.35V (0.33 to 0.37V)**	√
Ch3	0.358	**0.35V (0.33 to 0.37V)**	√
Ch4	0.359	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.986	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.988	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.985	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.983	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.012	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.018	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.011	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.012	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No……Mon56……
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1. Block diagram

2. Test equipment

3. Description

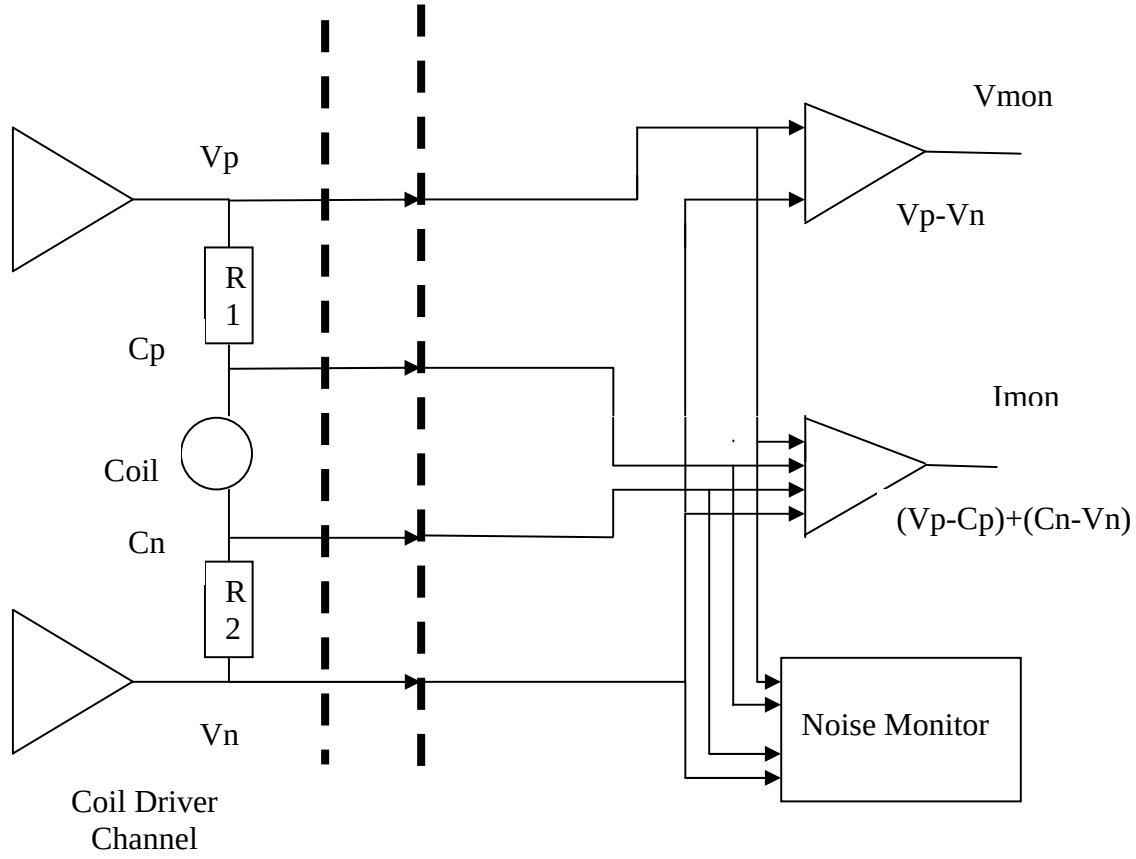
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No ……Mon56……...
Test Engineer ……Xen……
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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.93	√
-15V (TP6)	-15.02	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	300mA
-15v (TP6)	√	5mV	250mA

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.5	**2.4V to 2.6V**	√
Ch2	100	2.5	**2.4V to 2.6V**	√
Ch3	100	2.5	**2.4V to 2.6V**	√
Ch4	100	2.5	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.4	**2.4V to 2.6V**	√
Ch2	100	2.4	**2.4V to 2.6V**	√
Ch3	100	2.4	**2.4V to 2.6V**	√
Ch4	100	2.4	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100	1.8	**1.6V to 1.9V**	√
Ch2	100	1.8	**1.6V to 1.9V**	√
Ch3	100	1.8	**1.6V to 1.9V**	√
Ch4	100	1.8	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100	1.8	**1.6V to 1.9V**	√
Ch2	100	1.8	**1.6V to 1.9V**	√
Ch3	100	1.8	**1.6V to 1.9V**	√
Ch4	100	1.8	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1	100	4.8	**4.8V to 5.2V**	√
Ch2	100	4.8	**4.8V to 5.2V**	√
Ch3	100	4.8	**4.8V to 5.2V**	√
Ch4	100	4.8	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.5	1.5	1.5	1.5
TP6	4	4	4	4	2.3	2.3	2.3	2.3
TP7	8	8	8	8	3.4	3.5	3.5	3.4

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.5	1.5	1.5	1.5	√
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	√
TP7/TP6	2	2	2	2	1.5	1.5	1.5	1.5	√

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10	9.7 to 10V	√	4.6	4 to 5.5V	√
Ch2	TP10	10	9.7 to 10V	√	4.8	4 to 5.5V	√
Ch3	TP10	10	9.7 to 10V	√	4.6	4 to 5.5V	√
Ch4	TP10	10	9.7 to 10V	√	4.6	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1	3	2	**1.9 to 2.1V**	√
Ch2	3	2	**1.9 to 2.1V**	√
Ch3	3	2	**1.9 to 2.1V**	√
Ch4	3	2	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0	0	0	0	√
(2) 3V in	**1V +/- 0.1V**	1	1	1	1	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5	1.5	1.5	1.5	√
(4) 6V in	**2V +/- 0.1V**	2	2	2	2	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.715	**0.707 (0.68 to 0.72V)**	√
Ch2	0.708	**0.707 (0.68 to 0.72V)**	√
Ch3	0.716	**0.707 (0.68 to 0.72V)**	√
Ch4	0.712	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.360	**0.35V (0.33 to 0.37V)**	√
Ch2	0.354	**0.35V (0.33 to 0.37V)**	√
Ch3	0.360	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.992	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.984	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.992	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.988	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.021	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.013	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.014	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.013	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No……Mon57……
Test Engineer……Xen……
Date……16/10/09……

Contents

1. Block diagram

2. Test equipment

3. Description

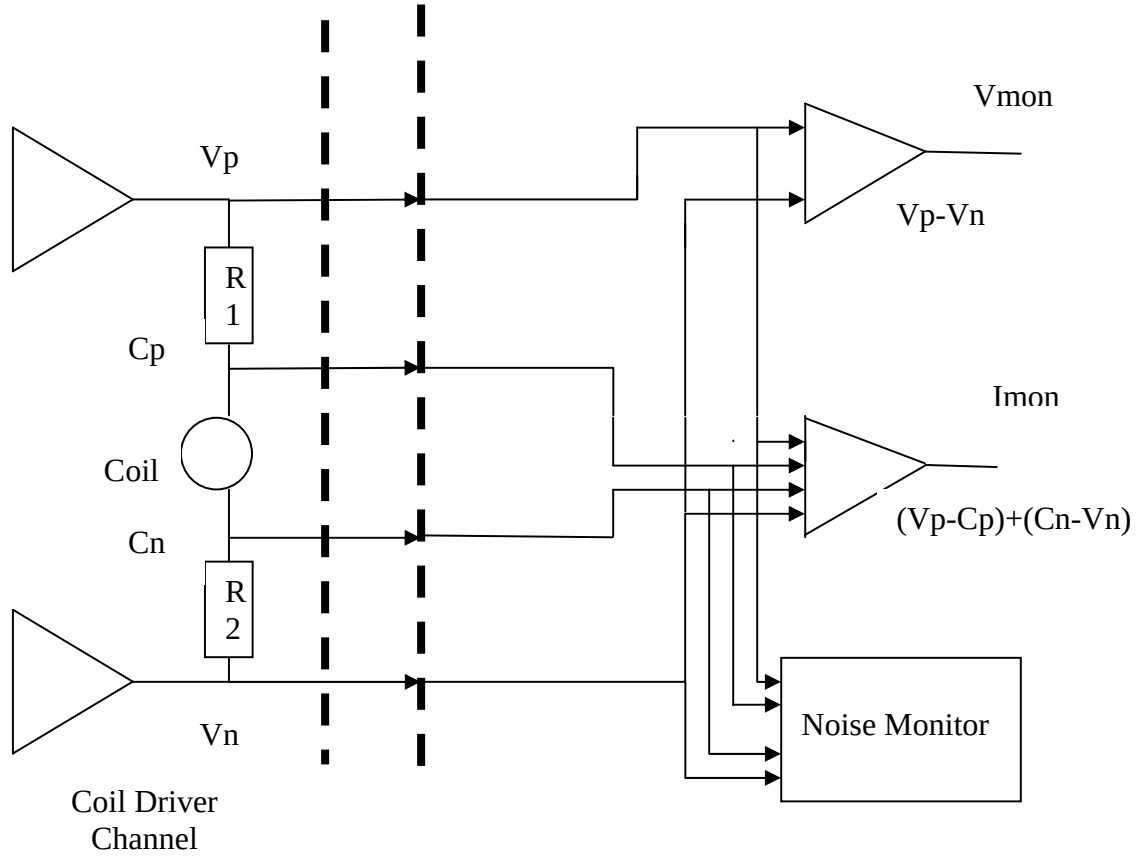
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No ……Mon57……...
Test Engineer ……Xen……
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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.98	√
-15V (TP6)	-14.93	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	300mA
-15v (TP6)	√	5mV	250mA

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.5	**2.4V to 2.6V**	√
Ch2	100	2.5	**2.4V to 2.6V**	√
Ch3	100	2.5	**2.4V to 2.6V**	√
Ch4	100	2.5	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.4	**2.4V to 2.6V**	√
Ch2	100	2.4	**2.4V to 2.6V**	√
Ch3	100	2.4	**2.4V to 2.6V**	√
Ch4	100	2.4	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100	1.9	**1.6V to 1.9V**	√
Ch2	100	1.9	**1.6V to 1.9V**	√
Ch3	100	1.9	**1.6V to 1.9V**	√
Ch4	100	1.9	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100	1.8	**1.6V to 1.9V**	√
Ch2	100	1.8	**1.6V to 1.9V**	√
Ch3	100	1.8	**1.6V to 1.9V**	√
Ch4	100	1.8	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1	100	4.8	**4.8V to 5.2V**	√
Ch2	100	4.8	**4.8V to 5.2V**	√
Ch3	100	4.8	**4.8V to 5.2V**	√
Ch4	100	4.8	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.5	1.5	1.5	1.5
TP6	4	4	4	4	2.3	2.2	2.3	2.2
TP7	8	8	8	8	3.4	3.4	3.4	3.4

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.5	1.5	1.5	1.5	√
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	√
TP7/TP6	2	2	2	2	1.5	1.5	1.5	1.5	√

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10	9.7 to 10V	√	4.6	4 to 5.5V	√
Ch2	TP10	10	9.7 to 10V	√	4.4	4 to 5.5V	√
Ch3	TP10	10	9.7 to 10V	√	4.4	4 to 5.5V	√
Ch4	TP10	10	9.7 to 10V	√	4.6	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1	3	2	**1.9 to 2.1V**	√
Ch2	3	2	**1.9 to 2.1V**	√
Ch3	3	2	**1.9 to 2.1V**	√
Ch4	3	2	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0	0	0	0	√
(2) 3V in	**1V +/- 0.1V**	1	1	1	1	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5	1.5	1.5	1.5	√
(4) 6V in	**2V +/- 0.1V**	2	2	2	2	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.712	**0.707 (0.68 to 0.72V)**	√
Ch2	0.712	**0.707 (0.68 to 0.72V)**	√
Ch3	0.711	**0.707 (0.68 to 0.72V)**	√
Ch4	0.711	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357	**0.35V (0.33 to 0.37V)**	√
Ch2	0.359	**0.35V (0.33 to 0.37V)**	√
Ch3	0.356	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.989	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.988	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.987	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.987	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.013	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.011	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.010	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.011	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No……Mon58……
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1. Block diagram

2. Test equipment

3. Description

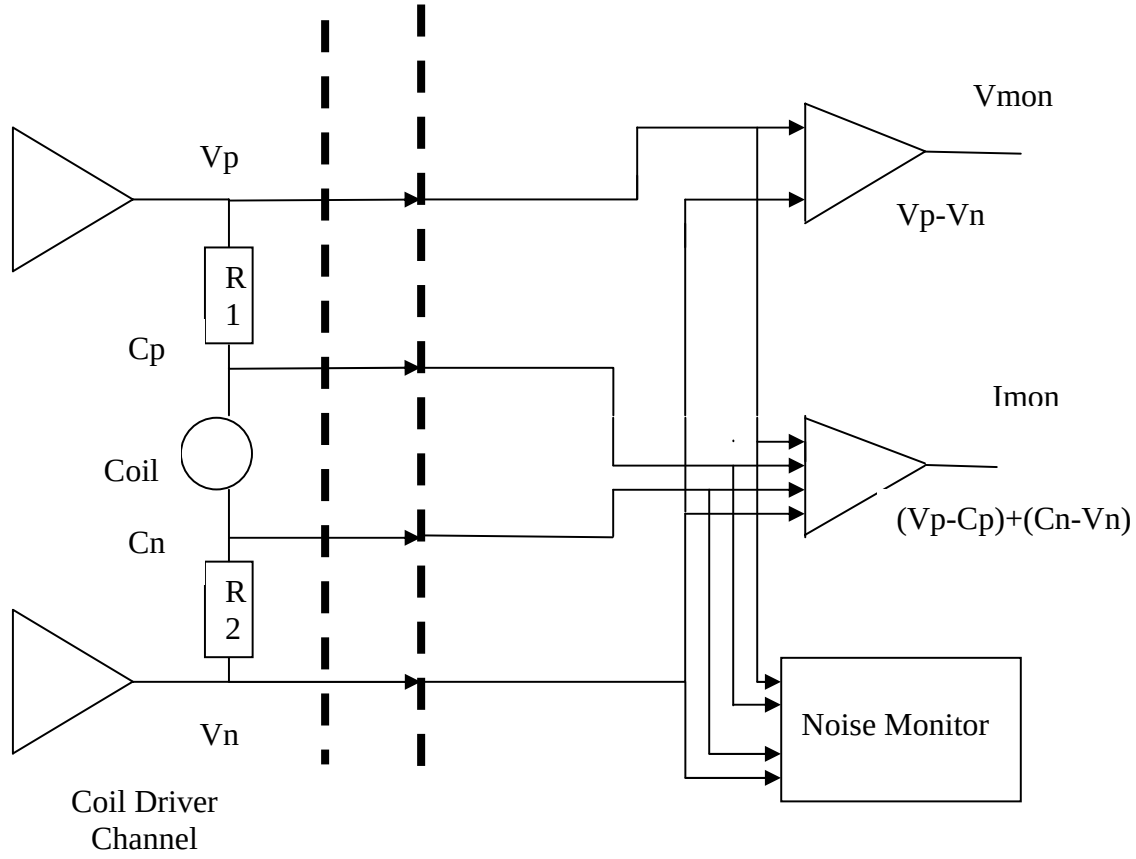
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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Test Engineer ……Xen……
Date ……16/10/09……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No ……Mon58……...
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Date ……16/10/09……

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.82	√
-15V (TP6)	-14.97	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	300mA
-15v (TP6)	√	5mV	250mA

Serial No ……Mon58……...
Test Engineer ……Xen……
Date ……16/10/09……

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.5	**2.4V to 2.6V**	√
Ch2	100	2.5	**2.4V to 2.6V**	√
Ch3	100	2.5	**2.4V to 2.6V**	√
Ch4	100	2.5	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100	2.4	**2.4V to 2.6V**	√
Ch2	100	2.4	**2.4V to 2.6V**	√
Ch3	100	2.4	**2.4V to 2.6V**	√
Ch4	100	2.4	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100	1.9	**1.6V to 1.9V**	√
Ch2	100	1.9	**1.6V to 1.9V**	√
Ch3	100	1.9	**1.6V to 1.9V**	√
Ch4	100	1.9	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100	1.8	**1.6V to 1.9V**	√
Ch2	100	1.8	**1.6V to 1.9V**	√
Ch3	100	1.8	**1.6V to 1.9V**	√
Ch4	100	1.8	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1	100	4.8	**4.8V to 5.2V**	√
Ch2	100	4.8	**4.8V to 5.2V**	√
Ch3	100	4.8	**4.8V to 5.2V**	√
Ch4	100	4.8	**4.8V to 5.2V**	√

Serial No ……Mon58……...
Test Engineer ……Xen……
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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.5	1.5	1.5	1.5
TP6	4	4	4	4	2.35	2.35	2.3	2.3
TP7	8	8	8	8	3.6	3.6	3.5	3.5

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.5	1.5	1.5	1.5	√
TP6/TP4	2	2	2	2	1.56	1.56	1.5	1.5	
TP7/TP6	2	2	2	2	1.5	1.5	1.5	1.5	√

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10	**9.7 to 10V**	√	4.4	**4 to 5.5V**	√
Ch2	**TP10**	10	**9.7 to 10V**	√	4.6	**4 to 5.5V**	√
Ch3	**TP10**	10	**9.7 to 10V**	√	4.8	**4 to 5.5V**	√
Ch4	**TP10**	10	**9.7 to 10V**	√	4.4	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1	3	2	**1.9 to 2.1V**	√
Ch2	3	2	**1.9 to 2.1V**	√
Ch3	3	2	**1.9 to 2.1V**	√
Ch4	3	2	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0	0	0	0	√
(2) 3V in	**1V +/- 0.1V**	1	1	1	1	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5	1.5	1.5	1.5	√
(4) 6V in	**2V +/- 0.1V**	2	2	2	2	√

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Test Engineer ……Xen……
Date ……16/10/09……

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.713	**0.707 (0.68 to 0.72V)**	√
Ch2	0.712	**0.707 (0.68 to 0.72V)**	√
Ch3	0.717	**0.707 (0.68 to 0.72V)**	√
Ch4	0.710	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.360	**0.35V (0.33 to 0.37V)**	√
Ch2	0.354	**0.35V (0.33 to 0.37V)**	√
Ch3	0.360	**0.35V (0.33 to 0.37V)**	√
Ch4	0.356	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.991	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.992	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.997	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.987	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.006	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.014	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.017	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.004	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon59……
Test Engineer…Simon Pyatt……
Date…26/01/10……

Contents

1. Block diagram

2. Test equipment

3. Description

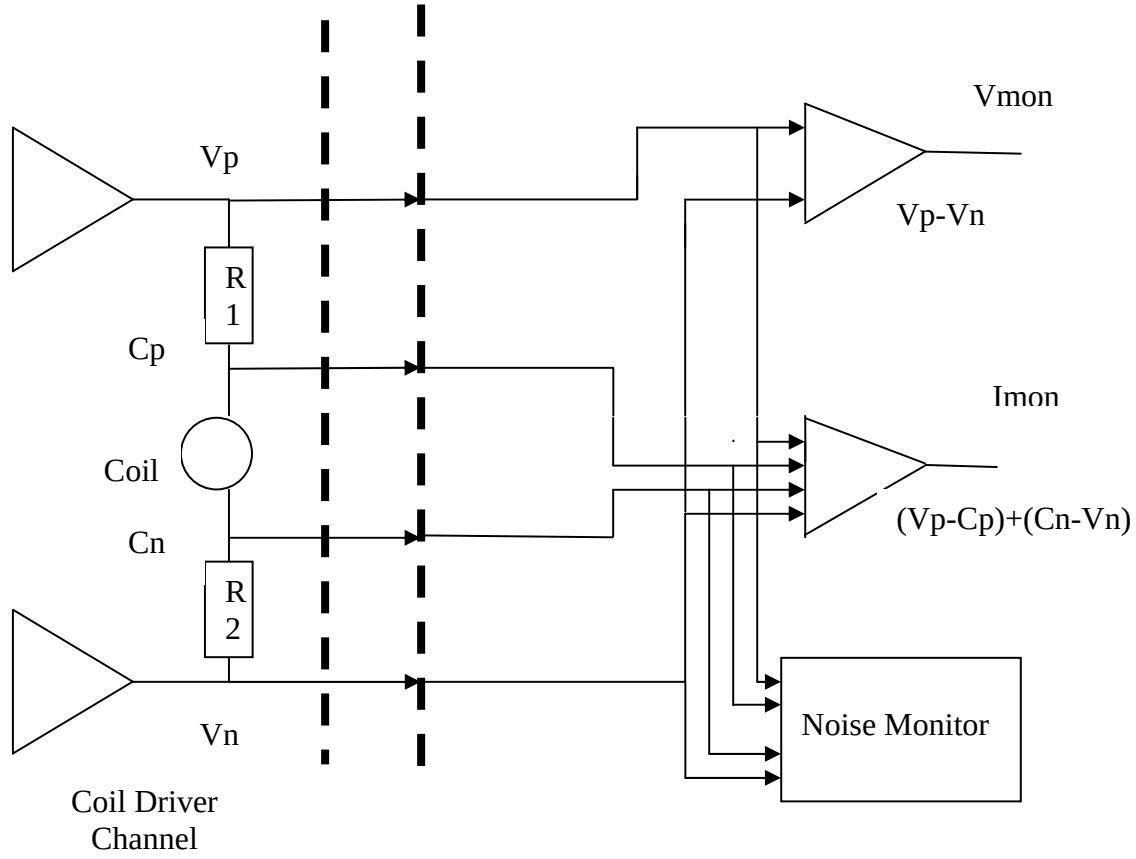
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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Test Engineer …Simon Pyatt…….
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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon59……...
Test Engineer …Simon Pyatt…….
Date …26/01/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	15.02V	√
-15V (TP6)	-15.07V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.8	2.9	3	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.4	1.45	1.5	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.3V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.715V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.359V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.99V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.99V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.992V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.991V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon60……
Test Engineer…Simon Pyatt……
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1. Block diagram

2. Test equipment

3. Description

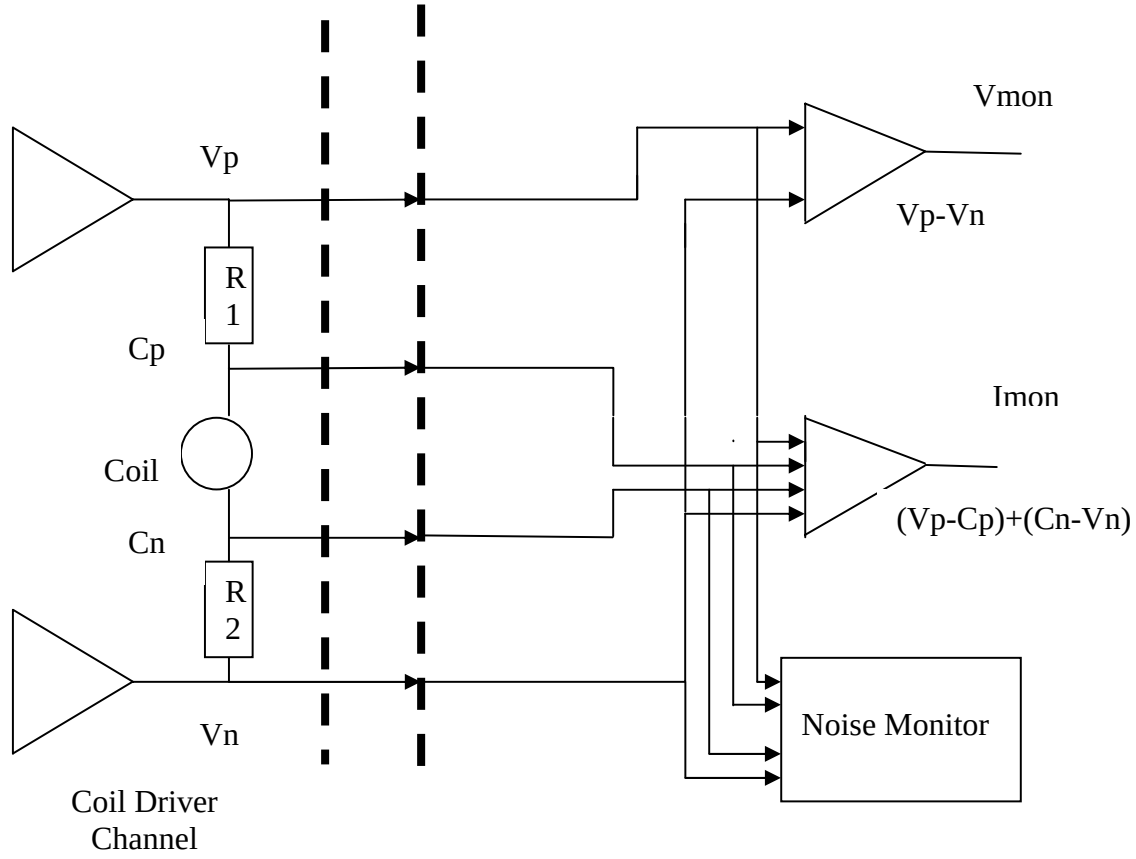
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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Test Engineer …Simon Pyatt…….
Date …26/01/10……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon60……...
Test Engineer …Simon Pyatt…….
Date …26/01/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.82V	√
-15V (TP6)	-15.07V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon60……...
Test Engineer …Simon Pyatt…….
Date …26/01/10…….

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Test Engineer …Simon Pyatt…….
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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

Serial No …mon60……...
Test Engineer …Simon Pyatt…….
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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.9	2.9	2.9	3

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.45	1.45	1.45	1.5	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.6V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.8V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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Test Engineer …Simon Pyatt…….
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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.715V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.988V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.990V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.985V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.987V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.02V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon61……
Test Engineer…Simon Pyatt……
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Contents

1. Block diagram

2. Test equipment

3. Description

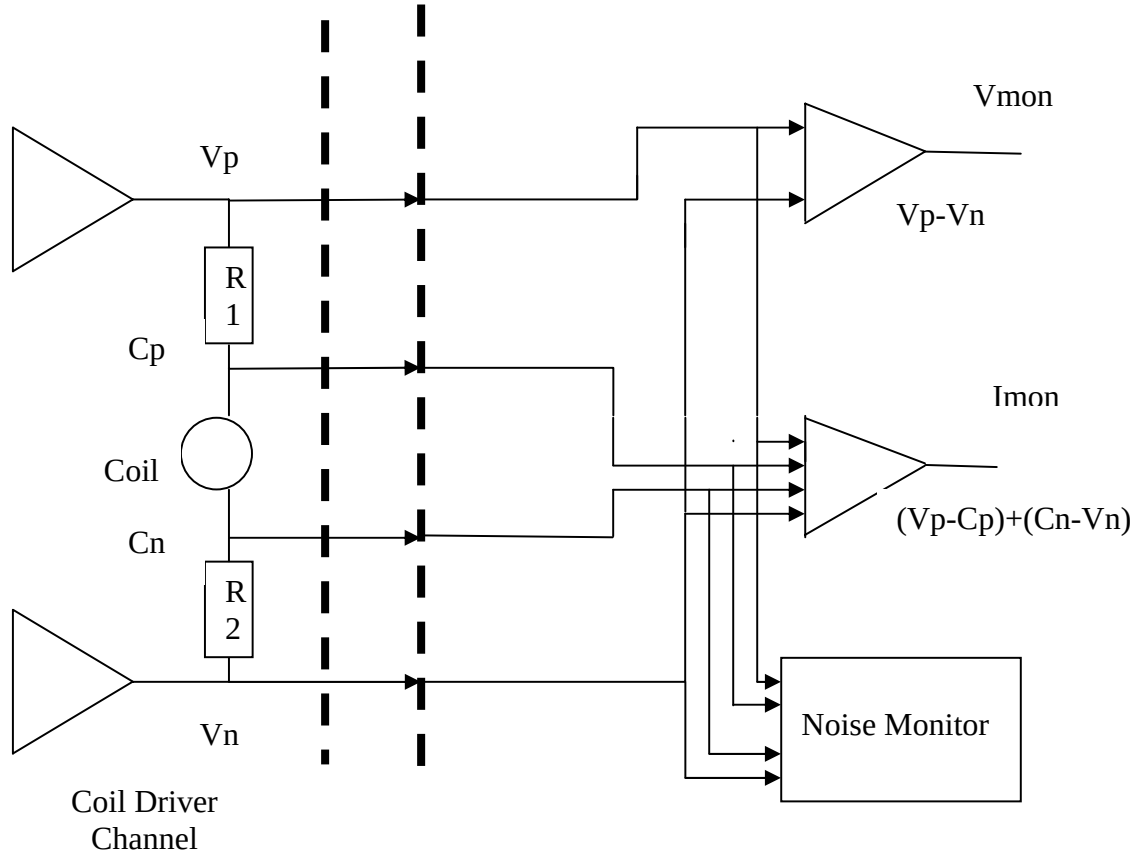
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon61……...
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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.95V	√
-15V (TP6)	-14.94V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	3	2.9	2.9	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.5	1.45	1.45	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.3V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.718V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.354V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.360V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.998V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.999V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.994V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.02V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon62……
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1. Block diagram

2. Test equipment

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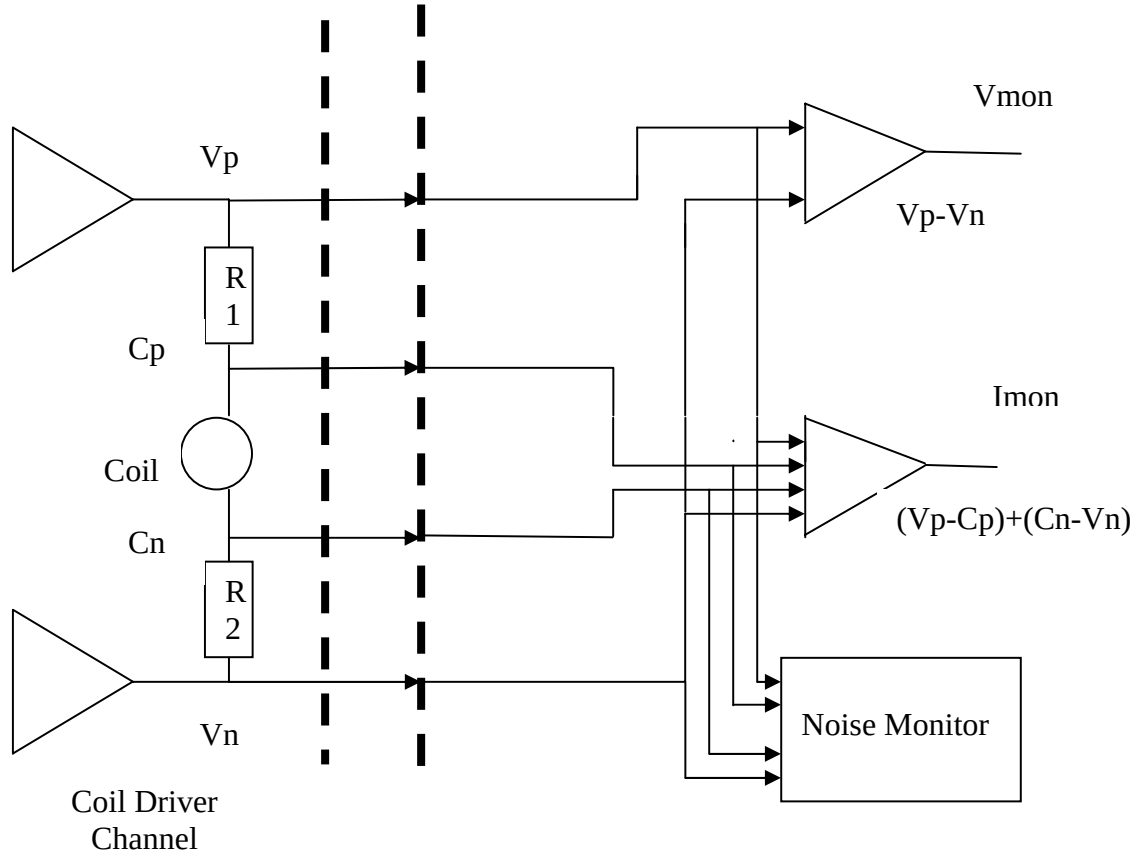
5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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Test Engineer …Simon Pyatt…….
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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon62……...
Test Engineer …Simon Pyatt…….
Date …27/01/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.84V	√
-15V (TP6)	-14.96V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon62……...
Test Engineer …Simon Pyatt…….
Date …27/01/10…….

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2	2	2
TP7	8	8	8	8	3.1	2.9	3	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.47	1.45	1.5	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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Test Engineer …Simon Pyatt…….
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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.718V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.717V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.361V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.360V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.993V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.996V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.991V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.994V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.02V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon63……
Test Engineer…Simon Pyatt……
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Contents

1. Block diagram

2. Test equipment

3. Description

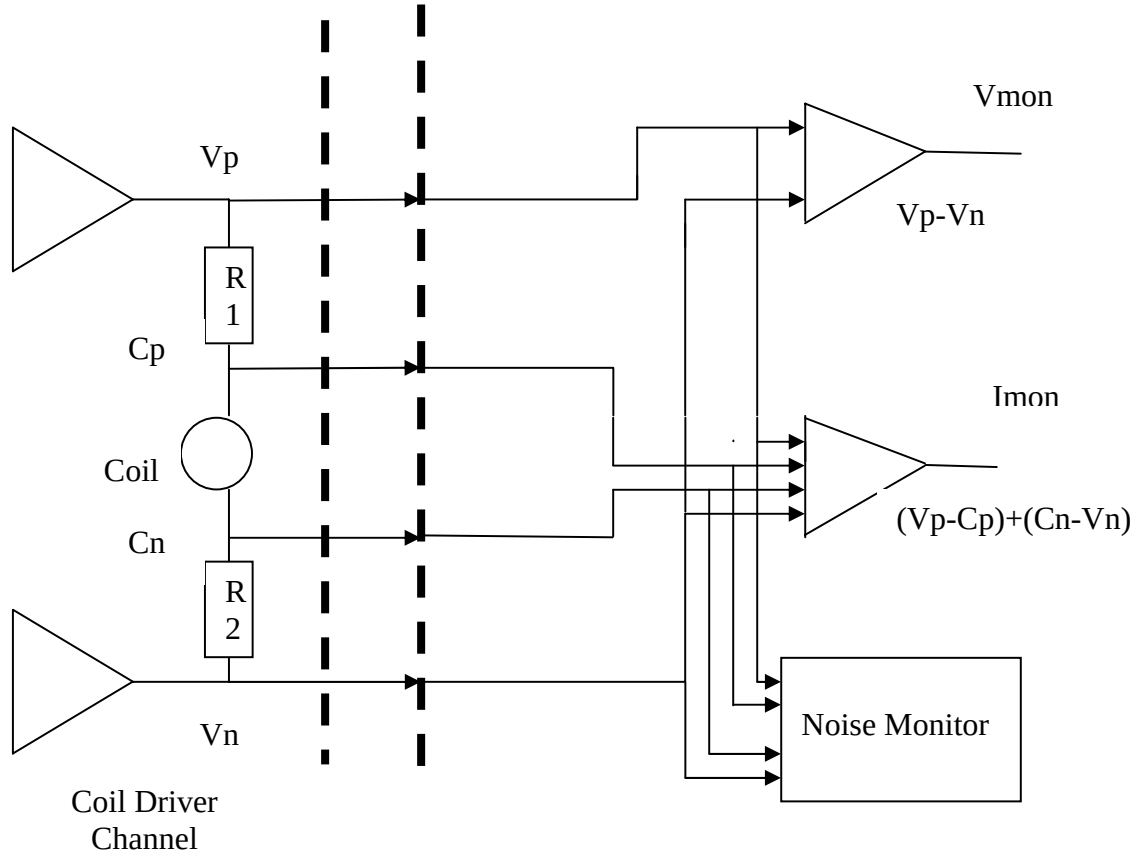
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	15.01V	√
-15V (TP6)	-14.98V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.9	2.9	2.8	2.8

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.45	1.45	1.4	1.4	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.8V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.3V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.8V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.718V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.720V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.710V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.715V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.362V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.362V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.995V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.996V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.984V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.990V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon64……
Test Engineer…Simon Pyatt……
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1. Block diagram

2. Test equipment

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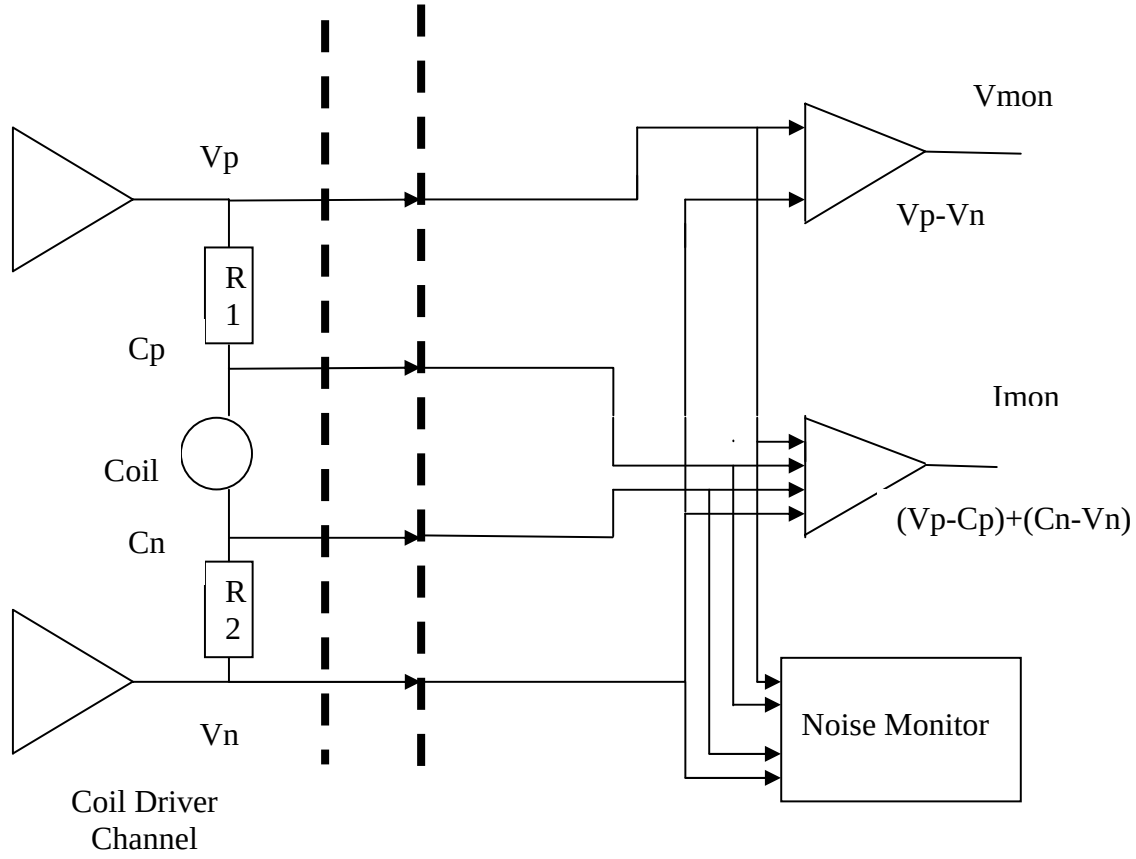
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK? J2 very slightly out of alignment**

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon64……...
Test Engineer …Simon Pyatt…….
Date …27/01/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.85V	√
-15V (TP6)	-14.94V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.27A
-15v (TP6)	√	5mV	0.25A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.9	2.9	3	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.45	1.45	1.5	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.3V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.3V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.717V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.712V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.356V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon65……
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Contents

1. Block diagram

2. Test equipment

3. Description

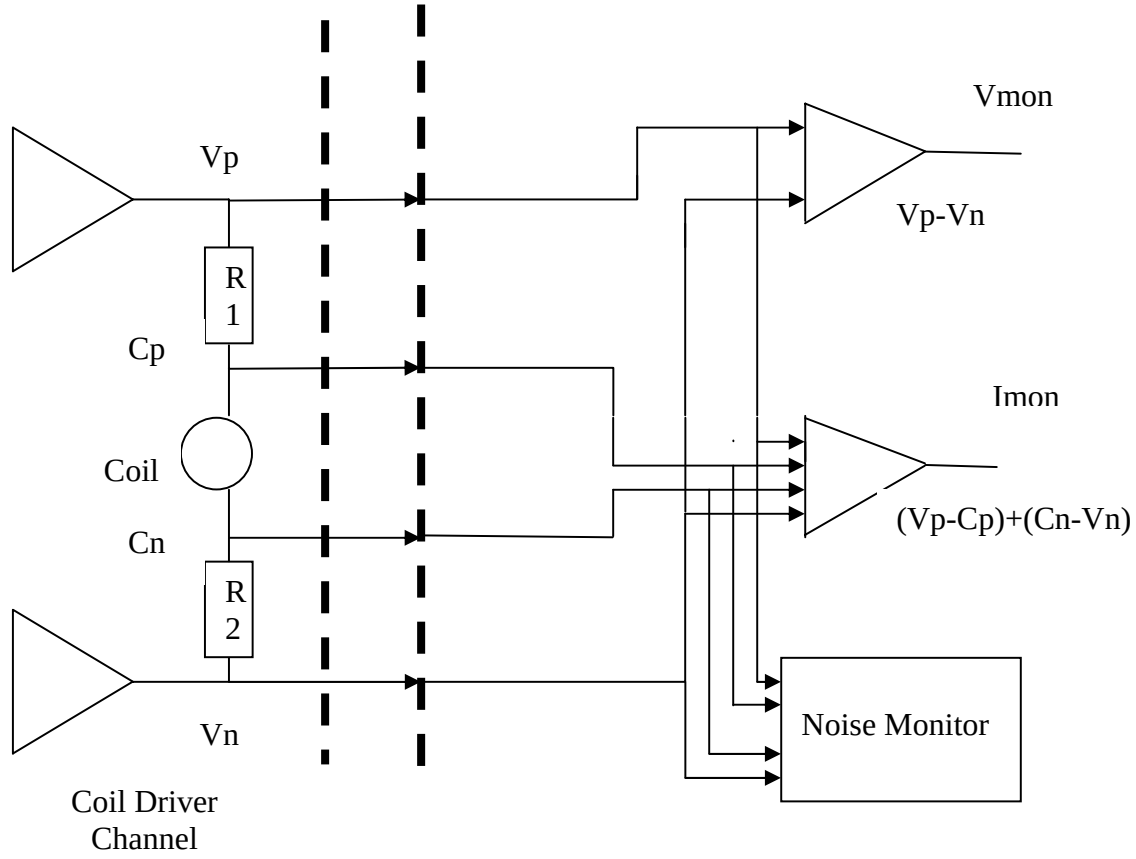
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon65……...
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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.93V	√
-15V (TP6)	-14.99V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.9	2.9	2.9	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.45	1.45	1.45	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.715V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.359V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.985V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.987V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.987V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.987V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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1. Block diagram

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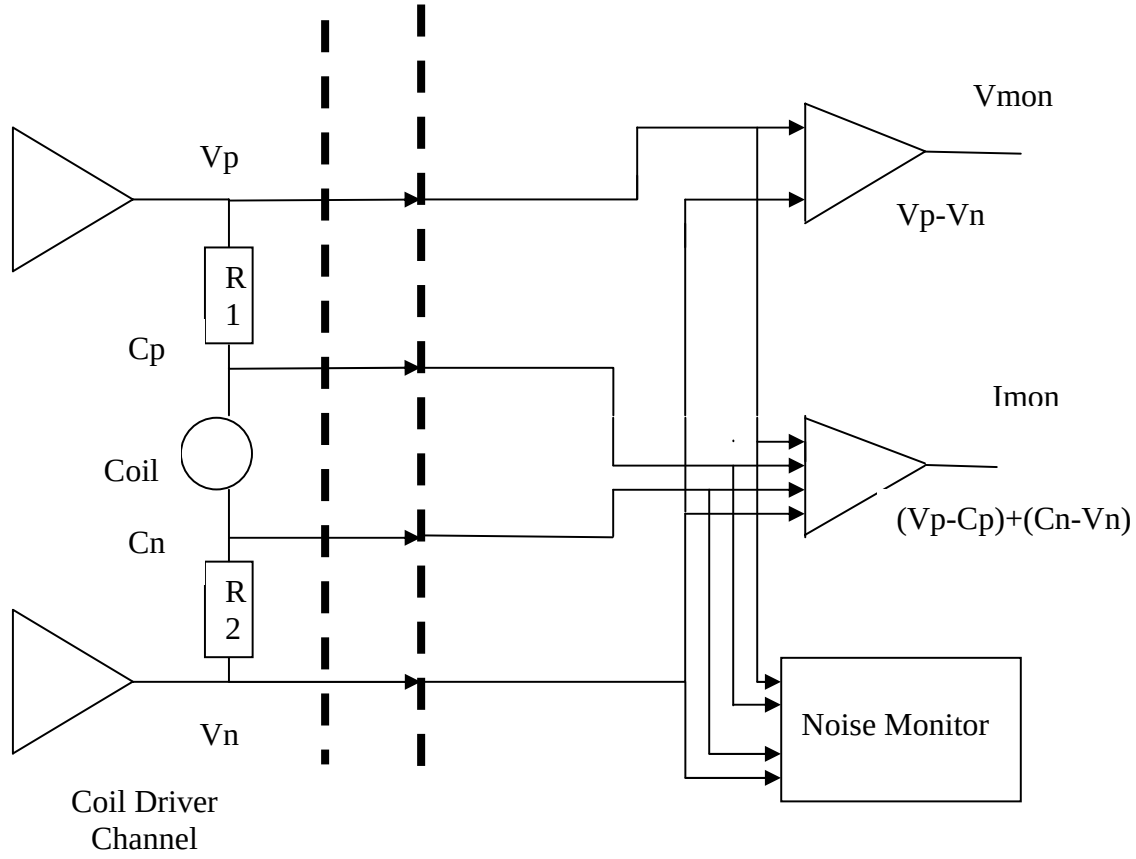
6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon66……...
Test Engineer …Simon Pyatt…….
Date …28/01/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.97V	√
-15V (TP6)	-14.96V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon66……...
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Date …28/01/10……

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.9	2.9	2.9	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.45	1.45	1.45	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.6V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.8V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.710V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.716V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.354V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon67……
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Contents

1. Block diagram

2. Test equipment

3. Description

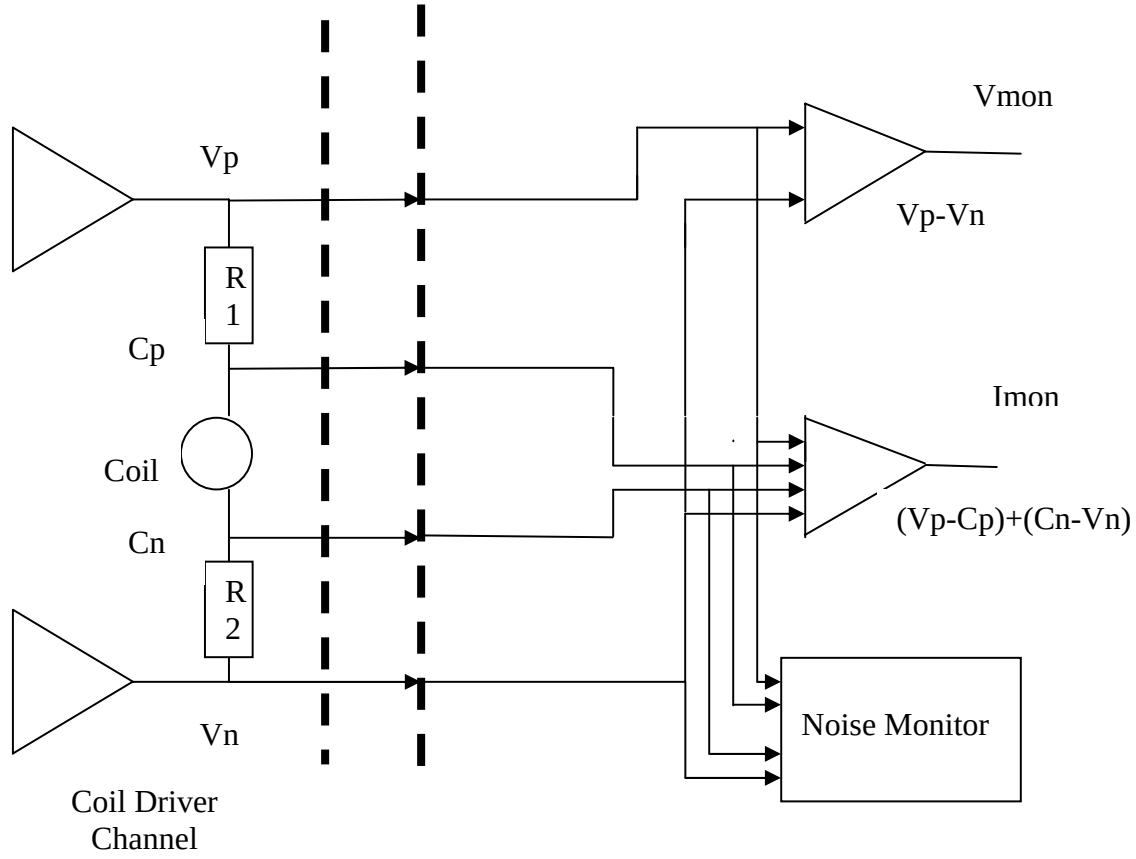
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.85V	√
-15V (TP6)	-14.95V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mv	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2.1	2.1
TP7	8	8	8	8	3.1	3.1	3.1	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.47	1.47	1.47	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.6V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.715V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.359V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.988V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.983V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.988V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.987V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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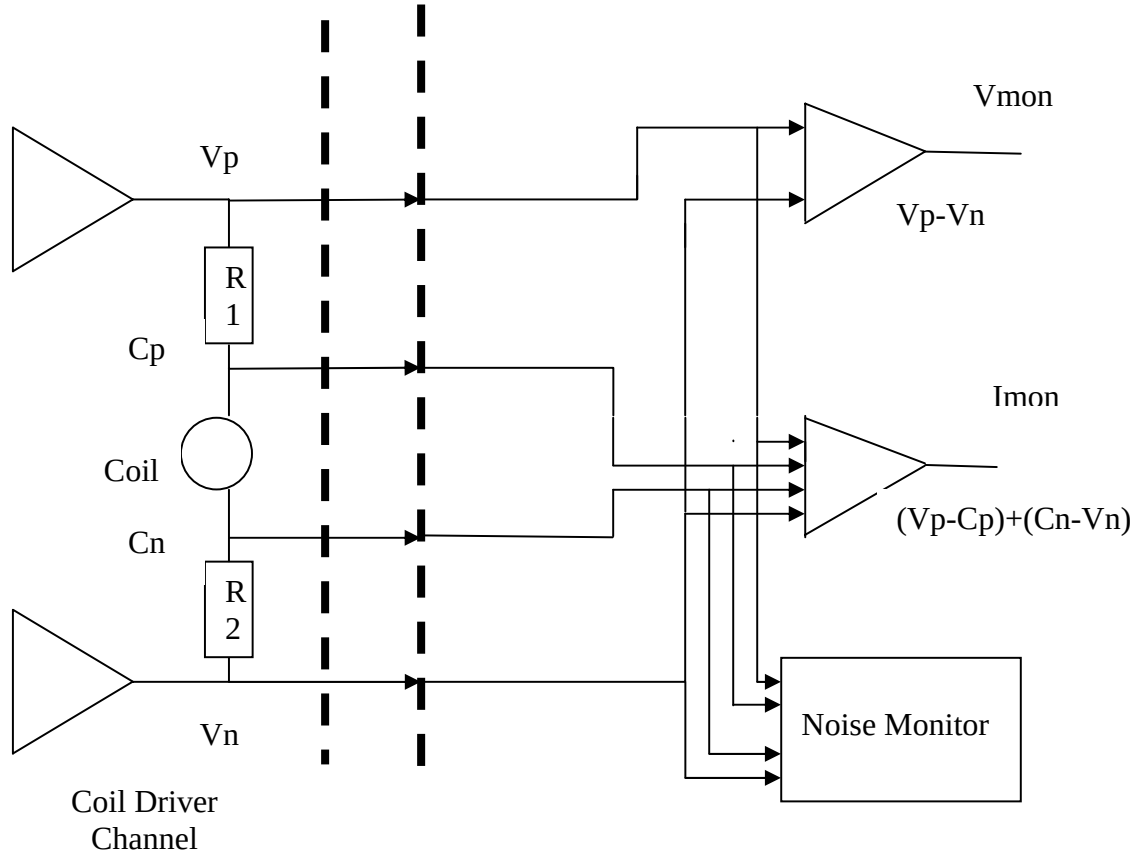
6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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Test Engineer …Simon Pyatt…….
Date …02/02/10……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon68……...
Test Engineer …Simon Pyatt…….
Date …02/02/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	15.03V	√
-15V (TP6)	-14.90V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.25A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2.1	2.1	2.1
TP7	8	8	8	8	3	3.1	3.1	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.5	1.47	1.47	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.7V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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Test Engineer …Simon Pyatt…….
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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.711V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.355V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.990V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.988V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.990V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.984V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon69……
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Contents

1. Block diagram

2. Test equipment

3. Description

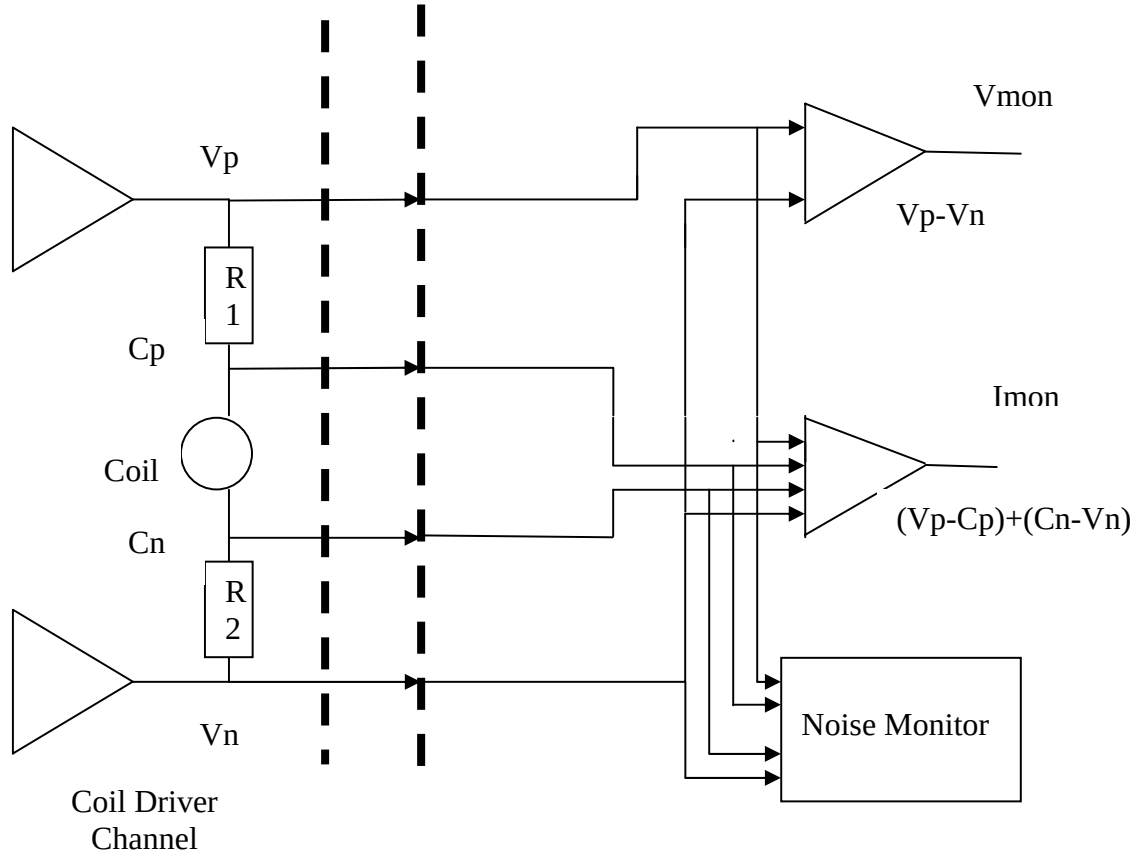
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

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Test Engineer ……
Date ……

NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.89V	√
-15V (TP6)	-14.92V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2.1	2.1
TP7	7.8	7.8	7.8	7.8	3.1	3.1	3.1	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	
TP7/TP6	1.95	1.95	1.95	1.95	1.47	1.47	1.47	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.6V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.8V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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Test Engineer …Simon Pyatt…….
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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.716V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon70……
Test Engineer…Simon Pyatt……
Date…03/02/10……

Contents

1. Block diagram

2. Test equipment

3. Description

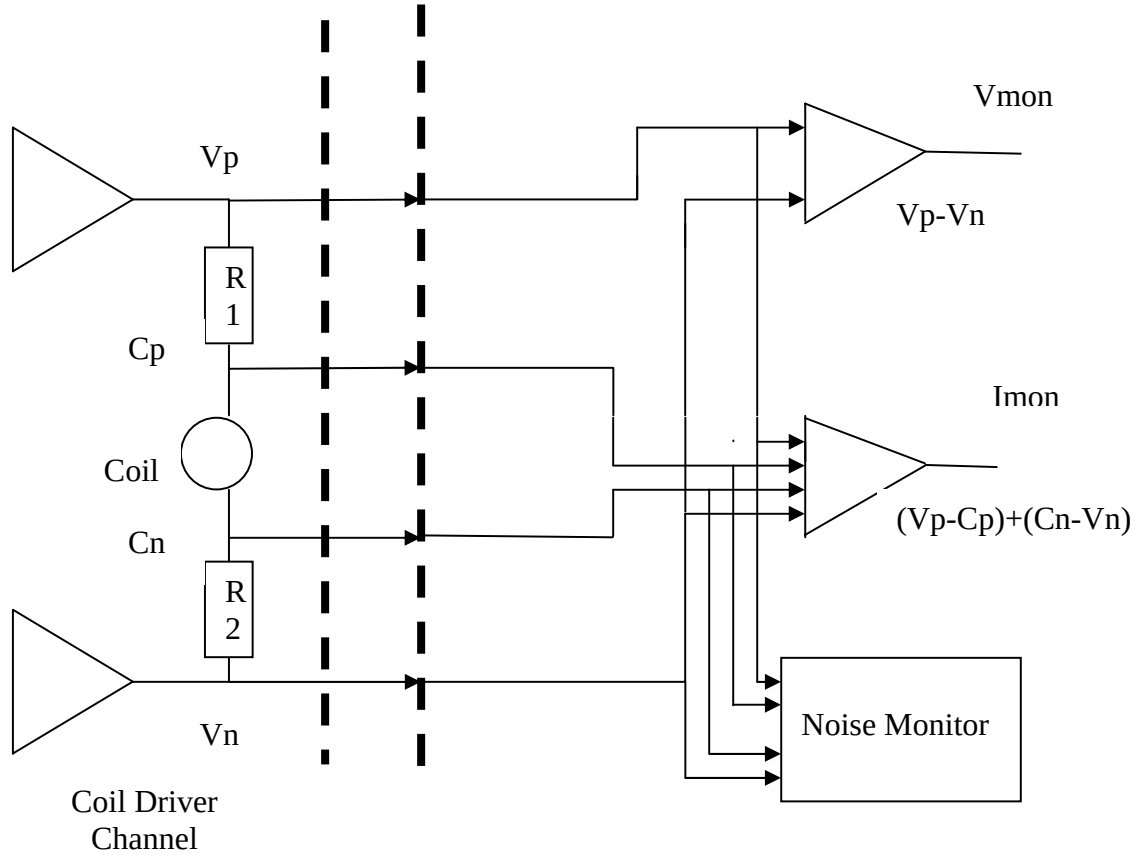
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

Serial No …mon70……..
Test Engineer …Simon Pyatt…….
Date …03/02/10……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon70……...
Test Engineer …Simon Pyatt…….
Date …03/02/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.95V	√
-15V (TP6)	-15.00V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon70……...
Test Engineer …Simon Pyatt…….
Date …03/02/10……

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

Serial No …mon70……...
Test Engineer …Simon Pyatt…….
Date …03/02/10……

Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

Serial No …mon70……...
Test Engineer …Simon Pyatt…….
Date …03/02/10……

Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2.1	2.1
TP7	8	8	8	8	3.1	3.1	3.1	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.47	1.47	1.47	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.6V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√

Serial No …mon70……...
Test Engineer …Simon Pyatt…….
Date …03/02/10…….

6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

Serial No …mon70……...
Test Engineer …Simon Pyatt…….
Date …03/02/10……

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.714V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.986V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.985V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.989V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.986V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.02V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon71……
Test Engineer…Simon Pyatt……
Date…04/02/10……

Contents

1. Block diagram

2. Test equipment

3. Description

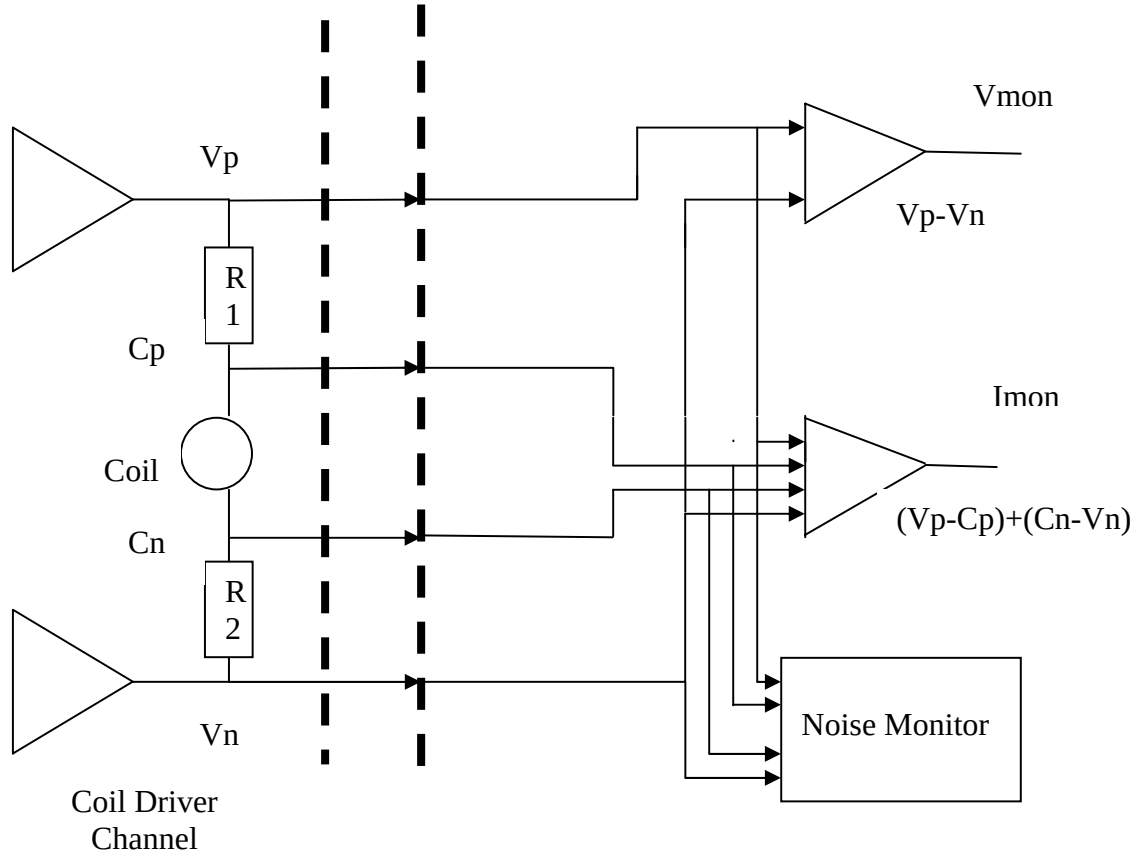
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

Serial No …mon71……..
Test Engineer …Simon Pyatt…….
Date …04/02/10……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon71……...
Test Engineer …Simon Pyatt…….
Date …04/02/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	15.00V	√
-15V (TP6)	-15.04V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon71……...
Test Engineer …Simon Pyatt…….
Date …04/02/10……

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

Serial No …mon71……...
Test Engineer …Simon Pyatt…….
Date …04/02/10……

Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

Serial No …mon71……...
Test Engineer …Simon Pyatt…….
Date …04/02/10……

Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2.1	2.1
TP7	8	8	8	8	3.1	3.1	3.1	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.47	1.47	1.47	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.8V	4 to 5.5V	√

Serial No …mon71……...
Test Engineer …Simon Pyatt…….
Date …04/02/10…….

6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

Serial No …mon71……...
Test Engineer …Simon Pyatt…….
Date …04/02/10…….

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.709V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.716V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.359V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.99V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.99V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.99V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.99V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon72……
Test Engineer…Simon Pyatt……
Date…04/02/10……

Contents

1. Block diagram

2. Test equipment

3. Description

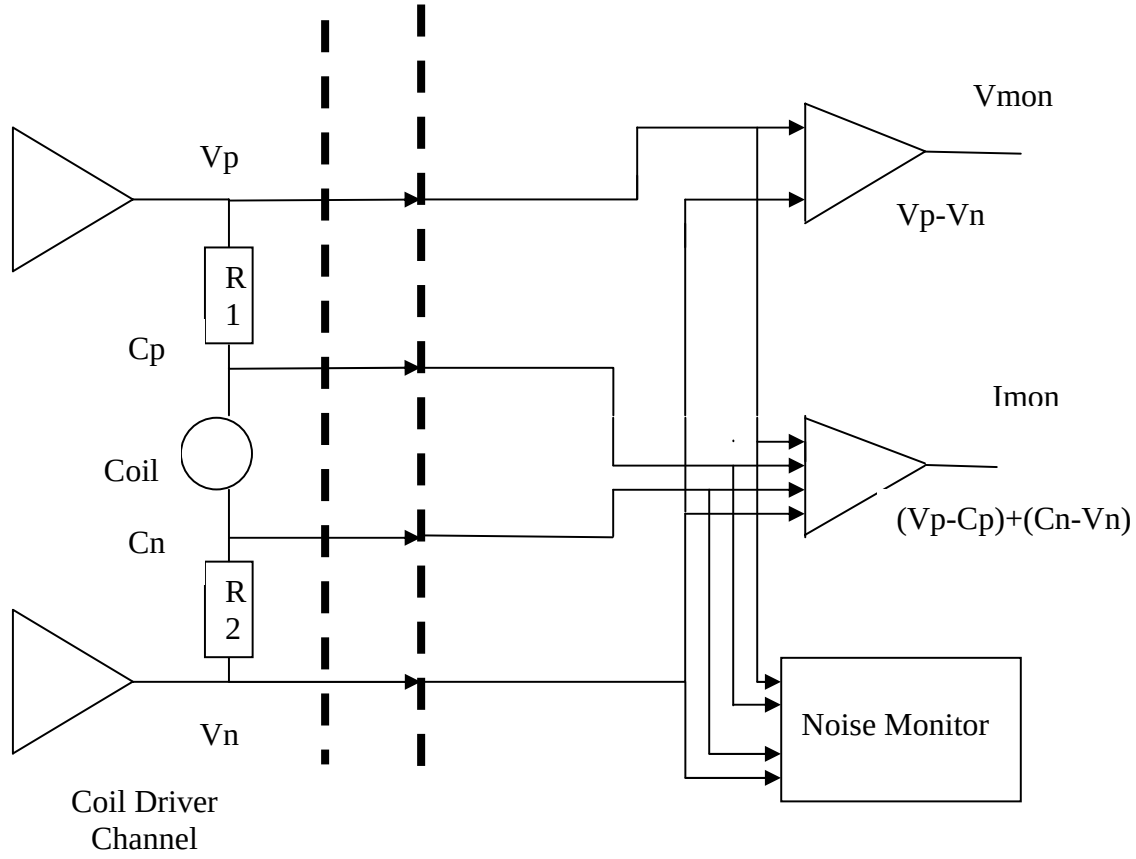
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

Serial No …mon72……..
Test Engineer …Simon Pyatt…….
Date …04/02/10……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon72……...
Test Engineer …Simon Pyatt…….
Date …04/02/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.98V	√
-15V (TP6)	-14.91V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon72……...
Test Engineer …Simon Pyatt…….
Date …04/02/10……

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Test Engineer …Simon Pyatt…….
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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

Serial No …mon72……...
Test Engineer …Simon Pyatt…….
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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2	2.1
TP7	8	8	8	8	3.1	3.1	3	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.42	1.5	
TP7/TP6	2	2	2	2	1.47	1.47	1.5	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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Test Engineer …Simon Pyatt…….
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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.710V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.717V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.716V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.354V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.360V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.983V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.982V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.987V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.985V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.02V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon73……
Test Engineer…Simon Pyatt……
Date…04/02/10……

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1. Block diagram

2. Test equipment

3. Description

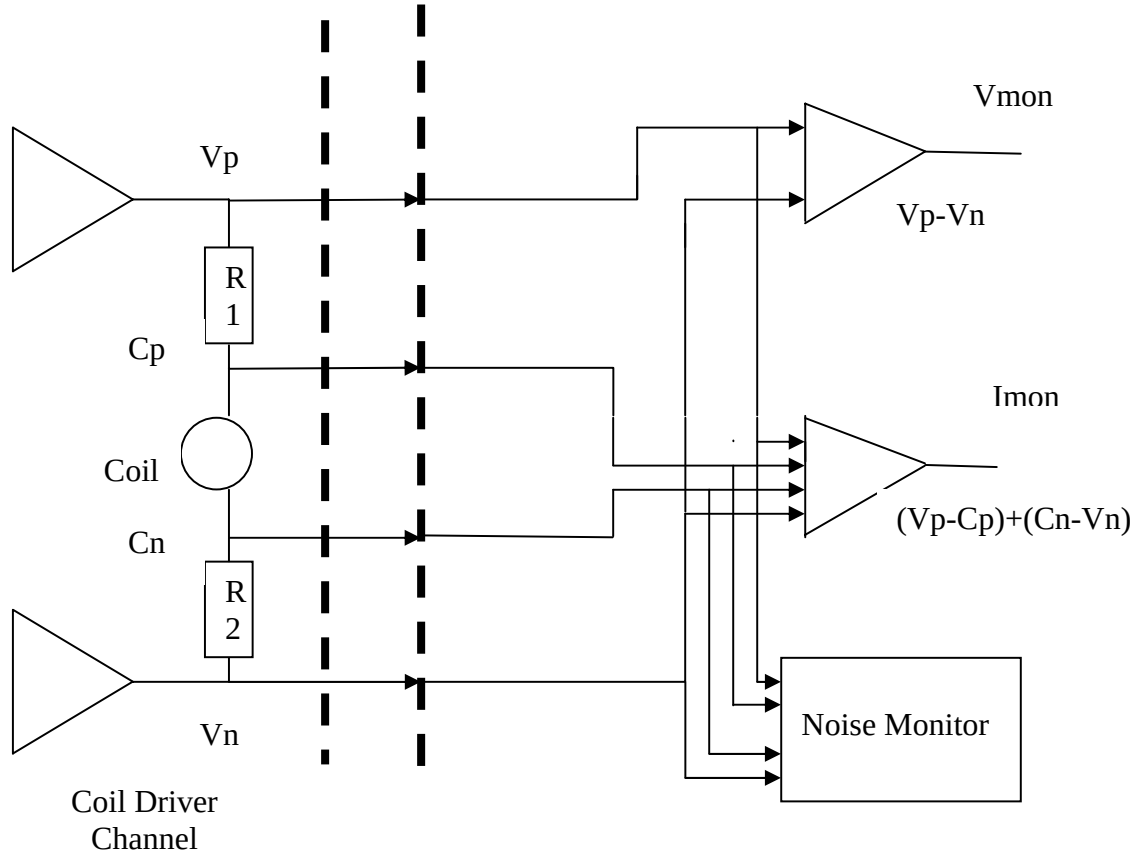
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

Serial No …mon73……..
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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon73……...
Test Engineer …Simon Pyatt…….
Date …04/02/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.87V	√
-15V (TP6)	-14.99V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon73……...
Test Engineer …Simon Pyatt…….
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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

Serial No …mon73……...
Test Engineer …Simon Pyatt…….
Date …04/02/10……

Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

Serial No …mon73……...
Test Engineer …Simon Pyatt…….
Date …04/02/10……

Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.9	2.9	2.9	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.45	1.45	1.45	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.7V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

Serial No …mon73……...
Test Engineer …Simon Pyatt…….
Date …05/02/10……

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.718V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.717V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.361V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.359V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.996V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.990V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.991V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.994V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon74……
Test Engineer…Simon Pyatt……
Date…05/02/10……

Contents

1. Block diagram

2. Test equipment

3. Description

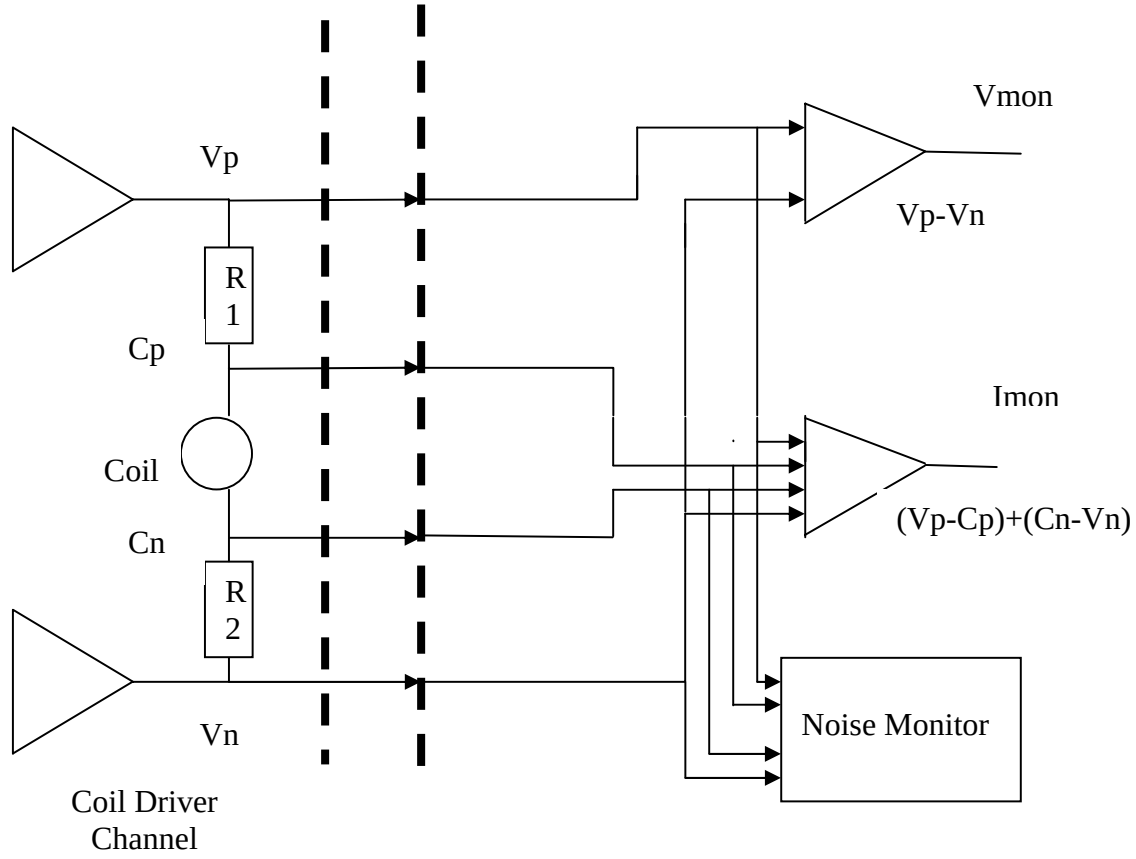
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

Serial No …mon74……..
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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon74……...
Test Engineer …Simon Pyatt…….
Date …05/02/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.86V	√
-15V (TP6)	-14.99V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon74……...
Test Engineer …Simon Pyatt…….
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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

Serial No …mon74……...
Test Engineer …Simon Pyatt…….
Date …05/02/10…….

Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.6V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.6V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

Serial No …mon74……...
Test Engineer …Simon Pyatt…….
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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	3	2.8	2.8	2.8

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.5	1.4	1.4	1.4	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.6	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.6	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.6	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.5	4 to 5.5V	√

Serial No …mon74……...
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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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Test Engineer …Simon Pyatt…….
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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.715V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.987V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.983V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.982V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.980V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon75……
Test Engineer…Simon Pyatt……
Date…05/02/10……

Contents

1. Block diagram

2. Test equipment

3. Description

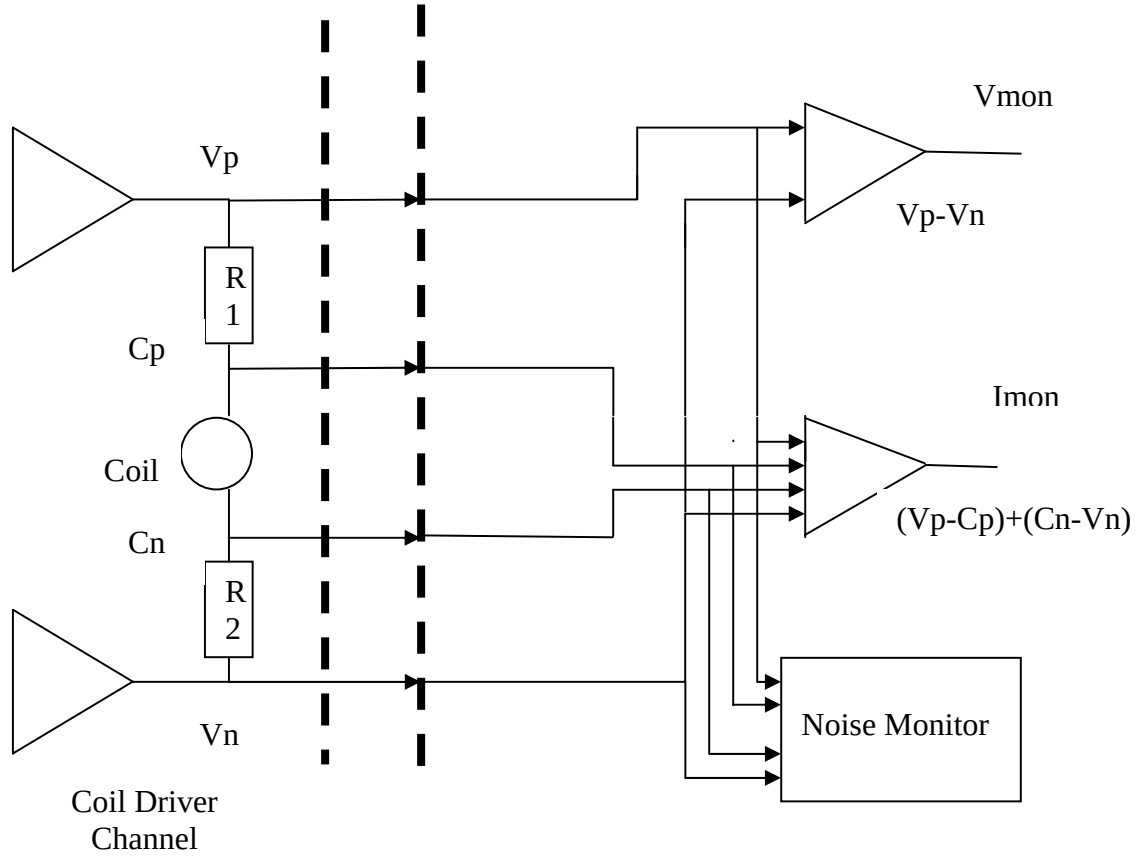
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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Test Engineer …Simon Pyatt…….
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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon75……...
Test Engineer …Simon Pyatt…….
Date …05/02/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.87V	√
-15V (TP6)	-15.03V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon75……...
Test Engineer …Simon Pyatt…….
Date …05/02/10……

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

Serial No …mon75……...
Test Engineer …Simon Pyatt…….
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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.6V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

Serial No …mon75……...
Test Engineer …Simon Pyatt…….
Date …05/02/10……

Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.9	2.9	2.9	3

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.45	1.45	1.45	1.5	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.6V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

Serial No …mon75……...
Test Engineer …Simon Pyatt…….
Date …15/02/10…….

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.715V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.987V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.985V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.986V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.988V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon76……
Test Engineer…Simon Pyatt……
Date…15/02/10……

Contents

1. Block diagram

2. Test equipment

3. Description

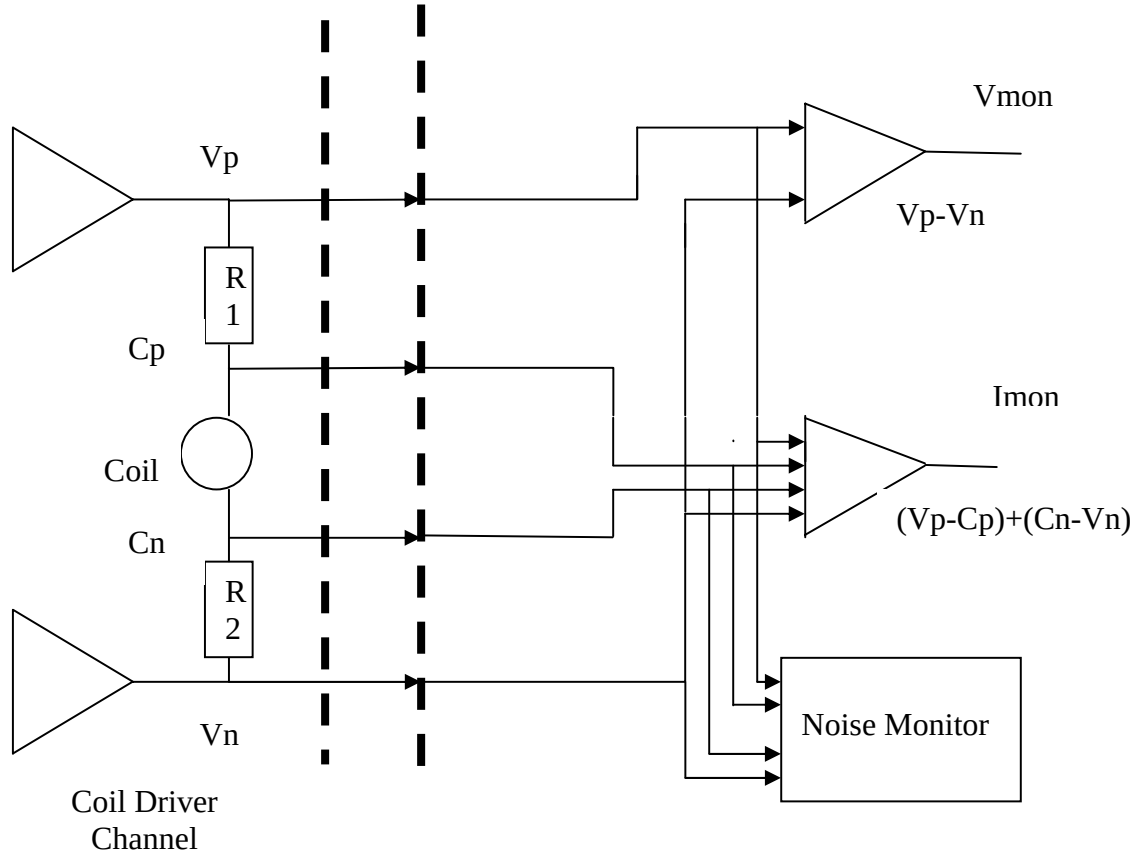
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon76……...
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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.88V	√
-15V (TP6)	-14.88V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	3.9	3.9	3.9	3.9	2.1	2	2	2.1
TP7	7.8	7.8	7.8	7.8	3.1	3	3	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	1.95	1.95	1.95	1.95	1.5	1.42	1.42	1.5	
TP7/TP6	2	2	2	2	1.47	1.5	1.5	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.8V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.717V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.713V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.361V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.994V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.990V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.988V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.987V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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1. Block diagram

2. Test equipment

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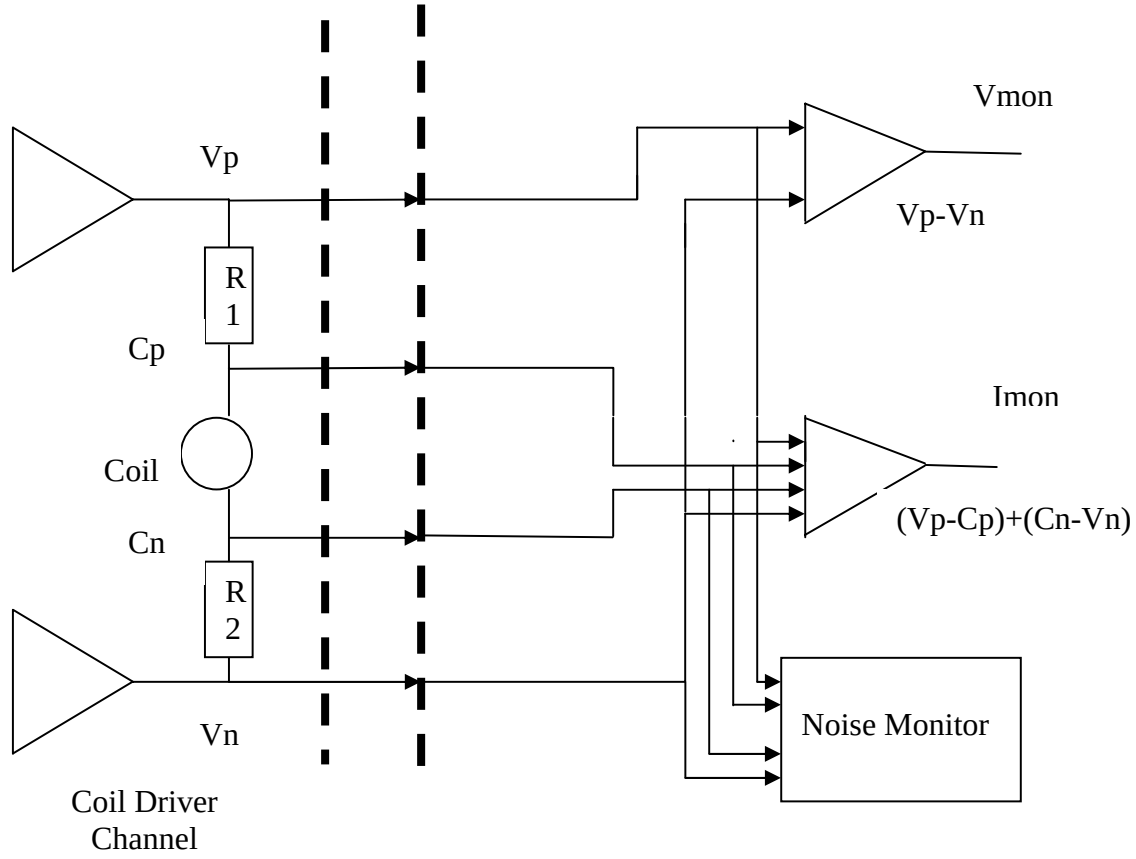
6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon77……...
Test Engineer …Simon Pyatt…….
Date …15/02/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.86V	√
-15V (TP6)	-14.91V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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Test Engineer …Simon Pyatt…….
Date …15/02/10……

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2	2.1
TP7	8	8	8	8	3.1	3.1	2.9	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.42	1.5	
TP7/TP6	2	2	2	2	1.47	1.47	1.45	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.6V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.6V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.6V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.710V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.712V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon78……
Test Engineer…Simon Pyatt……
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Contents

1. Block diagram

2. Test equipment

3. Description

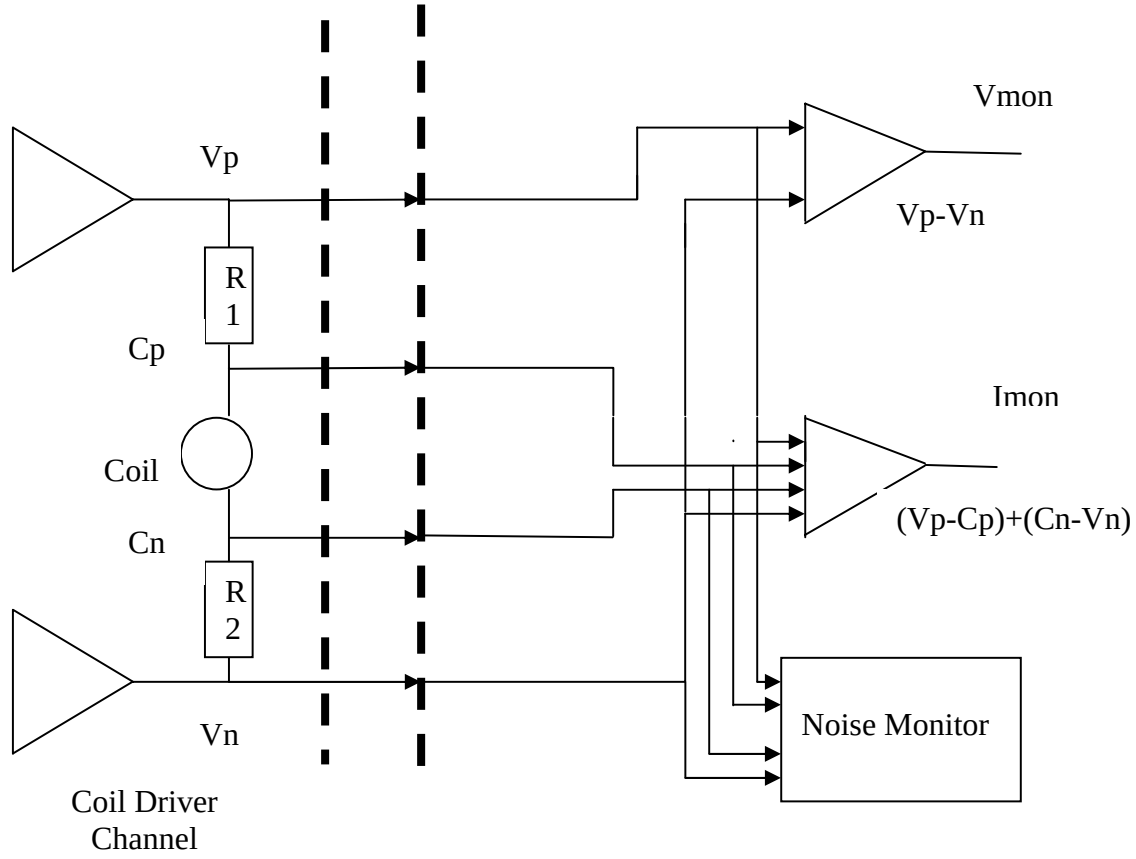
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon78……...
Test Engineer …Simon Pyatt…….
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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.87V	√
-15V (TP6)	-15.01V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.9	2.8	2.8	2.8

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.45	1.4	1.4	1.4	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.6V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.712V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.356V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.997V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.995V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.03V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon79……
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1. Block diagram

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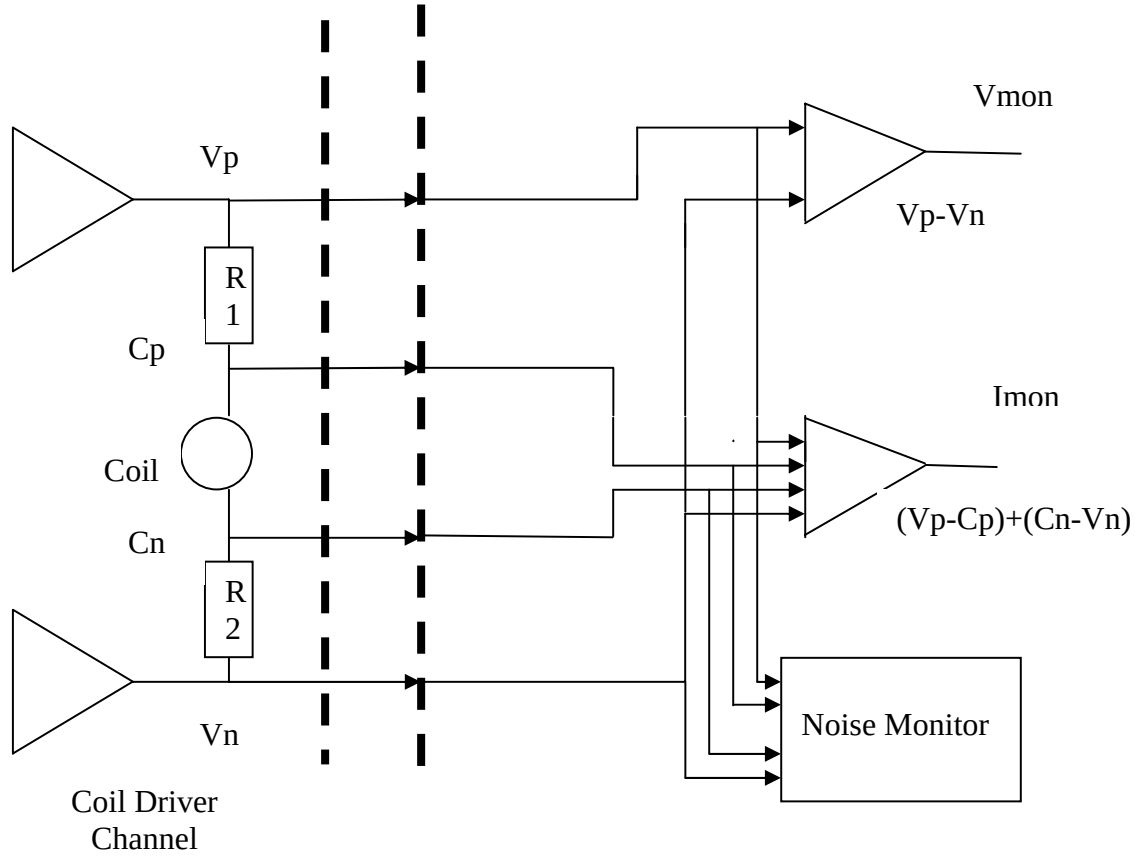
6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon79……...
Test Engineer …Simon Pyatt…….
Date …16/02/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.89V	√
-15V (TP6)	-15.02V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon79……...
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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2.1	2
TP7	8	8	8	8	3.1	3.1	3.1	3

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.42	
TP7/TP6	2	2	2	2	1.47	1.47	1.47	1.5	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.6V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.6V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.7V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.7V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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Test Engineer …Simon Pyatt…….
Date …16/02/10……

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.710V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.717V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.713V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.982V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.989V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.987V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.982V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon80……
Test Engineer…Simon Pyatt……
Date…16/02/10……

Contents

1. Block diagram

2. Test equipment

3. Description

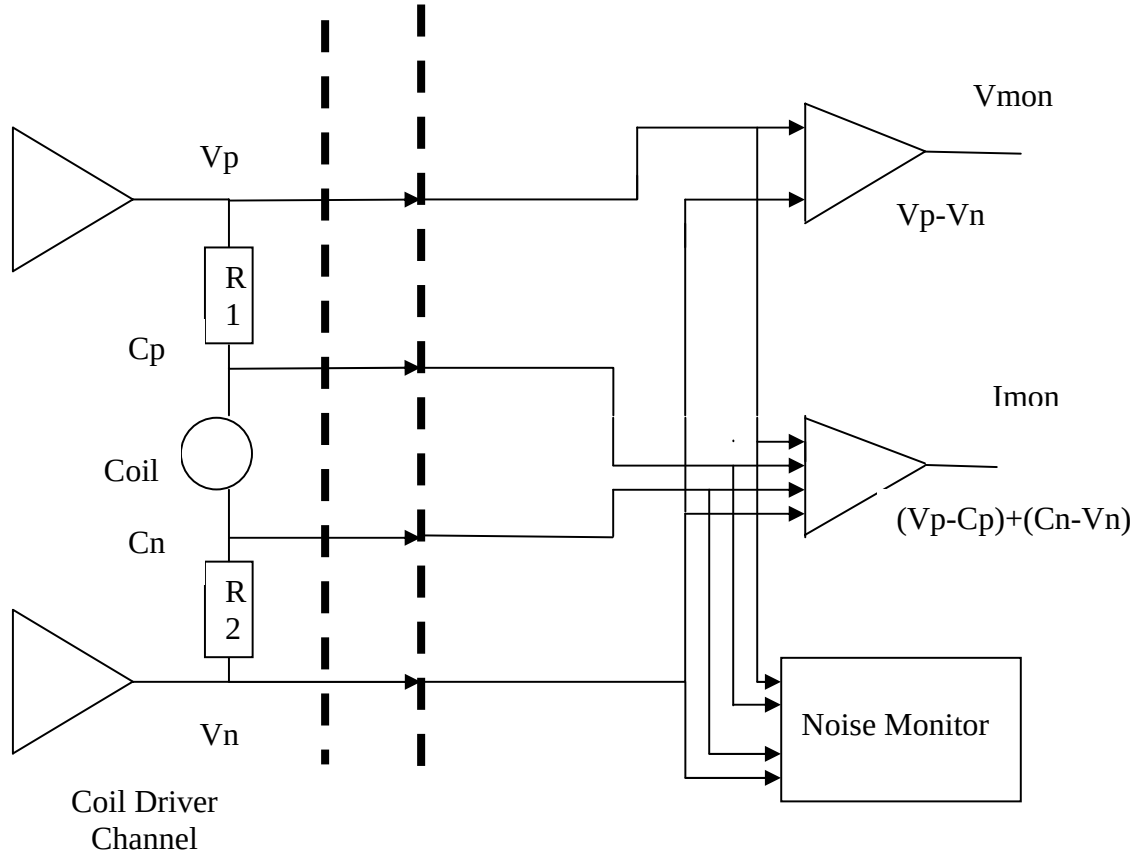
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

Serial No …mon80……..
Test Engineer …Simon Pyatt…….
Date …16/02/10……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon80……...
Test Engineer …Simon Pyatt…….
Date …16/02/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.93V	√
-15V (TP6)	-14.89V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon80……...
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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Test Engineer …Simon Pyatt…….
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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.6V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

Serial No …mon80……...
Test Engineer …Simon Pyatt…….
Date …16/02/10……

Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.9	2.9	2.9	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.45	1.45	1.45	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.6V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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Test Engineer …Simon Pyatt…….
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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.715V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.359V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.987V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.987V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.984V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.984V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon81……
Test Engineer…Simon Pyatt……
Date…16/02/10……

Contents

1. Block diagram

2. Test equipment

3. Description

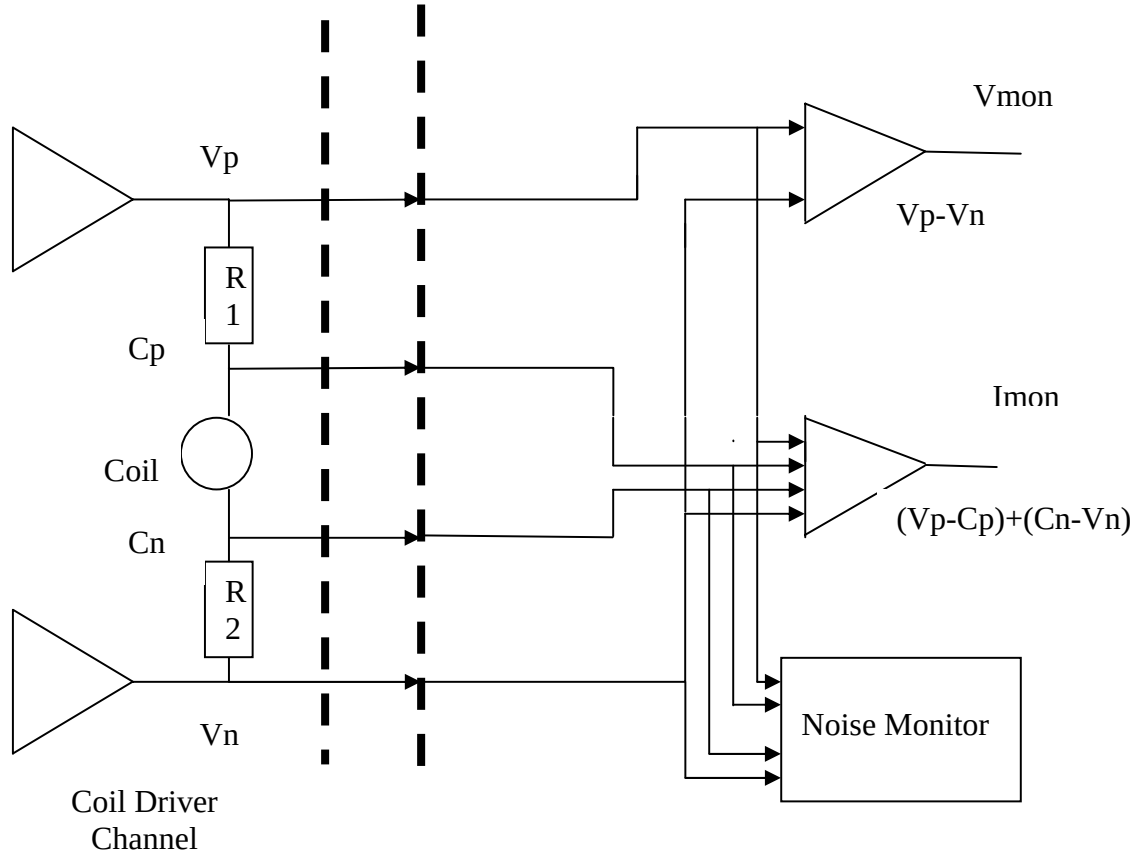
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

Serial No …mon81……..
Test Engineer …Simon Pyatt…….
Date …16/02/10……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon81……...
Test Engineer …Simon Pyatt…….
Date …16/02/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.96V	√
-15V (TP6)	-15.11V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon81……...
Test Engineer …Simon Pyatt…….
Date …16/02/10……

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

Serial No …mon81……...
Test Engineer …Simon Pyatt…….
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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

Serial No …mon81……...
Test Engineer …Simon Pyatt…….
Date …16/02/10……

Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.8	2.8	3	2.8

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.4	1.4	1.5	1.4	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.8V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.6V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√

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Date …16/02/10…….

6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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Test Engineer …Simon Pyatt…….
Date …17/02/10…….

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.709V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.717V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.719V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.354V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.360V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.359V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.986V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.996V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.989V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.997V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon82……
Test Engineer…Simon Pyatt……
Date…17/02/10……

Contents

1. Block diagram

2. Test equipment

3. Description

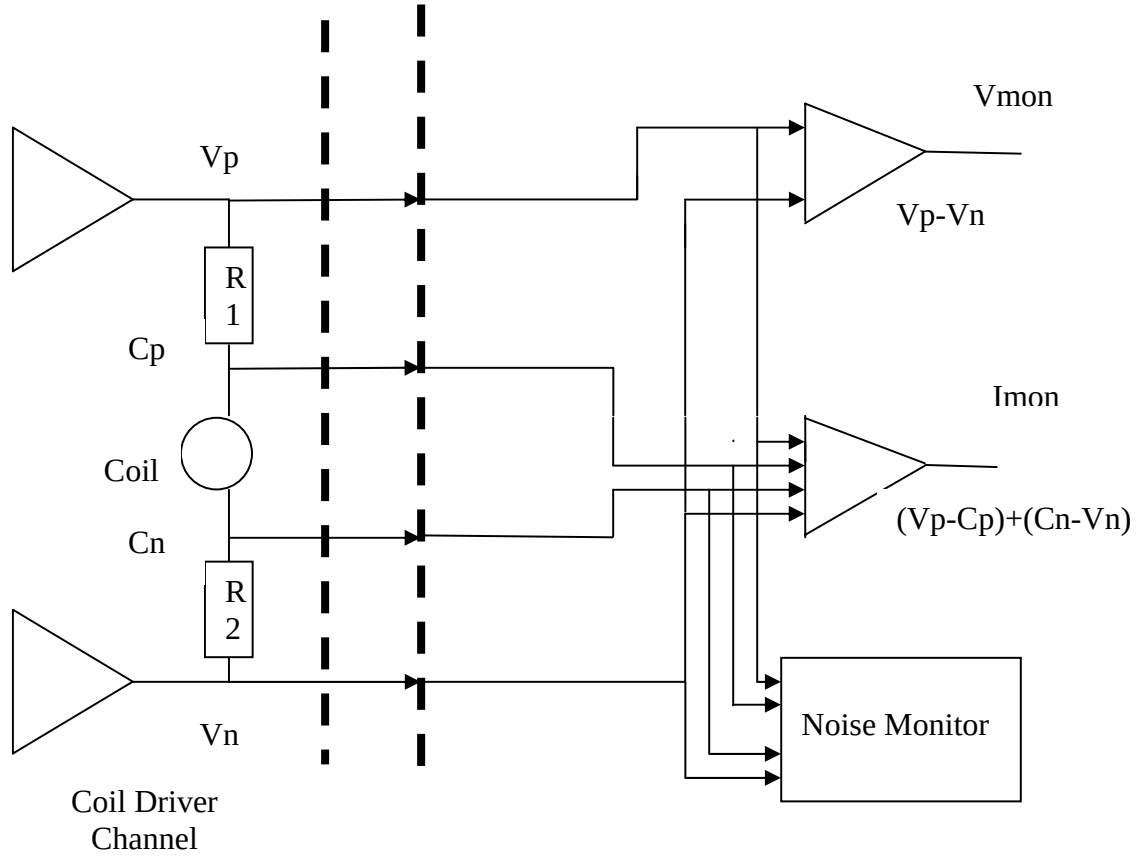
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon82……...
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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.95V	√
-15V (TP6)	-15.03V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.6V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.8	2.9	2.9	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.4	1.45	1.45	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.6	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.4	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.2	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.3	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.719V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.360V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.361V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.989V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.983V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.984V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.991V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.02V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.02V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon83……
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1. Block diagram

2. Test equipment

3. Description

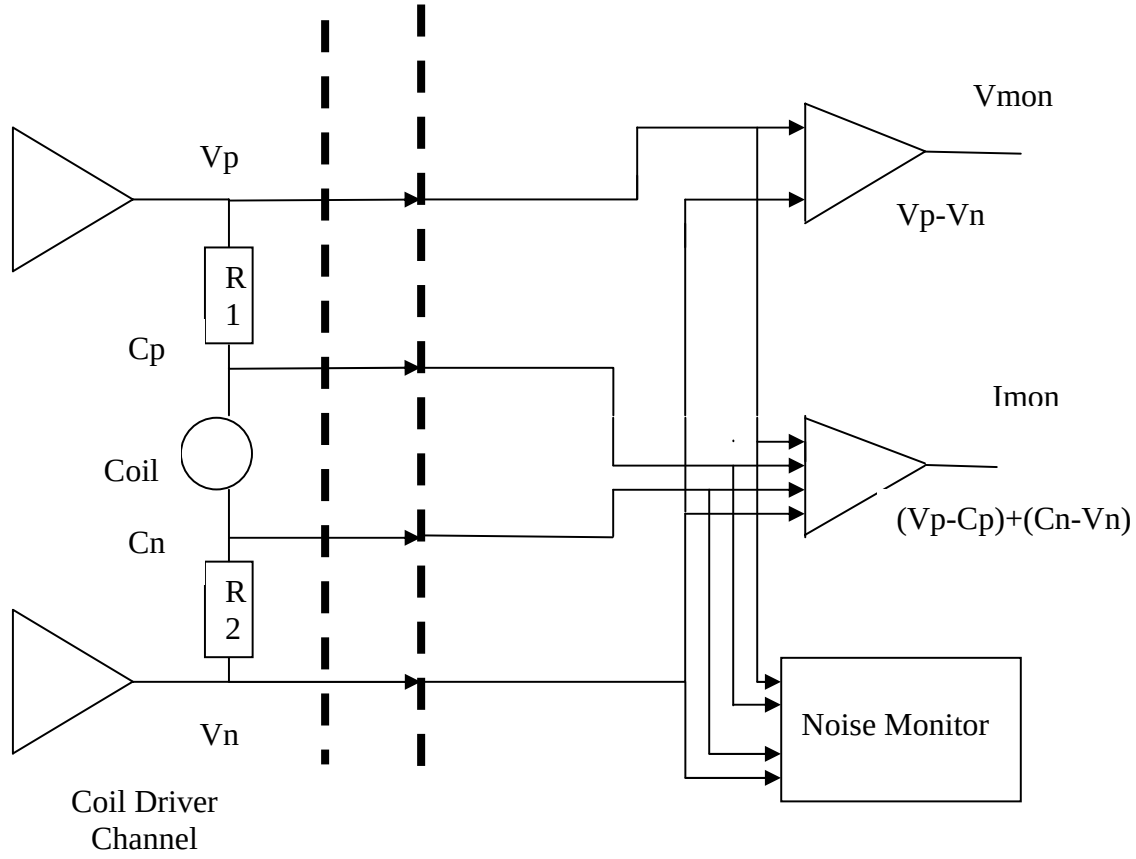
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon83……...
Test Engineer …Simon Pyatt…….
Date …17/02/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.89V	√
-15V (TP6)	-15.06V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon83……...
Test Engineer …Simon Pyatt…….
Date …17/02/10……

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

Serial No …mon83……...
Test Engineer …Simon Pyatt…….
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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

Serial No …mon83……...
Test Engineer …Simon Pyatt…….
Date …18/02/10……

Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.9	2.8	2.9	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.45	1.4	1.45	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.7V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.3V	**4 to 5.5V**	√

Serial No …mon83……...
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Date …18/02/10…….

6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

Serial No …mon83……...
Test Engineer …Simon Pyatt…….
Date …18/02/10……

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.714V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.356V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.985V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.981V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.982V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.983V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon84……
Test Engineer…Simon Pyatt……
Date…18/02/10……

Contents

1. Block diagram

2. Test equipment

3. Description

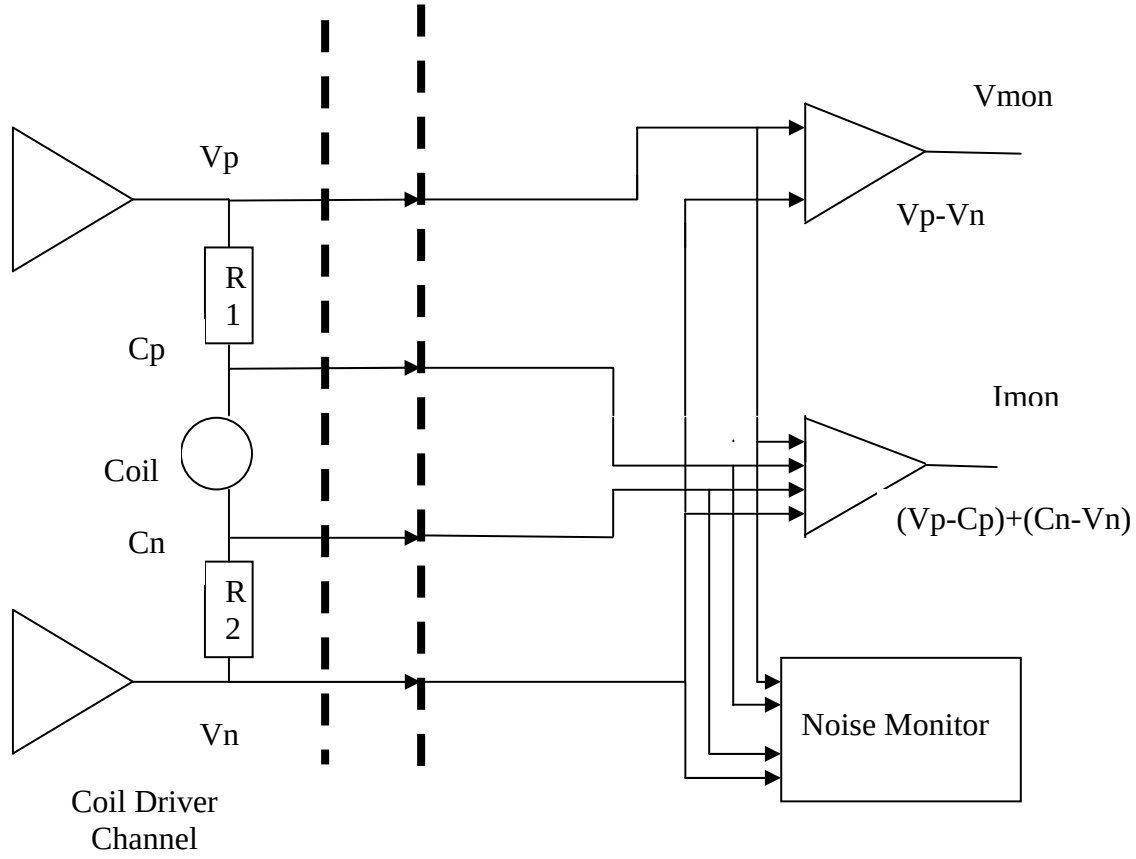
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon84……...
Test Engineer …Simon Pyatt…….
Date …18/02/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.87V	√
-15V (TP6)	-14.92V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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Test Engineer …Simon Pyatt…….
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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Test Engineer …Simon Pyatt…….
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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.6V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Test Engineer …Simon Pyatt…….
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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.8	2.8	2.8	2.8

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	√
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	√
TP7/TP6	2	2	2	2	1.4	1.4	1.4	1.4	√

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

Serial No …mon84……...
Test Engineer …Simon Pyatt…….
Date …18/02/10…….

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.712V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.984V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.986V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.980V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.980V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon85……
Test Engineer…Simon Pyatt……
Date…18/02/10……

Contents

1. Block diagram

2. Test equipment

3. Description

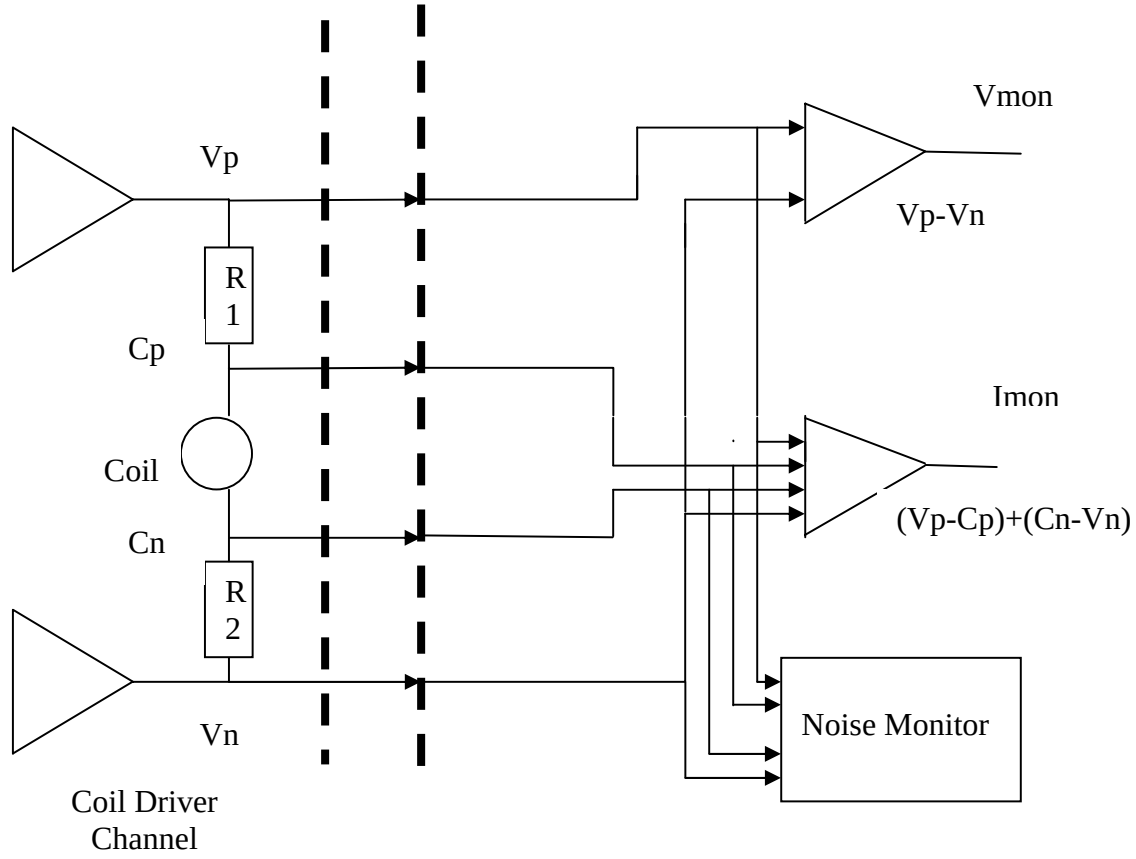
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

Serial No …mon85……..
Test Engineer …Simon Pyatt…….
Date …18/02/10……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon85……...
Test Engineer …Simon Pyatt…….
Date …18/02/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.83V	√
-15V (TP6)	-15.03V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon85……...
Test Engineer …Simon Pyatt…….
Date …18/02/10……

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.8	2.8	2.8	2.8

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.4	1.4	1.4	1.4	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.714V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.988V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.985V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.986V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.986V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon86……
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1. Block diagram

2. Test equipment

3. Description

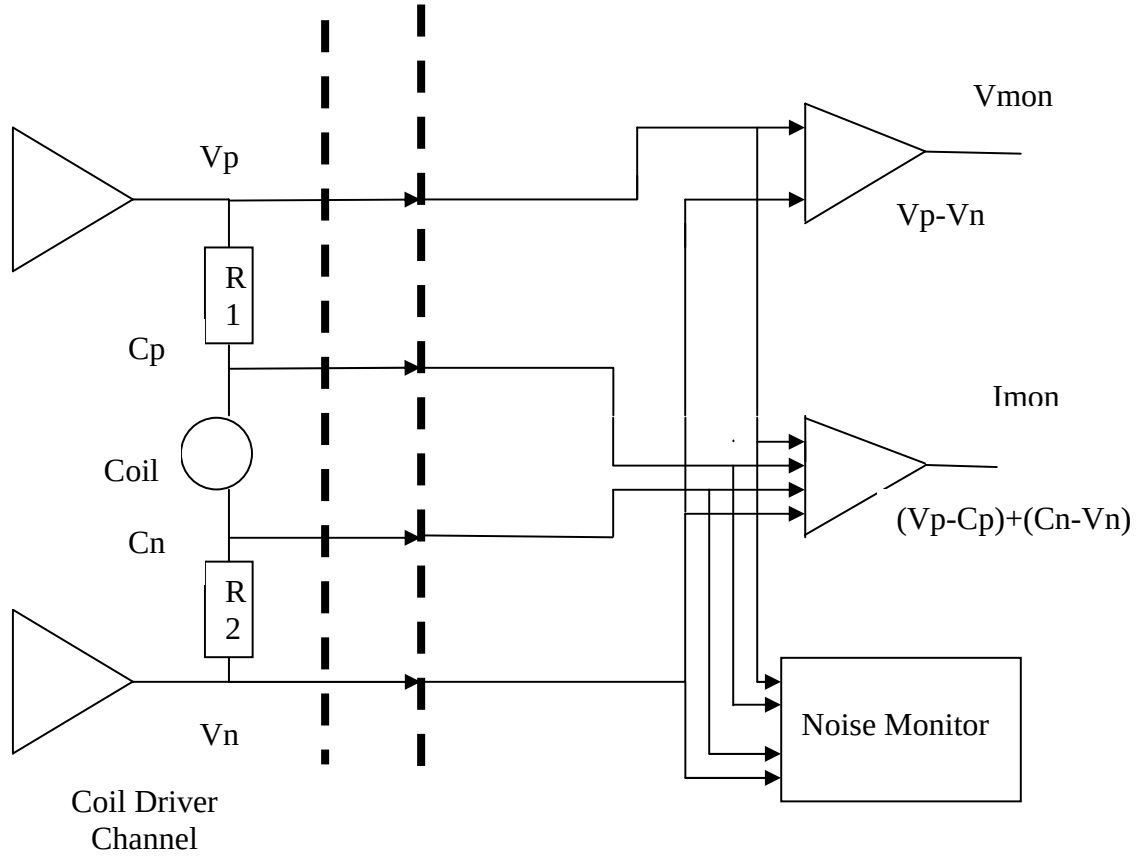
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon86……...
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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.85V	√
-15V (TP6)	-14.95V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.8	2.8	2.8	2.8

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.4	1.4	1.4	1.4	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.715V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon87……
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1. Block diagram

2. Test equipment

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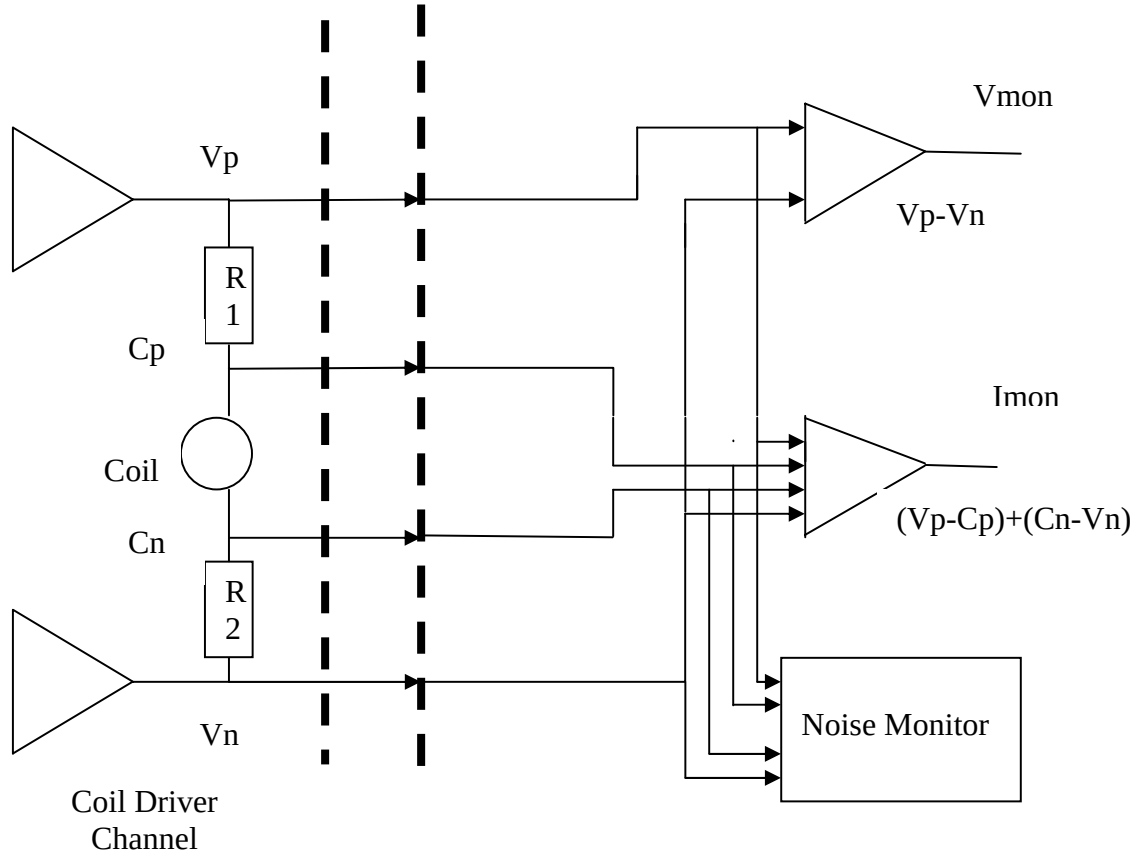
5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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Date …19/02/10……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon87……...
Test Engineer …Simon Pyatt…….
Date …19/02/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	15.01V	√
-15V (TP6)	-15.03V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon87……...
Test Engineer …Simon Pyatt…….
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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.6V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.9	2.9	2.8	2.8

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.45	1.45	1.4	1.4	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.8V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.8V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.716V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.359V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.981V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.979V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.978V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.982V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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Contents

1. Block diagram

2. Test equipment

3. Description

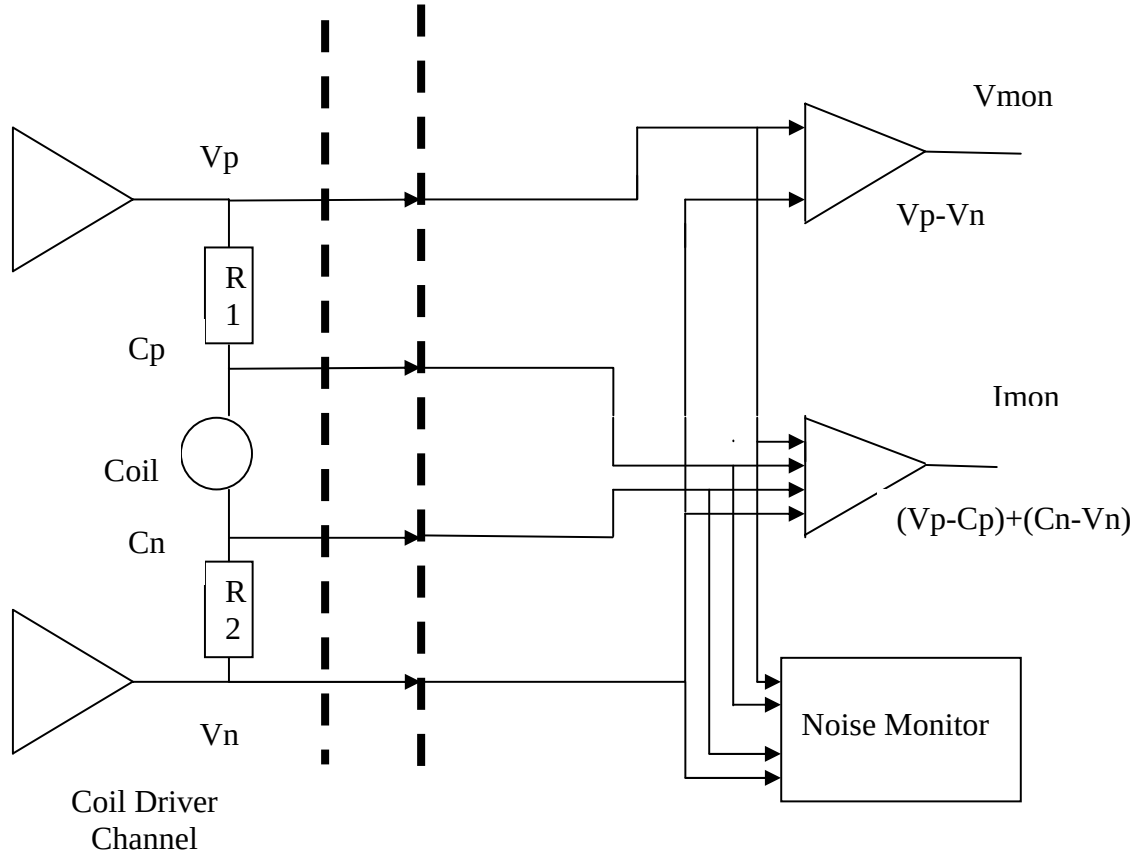
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

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NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.87V	√
-15V (TP6)	-14.93V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7	**1.6V to 1.9V**	√
Ch2	100mV	1.7	**1.6V to 1.9V**	√
Ch3	100mV	1.7	**1.6V to 1.9V**	√
Ch4	100mV	1.7	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.8	2.8	2.8	2.8

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.4	1.4	1.4	1.4	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.3	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.3	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.5	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.3	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.719V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.361V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.991V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.988V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.992V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.995V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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Date…23/02/10……

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1. Block diagram

2. Test equipment

3. Description

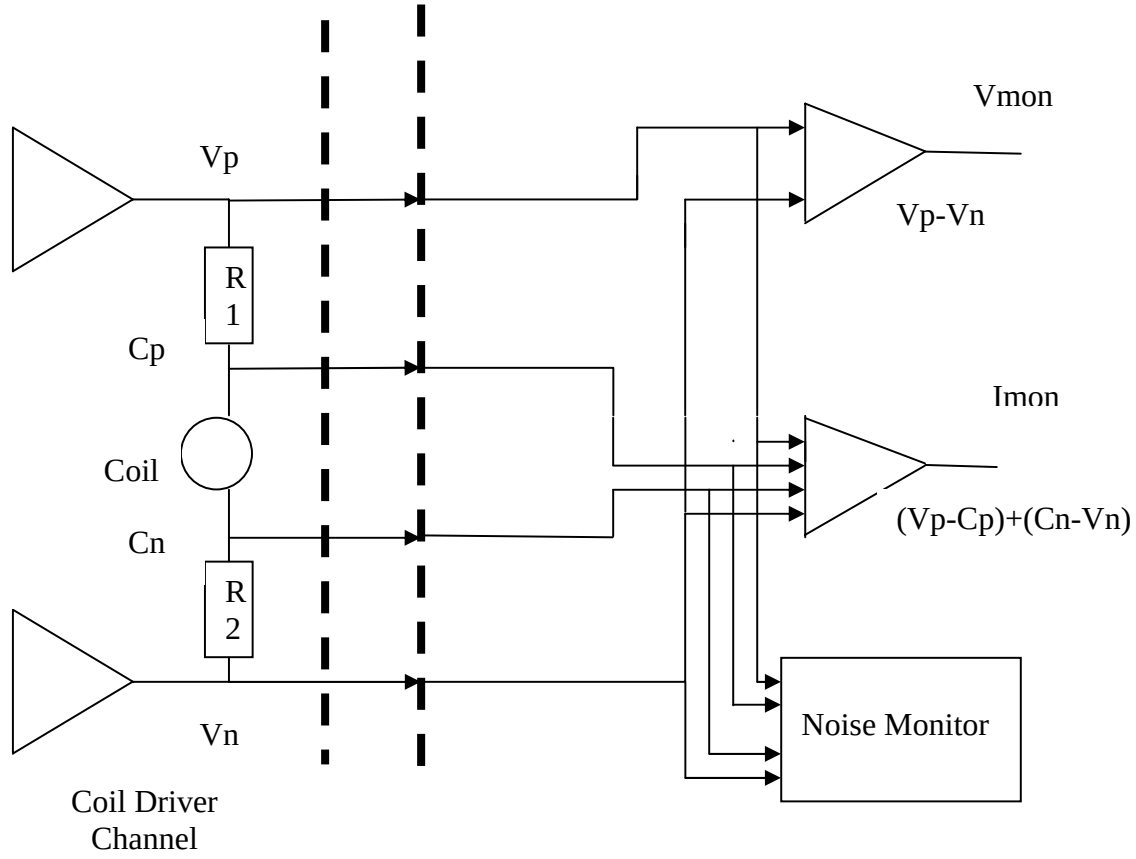
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

Serial No …mon89……..
Test Engineer …Simon Pyatt…….
Date …23/02/10……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon89……...
Test Engineer …Simon Pyatt…….
Date …23/02/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.94V	√
-15V (TP6)	-14.98V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.25A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

Serial No …mon89……...
Test Engineer …Simon Pyatt…….
Date …23/02/10……

Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

Serial No …mon89……...
Test Engineer …Simon Pyatt…….
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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2.1	2.1	2.1
TP7	8	8	8	8	2.8	3	3.1	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.4	1.42	1.47	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.6V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√

Serial No …mon89……...
Test Engineer …Simon Pyatt…….
Date …23/02/10……

6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

Serial No …mon89……...
Test Engineer …Simon Pyatt…….
Date …23/02/10……

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.710V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.716V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.991V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.987V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.991V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.994V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon90……
Test Engineer…Simon Pyatt……
Date…24/02/10……

Contents

1. Block diagram

2. Test equipment

3. Description

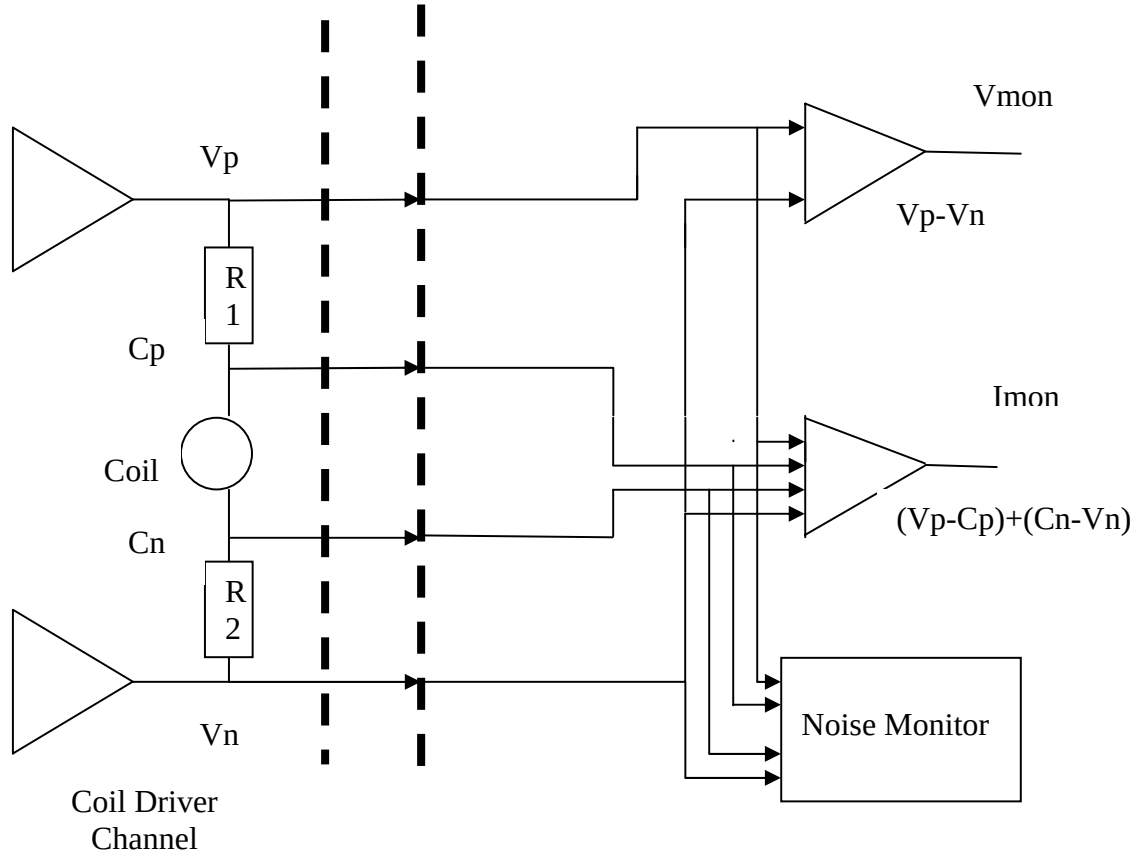
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

Serial No …mon90……..
Test Engineer …Simon Pyatt…….
Date …24/02/10……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon90……...
Test Engineer …Simon Pyatt…….
Date …24/02/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.92V	√
-15V (TP6)	-14.92V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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Test Engineer …Simon Pyatt…….
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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Test Engineer …Simon Pyatt…….
Date …24/02/10…….

Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Test Engineer …Simon Pyatt…….
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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.8	2.8	2.8	2.8

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.4	1.4	1.4	1.4	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.6V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.8V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.6V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.6V	**4 to 5.5V**	√

Serial No …mon90……...
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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

Serial No …mon90……...
Test Engineer …Simon Pyatt…….
Date …24/02/10…….

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.710V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.707V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.353V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.352V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.980V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.984V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.977V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.974V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon91……
Test Engineer…Simon Pyatt……
Date…24/02/10……

Contents

1. Block diagram

2. Test equipment

3. Description

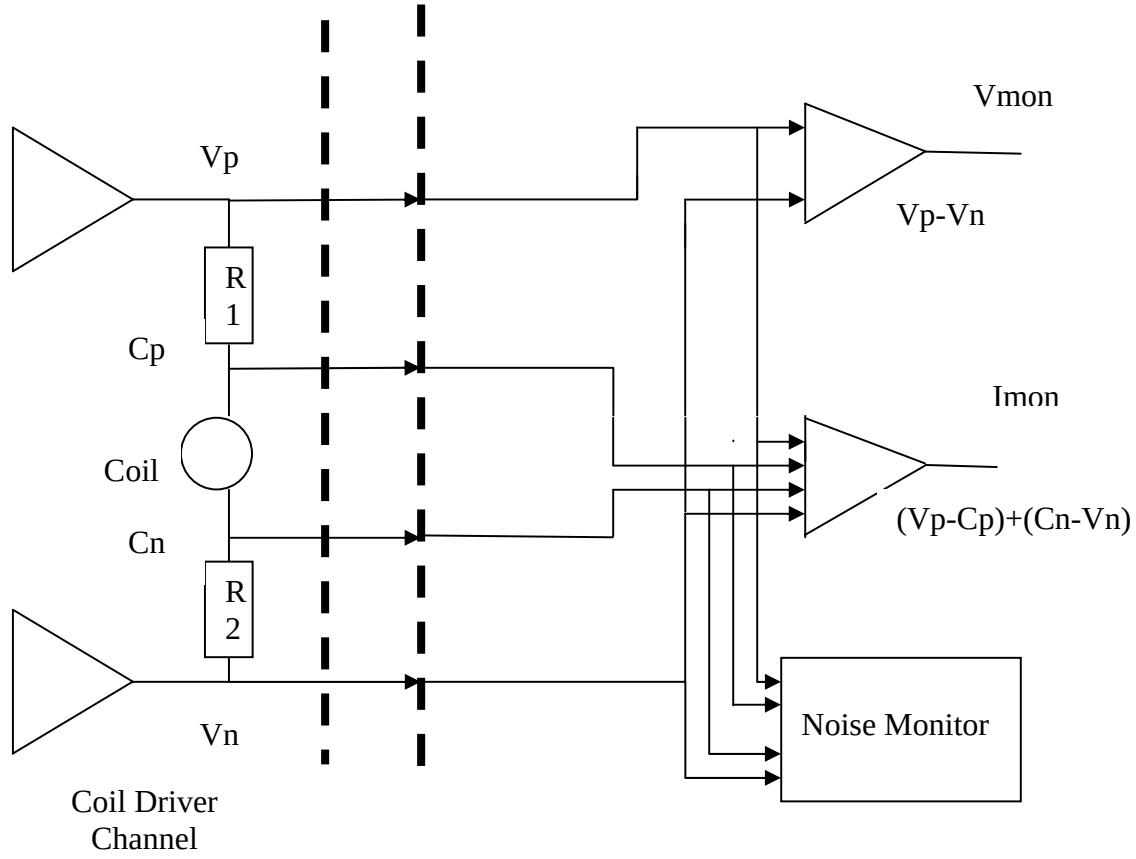
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Replaced IC10 on channel 3, original was faulty.

Replaced C9 on channel 4, damaged during replacement of IC10, ch3.

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NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.88V	√
-15V (TP6)	-15.03V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2.1	2
TP7	8	8	8	8	3.1	3.1	3.1	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.42	
TP7/TP6	2	2	2	2	1.47	1.47	1.47	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.3V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.6V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.708V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.352V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.984V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.984V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.983V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.977V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.06V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon92……
Test Engineer…Simon Pyatt……
Date…25/02/10……

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1. Block diagram

2. Test equipment

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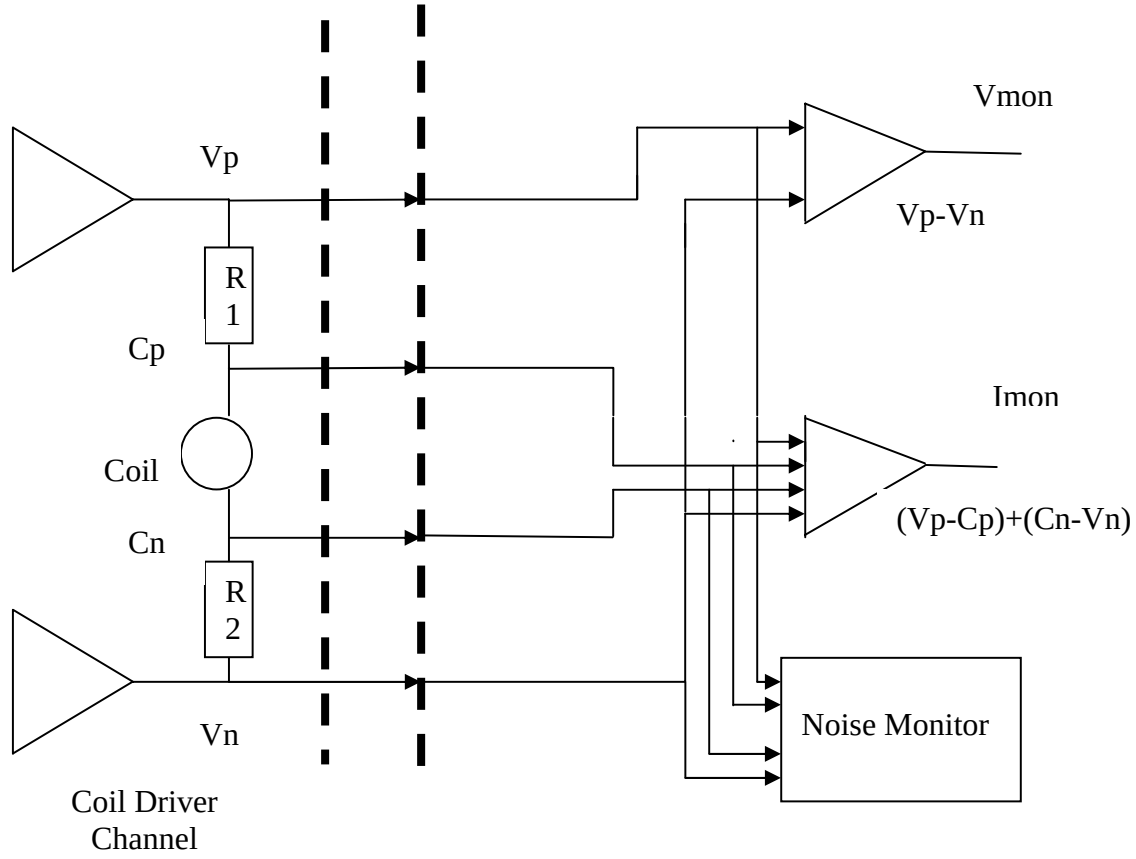
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Positive voltage regulator (LM2940CS) replaced. Old regulator failed noise test.

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Date ……

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.77V	√
-15V (TP6)	-15.02V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.6V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.8	2.9	2.8	2.8

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.4	1.45	1.4	1.4	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.6V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.711V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.355V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.984V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.984V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.984V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.981V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon93……
Test Engineer…Simon Pyatt……
Date…26/02/10……

Contents

1. Block diagram

2. Test equipment

3. Description

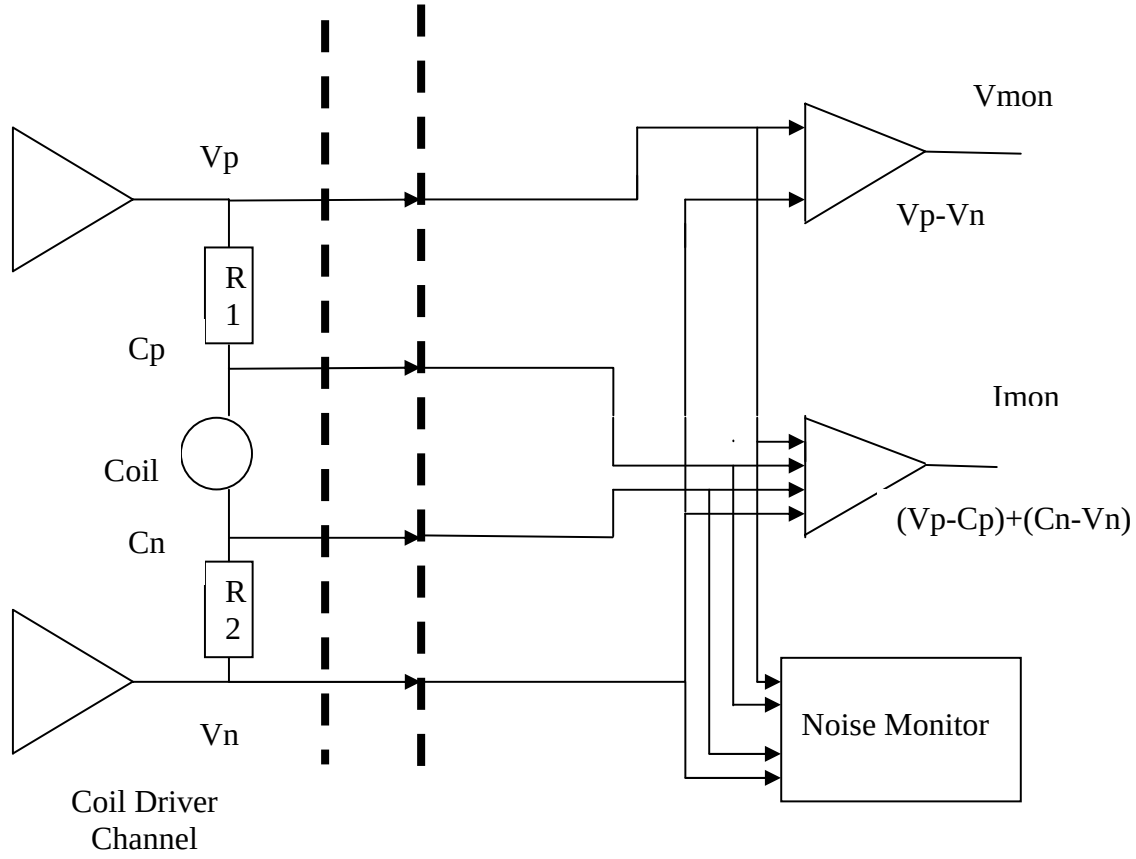
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK? √**
Comments

Solder mask covering vias.

Visual overall check **OK? √**
Solder joint **OK? √**
Placement **OK? √**

Modifications

Positive regulator (LM2940CS) replaced. Old regulator failed noise test.

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NOTES

Serial No …mon93……...
Test Engineer …Simon Pyatt…….
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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.80V	√
-15V (TP6)	-14.92V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2.1	2.1
TP7	8	8	8	8	3.1	3.1	3.1	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.47	1.47	1.47	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.711V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.356V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.983V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.981V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.983V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.978V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon94……
Test Engineer…Simon Pyatt……
Date…26/02/10……

Contents

1. Block diagram

2. Test equipment

3. Description

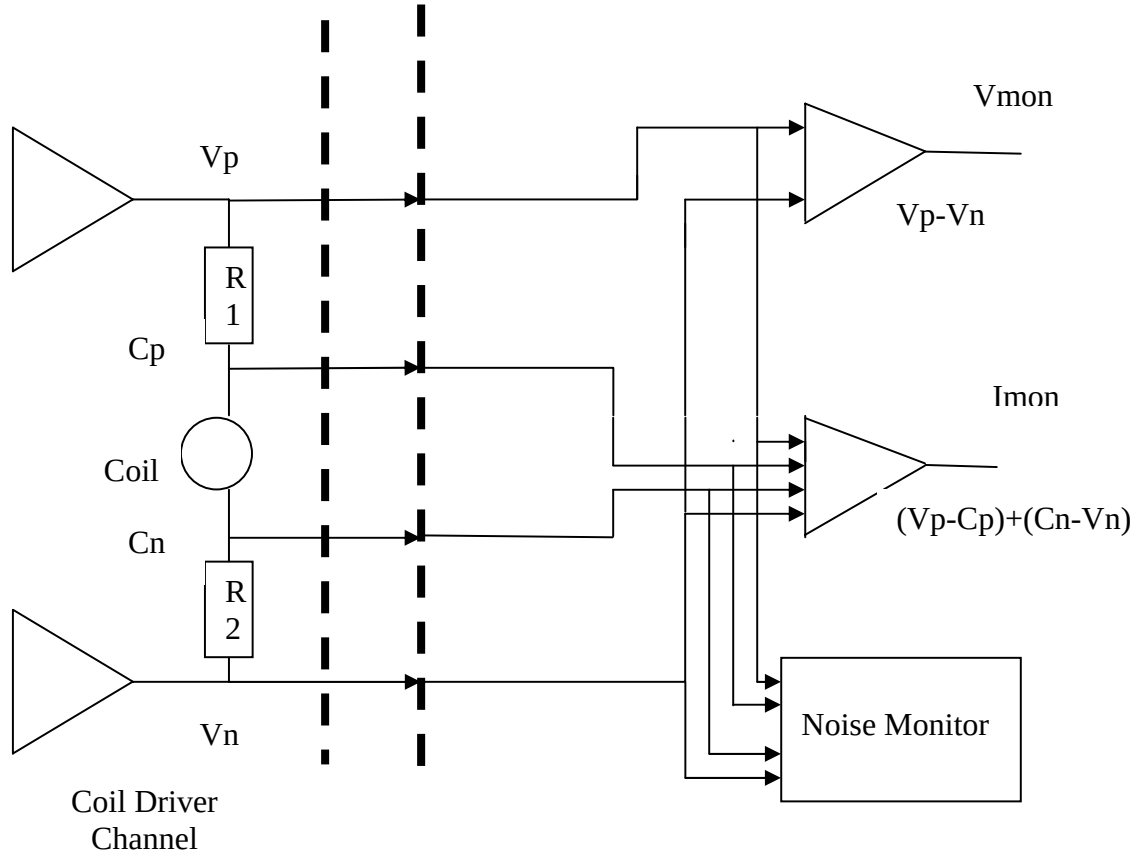
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Positive regulator (LM2940CS) replaced. Old regulator failed noise test.

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon94……...
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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.90V	√
-15V (TP6)	-15.09V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.9	2.8	2.9	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.45	1.4	1.45	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.3V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.3V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.707V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.712V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.353V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.356V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.987V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.979V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.986V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.984V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon95……
Test Engineer…Simon Pyatt……
Date…01/03/10……

Contents

1. Block diagram

2. Test equipment

3. Description

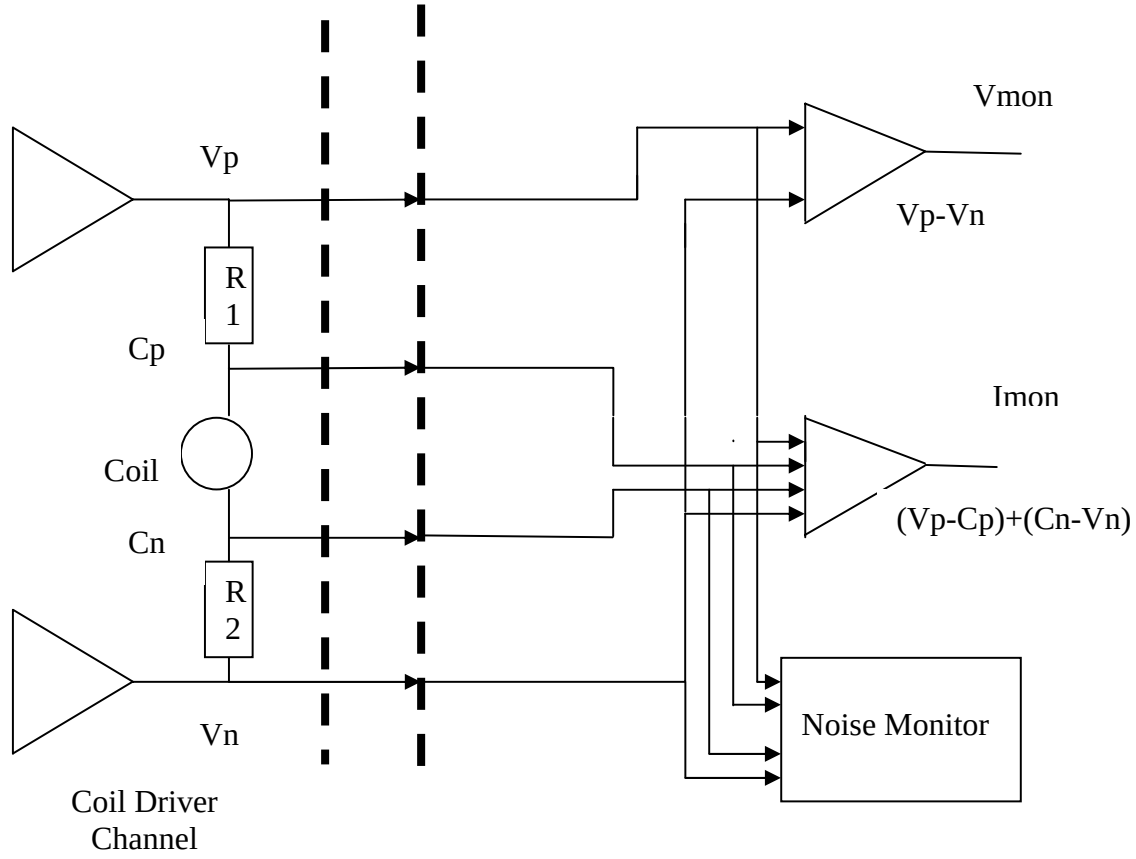
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

Serial No …mon95……..
Test Engineer …Simon Pyatt……
Date …01/03/10……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Positive regulator (LM2940CS) replaced. Old regulator failed noise test.

RMS TO DC converter (AD736JRZ) replaced. Original faulty.

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon95……...
Test Engineer …Simon Pyatt…….
Date …01/03/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	15.00V	√
-15V (TP6)	-14.93V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon95……...
Test Engineer …Simon Pyatt…….
Date …01/03/10……

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Test Engineer …Simon Pyatt…….
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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2	2.1	2
TP7	8	8	8	8	3.1	3	3.1	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.42	1.5	1.42	
TP7/TP6	2	2	2	2	1.47	1.5	1.47	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.6V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.8V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.709V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.715V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.354V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.985V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.977V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.980V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.982V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon96……
Test Engineer…Simon Pyatt……
Date…01/03/10……

Contents

1. Block diagram

2. Test equipment

3. Description

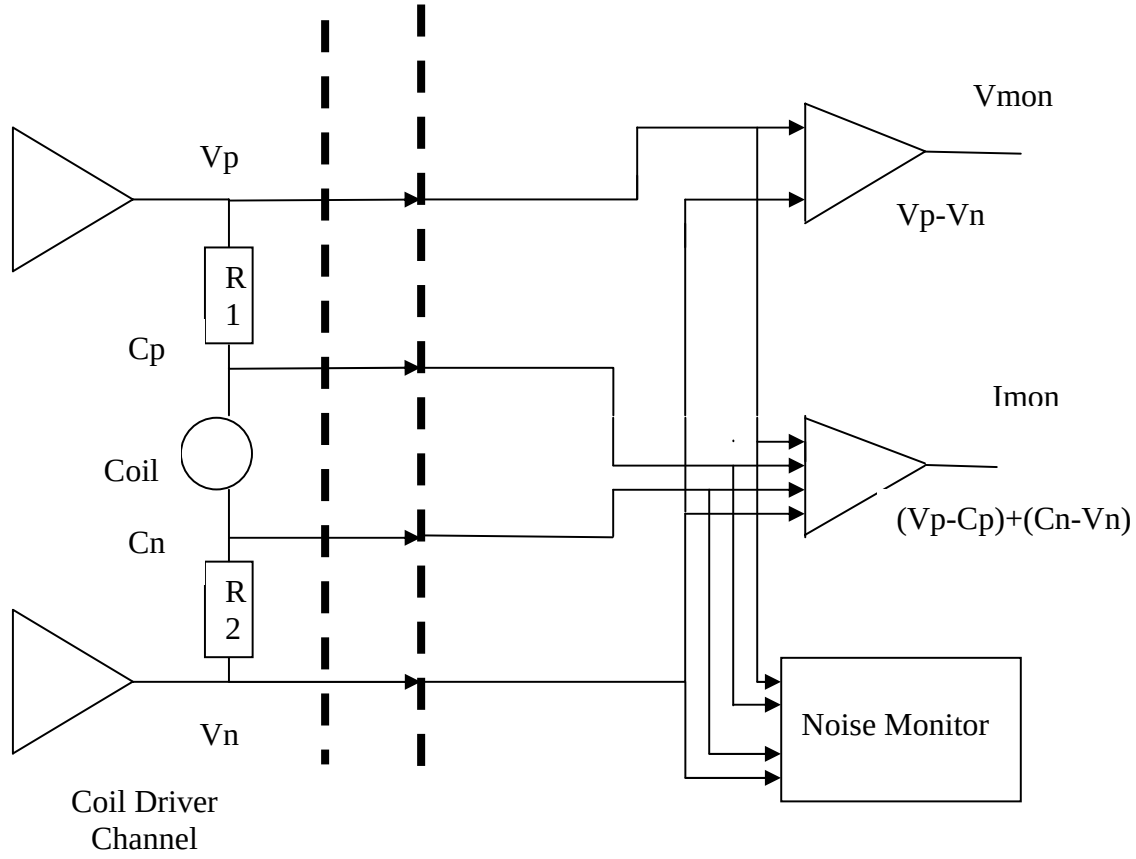
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

Serial No …mon96……..
Test Engineer …Simon Pyatt…….
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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Positive voltage regulator (LM2940CS) replaced. Original was faulty.

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon96……...
Test Engineer …Simon Pyatt…….
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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	15.05V	√
-15V (TP6)	-14.94V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon96……...
Test Engineer …Simon Pyatt…….
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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

Serial No …mon96……...
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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Test Engineer …Simon Pyatt…….
Date …01/03/10……

Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.9	2.9	2.8	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.45	1.45	1.4	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.8V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√

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Test Engineer …Simon Pyatt…….
Date …02/03/10…….

6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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Test Engineer …Simon Pyatt…….
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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.714V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.990V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.988V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.985V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.985V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon97……
Test Engineer…Simon Pyatt……
Date…02/03/10……

Contents

1. Block diagram

2. Test equipment

3. Description

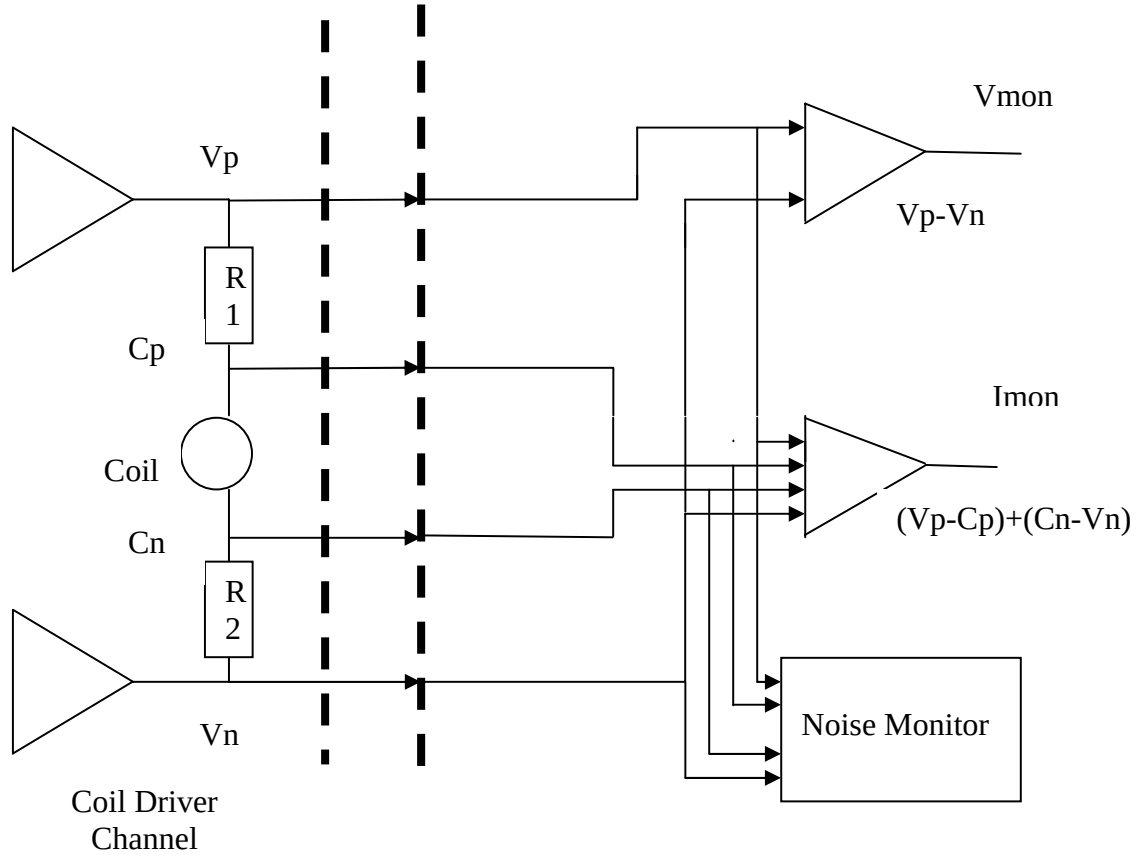
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Negative voltage regulator (LM2990S) replaced. Original was faulty.

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon97……...
Test Engineer …Simon Pyatt…….
Date …02/03/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.92V	√
-15V (TP6)	-14.99V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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Test Engineer …Simon Pyatt…….
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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Test Engineer …Simon Pyatt…….
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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.9	2.9	2.9	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.45	1.45	1.45	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.6V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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Test Engineer …Simon Pyatt…….
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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.717V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.710V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.714V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.360V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.980V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.986V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.974V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.981V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon98……
Test Engineer…Simon Pyatt……
Date…02/03/10……

Contents

1. Block diagram

2. Test equipment

3. Description

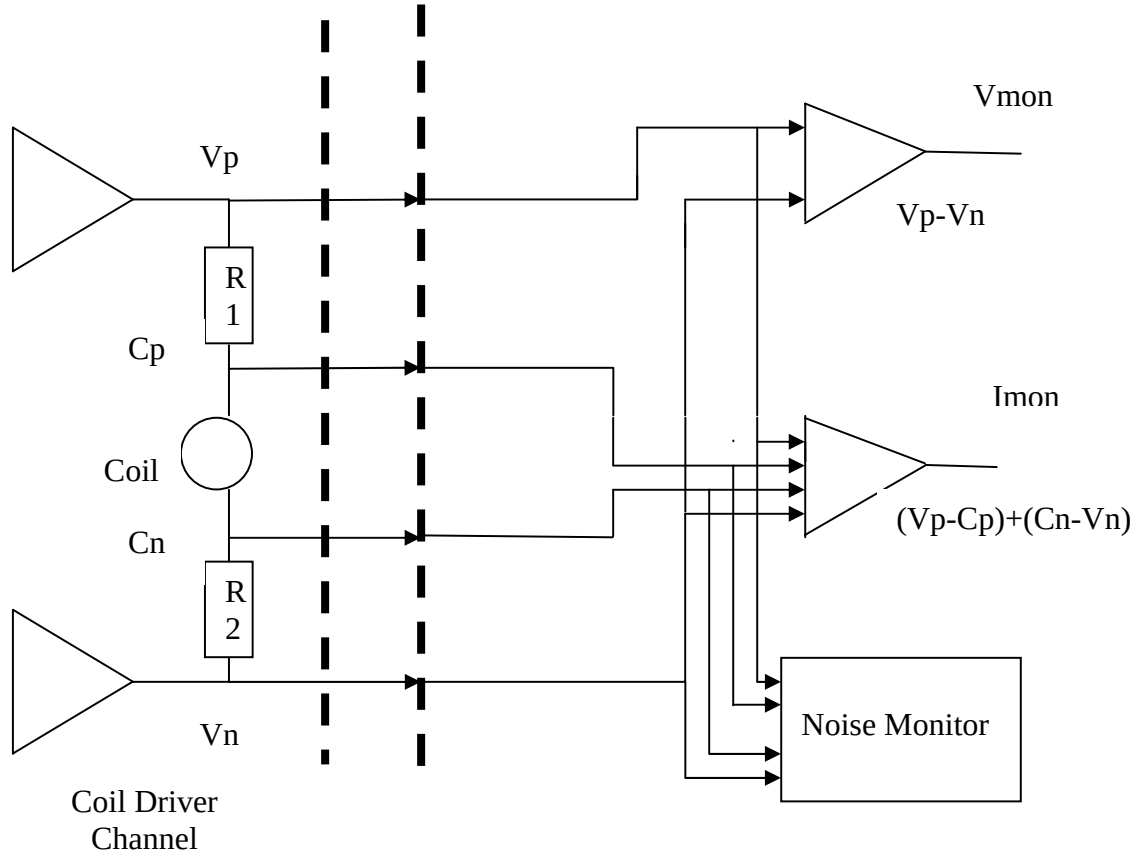
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Large blemish on back of PCB under J1 connector.

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon98……...
Test Engineer …Simon Pyatt…….
Date …02/03/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.83V	√
-15V (TP6)	-15.04V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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Test Engineer …Simon Pyatt…….
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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

Serial No …mon98……...
Test Engineer …Simon Pyatt…….
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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2	2.1	2.1
TP7	8	8	8	8	3.1	3	3.1	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.42	1.5	1.5	
TP7/TP6	2	2	2	2	1.47	1.5	1.47	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.6V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.6V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.8V	4 to 5.5V	√

Serial No …mon98……...
Test Engineer …Simon Pyatt…….
Date …02/03/10…….

6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

Serial No …mon98……...
Test Engineer …Simon Pyatt…….
Date …02/03/10……

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.714V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon99……
Test Engineer…Simon Pyatt……
Date…02/03/10……

Contents

1. Block diagram

2. Test equipment

3. Description

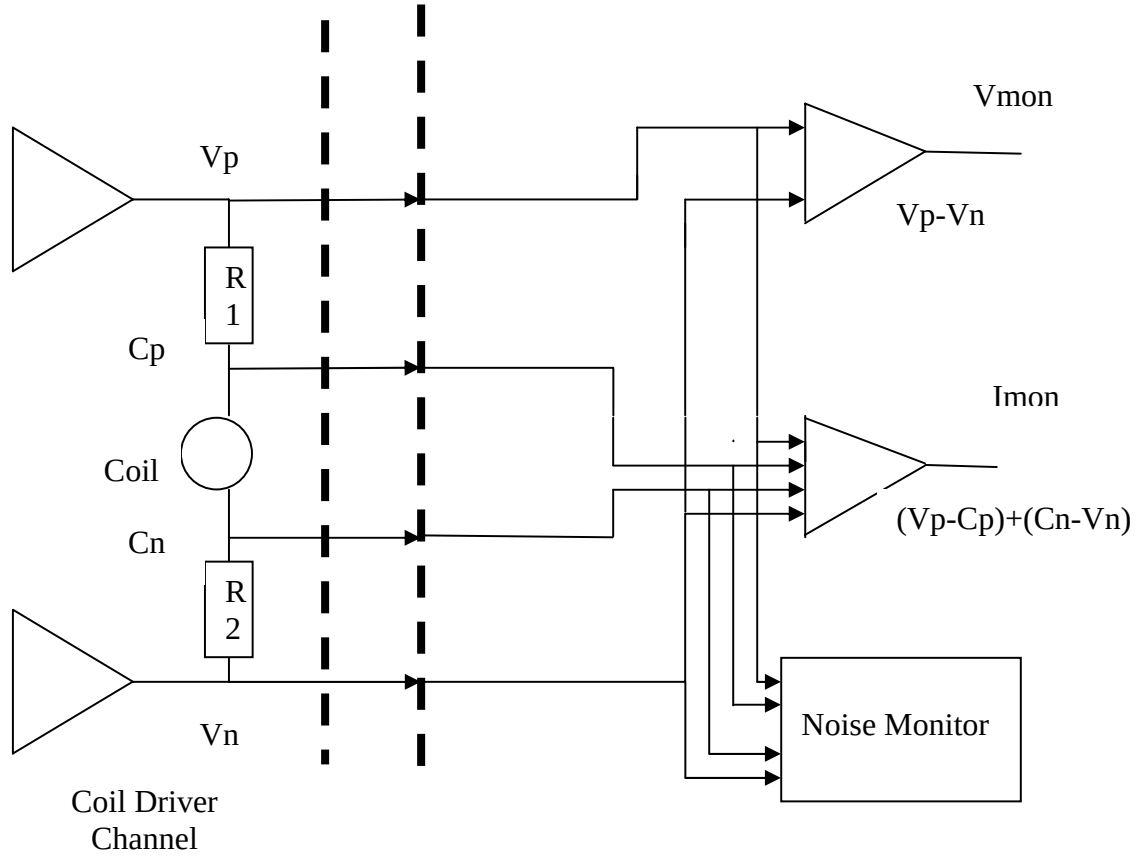
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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Test Engineer …Simon Pyatt…….
Date …02/03/10……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Positive regulator (LM2940CS) replaced. Original was faulty.

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon99……...
Test Engineer …Simon Pyatt…….
Date …02/03/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.91V	√
-15V (TP6)	-14.99V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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Test Engineer …Simon Pyatt…….
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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Test Engineer …Simon Pyatt…….
Date …02/03/10……

Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Test Engineer …Simon Pyatt…….
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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.8	2.9	2.9	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.4	1.45	1.45	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.6V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.6V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√

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Date …02/03/10…….

6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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Test Engineer …Simon Pyatt…….
Date …02/03/10…….

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.719V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.717V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.715V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.363V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.361V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.359V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.02V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No ……Mon100……...
Test Engineer …Simon……
Date ……19/10/09……

Contents

1. Block diagram

2. Test equipment

3. Description

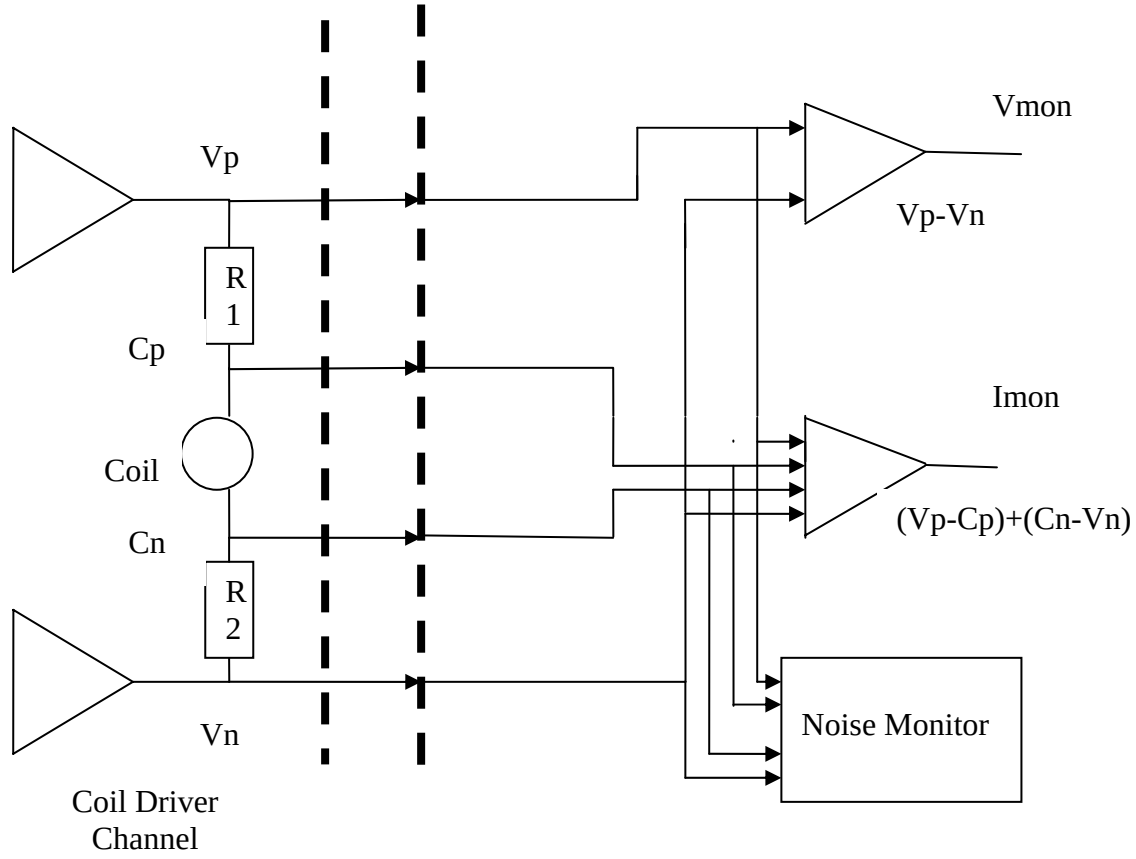
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15v power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9K resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15v and -15v, the sum of which is 30v, would give an output of 30v/3 = 10v.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9K resistors for R1 and R2. The coil is simulated by two 3.9K resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15v in the output will be 5v.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

Serial No ……Mon100……...
Test Engineer …Simon Pyatt……
Date …19/10/09……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No ……mon100……...
Test Engineer ……Simon Pyatt……
Date ……19/10/09……

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3v.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5v)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5v)
+15v (TP4)	14.93	√
-15v (TP6)	-14.93	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.22
-15v (TP6)	√	5mV	0.21

Serial No ……mon100……...
Test Engineer …Simon Pyatt……
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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20 Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0v

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/Fail
Ch1	**100mV**	**2.4V**	2.4V to 2.6V	√
Ch2	**100mV**	**2.4V**	2.4V to 2.6V	√
Ch3	**100mV**	**2.4V**	2.4V to 2.6V	√
Ch4	**100mV**	**2.4V**	2.4V to 2.6V	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/Fail
Ch1	**100mV**	**2.4V**	2.4V to 2.6V	√
Ch2	**100mV**	**2.4V**	2.4V to 2.6V	√
Ch3	**100mV**	**2.4V**	2.4V to 2.6V	√
Ch4	**100mv**	**2.4V**	2.4V to 2.6V	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5 Hz:
Amplitude= 100mV pk/pk
Ground reference = Power 0v

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/Fail
Ch1	**100mV**	**1.7V**	**1.6v to 1.9v**	√
Ch2	**100mV**	**1.7V**	**1.6v to 1.9v**	√
Ch3	**100mV**	**1.7V**	**1.6v to 1.9v**	√
Ch4	**100mV**	**1.7V**	**1.6v to 1.9v**	√

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Test Engineer …Simon Pyatt…….
Date …19/10/09……

Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/Fail
Ch1	**100mV**	**1.7V**	**1.6v to 1.9v**	√
Ch2	**100mV**	**1.7V**	**1.6v to 1.9v**	√
Ch3	**100mV**	**1.7V**	**1.6v to 1.9v**	√
Ch4	**100mV**	**1.7V**	**1.6v to 1.9v**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20 Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/Fail
Ch1		**4.8V**	**4.8v to 5.2v**	√
Ch2		**4.8V**	**4.8v to 5.2v**	√
Ch3		**4.8V**	**4.8v to 5.2v**	√
Ch4		**4.8V**	**4.8v to 5.2v**	√

Serial No …mon100……...
Test Engineer ……Simon Pyatt…….
Date ……19/10/09……

Gains of Successive Stages:
Make measurements at 100 Hz, then at 5 Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1V	1V	1V	1V	1V	1V	1V	1V
TP4	2V	2V	2V	2V	1.5V	1.5V	1.5V	1.5V
TP6	4V	4V	4V	4V	2.2V	2.2V	2.2V	2.1V
TP7	8V	8V	8V	8V	3.2V	3.2V	3.2V	3.2V

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5 Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	√
TP6/TP4	2	2	2	2	1.4	1.4	1.4	1.4	√
TP7/TP6	2	2	2	2	1.5	1.5	1.5	1.5	√

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5Khz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500hz**	**OK?**	**5 KHz (V peak)**	**Spec @ 5KHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10v**	√	4.4V	**4 to 5.5v**	√
Ch2	**TP10**	10V	**9.7 to 10v**	√	4.4V	**4 to 5.5v**	√
Ch3	**TP10**	10V	**9.7 to 10v**	√	4.4V	**4 to 5.5v**	√
Ch4	**TP10**	10V	**9.7 to 10v**	√	4.4V	**4 to 5.5v**	√

Serial No ……mon100……...
Test Engineer …Simon Pyatt……
Date …20/10/09……

6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30 Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/Fail
Ch1	**3V**	**2V**	**1.9 to 2.1v**	√
Ch2	**3V**	**2V**	**1.9 to 2.1v**	√
Ch3	**3V**	**2V**	**1.9 to 2.1v**	√
Ch4	**3V**	**2V**	**1.9 to 2.1v**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set
Frequency to 100Hz
The input voltage between TP8 and TP9 to 3v Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0v in	**0v +/- 0.1v**	0V	0V	0V	0V	√
(2) 3v in	**1v +/- 0.1v**	1V	1V	1V	1V	√
(3) 4.5vin	**1.5v +/- 0.1v**	1.5V	1.5V	1.5V	1.5V	√
(4) 6v in	**2v +/- 0.1v**	2V	2V	2V	2V	√

Serial No …mon100……..
Test Engineer …Simon Pyatt…….
Date …20/10/09…….

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30 Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s dc output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	**0.711V**	**0.707 (0.68 to 0.72)**	√
Ch2	**0.710V**	**0.707 (0.68 to 0.72)**	√
Ch3	**0.711V**	**0.707 (0.68 to 0.72)**	√
Ch4	**0.712V**	**0.707 (0.68 to 0.72)**	√
1.5V peak			
Ch1	**0.355V**	**0.35v (0.33 to 0.37)**	√
Ch2	**0.355V**	**0.35v (0.33 to 0.37)**	√
Ch3	**0.353V**	**0.35v (0.33 to 0.37)**	√
Ch4	**0.355V**	**0.35v (0.33 to 0.37)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3v peak and the frequency to 30 Hz.

3v peak Square Wave		Expected value (volts dc)	Pass/ Fail
Ch1, TP13	0.98V	**1v (0.9 to 1.1v)**	√
Ch2, TP13	0.98V	**1v (0.9 to 1.1v)**	√
Ch3, TP13	0.98V	**1v (0.9 to 1.1v)**	√
Ch4, TP13	0.98V	**1v (0.9 to 1.1v)**	√

DC input

Apply a 3v dc input between TP8 and TP9.

3v DC		Expected value (volts dc)	Pass/ Fail
Ch1, TP13	1V	**1v (0.9 to 1.1v)**	√
Ch2, TP13	1V	**1v (0.9 to 1.1v)**	√
Ch3, TP13	1V	**1v (0.9 to 1.1v)**	√
Ch4, TP13	1V	**1v (0.9 to 1.1v)**	√

MONITOR BOARD TEST PLAN

Serial No …mon101……...
Test Engineer ……Simon Pyatt……
Date …20/10/09……

Contents

1. Block diagram

2. Test equipment

3. Description

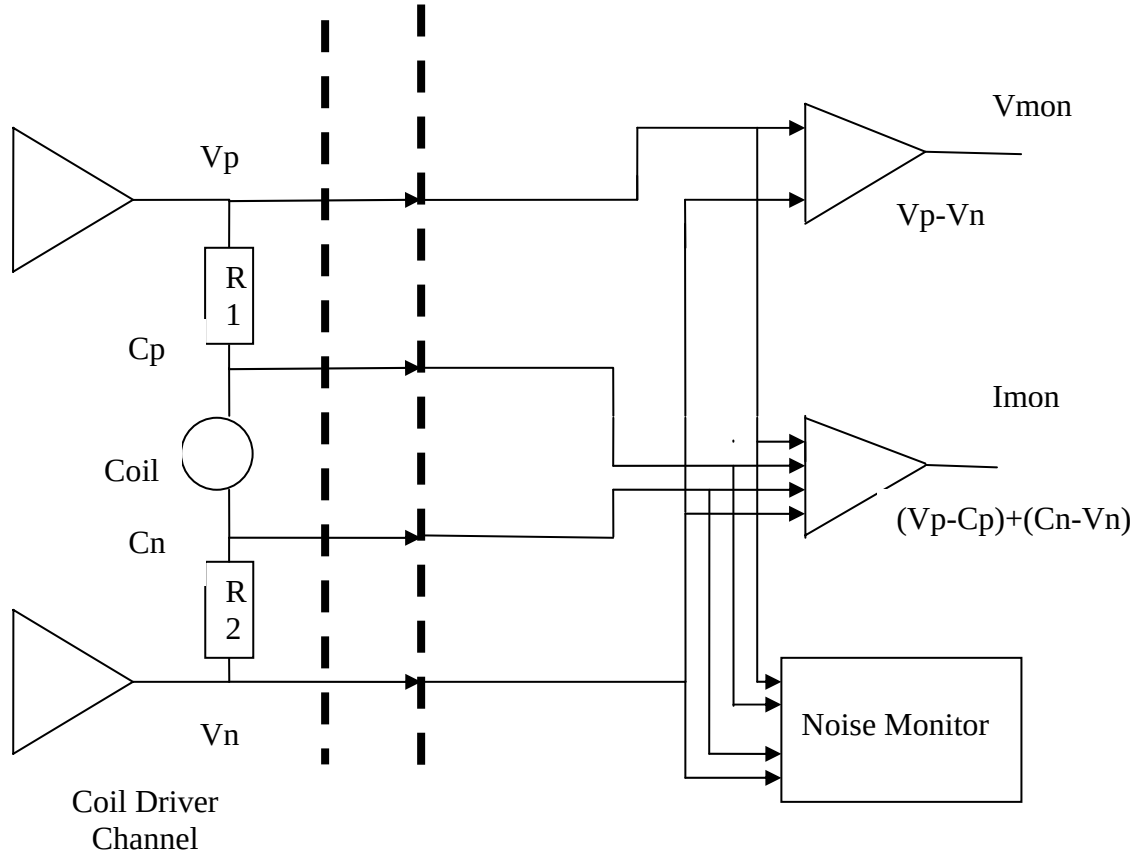
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15v power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9K resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15v and -15v, the sum of which is 30v, would give an output of 30v/3 = 10v.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9K resistors for R1 and R2. The coil is simulated by two 3.9K resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15v in the output will be 5v.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon101……...
Test Engineer …Simon Pyatt…….
Date ……20/10/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3v.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5v)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5v)
+15v (TP4)	14.79V	√
-15v (TP6)	-14.91V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the powe supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mA	0.28A
-15v (TP6)	√	5mA	0.26A

Serial No ……mon101……...
Test Engineer ……Simon Pyatt……
Date ……20/10/09……

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20 Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0v

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/Fail
Ch1	**100mV**	**2.4V**	2.4V to 2.6V	√
Ch2	**100mV**	**2.4V**	2.4V to 2.6V	√
Ch3	**100mV**	**2.4V**	2.4V to 2.6V	√
Ch4	**100mV**	**2.4V**	2.4V to 2.6V	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/Fail
Ch1	**100mV**	**2.4V**	2.4V to 2.6V	√
Ch2	**100mV**	**2.4V**	2.4V to 2.6V	√
Ch3	**100mV**	**2.4V**	2.4V to 2.6V	√
Ch4	**100mV**	**2.4V**	2.4V to 2.6V	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5 Hz:
Amplitude= 100mV pk/pk
Ground reference = Power 0v

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/Fail
Ch1	**100mV**	**1.9V**	**1.6v to 1.9v**	√
Ch2	**100mV**	**1.9V**	**1.6v to 1.9v**	√
Ch3	**100mV**	**1.9V**	**1.6v to 1.9v**	√
Ch4	**100mV**	**1.9V**	**1.6v to 1.9v**	√

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Test Engineer ……Simon Pyatt…….
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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/Fail
Ch1	**100mV**	**1.8V**	**1.6v to 1.9v**	√
Ch2	**100mV**	**1.8V**	**1.6v to 1.9v**	√
Ch3	**100mV**	**1.8V**	**1.6v to 1.9v**	√
Ch4	**100mV**	**1.8V**	**1.6v to 1.9v**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20 Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/Fail
Ch1	**100mV**	**4.9V**	**4.8v to 5.2v**	√
Ch2	**100mV**	**4.9V**	**4.8v to 5.2v**	√
Ch3	**100mV**	**4.9V**	**4.8v to 5.2v**	√
Ch4	**100mV**	**4.9V**	**4.8v to 5.2v**	√

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Gains of Successive Stages:
Make measurements at 100 Hz, then at 5 Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1V	1V	1V	1V	1V	1V	1V	1V
TP4	2V	2V	2V	2V	1.4V	1.4V	1.4V	1.4V
TP6	4V	4V	4V	4V	2.1V	2.1V	2V	2V
TP7	8V	8V	8V	8V	3.1V	3.1V	3.2V	3.2V

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5 Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	√
TP6/TP4	2	2	2	2	1.5	1.5	1.42	1.42	√
TP7/TP6	2	2	2	2	1.47	1.47	1.6	1.6	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5Khz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500hz**	**OK?**	**5 KHz (V peak)**	**Spec @ 5KHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10v**	√	4.9V	**4 to 5.5v**	√
Ch2	**TP10**	10V	**9.7 to 10v**	√	4.9V	**4 to 5.5v**	√
Ch3	**TP10**	10V	**9.7 to 10v**	√	4.9V	**4 to 5.5v**	√
Ch4	**TP10**	10V	**9.7 to 10v**	√	4.9V	**4 to 5.5v**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30 Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/Fail
Ch1	**3V**	**2V**	**1.9 to 2.1v**	√
Ch2	**3V**	**2V**	**1.9 to 2.1v**	√
Ch3	**3V**	**2V**	**1.9 to 2.1v**	√
Ch4	**3V**	**2V**	**1.9 to 2.1v**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set
Frequency to 100Hz
The input voltage between TP8 and TP9 to 3v Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0v in	**0v +/- 0.1v**	0V	0V	0V	0V	√
(2) 3v in	**1v +/- 0.1v**	1V	1V	1V	1V	√
(3) 4.5vin	**1.5v +/- 0.1v**	1.5V	1.5V	1.5V	1.5V	√
(4) 6v in	**2v +/- 0.1v**	2V	2V	2V	2V	√

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Test Engineer …Simon Pyatt…….
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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30 Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s dc output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.717V	0.707 (0.68 to 0.72)	√
Ch2	0.712V	0.707 (0.68 to 0.72)	√
Ch3	0.714V	0.707 (0.68 to 0.72)	√
Ch4	0.712V	0.707 (0.68 to 0.72)	√
1.5V peak			
Ch1	0.361V	0.35v (0.33 to 0.37)	√
Ch2	0.355V	0.35v (0.33 to 0.37)	√
Ch3	0.358V	0.35v (0.33 to 0.37)	√
Ch4	0.356V	0.35v (0.33 to 0.37)	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3v peak and the frequency to 30 Hz.

3v peak Square Wave		Expected value (volts dc)	Pass/ Fail
Ch1, TP13	1V	1v (0.9 to 1.1v)	√
Ch2, TP13	0.997V	1v (0.9 to 1.1v)	√
Ch3, TP13	0.999V	1v (0.9 to 1.1v)	√
Ch4, TP13	0.996V	1v (0.9 to 1.1v)	√

DC input

Apply a 3v dc input between TP8 and TP9.

3v DC		Expected value (volts dc)	Pass/ Fail
Ch1, TP13	1V	1v (0.9 to 1.1v)	√
Ch2, TP13	1V	1v (0.9 to 1.1v)	√
Ch3, TP13	1V	1v (0.9 to 1.1v)	√
Ch4, TP13	1V	1v (0.9 to 1.1v)	√

MONITOR BOARD TEST PLAN

Serial No…mon102……
Test Engineer…Simon Pyatt……
Date…22/10/09……

Contents

1. Block diagram

2. Test equipment

3. Description

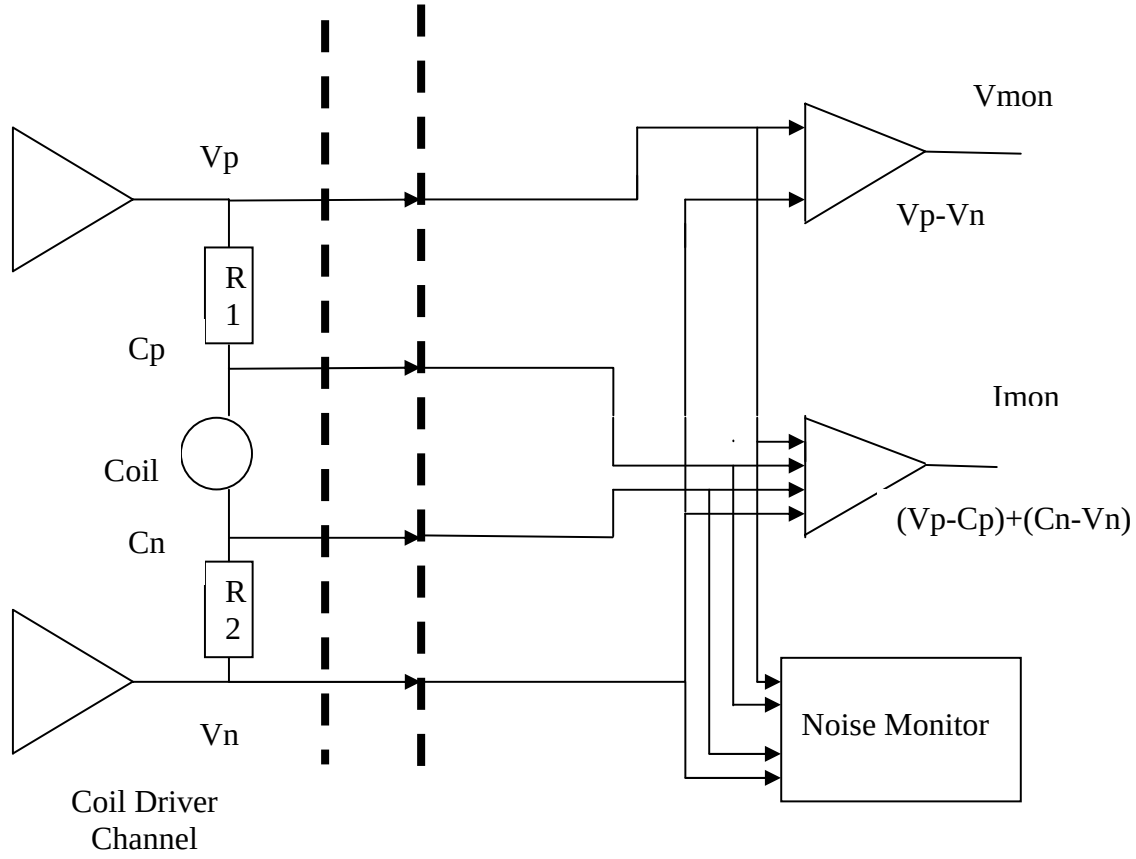
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

Serial No …mon102……..
Test Engineer …Simon Pyatt…….
Date …22/10/09……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK? DS1 is at an angle**

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon102……..
Test Engineer …Simon Pyatt…….
Date …22/10/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.96V	√
-15V (TP6)	-14.99V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	2mA	0.28A
-15v (TP6)	√	5mA	0.26A

Serial No …mon102……...
Test Engineer …Simon Pyatt…….
Date …22/10/09……

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.8V	**4.8V to 5.2V**	√
Ch2		4.8V	**4.8V to 5.2V**	√
Ch3		4.8V	**4.8V to 5.2V**	√
Ch4		4.8V	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1V	1V	1V	1V	1V	1V	1V	1V
TP4	2V	2V	2V	2V	1.4V	1.4V	1.4V	1.4V
TP6	4V	4V	4V	4V	2.2V	2V	2.1V	2.1V
TP7	8V	8V	8V	8V	3.1V	3V	3.1V	3.1V

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	√
TP6/TP4	2	2	2	2	1.57	1.42	1.5	1.5	
TP7/TP6	2	2	2	2	1.4	1.5	1.47	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	**TP10**	9.9V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√
Ch2	**TP10**	9.9V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√
Ch3	**TP10**	9.9V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√
Ch4	**TP10**	9.9V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.714V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.996V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.995V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.998V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.995V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No……mon103……
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1. Block diagram

2. Test equipment

3. Description

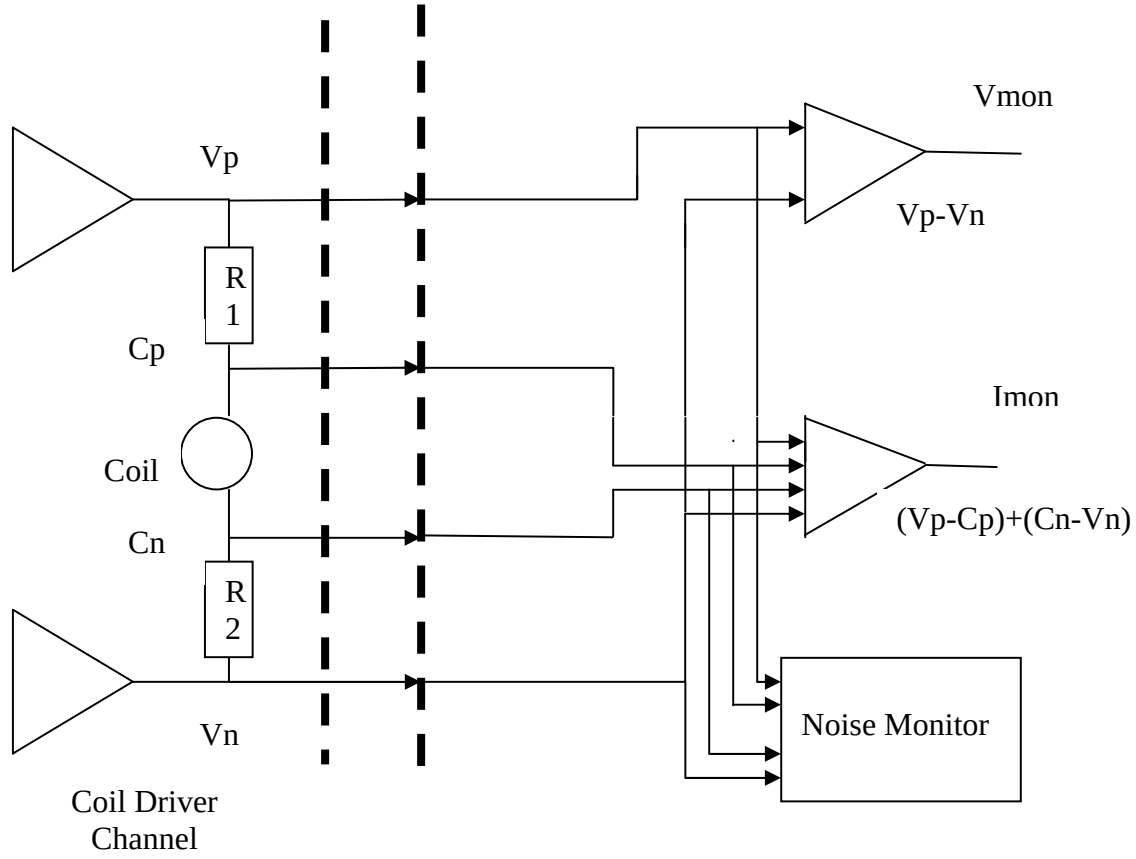
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

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Date ……

NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.9V	√
-15V (TP6)	15.04V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	6mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.5V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.6V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.8V	**4.8V to 5.2V**	√
Ch2		4.8V	**4.8V to 5.2V**	√
Ch3		4.8V	**4.8V to 5.2V**	√
Ch4		4.8V	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1V	1V	1V	1V	1V	1V	1V	1V
TP4	2V	2V	2V	2V	1.4V	1.3V	1.4V	1.4V
TP6	4V	4V	4V	4V	2V	2V	2V	2V
TP7	8V	8V	8V	8V	2.8V	2.8V	2.9V	2.9V

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.3	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.53	1.42	1.42	
TP7/TP6	2	2	2	2	1.4	1.4	1.45	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	**TP10**	10V	**9.7 to 10V**		4.8V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**		4.8V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**		4.7V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**		4.8V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.4V	1.4V	1.4V	1.4V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.715V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.359V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.983V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.981V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.980V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.983V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.00V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.02V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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1. Block diagram

2. Test equipment

3. Description

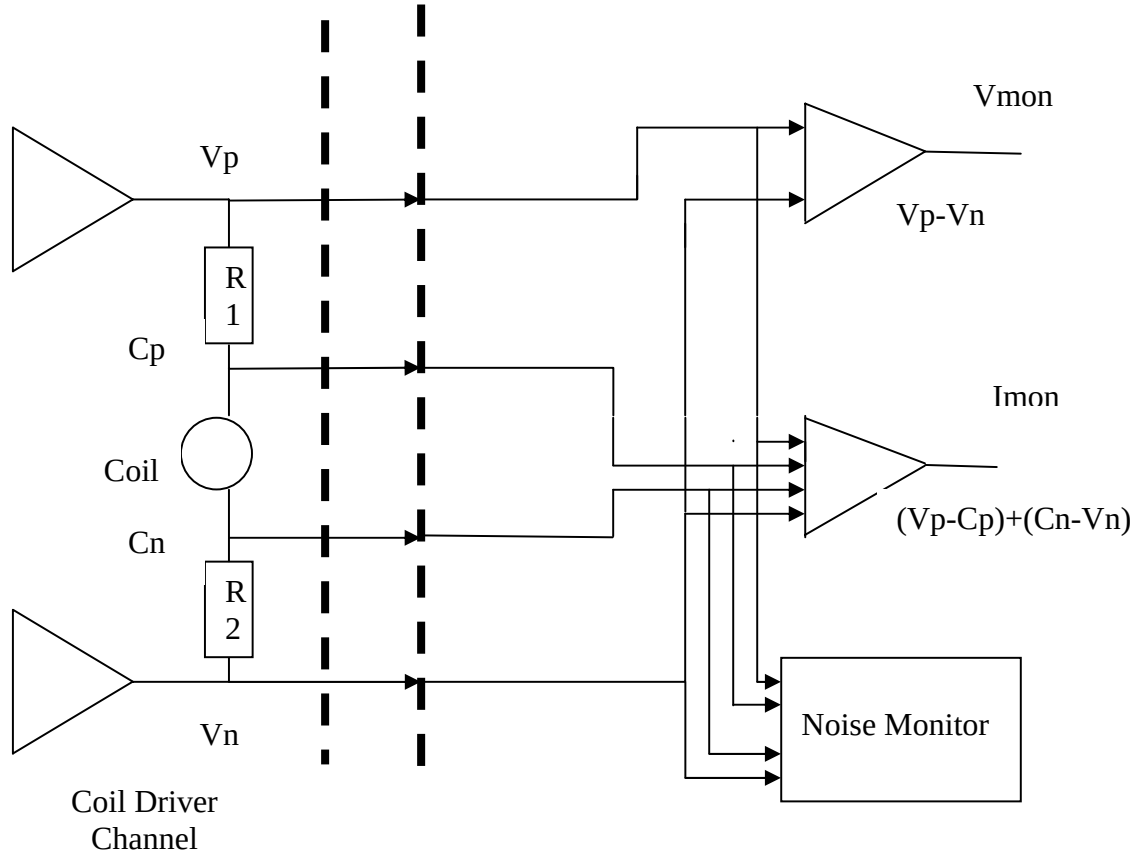
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK? C17 slightly lifted off board**

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon104……...
Test Engineer …Simon Pyatt…….
Date …22/10/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.80V	√
-15V (TP6)	-15.04V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mA	0.28A
-15v (TP6)	√	5mA	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.9V	**4.8V to 5.2V**	√
Ch2		4.9V	**4.8V to 5.2V**	√
Ch3		4.9V	**4.8V to 5.2V**	√
Ch4		4.9V	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1V	1V	1V	1V	1V	1V	1V	1V
TP4	2V	2V	2V	2V	1.4V	1.4V	1.4V	1.4V
TP6	4V	4V	4V	4V	2V	2V	2V	2V
TP7	8V	8V	8V	8V	2.8V	2.8V	3V	3V

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.4	1.4	1.5	1.5	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.714V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.979	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.978	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.978	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.980	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No……mon105……
Test Engineer……Simon Pyatt……
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Contents

1. Block diagram

2. Test equipment

3. Description

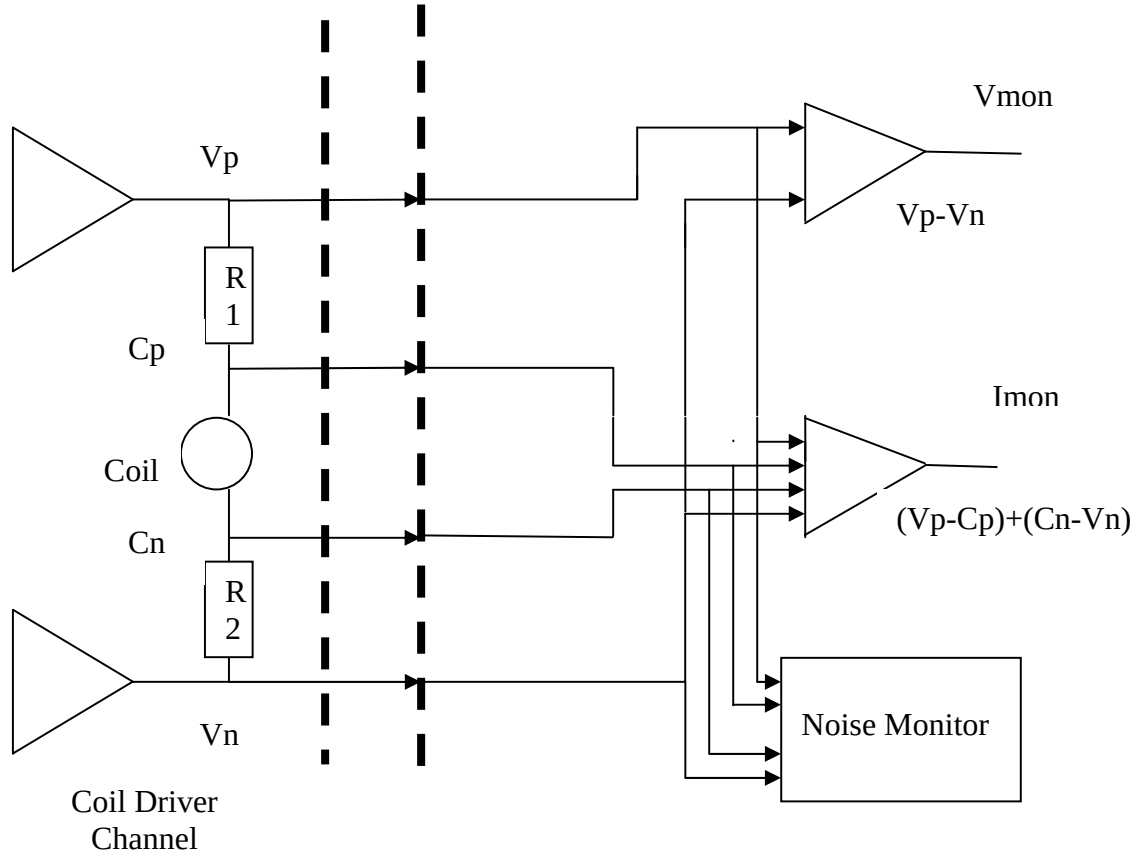
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

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NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.96V	√
-15V (TP6)	15.02V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mA	0.28A
-15v (TP6)	√	5mA	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mA	2.4V	**2.4V to 2.6V**	√
Ch2	100mA	2.4V	**2.4V to 2.6V**	√
Ch3	100mA	2.4V	**2.4V to 2.6V**	√
Ch4	100mA	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mA	2.4V	**2.4V to 2.6V**	√
Ch2	100mA	2.4V	**2.4V to 2.6V**	√
Ch3	100mA	2.4V	**2.4V to 2.6V**	√
Ch4	100mA	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mA	1.7V	**1.6V to 1.9V**	√
Ch2	100mA	1.7V	**1.6V to 1.9V**	√
Ch3	100mA	1.7V	**1.6V to 1.9V**	√
Ch4	100mA	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mA	1.7V	**1.6V to 1.9V**	√
Ch2	100mA	1.7V	**1.6V to 1.9V**	√
Ch3	100mA	1.7V	**1.6V to 1.9V**	√
Ch4	100mA	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.9V	**4.8V to 5.2V**	√
Ch2		4.9V	**4.8V to 5.2V**	√
Ch3		4.9V	**4.8V to 5.2V**	√
Ch4		4.9V	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1V	1V	1V	1V	1V	1V	1V	1V
TP4	2V	2V	2V	2V	1.4V	1.4V	1.4V	1.4V
TP6	4V	4V	4V	4V	2V	2V	2V	1.9V
TP7	8V	8V	8V	8V	2.9V	2.8V	2.9V	2.7V

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.35	
TP7/TP6	2	2	2	2	1.45	1.4	1.45	1.42	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.713V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.355V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.992V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.992V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.992V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.990V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon106……
Test Engineer…Simon Pyatt……
Date…23/10/09……

Contents

1. Block diagram

2. Test equipment

3. Description

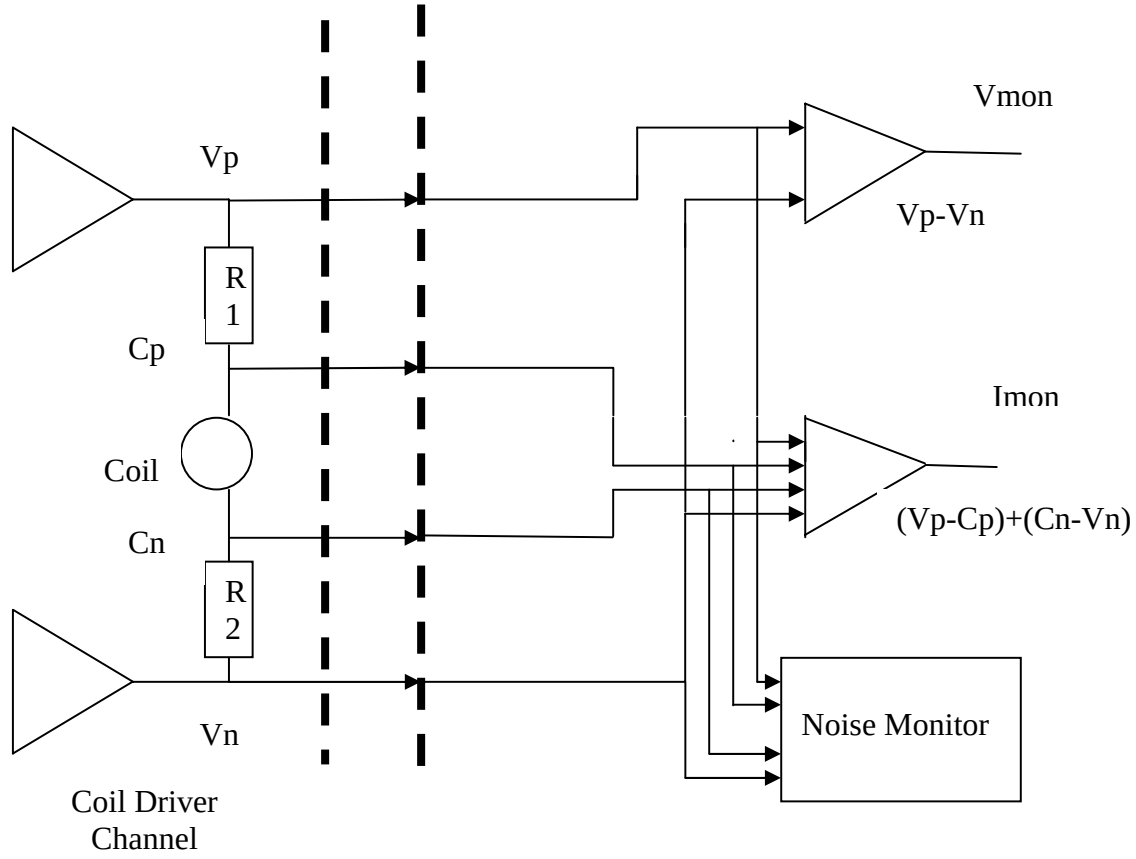
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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Test Engineer …Simon Pyatt…….
Date …23/10/09……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon106……...
Test Engineer ……Simon Pyatt…….
Date …23/10/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.96V	√
-15V (TP6)	15V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mA	0.27A
-15v (TP6)	√	5mA	0.25A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	101mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	101mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Test Engineer ……Simon Pyatt…….
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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.9V	**4.8V to 5.2V**	√
Ch2		4.9V	**4.8V to 5.2V**	√
Ch3		4.9V	**4.8V to 5.2V**	√
Ch4		4.9V	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1V	1V	1V	1V	1V	1V	1V	1V
TP4	2V	2V	2V	2V	1.4V	1.4V	1.4V	1.4V
TP6	4V	4V	4V	4V	2V	2.1V	2V	2.1V
TP7	8V	8V	8V	8V	2.8V	3V	2.9V	3V

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.5	1.42	1.5	
TP7/TP6	2	2	2	2	1.4	1.42	1.45	1.42	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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Test Engineer ……Simon Pyatt…….
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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.707V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.709V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.709V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.710V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.352V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.354V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.355V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.978V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.977V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.976V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.977V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon107……
Test Engineer…Simon Pyatt……
Date……28/10/09……

Contents

1. Block diagram

2. Test equipment

3. Description

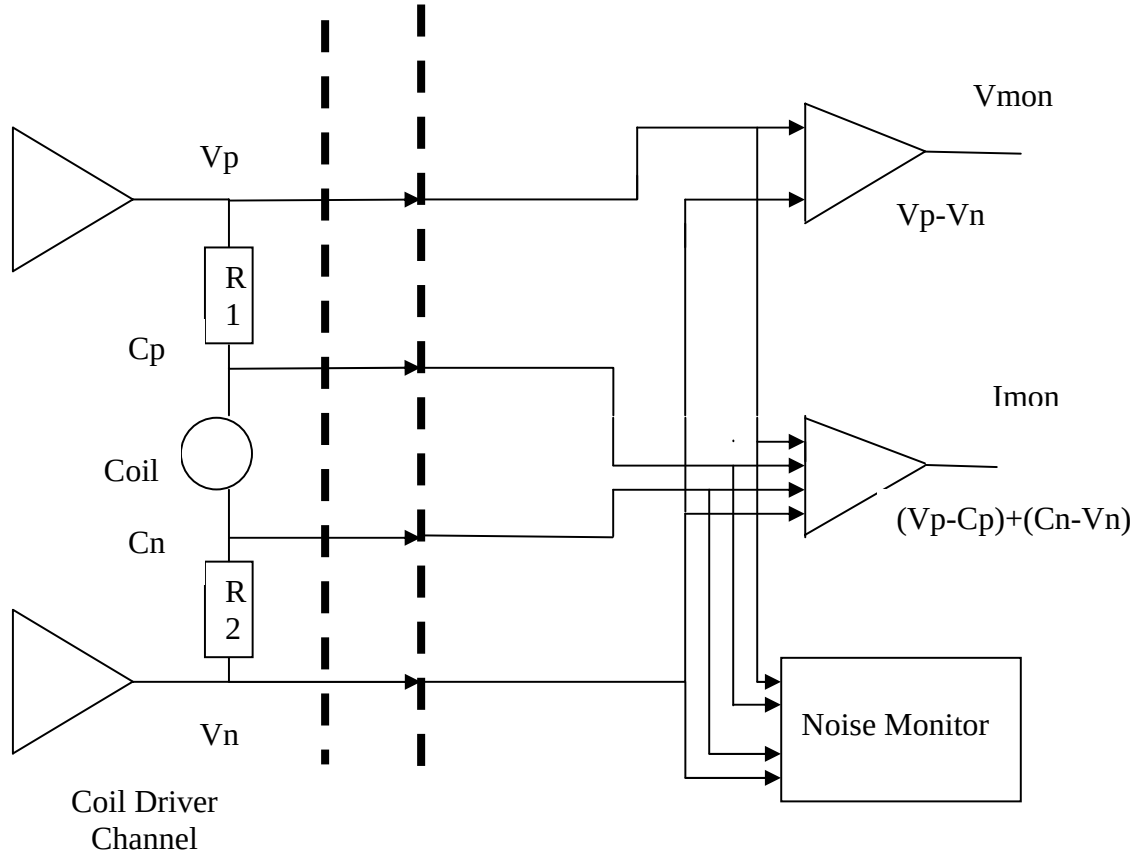
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon107……...
Test Engineer …Simon Pyatt…….
Date …28/10/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.96V	√
-15V (TP6)	-14.93V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.25A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.9V	**4.8V to 5.2V**	√
Ch2		4.9V	**4.8V to 5.2V**	√
Ch3		4.9V	**4.8V to 5.2V**	√
Ch4		4.9V	**4.8V to 5.2V**	√

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Test Engineer …Simon Pyatt…….
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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2.1	2.1
TP7	8	8	8	8	3.1	3.1	3.1	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.47	1.47	1.47	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

Serial No …mon107……...
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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.712V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.356V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.997V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.994V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon108……
Test Engineer…Simon Pyatt……
Date…26/10/09……

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1. Block diagram

2. Test equipment

3. Description

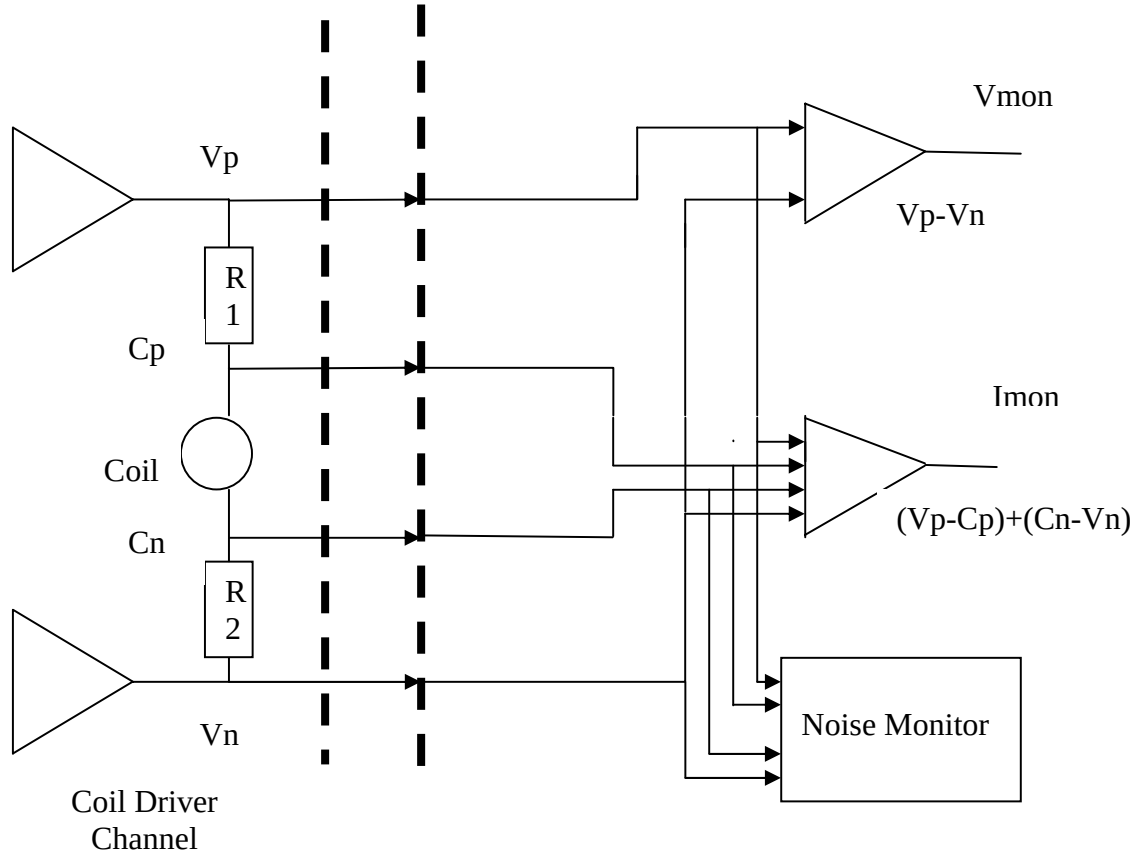
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

Serial No…mon108……
Test Engineer…Simon Pyatt……
Date…26/10/09……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK? P2 and D5 slightly crooked**

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon108……...
Test Engineer …Simon Pyatt…….
Date …26/10/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.95V	√
-15V (TP6)	-14.91V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mA	0.28A
-15v (TP6)	√	5mA	0.26A

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Test Engineer …Simon Pyatt…….
Date …26/10/09…….

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Test Engineer …Simon Pyatt…….
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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.9V	**4.8V to 5.2V**	√
Ch2		4.9V	**4.8V to 5.2V**	√
Ch3		4.9V	**4.8V to 5.2V**	√
Ch4		4.9V	**4.8V to 5.2V**	√

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Test Engineer …Simon Pyatt……
Date …26/10/09……

Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2.1	2.1
TP7	8	8	8	8	3	3.1	3.1	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.42	1.47	1.47	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.9V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.9V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.9V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.9V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.714V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.983V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.983V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.983V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.983V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon109……
Test Engineer…Simon Pyatt……
Date…26/10/09……

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1. Block diagram

2. Test equipment

3. Description

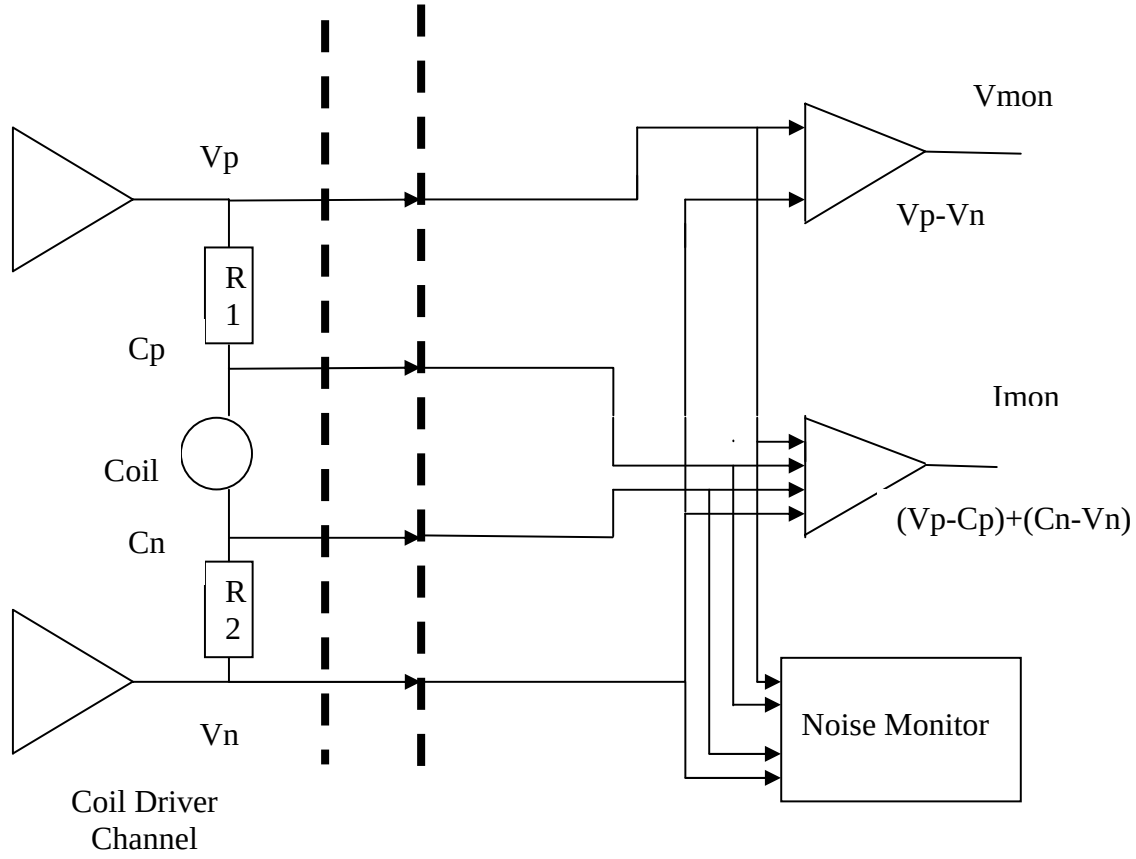
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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Test Engineer …Simon Pyatt…….
Date ……26/10/09……

4. Inspection

Workmanship

General **OK? √**
Comments

Visual overall check **OK? √**
Solder joint **OK? √**
Placement **OK? DS1 slightly crooked**

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon109……...
Test Engineer …Simon Pyatt…….
Date …26/10/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.91V	√
-15V (TP6)	-14.99V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mA	0.28A
-15v (TP6)	√	5mA	0.26A

Serial No …mon109……...
Test Engineer …Simon Pyatt…….
Date …26/10/09…….

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

Serial No …mon109……...
Test Engineer …Simon Pyatt…….
Date …26/10/09……

Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.9V	**4.8V to 5.2V**	√
Ch2		4.9V	**4.8V to 5.2V**	√
Ch3		4.9V	**4.8V to 5.2V**	√
Ch4		4.9V	**4.8V to 5.2V**	√

Serial No …mon109……...
Test Engineer …Simon Pyatt…….
Date …26/10/09……

Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	3	3	3	3

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.5	1.5	1.5	1.5	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.3V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.3V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√

Serial No …mon109……...
Test Engineer …Simon Pyatt…….
Date …26/10/09…….

6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

Serial No …mon109……...
Test Engineer …Simon Pyatt…….
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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.708V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.712V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.353V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.355V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.99V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.986V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.98V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.984V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon110……
Test Engineer…Simon Pyatt……
Date…27/10/09……

Contents

1. Block diagram

2. Test equipment

3. Description

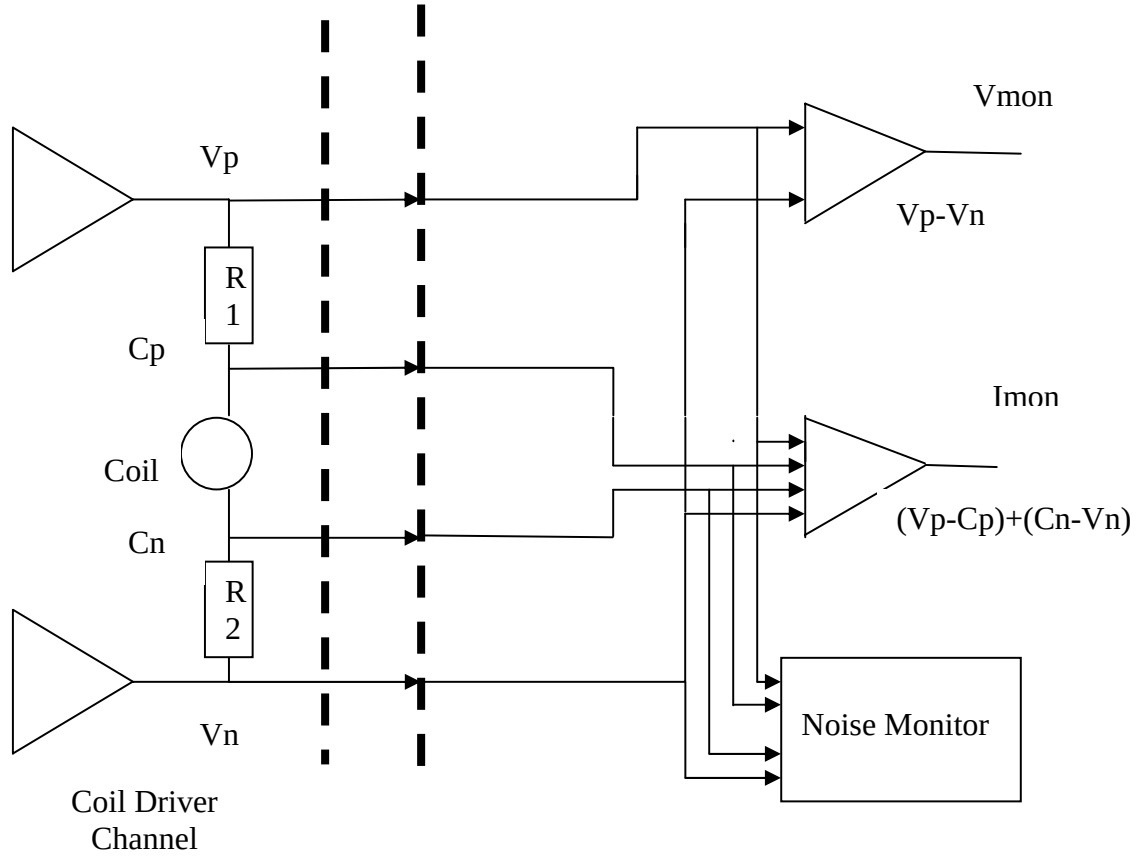
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

Serial No …mon110……..
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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK? D6 Slightly crooked**

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon110……...
Test Engineer …Simon Pyatt…….
Date …27/10/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.83V	√
-15V (TP6)	-15V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mA	0.28A
-15v (TP6)	√	5mA	0.25A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.9V	**4.8V to 5.2V**	√
Ch2		4.9V	**4.8V to 5.2V**	√
Ch3		4.9V	**4.8V to 5.2V**	√
Ch4		4.9V	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2.1	2.1	2.1
TP7	8	8	8	8	3	3.1	3.1	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.5	1.47	1.47	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	9.9V	9.7 to 10V	√	4.9V	4 to 5.5V	√
Ch2	TP10	9.9V	9.7 to 10V	√	4.9V	4 to 5.5V	√
Ch3	TP10	9.9V	9.7 to 10V	√	4.9V	4 to 5.5V	√
Ch4	TP10	9.9V	9.7 to 10V	√	4.9V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.707V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.712V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.354V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.356V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.988V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.991V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.993V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.991V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon111……
Test Engineer……Simon Pyatt……
Date……27/10/09……

Contents

1. Block diagram

2. Test equipment

3. Description

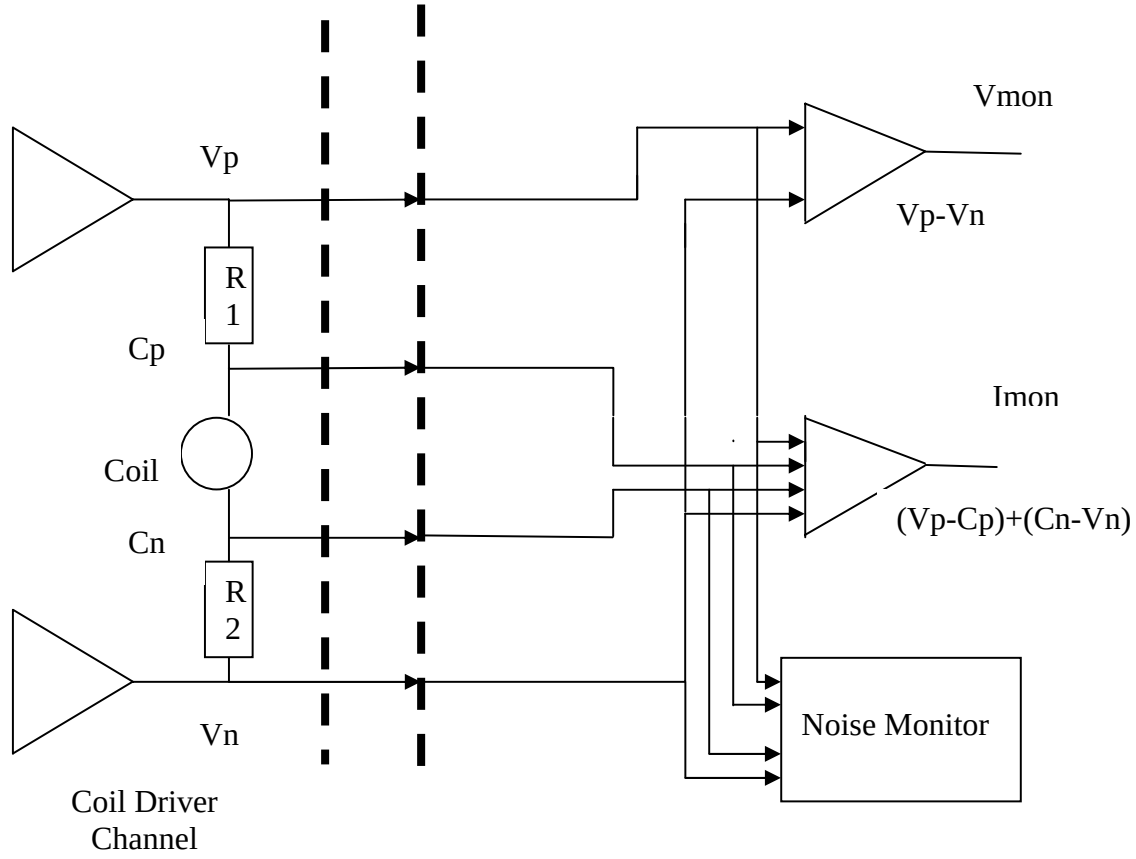
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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Test Engineer …Simon Pyatt…….
Date …27/10/09……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon111……...
Test Engineer …Simon Pyatt…….
Date ……27/10/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.92V	√
-15V (TP6)	-14.90V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mA	0.28A
-15v (TP6)	√	5mA	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mA	2.4V	**2.4V to 2.6V**	√
Ch2	100mA	2.4V	**2.4V to 2.6V**	√
Ch3	100mA	2.4V	**2.4V to 2.6V**	√
Ch4	100mA	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mA	2.4V	**2.4V to 2.6V**	√
Ch2	100mA	2.4V	**2.4V to 2.6V**	√
Ch3	100mA	2.4V	**2.4V to 2.6V**	√
Ch4	100mA	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mA	1.7V	**1.6V to 1.9V**	√
Ch2	100mA	1.7V	**1.6V to 1.9V**	√
Ch3	100mA	1.7V	**1.6V to 1.9V**	√
Ch4	100mA	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mA	1.7V	**1.6V to 1.9V**	√
Ch2	100mA	1.7V	**1.6V to 1.9V**	√
Ch3	100mA	1.7V	**1.6V to 1.9V**	√
Ch4	100mA	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.9V	**4.8V to 5.2V**	√
Ch2		4.9V	**4.8V to 5.2V**	√
Ch3		4.9V	**4.8V to 5.2V**	√
Ch4		4.9V	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.2	2.1	2	2.1
TP7	8	8	8	8	3.2	3	2.9	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.57	1.5	1.42	1.5	
TP7/TP6	2	2	2	2	1.45	1.42	1.45	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.9V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.9V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.9V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.9V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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Test Engineer …Simon Pyatt…….
Date …27/10/09…….

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.709V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.717V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.712V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.360V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.356V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.995V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.988V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.996V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.989V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon113……
Test Engineer…Simon Pyatt……
Date…27/10/09……

Contents

1. Block diagram

2. Test equipment

3. Description

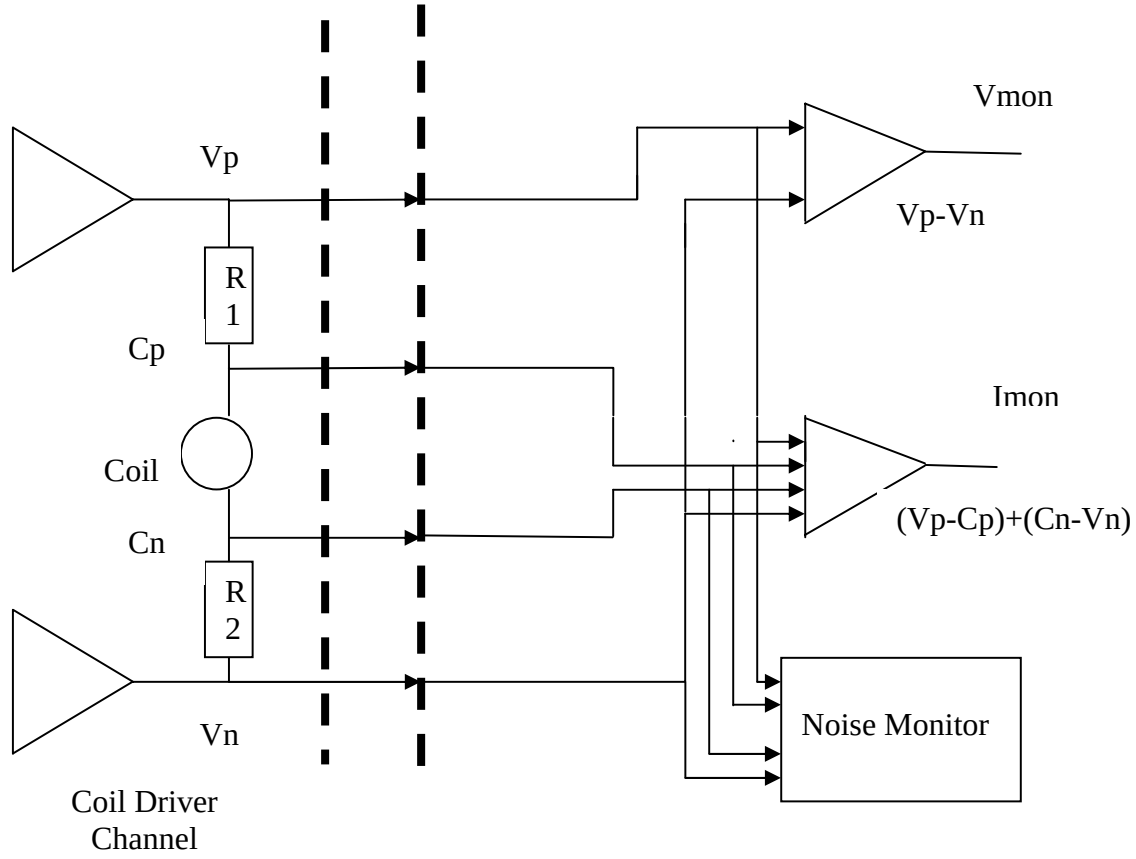
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon112……...
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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.89V	√
-15V (TP6)	-14.90v	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mA	0.28A
-15v (TP6)	√	5mA	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.9V	**4.8V to 5.2V**	√
Ch2		4.9V	**4.8V to 5.2V**	√
Ch3		4.9V	**4.8V to 5.2V**	√
Ch4		4.9V	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2	2.1
TP7	8	8	8	8	3.1	3	2.9	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.42	1.5	
TP7/TP6	2	2	2	2	1.47	1.42	1.45	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	5.5V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	5.5V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	5.5V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	5.5V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.710V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.709V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.716V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.354V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.359V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.993V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.989V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.987V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.994V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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1. Block diagram

2. Test equipment

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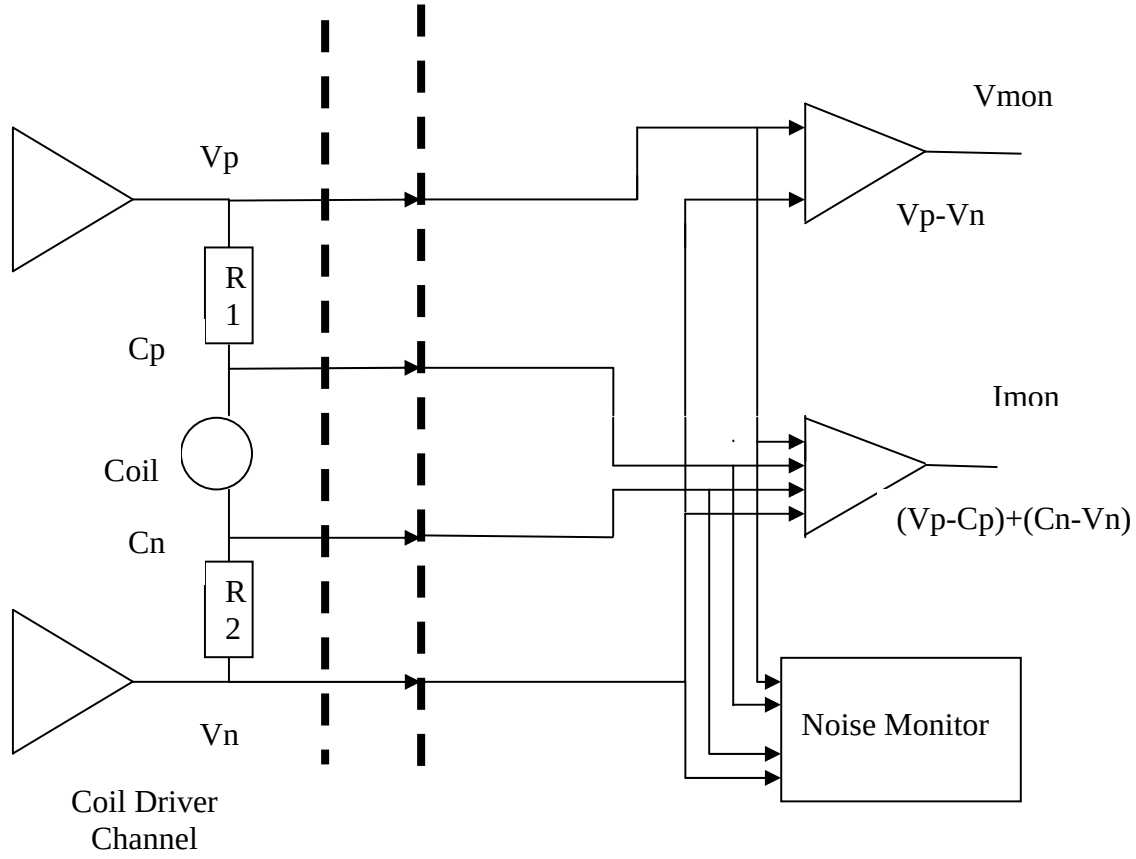
6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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Test Engineer …Simon Pyatt……
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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon113……...
Test Engineer …Simon Pyatt…….
Date …27/10/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.83V	√
-15V (TP6)	-14.97V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mA	0.28A
-15v (TP6)	√	5mA	0.26A

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Test Engineer …Simon Pyatt…….
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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.9V	**4.8V to 5.2V**	√
Ch2		4.9V	**4.8V to 5.2V**	√
Ch3		4.9V	**4.8V to 5.2V**	√
Ch4		4.9V	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2.1	2.1
TP7	8	8	8	8	3.1	3.1	3.1	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.47	1.47	1.47	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.9V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.9V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.9V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.9V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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Test Engineer …Simon Pyatt…….
Date …27/10/09…….

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.709V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.708V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.714V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.353V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.978V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.981V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.974V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.981V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.225V	**1V (0.9 to 1.1V)**	
Ch2, TP13	1.238V	**1V (0.9 to 1.1V)**	
Ch3, TP13	1.220V	**1V (0.9 to 1.1V)**	
Ch4, TP13	1.232V	**1V (0.9 to 1.1V)**	

MONITOR BOARD TEST PLAN

Serial No…mon114……
Test Engineer…Simon Pyatt……
Date…28/10/09……

Contents

1. Block diagram

2. Test equipment

3. Description

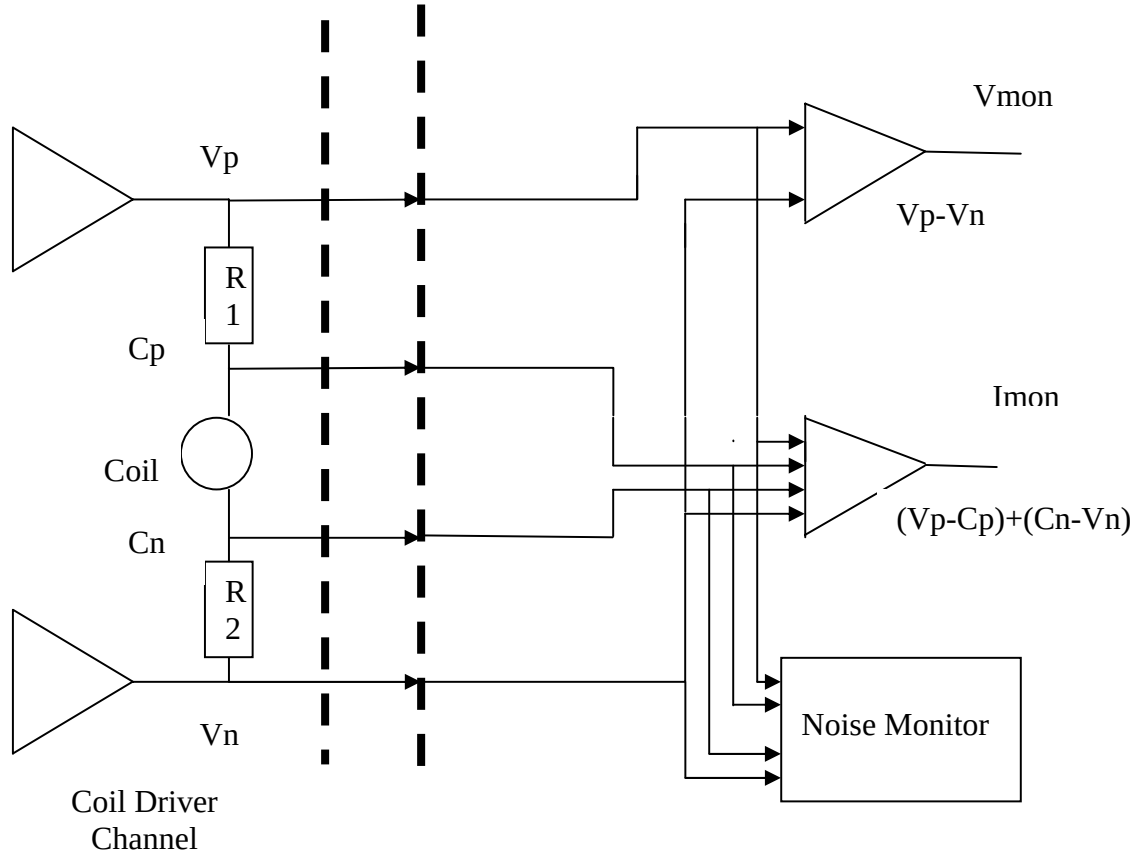
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon114……..
Test Engineer …Simon Pyatt…….
Date …28/10/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.96V	√
-15V (TP6)	-14.97V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mA	0.28A
-15v (TP6)	√	5mA	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.5V	**2.4V to 2.6V**	√
Ch2	100mV	2.5V	**2.4V to 2.6V**	√
Ch3	100mV	2.5V	**2.4V to 2.6V**	√
Ch4	100mV	2.5V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.9V	**4.8V to 5.2V**	√
Ch2		4.9V	**4.8V to 5.2V**	√
Ch3		4.9V	**4.8V to 5.2V**	√
Ch4		4.9V	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.2	2.1	2.1	2.1
TP7	8	8	8	8	3.2	3.1	3.1	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.57	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.45	1.47	1.47	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.717V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.712V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.361V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.355V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.983V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.984V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.986V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.980V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon115……
Test Engineer…Simon Pyatt……
Date…28/10/09……

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1. Block diagram

2. Test equipment

3. Description

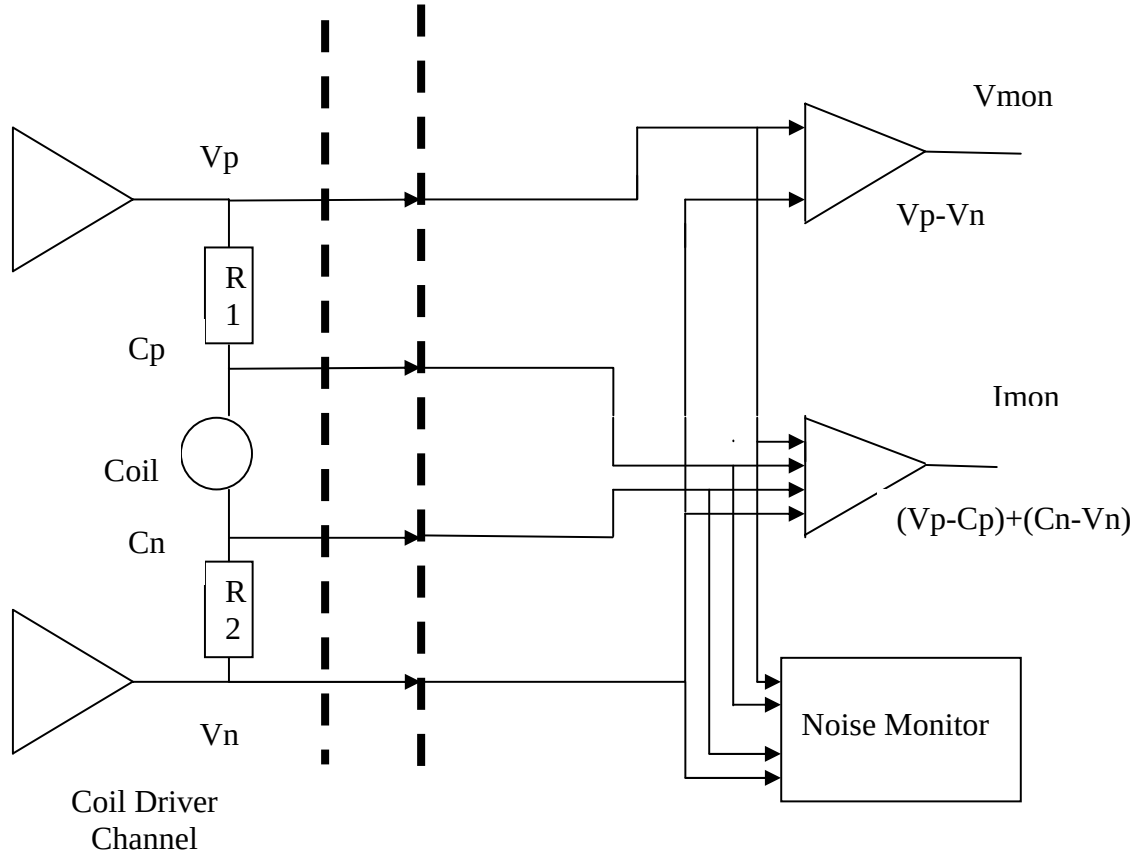
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon115……...
Test Engineer …Simon Pyatt…….
Date …28/10/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.93V	√
-15V (TP6)	-14.97V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mA	0.28A
-15v (TP6)	√	5mA	0.25A

Serial No …mon115……...
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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.5V	**2.4V to 2.6V**	√
Ch2	100mV	2.5V	**2.4V to 2.6V**	√
Ch3	100mV	2.5V	**2.4V to 2.6V**	√
Ch4	100mV	2.5V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

Serial No …mon115……...
Test Engineer …Simon Pyatt…….
Date …28/10/09……

Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.9V	**4.8V to 5.2V**	√
Ch2		4.9V	**4.8V to 5.2V**	√
Ch3		4.9V	**4.8V to 5.2V**	√
Ch4		4.9V	**4.8V to 5.2V**	√

Serial No …mon115……..
Test Engineer …Simon Pyatt…….
Date …28/10/09……

Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.5	1.4	1.5	1.4
TP6	4	4	4	4	2.2	2.1	2.2	2.1
TP7	8	8	8	8	3.2	3.3	3.3	3.3

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.5	1.4	1.5	1.4	
TP6/TP4	2	2	2	2	1.46	1.5	1.46	1.5	
TP7/TP6	2	2	2	2	1.45	1.57	1.5	1.57	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.9V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.9V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.9V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.9V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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Test Engineer …Simon Pyatt…….
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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.717V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.715V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.997V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.995V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.992V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.993V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.996V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.996V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.997V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon116……
Test Engineer…Simon Pyatt……
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Contents

1. Block diagram

2. Test equipment

3. Description

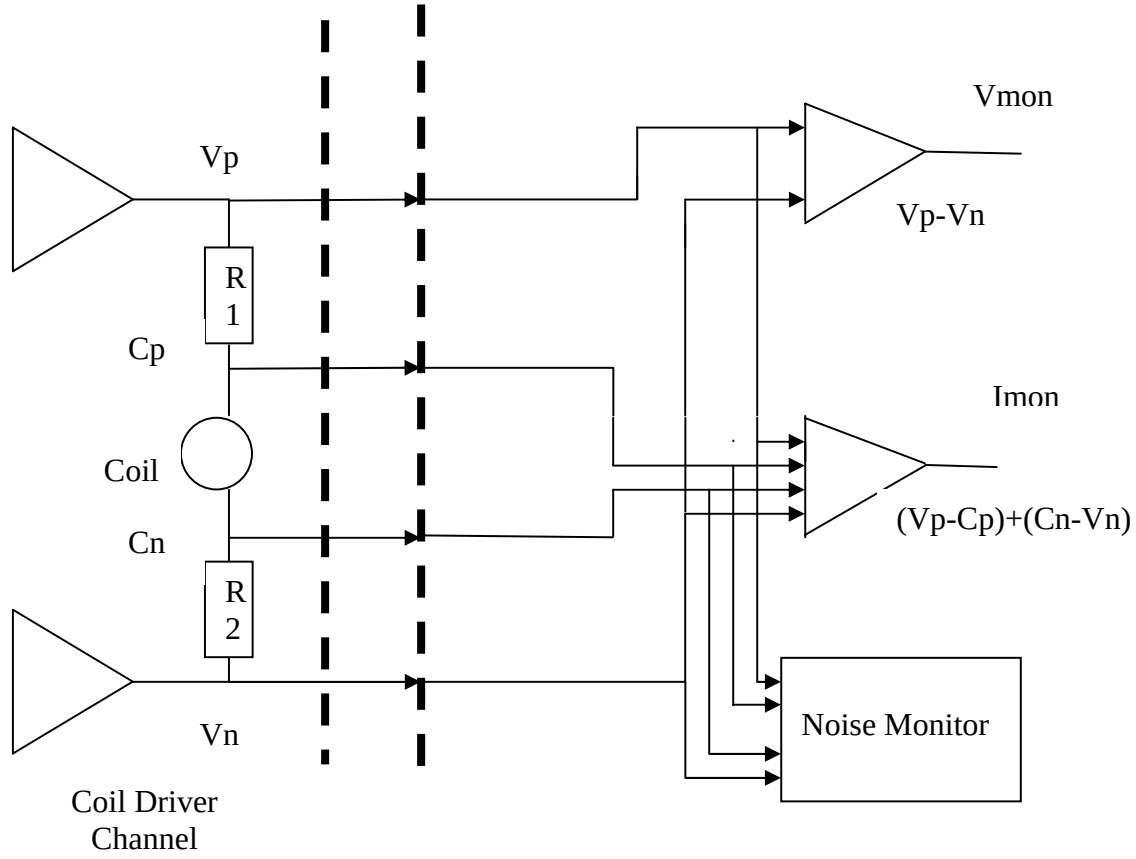
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

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Date ……

NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.94V	√
-15V (TP6)	-14.89V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mA	0.28A
-15v (TP6)	√	5mA	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.9V	**4.8V to 5.2V**	√
Ch2		4.9V	**4.8V to 5.2V**	√
Ch3		4.9V	**4.8V to 5.2V**	√
Ch4		4.9V	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2.1	2.1
TP7	8	8	8	8	3.1	3.1	3.1	3

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.47	1.47	1.47	1.42	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.8V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.8V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.9V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.9V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.713V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.356V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.989V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.992V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.989V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.987V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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1. Block diagram

2. Test equipment

3. Description

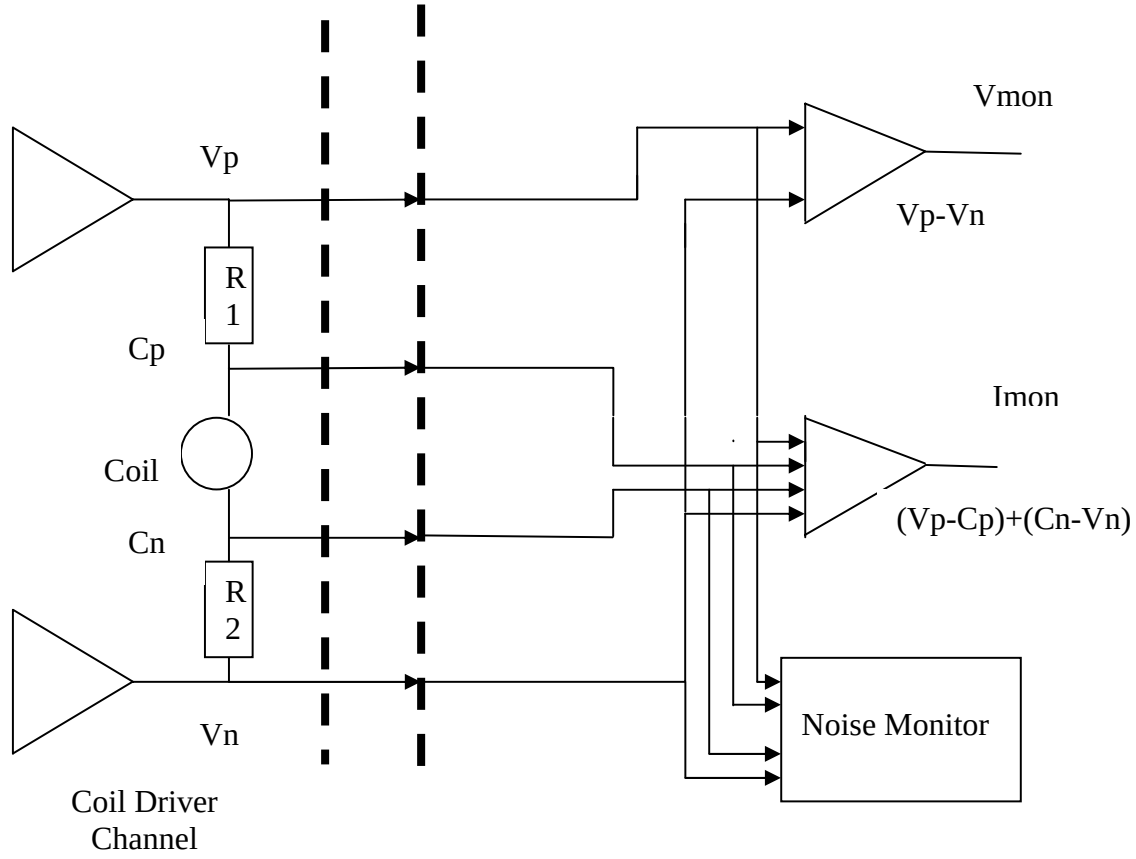
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

DS1 and DS2 alignment was off, they have been adjusted.

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NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.94V	√
-15V (TP6)	-15.01V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mA	0.28A
-15v (TP6)	√	5mA	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.6V	**1.6V to 1.9V**	√
Ch2	100mV	1.6V	**1.6V to 1.9V**	√
Ch3	100mV	1.6V	**1.6V to 1.9V**	√
Ch4	100mV	1.6V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.9V	**4.8V to 5.2V**	√
Ch2		4.9V	**4.8V to 5.2V**	√
Ch3		4.9V	**4.8V to 5.2V**	√
Ch4		4.9V	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2.1	2	2
TP7	8	8	8	8	2.9	3	2.9	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.5	1.42	1.42	
TP7/TP6	2	2	2	2	1.45	1.42	1.45	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.717V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.713V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.360V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.982V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.986V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.982V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.981V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.02V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.02V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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Contents

1. Block diagram

2. Test equipment

3. Description

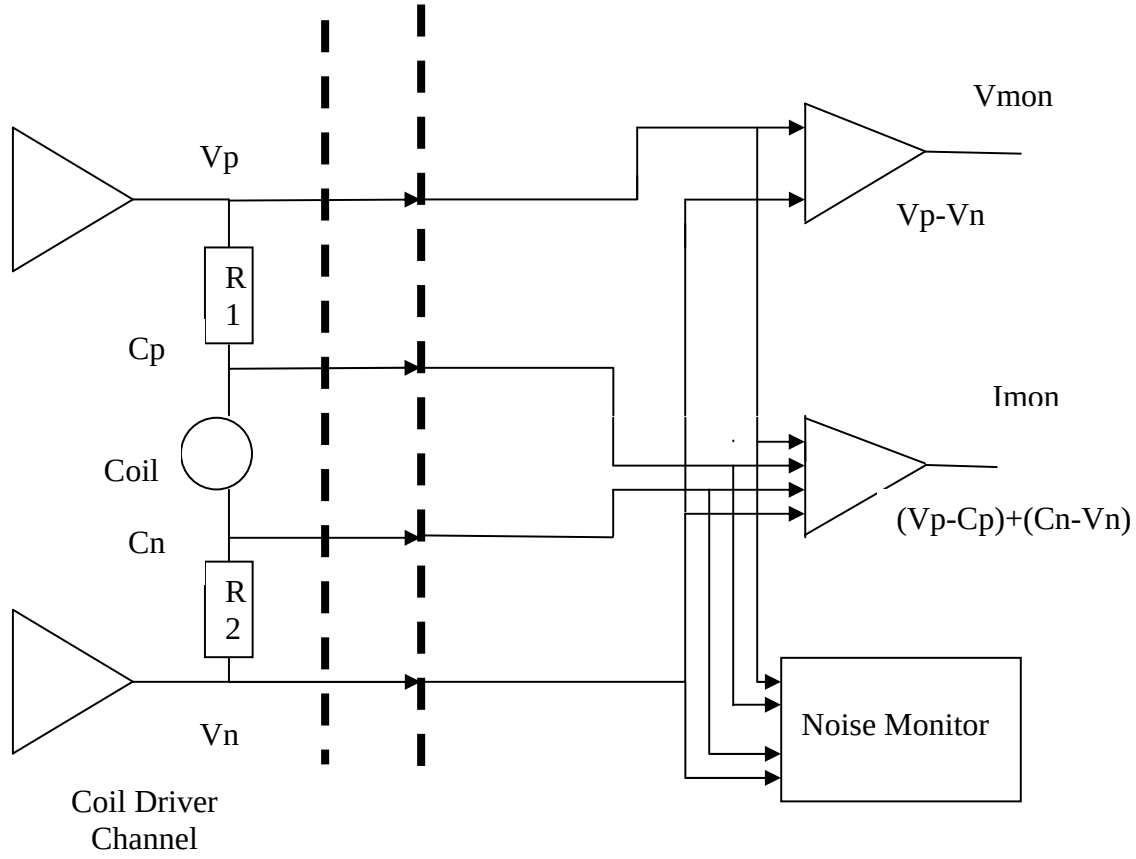
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Some through hole wires needed trimming down.

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.92V	√
-15V (TP6)	-14.92V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mA	0.28A
-15v (TP6)	√	5mA	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.9V	**4.8V to 5.2V**	√
Ch2		4.9V	**4.8V to 5.2V**	√
Ch3		4.9V	**4.8V to 5.2V**	√
Ch4		4.9V	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.3	1.4	1.4
TP6	4	4	4	4	2	1.8	1.9	1.9
TP7	8	8	8	8	2.9	2.5	2.6	2.7

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.3	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.38	1.35	1.35	
TP7/TP6	2	2	2	2	1.45	1.38	1.36	1.42	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.9V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.9V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.9V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.9V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.712V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.356V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.985V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.988V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.986V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.983V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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1. Block diagram

2. Test equipment

3. Description

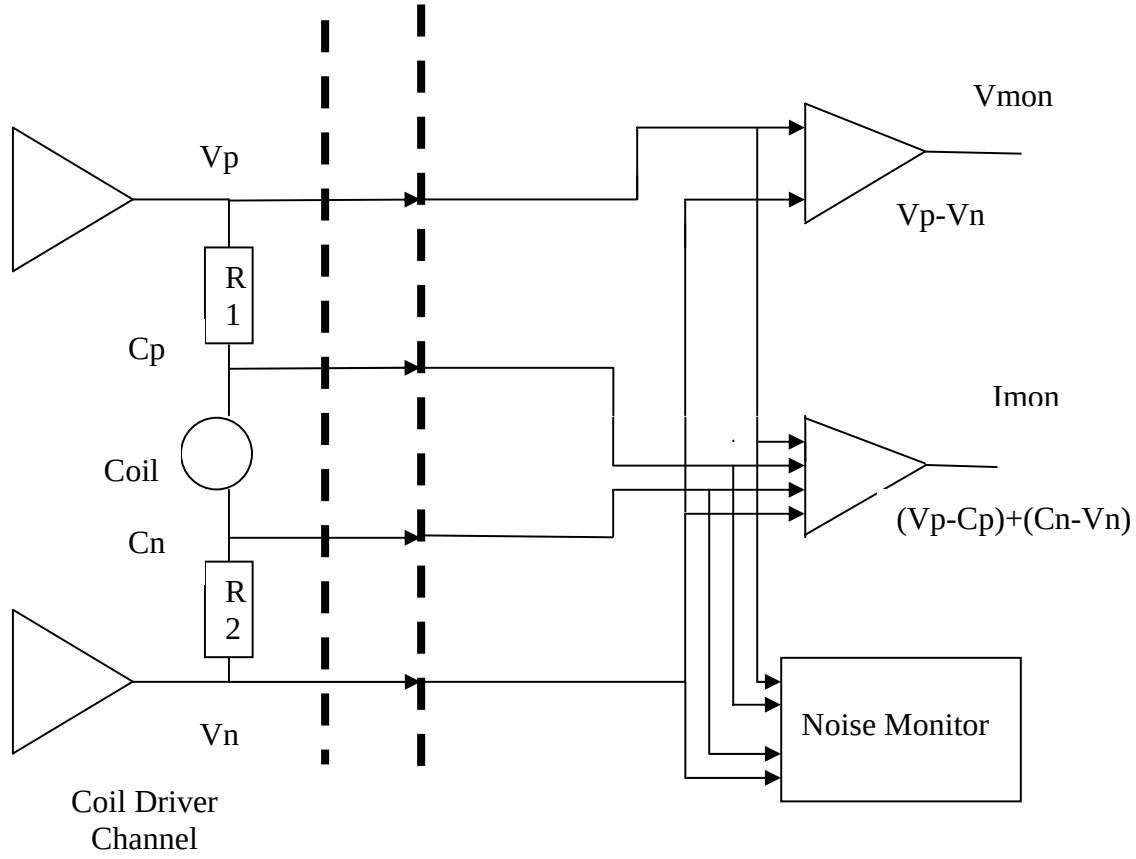
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

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Test Engineer ……
Date ……

NOTES

Serial No …mon119……...
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Date ……29/10/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.99V	√
-15V (TP6)	-14.99V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mA	0.28A
-15v (TP6)	√	5mA	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.6V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.9V	**4.8V to 5.2V**	√
Ch2		4.9V	**4.8V to 5.2V**	√
Ch3		4.9V	**4.8V to 5.2V**	√
Ch4		4.9V	**4.8V to 5.2V**	√

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Test Engineer …Simon Pyatt…….
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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.8	2.9	2.9	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.4	1.4	1.4	
TP7/TP6	2	2	2	2	1.4	1.45	1.45	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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Test Engineer …Simon Pyatt…….
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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.710V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.716V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.990V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.990V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.990V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.993V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon120……
Test Engineer…Simon Pyatt……
Date…30/10/09……

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1. Block diagram

2. Test equipment

3. Description

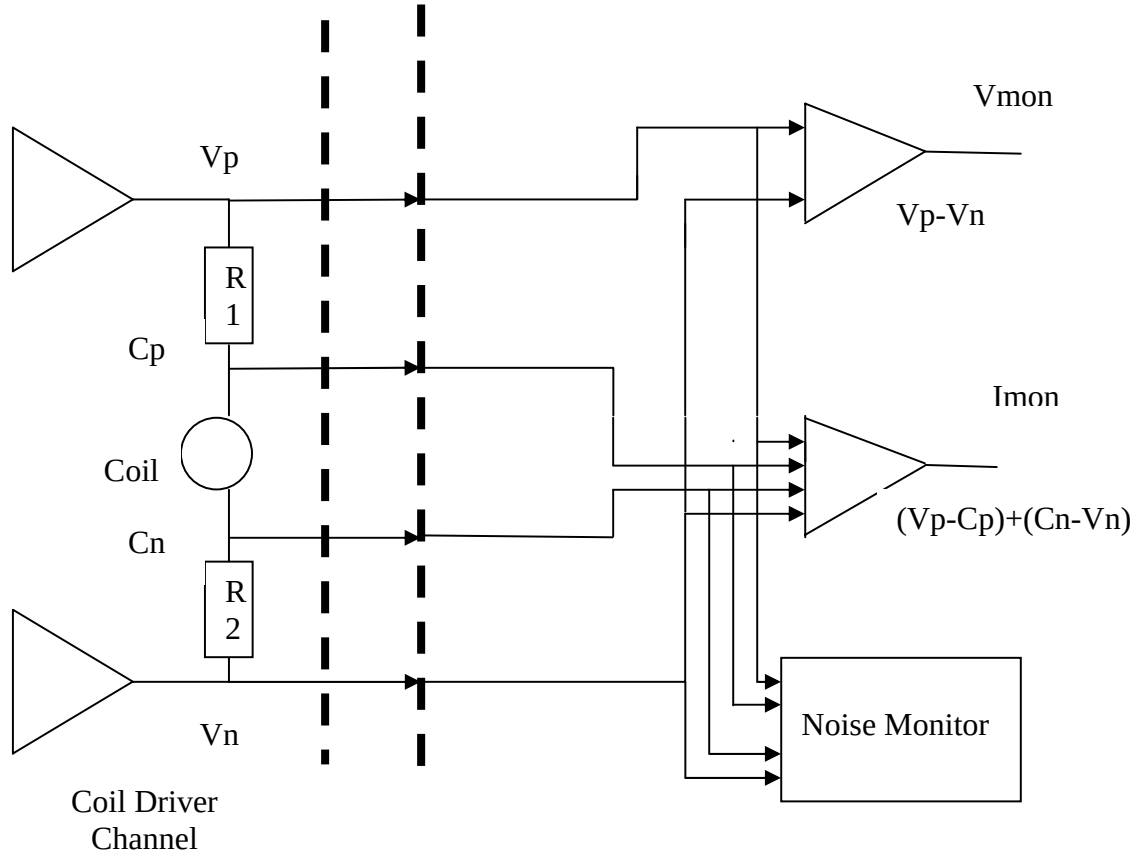
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon120……...
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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.92V	√
-15V (TP6)	-14.95V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mA	0.28A
-15v (TP6)	√	5mA	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mA	2.4V	**2.4V to 2.6V**	√
Ch2	100mA	2.4V	**2.4V to 2.6V**	√
Ch3	100mA	2.4V	**2.4V to 2.6V**	√
Ch4	100mA	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mA	2.4V	**2.4V to 2.6V**	√
Ch2	100mA	2.4V	**2.4V to 2.6V**	√
Ch3	100mA	2.4V	**2.4V to 2.6V**	√
Ch4	100mA	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mA	1.7V	**1.6V to 1.9V**	√
Ch2	100mA	1.7V	**1.6V to 1.9V**	√
Ch3	100mA	1.7V	**1.6V to 1.9V**	√
Ch4	100mA	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mA	1.7V	**1.6V to 1.9V**	√
Ch2	100mA	1.7V	**1.6V to 1.9V**	√
Ch3	100mA	1.7V	**1.6V to 1.9V**	√
Ch4	100mA	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.9V	**4.8V to 5.2V**	√
Ch2		4.9V	**4.8V to 5.2V**	√
Ch3		4.9V	**4.8V to 5.2V**	√
Ch4		4.9V	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2	2.1	2
TP7	8	8	8	8	2.9	2.9	3	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.42	1.5	1.42	
TP7/TP6	2	2	2	2	1.38	1.45	1.42	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.709V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.712V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.356V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.995V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.998V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.992V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.994V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.03V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.03V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon121……
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1. Block diagram

2. Test equipment

3. Description

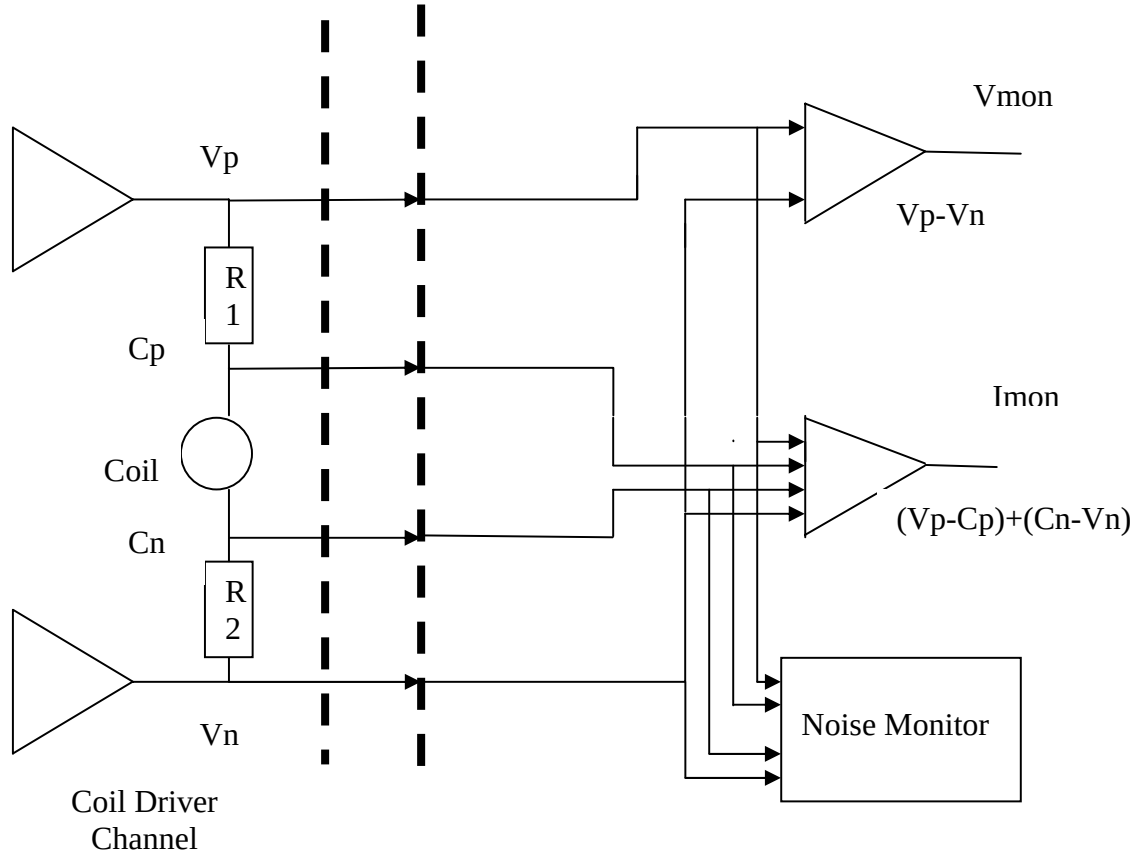
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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Test Engineer …Simon Pyatt…….
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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon121……...
Test Engineer …Simon Pyatt…….
Date ……30/10/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.92V	√
-15V (TP6)	-14.90V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mA	0.28A
-15v (TP6)	√	1mA	0.26A

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Test Engineer …Simon Pyatt…….
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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mA	2.4V	**2.4V to 2.6V**	√
Ch2	100mA	2.4V	**2.4V to 2.6V**	√
Ch3	100mA	2.4V	**2.4V to 2.6V**	√
Ch4	100mA	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mA	2.4V	**2.4V to 2.6V**	√
Ch2	100mA	2.4V	**2.4V to 2.6V**	√
Ch3	100mA	2.4V	**2.4V to 2.6V**	√
Ch4	100mA	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mA	1.7V	**1.6V to 1.9V**	√
Ch2	100mA	1.7V	**1.6V to 1.9V**	√
Ch3	100mA	1.7V	**1.6V to 1.9V**	√
Ch4	100mA	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mA	1.7V	**1.6V to 1.9V**	√
Ch2	100mA	1.7V	**1.6V to 1.9V**	√
Ch3	100mA	1.7V	**1.6V to 1.9V**	√
Ch4	100mA	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.9V	**4.8V to 5.2V**	√
Ch2		4.9V	**4.8V to 5.2V**	√
Ch3		4.9V	**4.8V to 5.2V**	√
Ch4		4.9V	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.9	2.9	2.8	2.8

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.45	1.45	1.4	1.4	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.9V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.9V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.9V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.8V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.711V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.355V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.991V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.99V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.984V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.982V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.02V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon122……
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1. Block diagram

2. Test equipment

3. Description

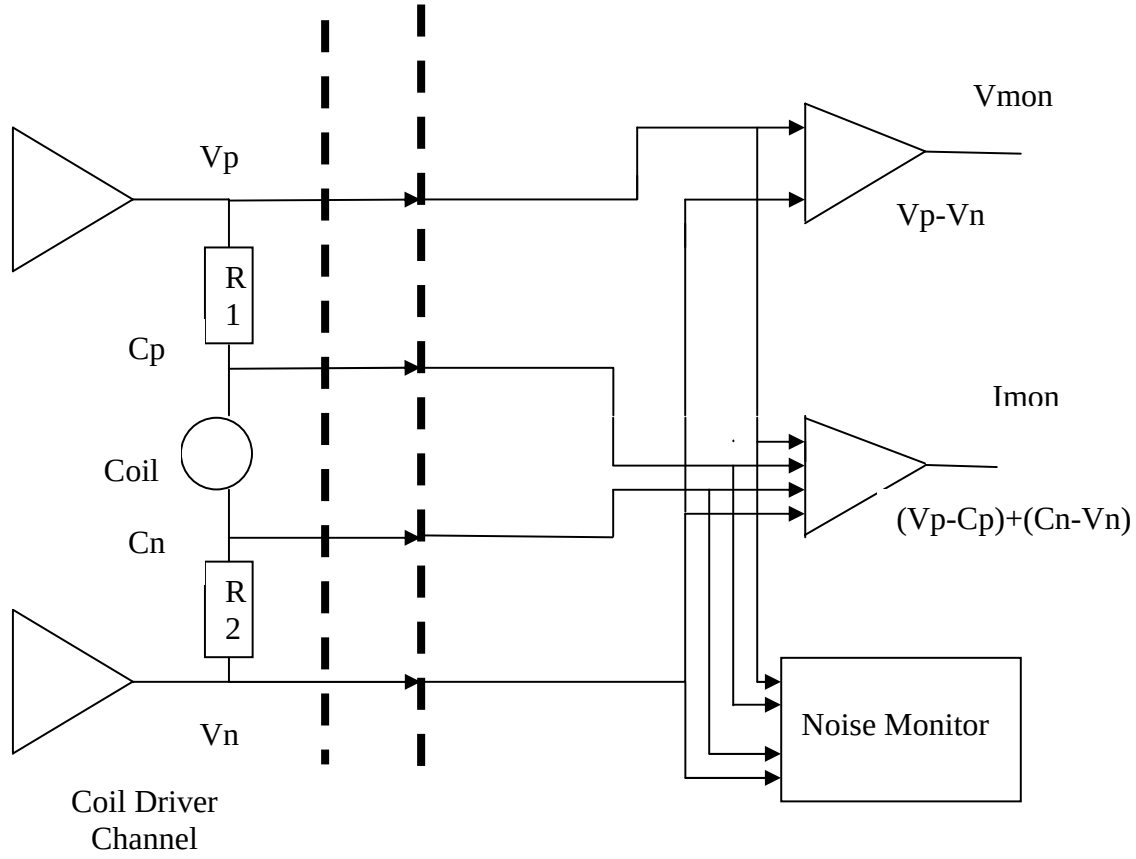
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.91V	√
-15V (TP6)	-14.96V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mA	0.28A
-15v (TP6)	√	1mA	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.9V	**4.8V to 5.2V**	√
Ch2		4.9V	**4.8V to 5.2V**	√
Ch3		4.9V	**4.8V to 5.2V**	√
Ch4		4.9V	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2	2	2
TP7	8	8	8	8	2.9	2.9	2.9	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.38	1.45	1.45	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.9V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.9V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.9V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.9V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.716V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.359V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.986V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.987V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.984V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.988V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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1. Block diagram

2. Test equipment

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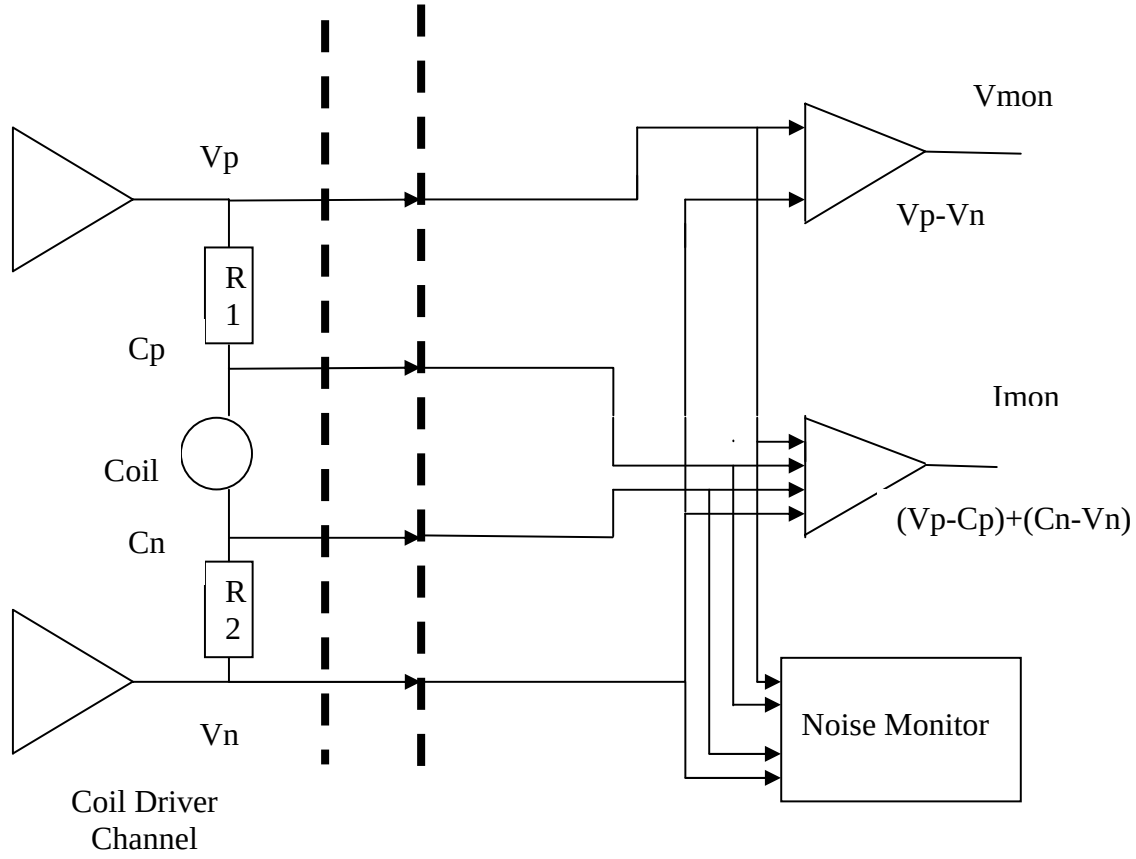
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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Test Engineer …Simon Pyatt…….
Date …02/11/09……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon123……...
Test Engineer …Simon Pyatt…….
Date …02/11/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.93V	√
-15V (TP6)	-14.96V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mA	0.28A
-15v (TP6)	√	5mA	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.9V	**4.8V to 5.2V**	√
Ch2		4.9V	**4.8V to 5.2V**	√
Ch3		4.9V	**4.8V to 5.2V**	√
Ch4		4.9V	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2	2.1	2
TP7	8	8	8	8	2.9	2.9	3.1	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.42	1.5	1.42	
TP7/TP6	2	2	2	2	1.38	1.45	1.47	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.9V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.9V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.9V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.9V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.709V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.354V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.987V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.985V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.984V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.980V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon124……
Test Engineer…Simon Pyatt……
Date…02/11/09……

Contents

1. Block diagram

2. Test equipment

3. Description

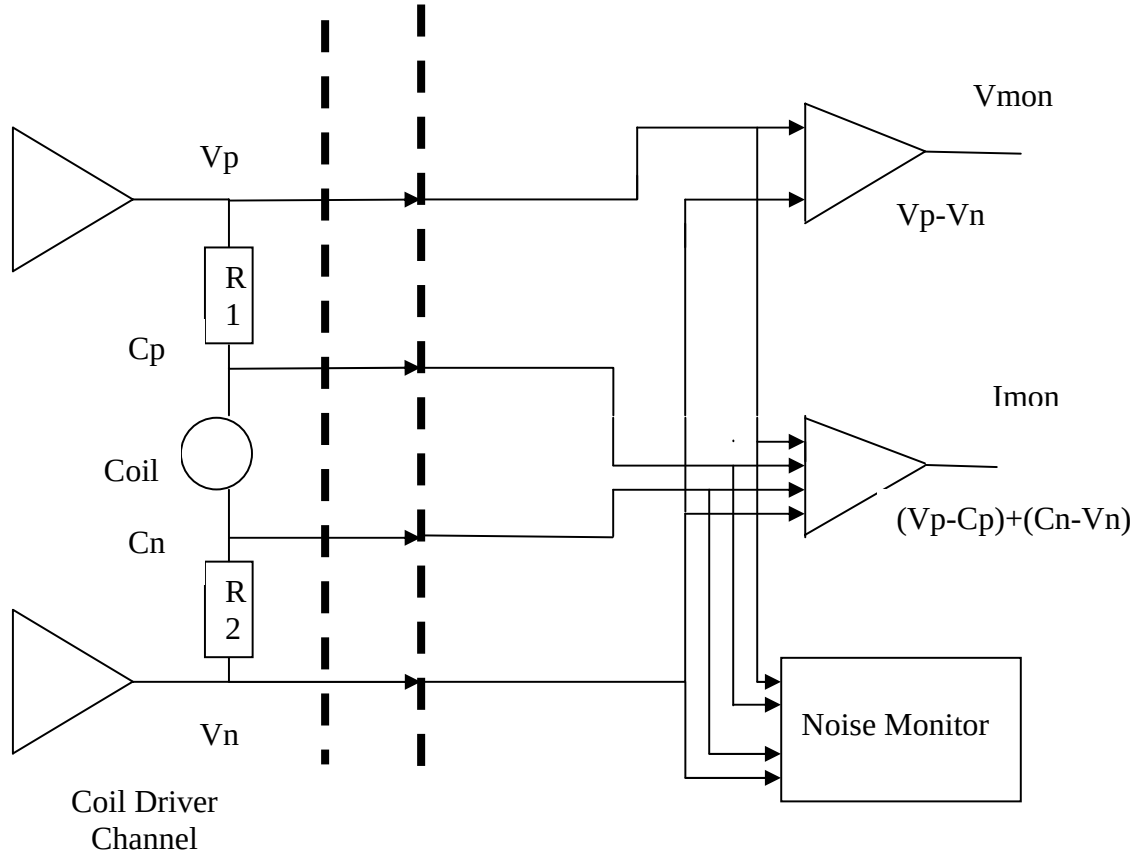
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

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NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.98V	√
-15V (TP6)	-14.97V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mA	0.28A
-15v (TP6)	√	5mA	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mA	2.4V	**2.4V to 2.6V**	√
Ch2	100mA	2.4V	**2.4V to 2.6V**	√
Ch3	100mA	2.4V	**2.4V to 2.6V**	√
Ch4	100mA	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mA	2.4V	**2.4V to 2.6V**	√
Ch2	100mA	2.4V	**2.4V to 2.6V**	√
Ch3	100mA	2.4V	**2.4V to 2.6V**	√
Ch4	100mA	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mA	1.8V	**1.6V to 1.9V**	√
Ch2	100mA	1.8V	**1.6V to 1.9V**	√
Ch3	100mA	1.8V	**1.6V to 1.9V**	√
Ch4	100mA	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mA	1.7V	**1.6V to 1.9V**	√
Ch2	100mA	1.7V	**1.6V to 1.9V**	√
Ch3	100mA	1.7V	**1.6V to 1.9V**	√
Ch4	100mA	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.9V	**4.8V to 5.2V**	√
Ch2		4.9V	**4.8V to 5.2V**	√
Ch3		4.9V	**4.8V to 5.2V**	√
Ch4		4.9V	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.9	2.9	2.9	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.35	
TP7/TP6	2	2	2	2	1.45	1.45	1.45	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.9V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.9V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.9V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.9V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.710V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.714V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.360V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.991V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.981V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.985V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.985V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.998V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon125……
Test Engineer…Simon Pyatt……
Date…02/11/09……

Contents

1. Block diagram

2. Test equipment

3. Description

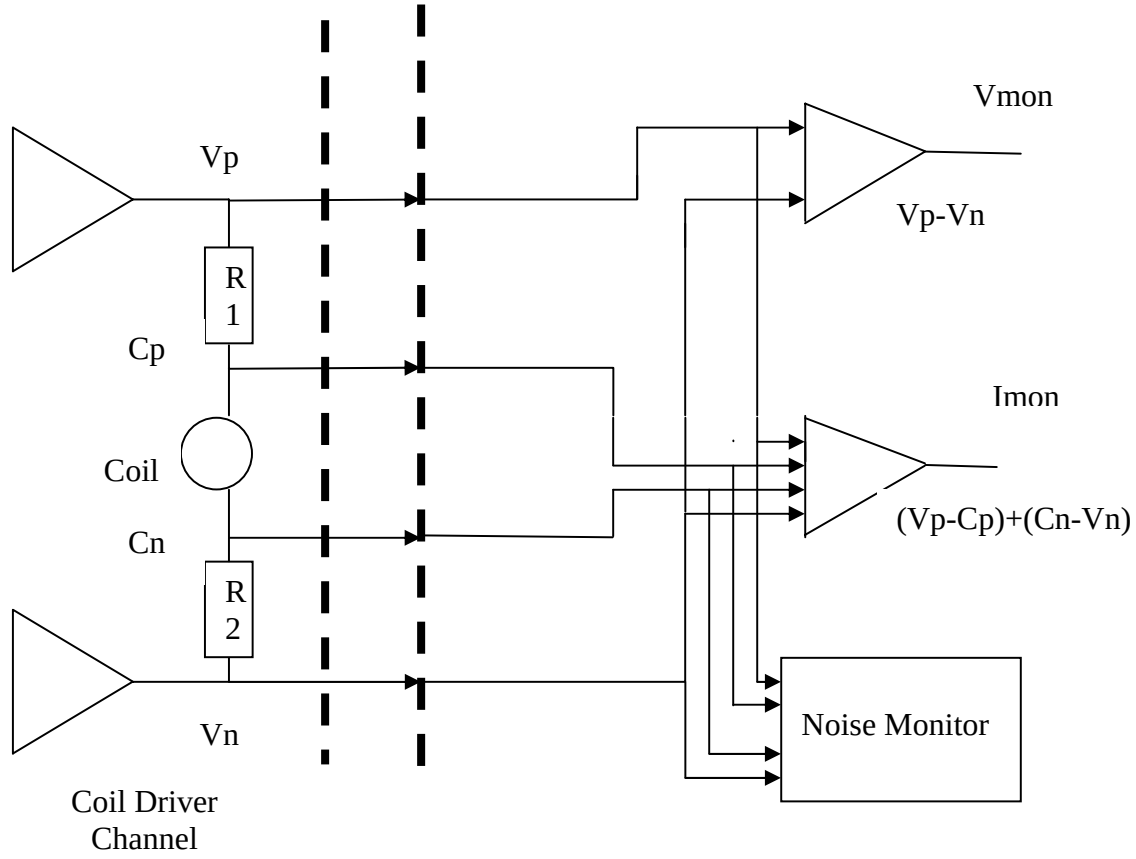
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

Serial No …mon125……..
Test Engineer …Simon Pyatt…….
Date …02/11/09……

4. Inspection

Workmanship

General **OK? √**
Comments

Visual overall check **OK? √**
Solder joint **OK? √**
Placement **OK? DS1, DS2, C9, C8, C10, C102 and C117 sitting slightly off the board.**

Modifications

Pins on back of board needed trimming down.

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon125……...
Test Engineer …Simon Pyatt…….
Date …02/11/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.79V	√
-15V (TP6)	-15.05V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mA	0.28A
-15v (TP6)	√	5mA	0.26A

Serial No …mon125……...
Test Engineer …Simon Pyatt…….
Date …02/11/09…….

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

Serial No …mon125……...
Test Engineer …Simon Pyatt…….
Date …03/11/09……

Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.9V	**4.8V to 5.2V**	√
Ch2		4.9V	**4.8V to 5.2V**	√
Ch3		4.9V	**4.8V to 5.2V**	√
Ch4		4.9V	**4.8V to 5.2V**	√

Serial No …mon125……...
Test Engineer …Simon Pyatt…….
Date …03/11/09……

Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	3	3	3	3

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.5	1.5	1.5	1.5	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√

Serial No …mon125……...
Test Engineer …Simon Pyatt…….
Date …03/11/09…….

6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

Serial No …mon125……...
Test Engineer …Simon Pyatt…….
Date …03/11/09…….

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.717V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.714V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.360V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.995V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.998V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.994V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.990V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon126……
Test Engineer…Simon Pyatt……
Date…03/11/09……

Contents

1. Block diagram

2. Test equipment

3. Description

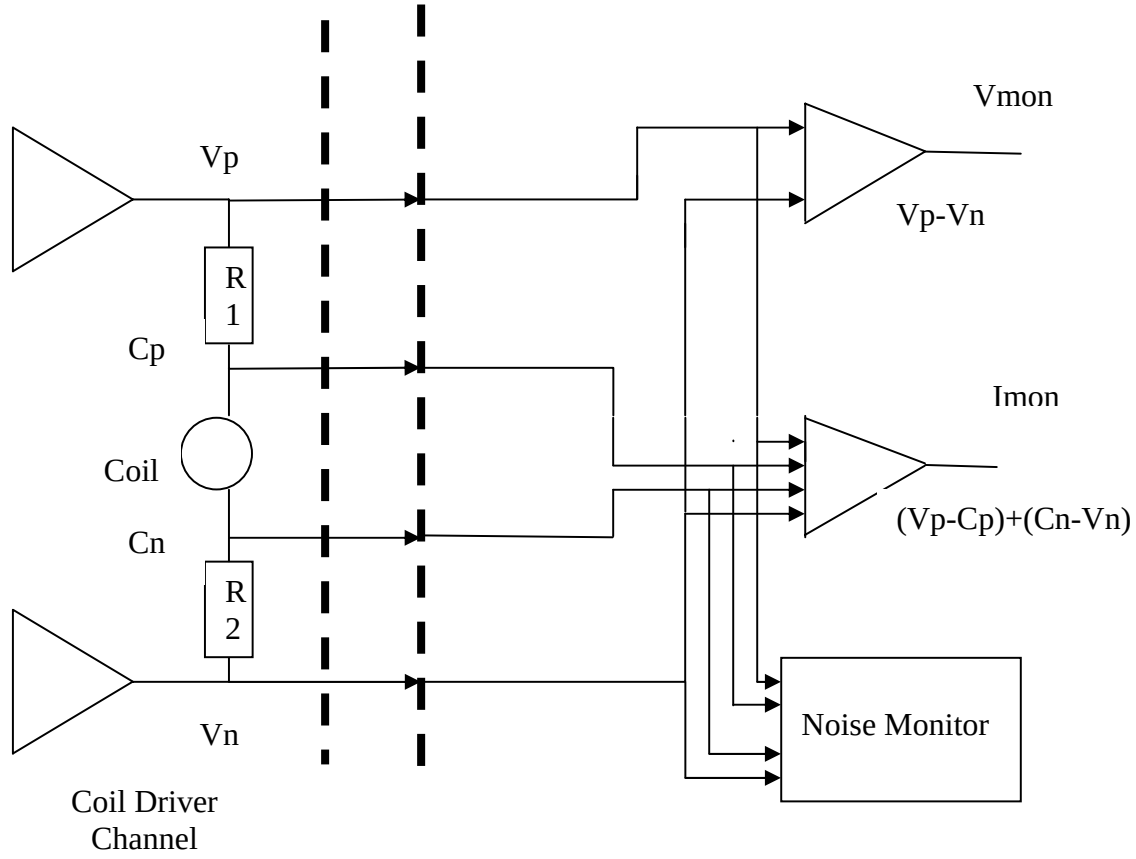
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

Serial No …mon126……..
Test Engineer …Simon Pyatt…….
Date …03/11/09……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Pins needed trimming down on back of board.

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon126……...
Test Engineer …Simon Pyatt…….
Date …03/11/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.80V	√
-15V (TP6)	-14.81V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mA	0.28A
-15v (TP6)	√	5mA	0.26A

Serial No …mon126……...
Test Engineer …Simon Pyatt…….
Date …03/11/09……

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

Serial No …mon126……...
Test Engineer …Simon Pyatt…….
Date …03/11/09……

Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.8V	**4.8V to 5.2V**	√
Ch2		4.8V	**4.8V to 5.2V**	√
Ch3		4.8V	**4.8V to 5.2V**	√
Ch4		4.8V	**4.8V to 5.2V**	√

Serial No …mon126……...
Test Engineer …Simon Pyatt…….
Date …03/11/09……

Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2.1	2.1
TP7	8	8	8	8	3.1	3.1	3.1	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.47	1.47	1.47	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√

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Test Engineer …Simon Pyatt…….
Date …03/11/09…….

6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

Serial No …mon126……...
Test Engineer …Simon Pyatt…….
Date …03/11/09…….

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.713V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.356V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.991V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.989V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.991V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.991V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.11V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.02V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon127……
Test Engineer…Simon Pyatt……
Date…03/11/09……

Contents

1. Block diagram

2. Test equipment

3. Description

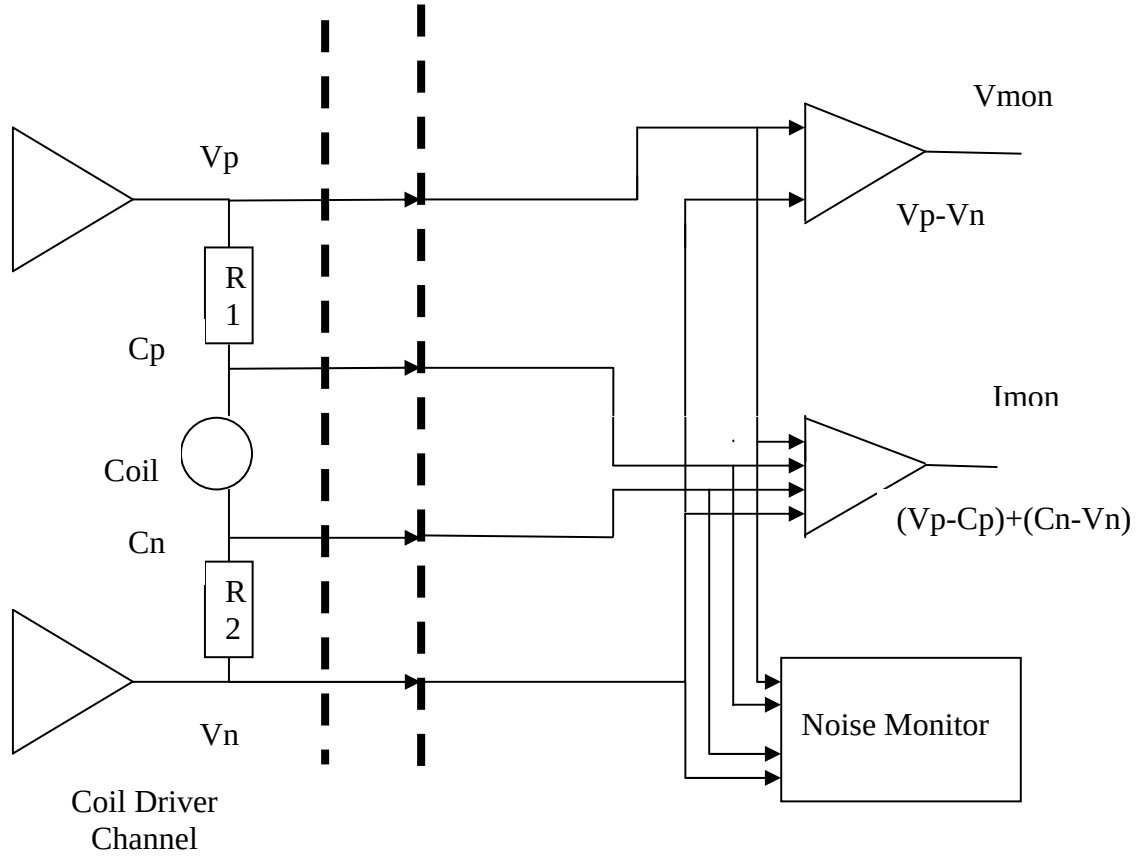
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

Serial No …mon127……..
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Date …03/11/09……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon127……...
Test Engineer …Simon Pyatt…….
Date …03/11/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.98V	√
-15V (TP6)	-15.02V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mA	0.28A
-15v (TP6)	√	5mA	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mA	2.4V	**2.4V to 2.6V**	√
Ch2	100mA	2.4V	**2.4V to 2.6V**	√
Ch3	100mA	2.4V	**2.4V to 2.6V**	√
Ch4	100mA	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mA	2.4V	**2.4V to 2.6V**	√
Ch2	100mA	2.4V	**2.4V to 2.6V**	√
Ch3	100mA	2.4V	**2.4V to 2.6V**	√
Ch4	100mA	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mA	1.7V	**1.6V to 1.9V**	√
Ch2	100mA	1.7V	**1.6V to 1.9V**	√
Ch3	100mA	1.7V	**1.6V to 1.9V**	√
Ch4	100mA	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mA	1.7V	**1.6V to 1.9V**	√
Ch2	100mA	1.7V	**1.6V to 1.9V**	√
Ch3	100mA	1.7V	**1.6V to 1.9V**	√
Ch4	100mA	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.8V	**4.8V to 5.2V**	√
Ch2		4.8V	**4.8V to 5.2V**	√
Ch3		4.8V	**4.8V to 5.2V**	√
Ch4		4.8V	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2.1	2.1
TP7	8	8	8	8	3.1	3	3	3

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.47	1.42	1.42	1.42	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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Test Engineer …Simon Pyatt…….
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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.710V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.709V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.707V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.714V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.354V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.352V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.983V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.980V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.975V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.983V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon128……
Test Engineer…Simon Pyatt……
Date…03/11/09……

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2. Test equipment

3. Description

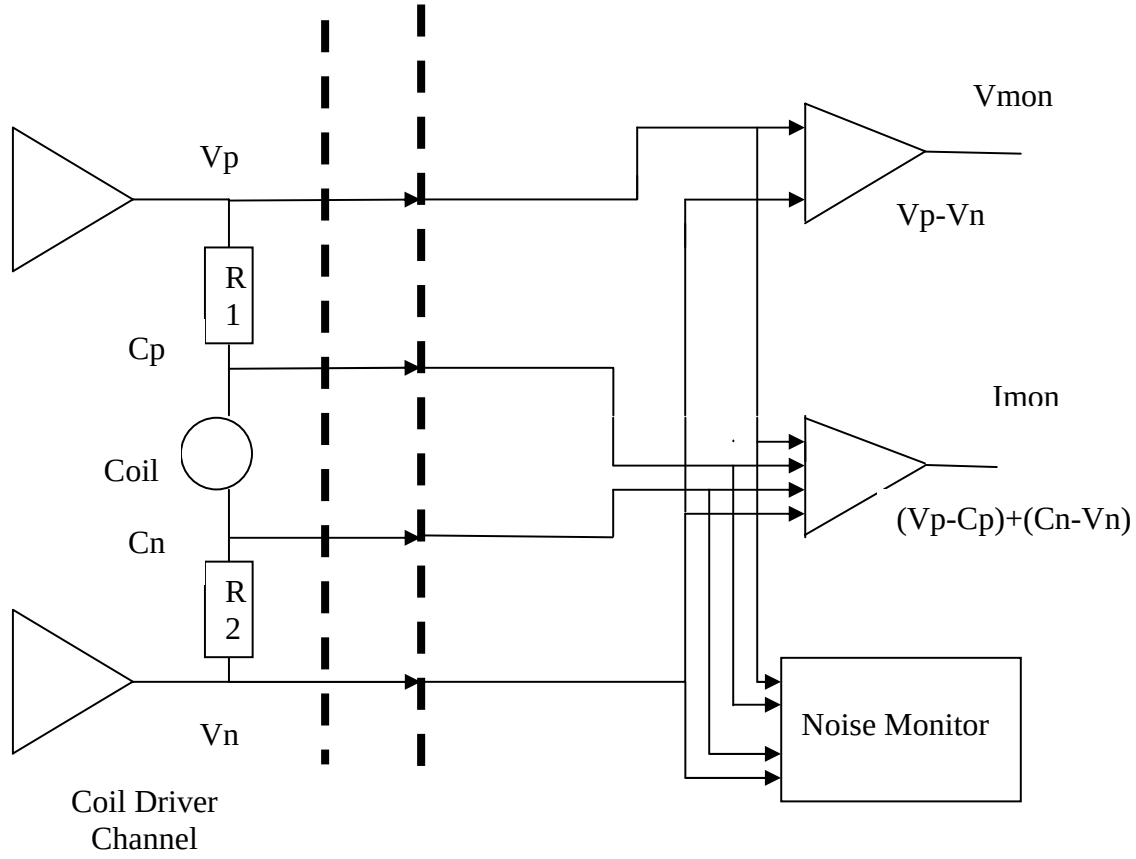
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon128……...
Test Engineer …Simon Pyatt…….
Date …03/11/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.93V	√
-15V (TP6)	-14.93V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mA	0.28A
-15v (TP6)	√	5mA	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.8V	**4.8V to 5.2V**	√
Ch2		4.8V	**4.8V to 5.2V**	√
Ch3		4.8V	**4.8V to 5.2V**	√
Ch4		4.8V	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2.1	2.1
TP7	8	8	8	8	3	3	3.1	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.42	1.42	1.47	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.3V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.8V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.710V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.710V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.712V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.355V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.985V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.982V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.984V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.984V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon129……
Test Engineer…Simon Pyatt……
Date…04/11/09……

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3. Description

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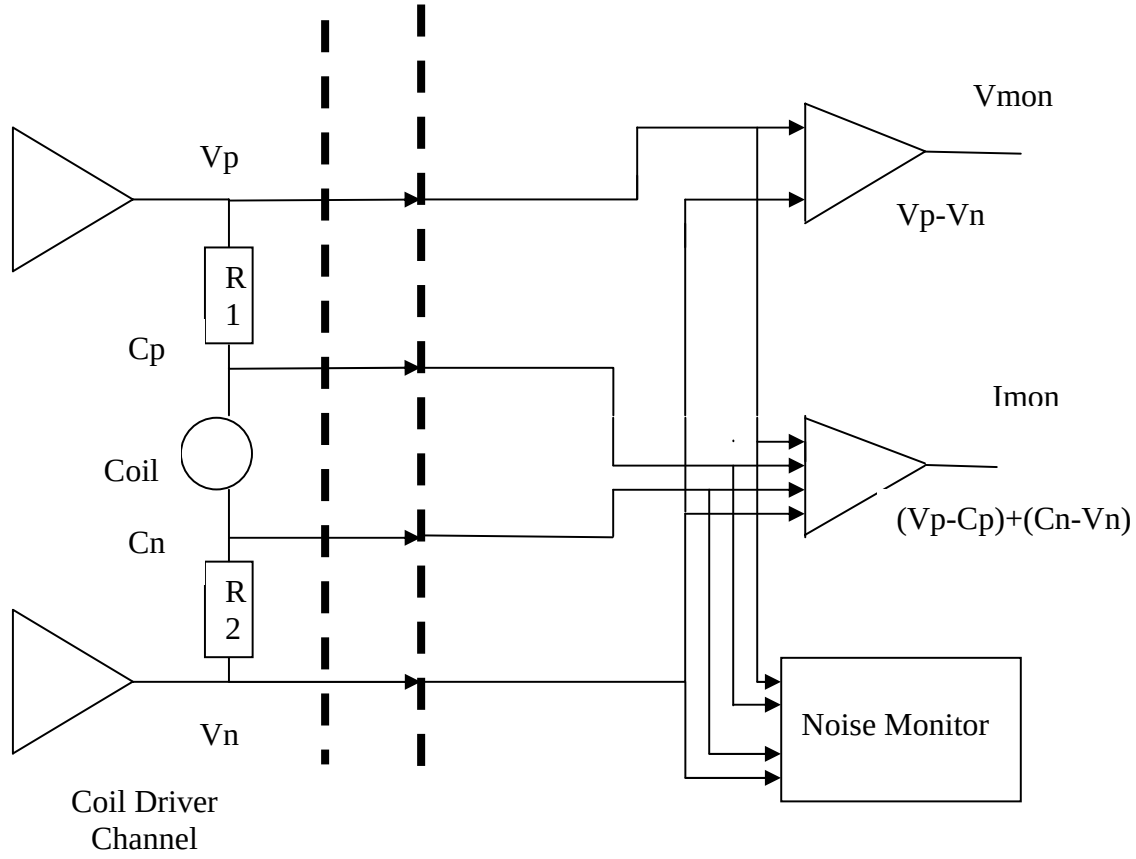
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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Test Engineer …Simon Pyatt…….
Date …04/11/09……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon129……...
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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.99V	√
-15V (TP6)	-14.97V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mA	0.28A
-15v (TP6)	√	5mA	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mA	2.4V	**2.4V to 2.6V**	√
Ch2	100mA	2.4V	**2.4V to 2.6V**	√
Ch3	100mA	2.4V	**2.4V to 2.6V**	√
Ch4	100mA	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mA	2.4V	**2.4V to 2.6V**	√
Ch2	100mA	2.4V	**2.4V to 2.6V**	√
Ch3	100mA	2.4V	**2.4V to 2.6V**	√
Ch4	100mA	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mA	1.8V	**1.6V to 1.9V**	√
Ch2	100mA	1.8V	**1.6V to 1.9V**	√
Ch3	100mA	1.8V	**1.6V to 1.9V**	√
Ch4	100mA	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mA	1.7V	**1.6V to 1.9V**	√
Ch2	100mA	1.7V	**1.6V to 1.9V**	√
Ch3	100mA	1.7V	**1.6V to 1.9V**	√
Ch4	100mA	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.8V	**4.8V to 5.2V**	√
Ch2		4.8V	**4.8V to 5.2V**	√
Ch3		4.8V	**4.8V to 5.2V**	√
Ch4		4.8V	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2	2
TP7	8	8	8	8	3.1	3.1	2.9	3

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.42	1.42	
TP7/TP6	2	2	2	2	1.47	1.47	1.45	1.5	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.8V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.709V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.355V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.986V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.988V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.982V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.978V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.11V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon130……
Test Engineer…Simon Pyatt……
Date…04/11/09……

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1. Block diagram

2. Test equipment

3. Description

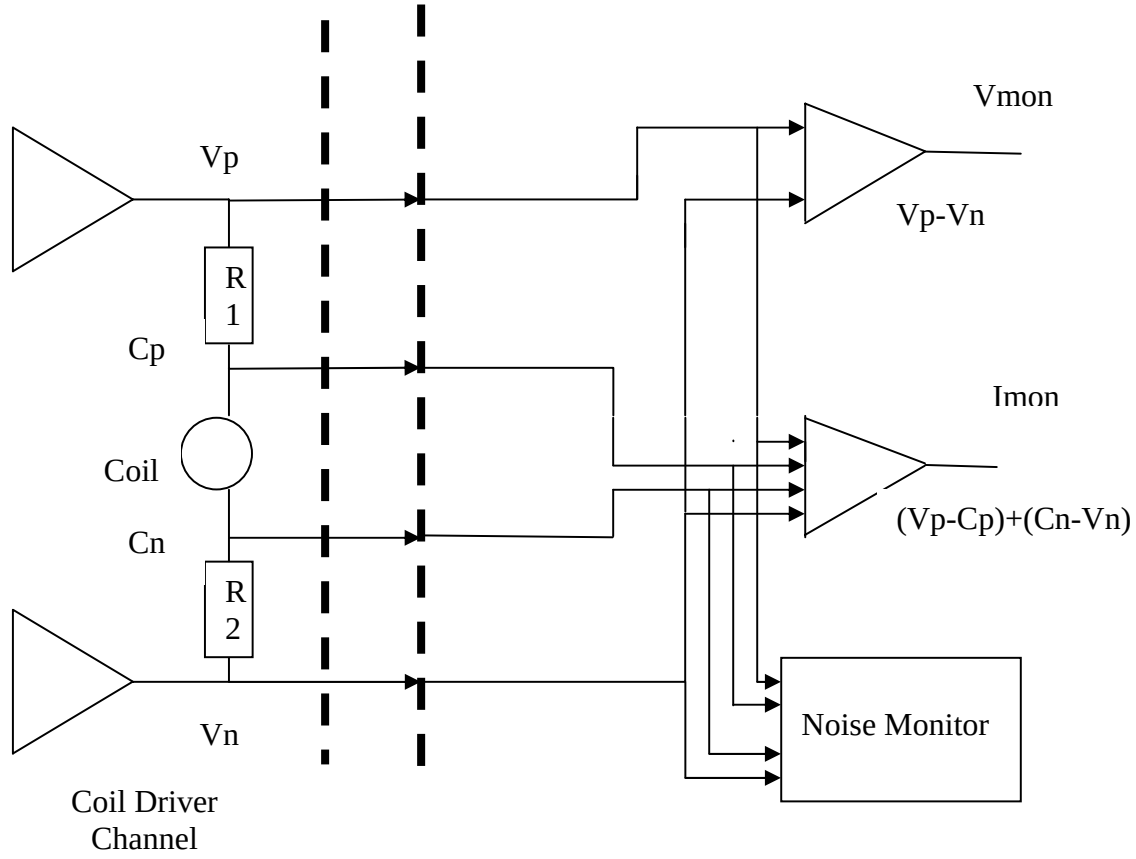
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Removed solder that was on one of the mounting holes. It was partially blocking the hole.

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Date ……

NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.91V	√
-15V (TP6)	-14.91V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	2mA	0.28A
-15v (TP6)	√	5mA	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1	100mV	4.8V	**4.8V to 5.2V**	√
Ch2	100mV	4.8V	**4.8V to 5.2V**	√
Ch3	100mV	4.8V	**4.8V to 5.2V**	√
Ch4	100mV	4.8V	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2.1	2.1
TP7	8	8	8	8	3.1	3.1	3.1	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.47	1.47	1.47	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.715V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.985V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.984V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.985V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.987V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon131……
Test Engineer…Simon Pyatt……
Date…04/11/09……

Contents

1. Block diagram

2. Test equipment

3. Description

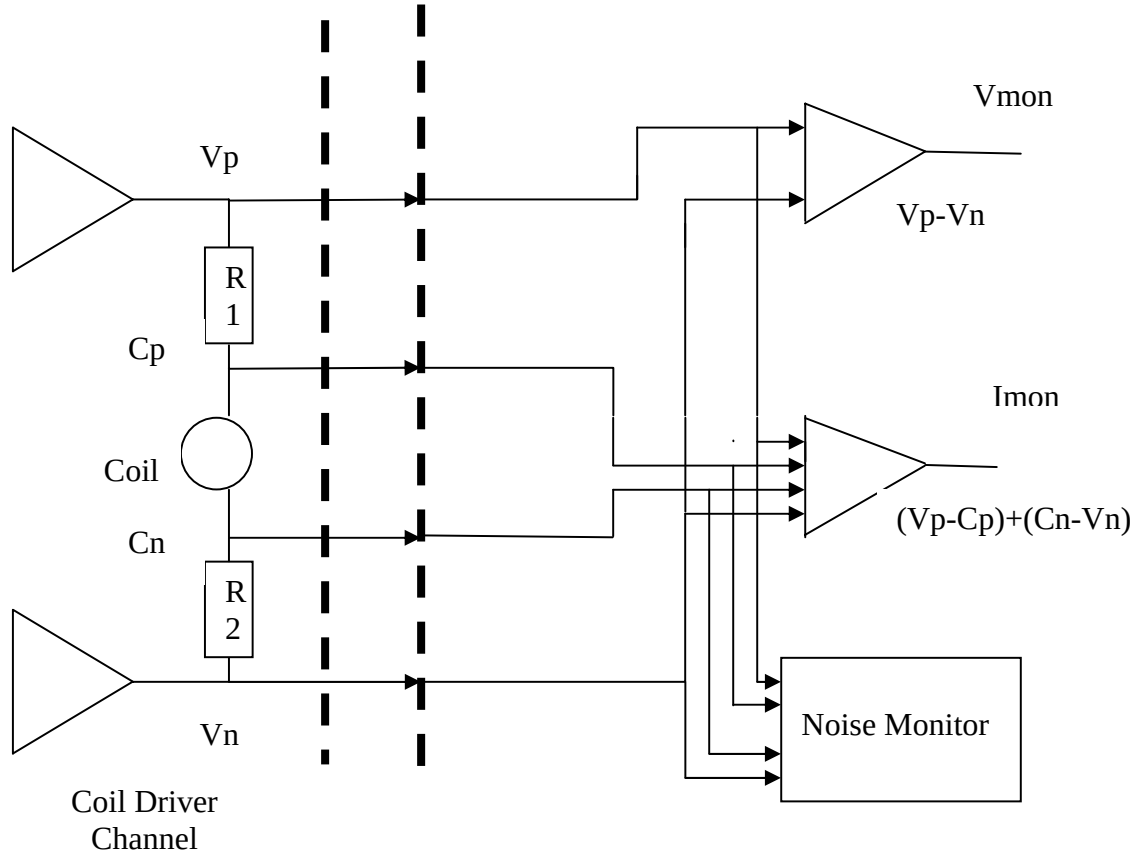
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon131……...
Test Engineer …Simon Pyatt…….
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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.99V	√
-15V (TP6)	-14.91V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mA	0.28A
-15v (TP6)	√	5mA	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.8V	**4.8V to 5.2V**	√
Ch2		4.8V	**4.8V to 5.2V**	√
Ch3		4.8V	**4.8V to 5.2V**	√
Ch4		4.8V	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	3	3	2.9	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.5	1.5	1.45	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.714V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.988V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.987V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.987V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.989V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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1. Block diagram

2. Test equipment

3. Description

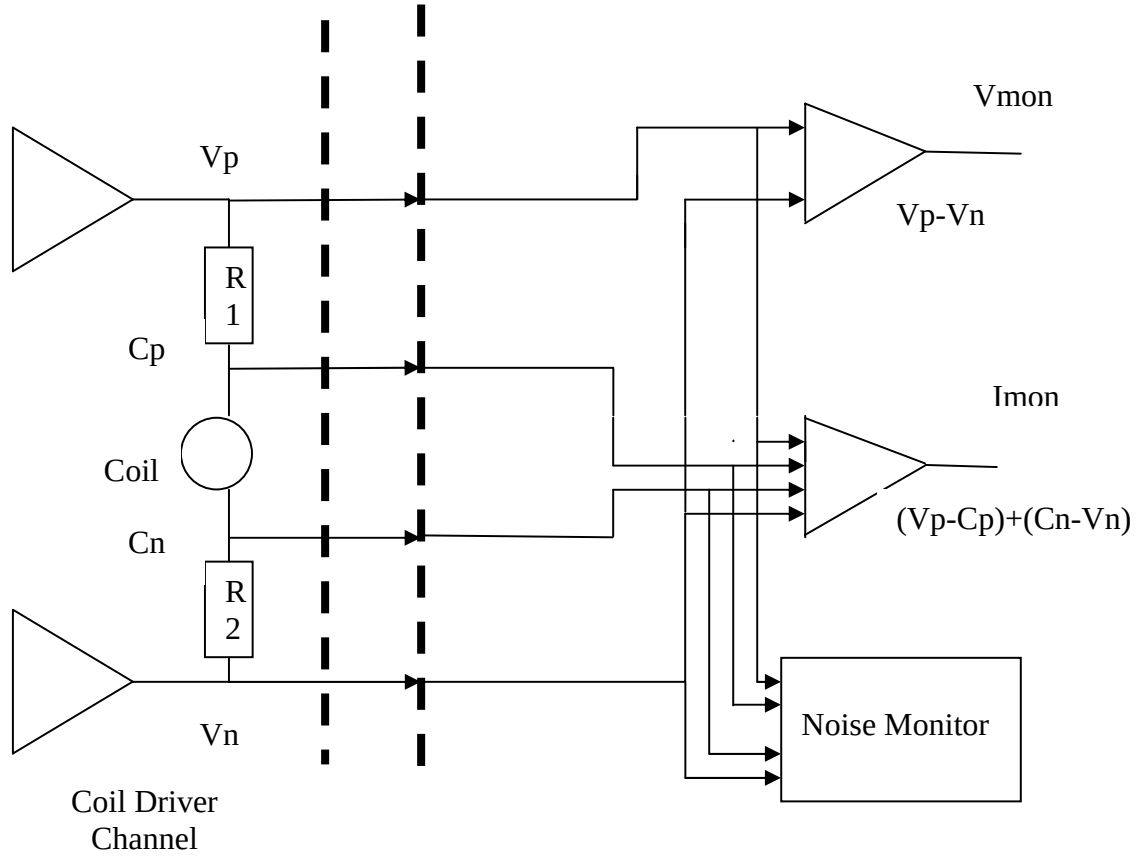
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon132……..
Test Engineer …Simon Pyatt…….
Date …04/11/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.82V	√
-15V (TP6)	-14.96V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Test Engineer …Simon Pyatt…….
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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.8V	**4.8V to 5.2V**	√
Ch2		4.8V	**4.8V to 5.2V**	√
Ch3		4.8V	**4.8V to 5.2V**	√
Ch4		4.8V	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2.1	2.1
TP7	8	8	8	8	3.1	3.1	3.1	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.47	1.47	1.47	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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Test Engineer …Simon Pyatt…….
Date …04/11/09…….

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.710V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.710V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.716V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.985V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.982V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.980V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.987V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.995V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon133……
Test Engineer…Simon Pyatt……
Date…04/11/09……

Contents

1. Block diagram

2. Test equipment

3. Description

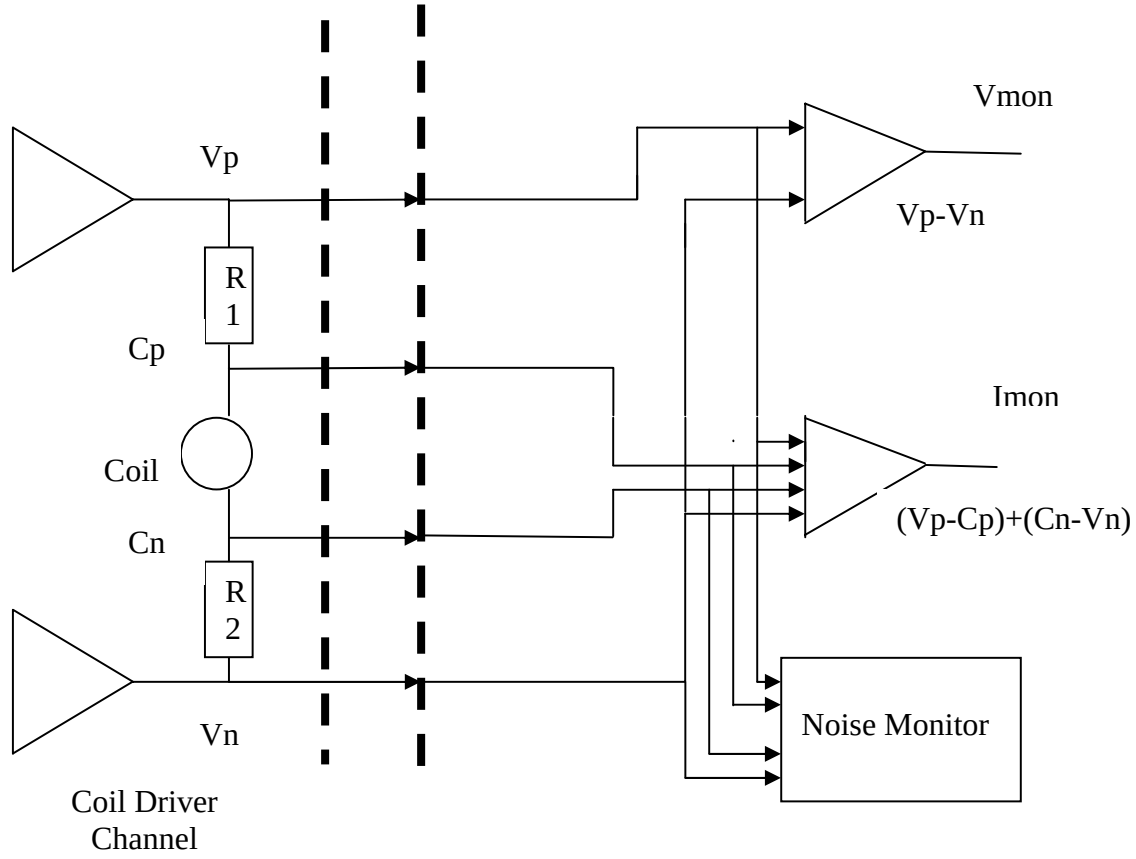
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK? √**
Comments

Visual overall check **OK? √**
Solder joint **OK? √**
Placement **OK? D5 slightly crooked**

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon133……...
Test Engineer …Simon Pyatt…….
Date …04/11/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.99V	√
-15V (TP6)	-14.97V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mA	0.28A
-15v (TP6)	√	5mA	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mA	2.4V	**2.4V to 2.6V**	√
Ch2	100mA	2.4V	**2.4V to 2.6V**	√
Ch3	100mA	2.4V	**2.4V to 2.6V**	√
Ch4	100mA	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mA	2.5V	**2.4V to 2.6V**	√
Ch2	100mA	2.5V	**2.4V to 2.6V**	√
Ch3	100mA	2.4V	**2.4V to 2.6V**	√
Ch4	100mA	2.5V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mA	1.7V	**1.6V to 1.9V**	√
Ch2	100mA	1.7V	**1.6V to 1.9V**	√
Ch3	100mA	1.7V	**1.6V to 1.9V**	√
Ch4	100mA	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mA	1.7V	**1.6V to 1.9V**	√
Ch2	100mA	1.7V	**1.6V to 1.9V**	√
Ch3	100mA	1.7V	**1.6V to 1.9V**	√
Ch4	100mA	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.8V	**4.8V to 5.2V**	√
Ch2		4.8V	**4.8V to 5.2V**	√
Ch3		4.8V	**4.8V to 5.2V**	√
Ch4		4.8V	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2.1	2
TP7	8	8	8	8	3	3	3	3

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.5	1.42	
TP7/TP6	2	2	2	2	1.5	1.5	1.42	1.5	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.3V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.708V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.722V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.714V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.354V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.362V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.356V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.991V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.985V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.992V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon134……
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Contents

1. Block diagram

2. Test equipment

3. Description

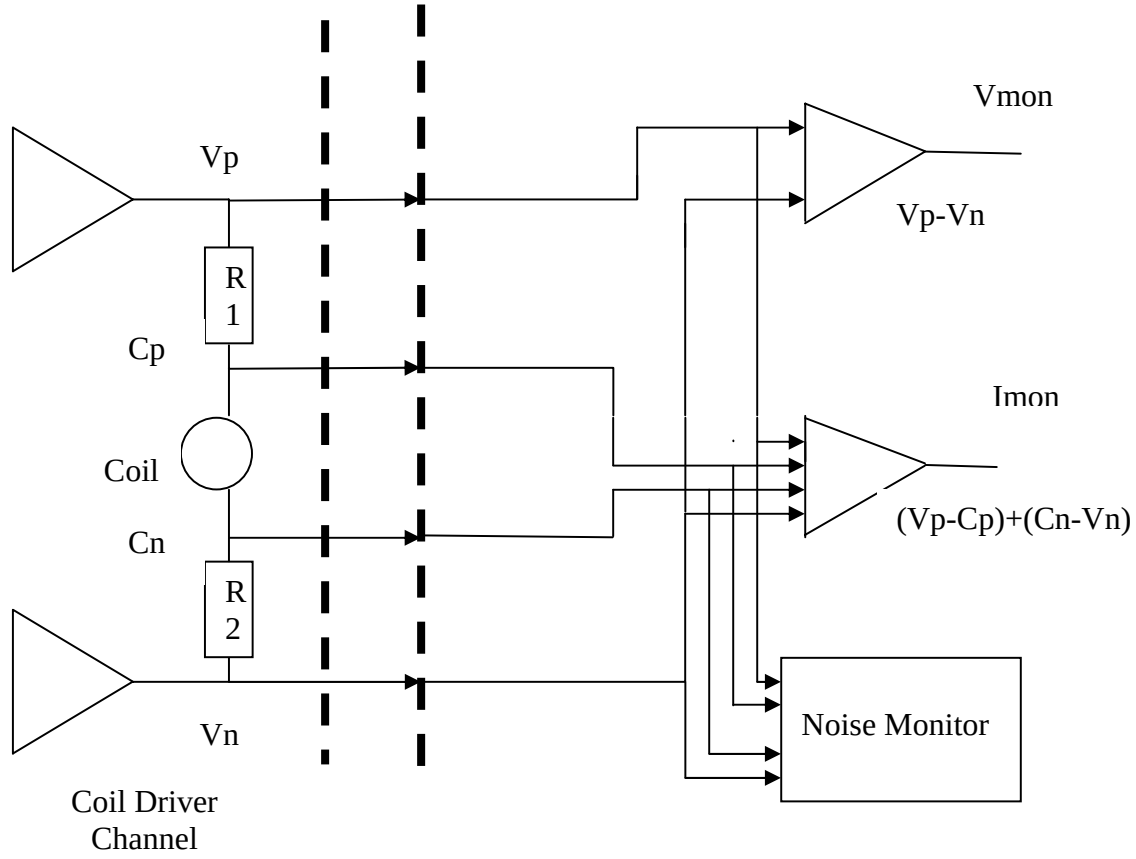
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon134……..
Test Engineer …Simon Pyatt…….
Date …05/11/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.94V	√
-15V (TP6)	-14.93V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon134……...
Test Engineer …Simon Pyatt…….
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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

Serial No …mon134……...
Test Engineer …Simon Pyatt…….
Date …05/11/09……

Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.8V	**4.8V to 5.2V**	√
Ch2		4.8V	**4.8V to 5.2V**	√
Ch3		4.8V	**4.8V to 5.2V**	√
Ch4		4.8V	**4.8V to 5.2V**	√

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Test Engineer …Simon Pyatt…….
Date …05/11/09……

Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2.1	2.1
TP7	8	8	8	8	3.1	3.1	3.1	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.47	1.47	1.47	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.3V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.3V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.710V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.709V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.354V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.355V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.976V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.975V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.972V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.970V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon135……
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Contents

1. Block diagram

2. Test equipment

3. Description

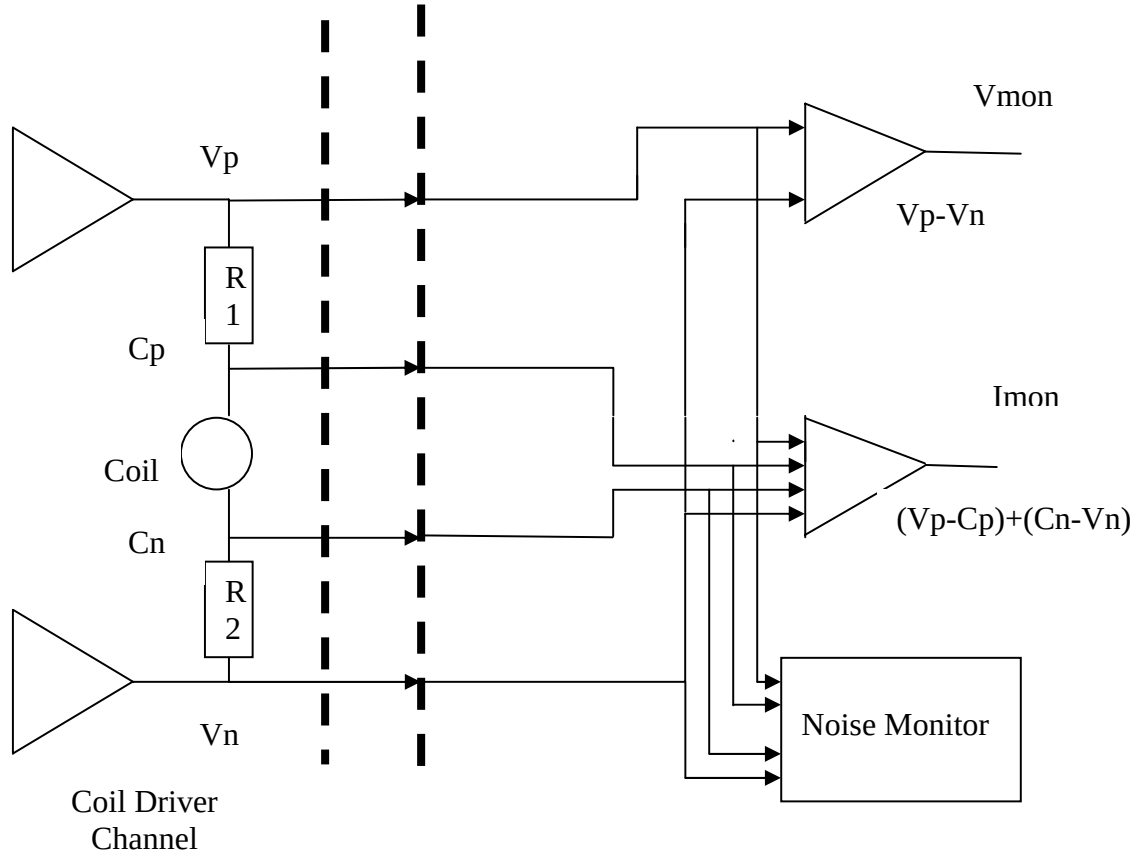
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.97V	√
-15V (TP6)	-15.03V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mA	0.28A
-15v (TP6)	√	5mA	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.8V	**4.8V to 5.2V**	√
Ch2		4.8V	**4.8V to 5.2V**	√
Ch3		4.8V	**4.8V to 5.2V**	√
Ch4		4.8V	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.5	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2.1	2.1
TP7	8	8	8	8	3.1	3.1	3.1	3

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.5	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.4	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.47	1.47	1.47	1.42	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.7V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.7V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.6V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.708V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.710V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.713V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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1. Block diagram

2. Test equipment

3. Description

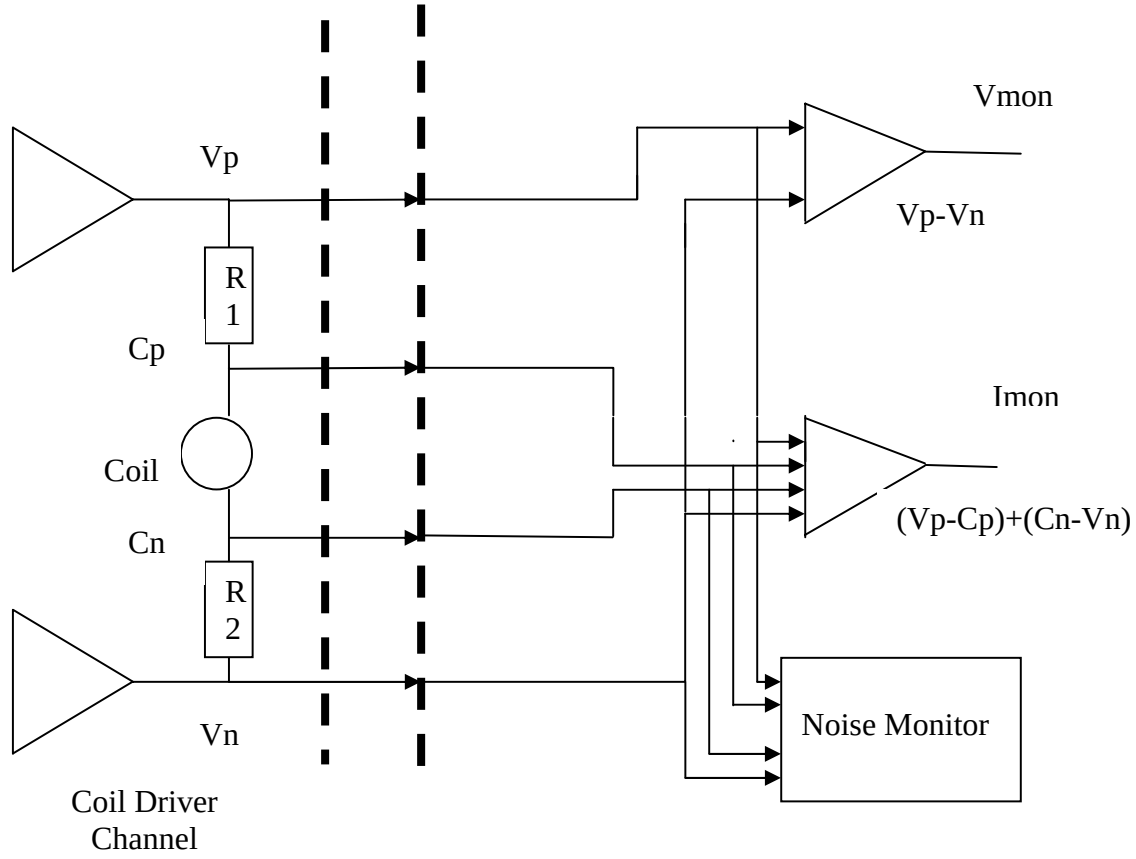
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon136……...
Test Engineer …Simon Pyatt…….
Date …06/11/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.99V	√
-15V (TP6)	-15.08V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mA	0.28A
-15v (TP6)	√	5mA	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.8V	**4.8V to 5.2V**	√
Ch2		4.8V	**4.8V to 5.2V**	√
Ch3		4.8V	**4.8V to 5.2V**	√
Ch4		4.8V	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2.1	2.1
TP7	8	8	8	8	3.1	3.1	3.1	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.42	1.42	1.42	1.42	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.712V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.355V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.978V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.980V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.981V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.977V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon137……
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Contents

1. Block diagram

2. Test equipment

3. Description

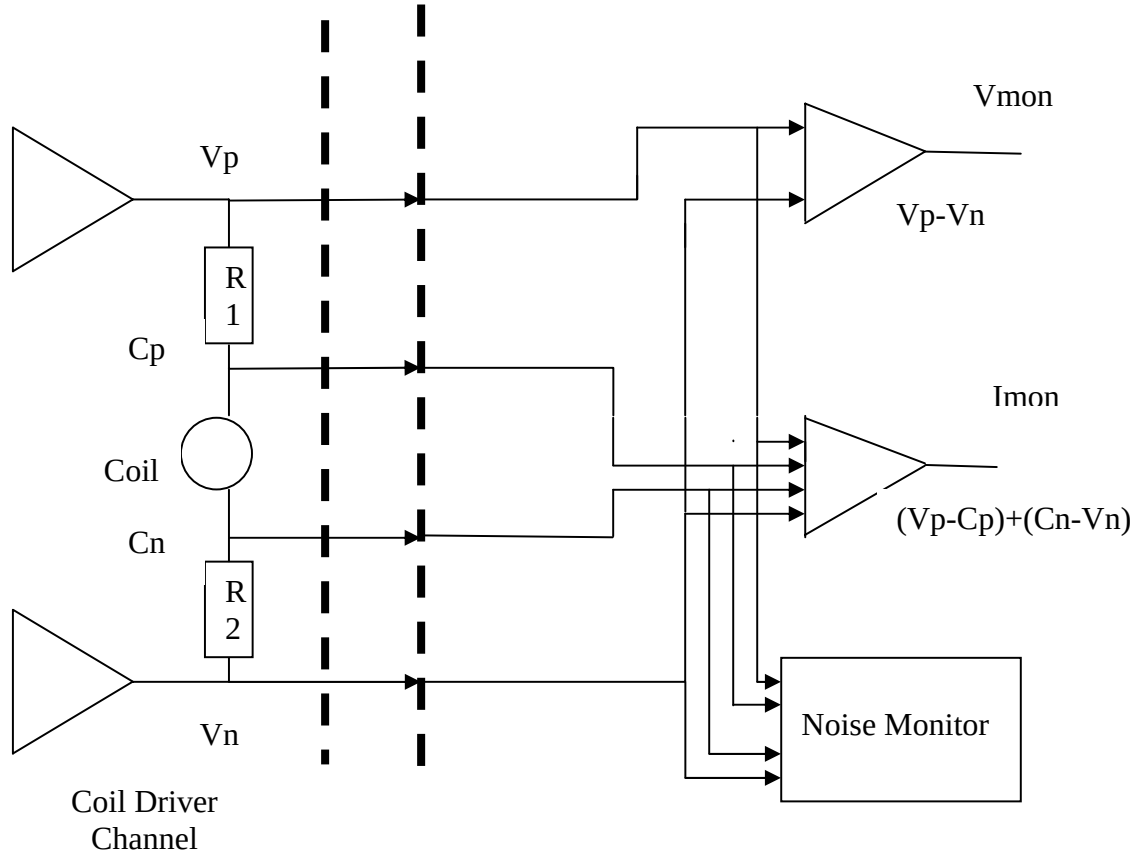
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.80V	√
-15V (TP6)	-14.99V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mA	0.28A
-15v (TP6)	√	5mA	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.5V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.8V	**4.8V to 5.2V**	√
Ch2		4.8V	**4.8V to 5.2V**	√
Ch3		4.8V	**4.8V to 5.2V**	√
Ch4		4.8V	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2	2	2
TP7	8	8	8	8	3.1	3	3	3

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.47	1.5	1.5	1.5	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.710V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.712V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.983	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.985	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.982	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.981	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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2. Test equipment

3. Description

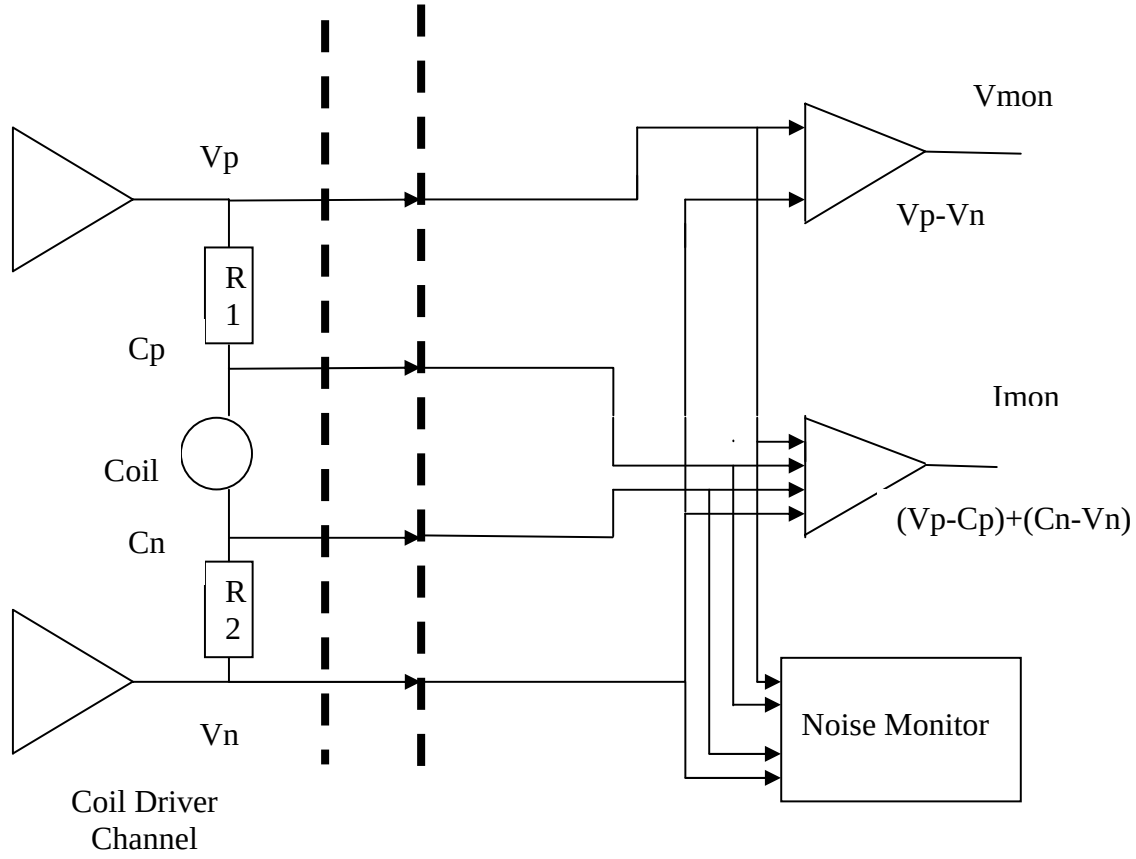
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon138……...
Test Engineer …Simon Pyatt…….
Date …06/11/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.98V	√
-15V (TP6)	-17.98V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mA	0.28A
-15v (TP6)	√	5mA	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mA	2.4V	**2.4V to 2.6V**	√
Ch2	100mA	2.4V	**2.4V to 2.6V**	√
Ch3	100mA	2.4V	**2.4V to 2.6V**	√
Ch4	100mA	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mA	2.4V	**2.4V to 2.6V**	√
Ch2	100mA	2.4V	**2.4V to 2.6V**	√
Ch3	100mA	2.4V	**2.4V to 2.6V**	√
Ch4	100mA	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mA	1.7V	**1.6V to 1.9V**	√
Ch2	100mA	1.8V	**1.6V to 1.9V**	√
Ch3	100mA	1.8V	**1.6V to 1.9V**	√
Ch4	100mA	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mA	1.7V	**1.6V to 1.9V**	√
Ch2	100mA	1.7V	**1.6V to 1.9V**	√
Ch3	100mA	1.7V	**1.6V to 1.9V**	√
Ch4	100mA	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.8V	**4.8V to 5.2V**	√
Ch2		4.8V	**4.8V to 5.2V**	√
Ch3		4.8V	**4.8V to 5.2V**	√
Ch4		4.8V	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2.1	2
TP7	8	8	8	8	3.1	3.1	3.1	3

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.47	1.47	1.47	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

Serial No …mon138……..
Test Engineer …Simon Pyatt…….
Date …09/11/09…….

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.714	**0.707 (0.68 to 0.72V)**	√
Ch2	0.712	**0.707 (0.68 to 0.72V)**	√
Ch3	0.712	**0.707 (0.68 to 0.72V)**	√
Ch4	0.710	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357	**0.35V (0.33 to 0.37V)**	√
Ch2	0.355	**0.35V (0.33 to 0.37V)**	√
Ch3	0.355	**0.35V (0.33 to 0.37V)**	√
Ch4	0.354	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.985V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.984V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.983V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.980V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon139……
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Contents

1. Block diagram

2. Test equipment

3. Description

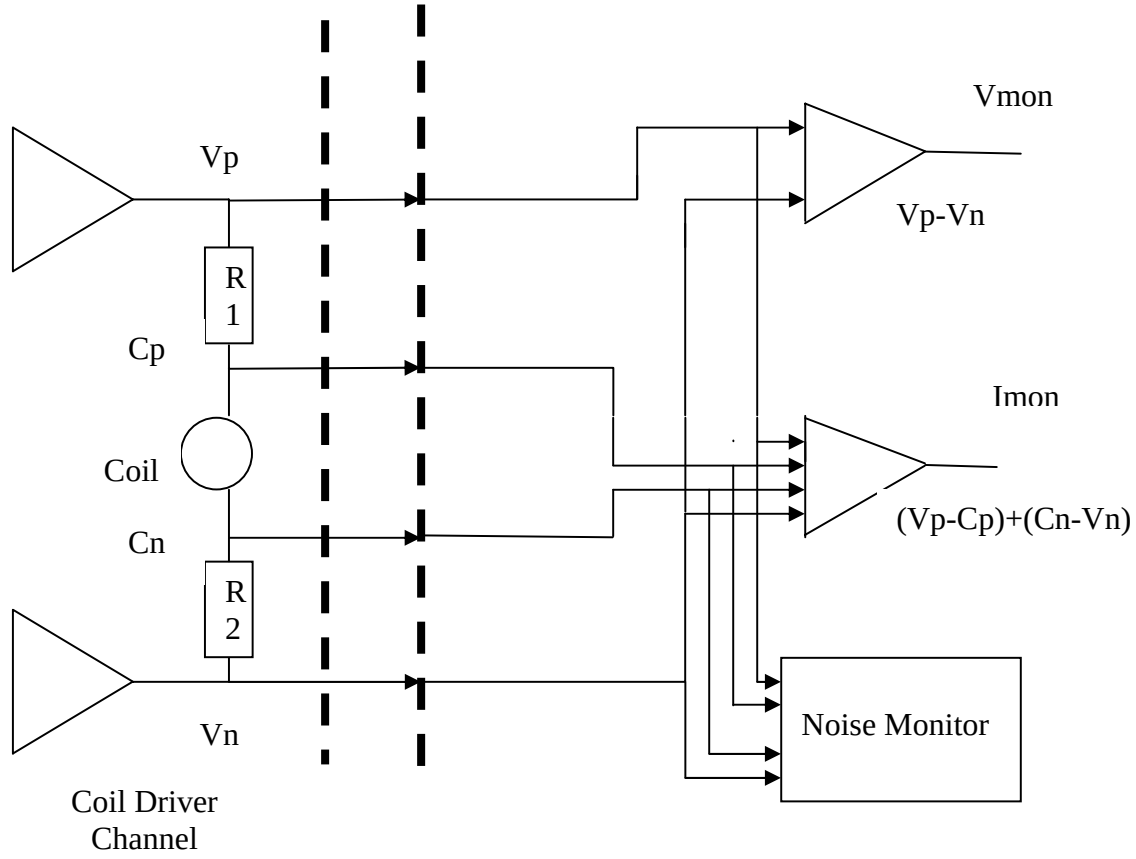
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon139……..
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Date …09/11/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.80V	√
-15V (TP6)	-14.86V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Test Engineer …Simon Pyatt…….
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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.8V	**4.8V to 5.2V**	√
Ch2		4.8V	**4.8V to 5.2V**	√
Ch3		4.8V	**4.8V to 5.2V**	√
Ch4		4.8V	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2.1	2.1
TP7	8	8	8	8	3.1	3.1	3.1	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.47	1.47	1.47	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.6V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.8V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.717V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.712V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.360V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.356V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.989V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.994V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.990V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.987V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon140……
Test Engineer…Simon Pyatt……
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1. Block diagram

2. Test equipment

3. Description

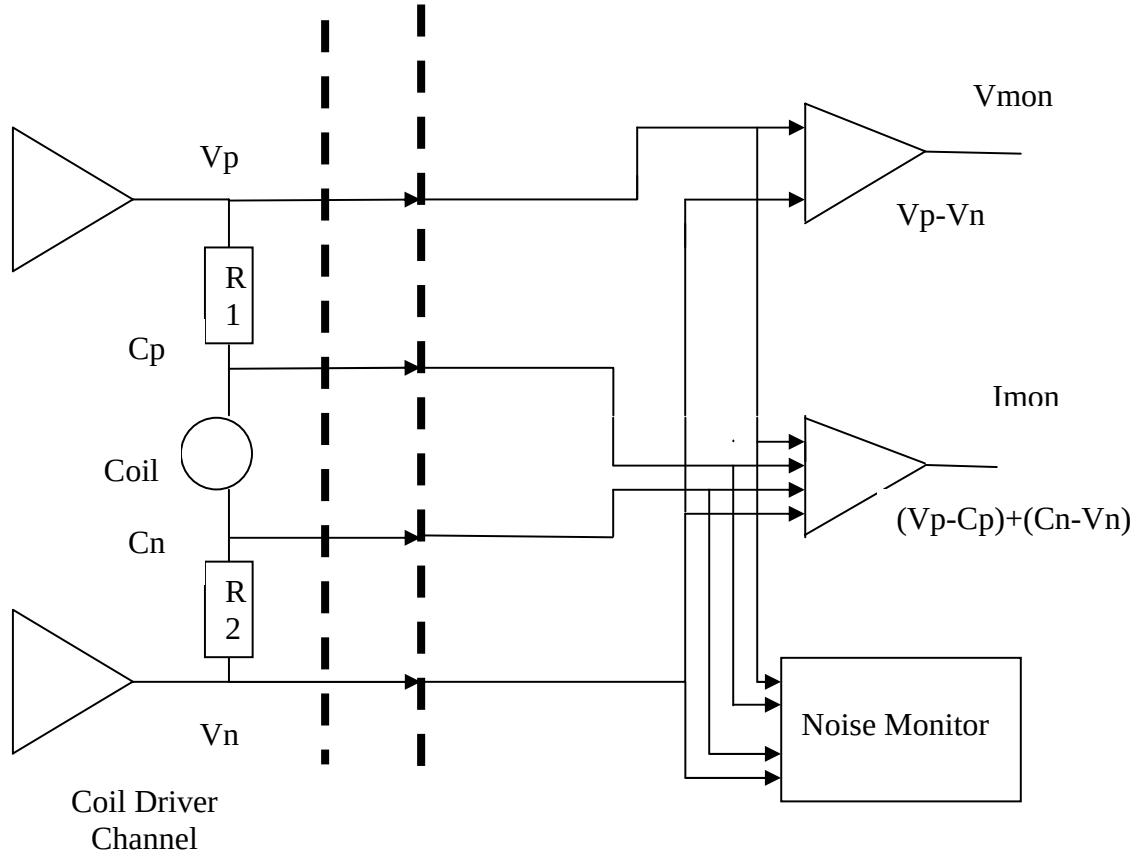
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon140……...
Test Engineer …Simon Pyatt…….
Date …09/11/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.96V	√
-15V (TP6)	-14.99V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon140……...
Test Engineer …Simon Pyatt…….
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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Test Engineer …Simon Pyatt…….
Date ……09/11/09……

Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.8V	**4.8V to 5.2V**	√
Ch2		4.8V	**4.8V to 5.2V**	√
Ch3		4.8V	**4.8V to 5.2V**	√
Ch4		4.8V	**4.8V to 5.2V**	√

Serial No …mon140……...
Test Engineer …Simon Pyatt…….
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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.9	3	3	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.45	1.5	1.5	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.8V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√

Serial No …mon140……...
Test Engineer …Simon Pyatt…….
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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

Serial No …mon140……...
Test Engineer …Simon Pyatt…….
Date ……09/11/09……

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.708V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.712V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.352V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.355V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon141……
Test Engineer…Simon Pyatt……
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Contents

1. Block diagram

2. Test equipment

3. Description

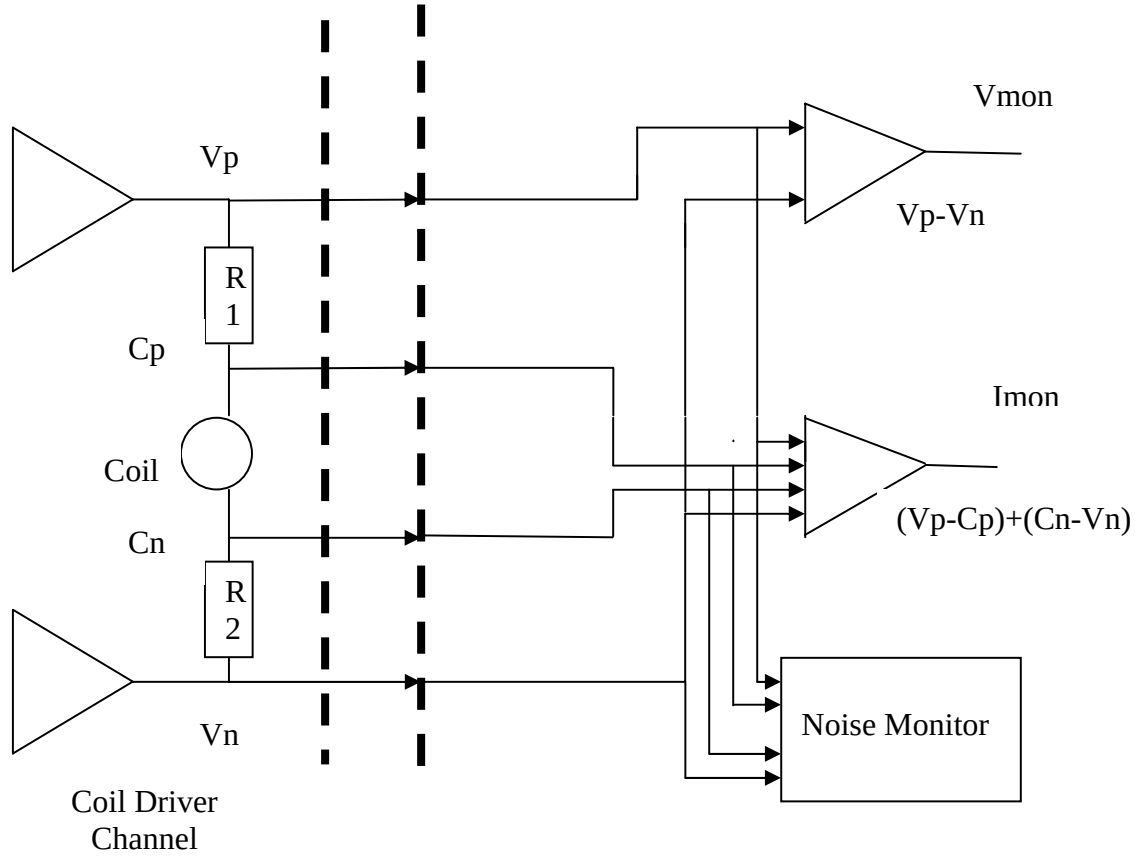
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK? D6 positioning is poor but electrically ok.**

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon141……...
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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.83V	√
-15V (TP6)	-14.95V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.5V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.5V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Test Engineer …Simon Pyatt…….
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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.6V	**1.6V to 1.9V**	√
Ch2	100mV	1.6V	**1.6V to 1.9V**	√
Ch3	100mV	1.6V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.8V	**4.8V to 5.2V**	√
Ch2		4.8V	**4.8V to 5.2V**	√
Ch3		4.8V	**4.8V to 5.2V**	√
Ch4		4.8V	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.9	3	2.9	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.45	1.5	1.45	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.3V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.8V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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Test Engineer …Simon Pyatt…….
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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.710V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.717V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.715V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.354V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.360V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.983V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.987V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.988V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.987V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon142……
Test Engineer…Simon Pyatt……
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1. Block diagram

2. Test equipment

3. Description

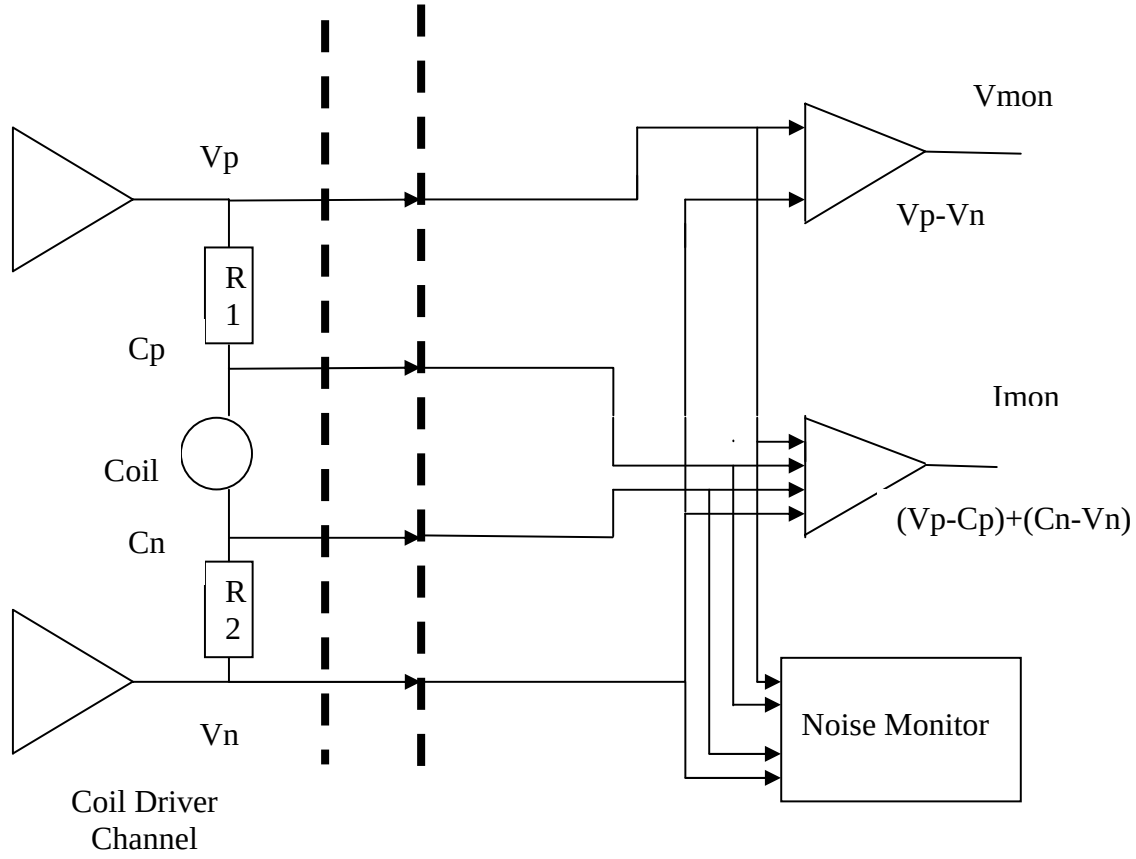
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon142……...
Test Engineer …Simon Pyatt…….
Date …10/11/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.95V	√
-15V (TP6)	-14.97V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mA	0.28A
-15v (TP6)	√	5mA	0.26A

Serial No …mon142……...
Test Engineer …Simon Pyatt…….
Date …10/11/09……

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.8V	**4.8V to 5.2V**	√
Ch2		4.8V	**4.8V to 5.2V**	√
Ch3		4.8V	**4.8V to 5.2V**	√
Ch4		4.8V	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.9	2.8	2.9	2.8

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.45	1.4	1.45	1.4	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.707V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.713V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.353V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.356V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.023V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon143……
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Contents

1. Block diagram

2. Test equipment

3. Description

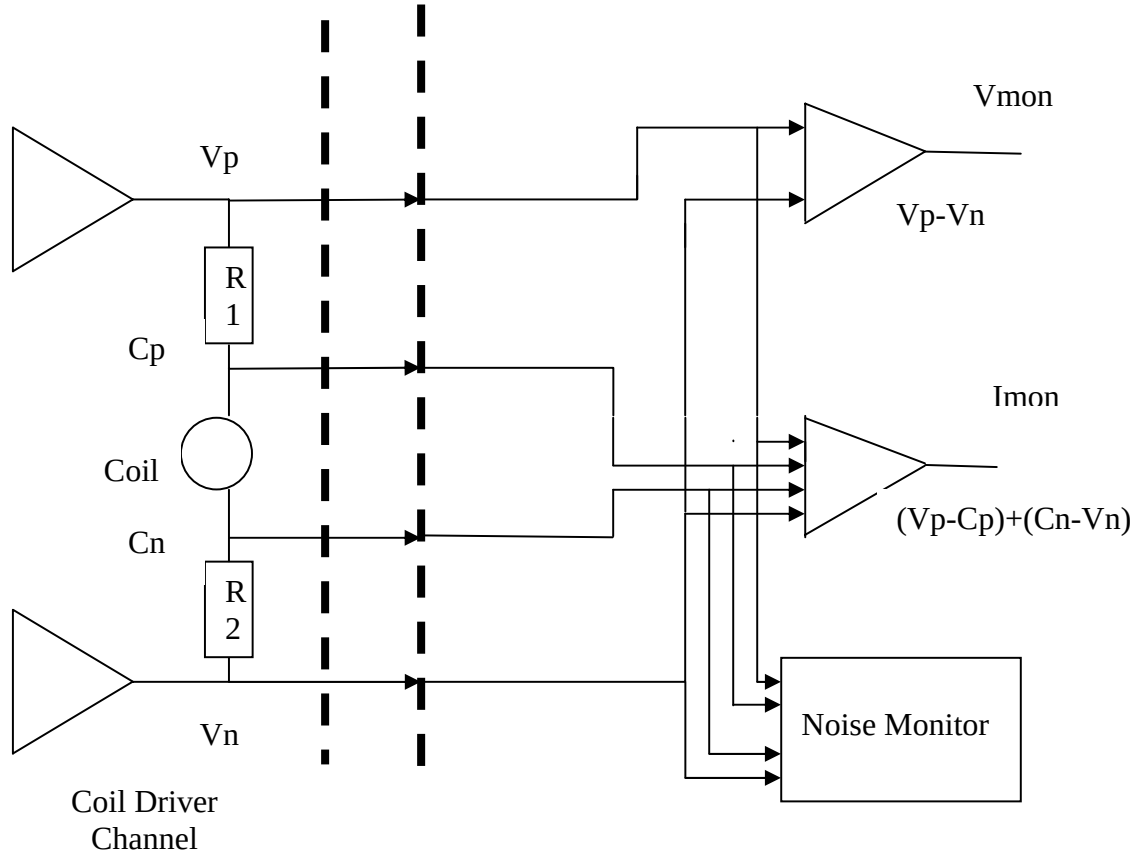
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.81V	√
-15V (TP6)	-14.97V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28
-15v (TP6)	√	5mV	0.26

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.6V	**1.6V to 1.9V**	√
Ch3	100mV	1.6V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.8V	**4.8V to 5.2V**	√
Ch2		4.8V	**4.8V to 5.2V**	√
Ch3		4.8V	**4.8V to 5.2V**	√
Ch4		4.8V	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	3	2.9	2.9	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.5	1.45	1.45	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.8V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.710V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.355V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.982V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.983V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.981V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.976V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.02V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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Contents

1. Block diagram

2. Test equipment

3. Description

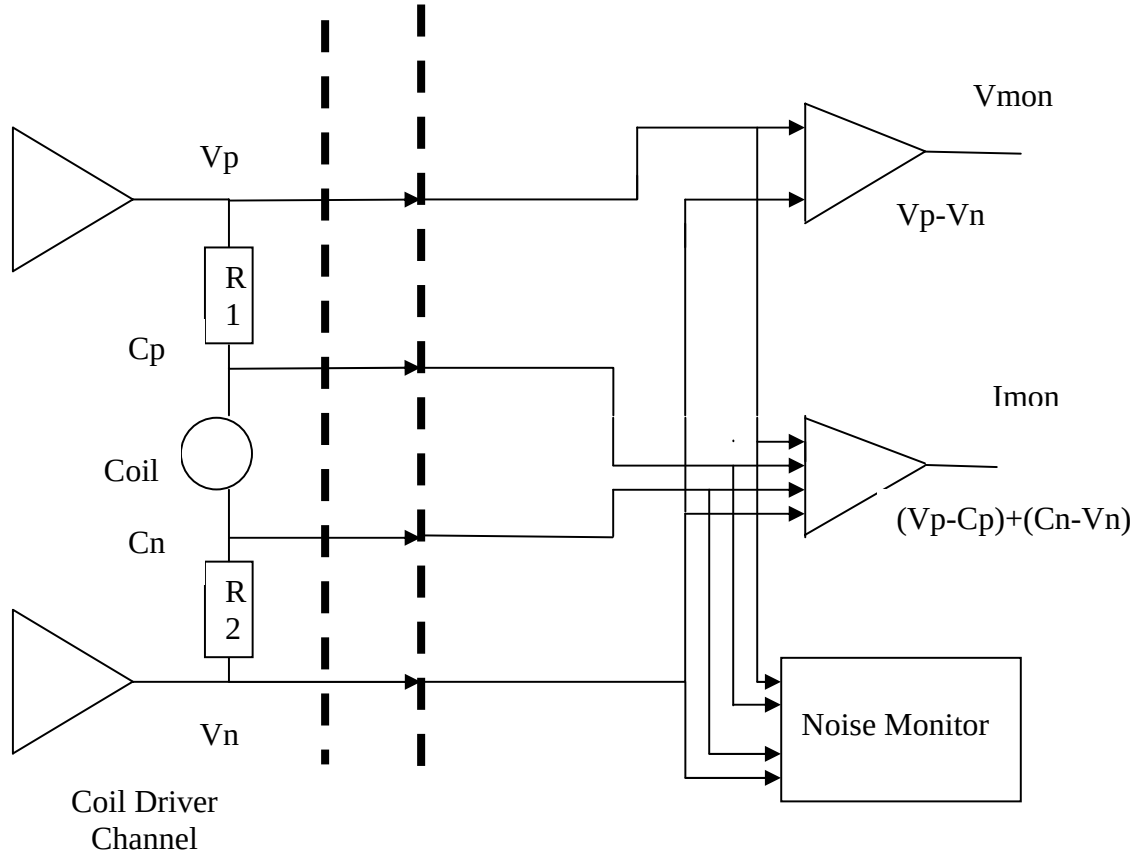
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon144……...
Test Engineer …Simon Pyatt…….
Date …10/11/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.93V	√
-15V (TP6)	-14.90V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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Test Engineer …Simon Pyatt…….
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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1	100mV	4.8V	**4.8V to 5.2V**	√
Ch2	100mV	4.8V	**4.8V to 5.2V**	√
Ch3	100mV	4.8V	**4.8V to 5.2V**	√
Ch4	100mV	4.8V	**4.8V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.9	2.9	2.9	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.45	1.45	1.45	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.8V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.3V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.710V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.712V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.360V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.355V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.993V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.987V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.988V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.987V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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1. Block diagram

2. Test equipment

3. Description

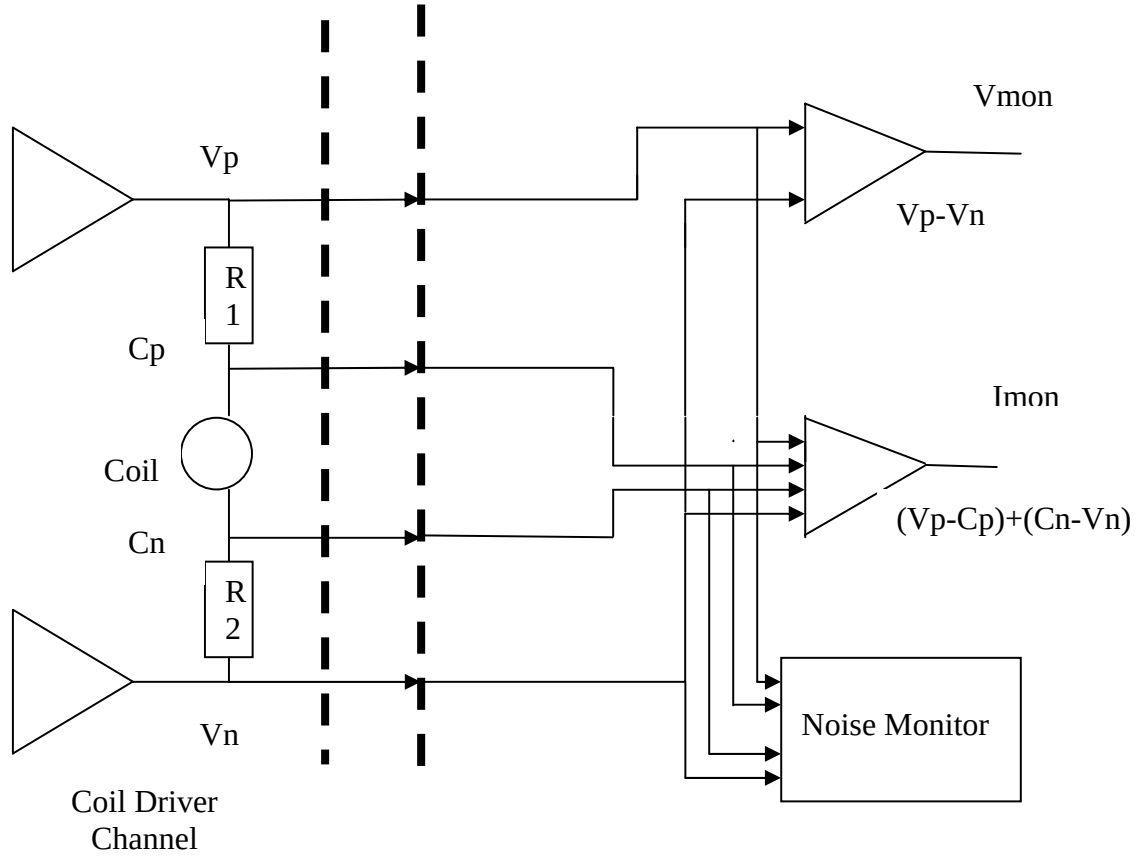
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.83V	√
-15V (TP6)	-15.02V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28
-15v (TP6)	√	5mV	0.26

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.5V	**2.4V to 2.6V**	√
Ch2	100mV	2.5V	**2.4V to 2.6V**	√
Ch3	100mV	2.5V	**2.4V to 2.6V**	√
Ch4	100mV	2.5V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.8V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.8V	**4.7V to 5.2V**	√
Ch4		4.8V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2.1	2.1
TP7	8	8	8	8	3.1	3.1	3.1	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.47	1.47	1.47	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.8V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.707V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.718V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.714V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.354V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.361V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.976V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.987V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.981V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.981V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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1. Block diagram

2. Test equipment

3. Description

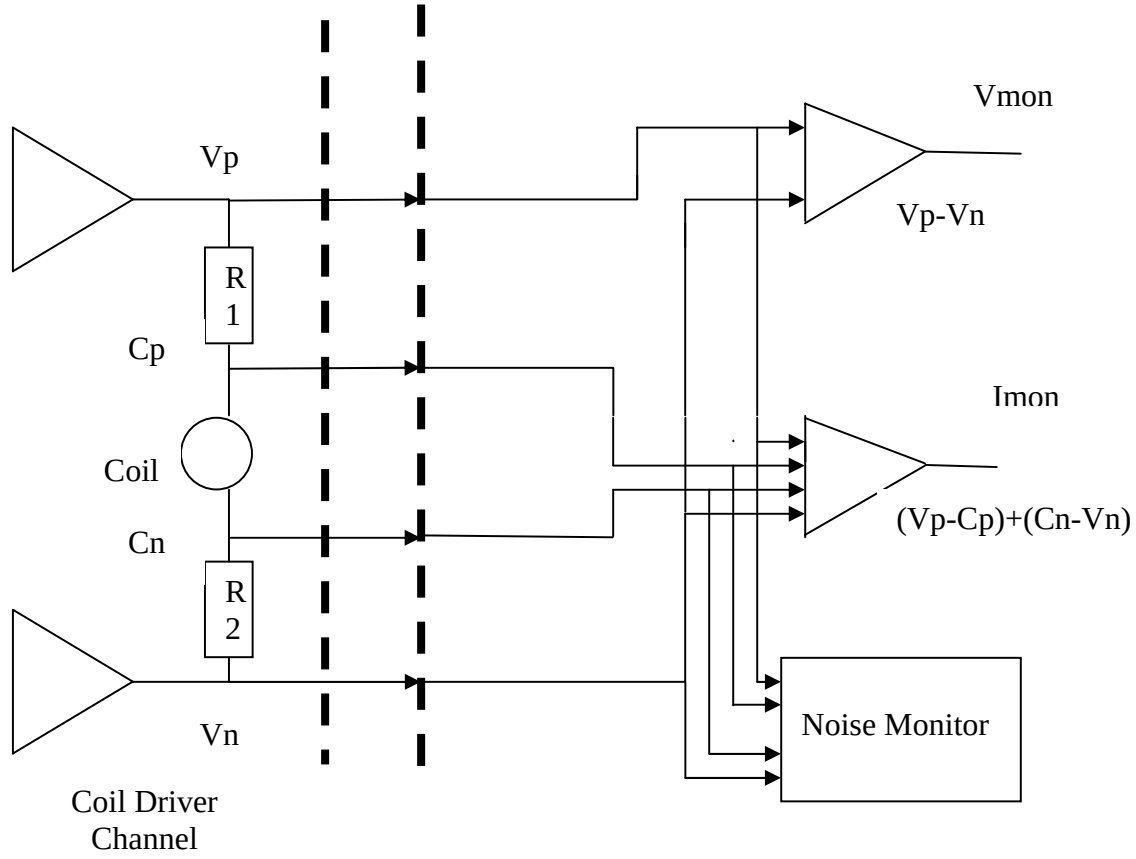
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

Serial No …mon146……..
Test Engineer …Simon Pyatt…….
Date …11/11/09……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon146……..
Test Engineer …Simon Pyatt…….
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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.96V	√
-15V (TP6)	-14.93V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.8V	**4.7V to 5.2V**	√

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Test Engineer …Simon Pyatt…….
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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2.1	2.1
TP7	8	8	8	8	3.1	3.1	3.2	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.47	1.47	1.52	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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Test Engineer …Simon Pyatt…….
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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.715V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.359V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.987V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.989V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.991V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.991V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon147……
Test Engineer…Simon Pyatt……
Date…11/11/09……

Contents

1. Block diagram

2. Test equipment

3. Description

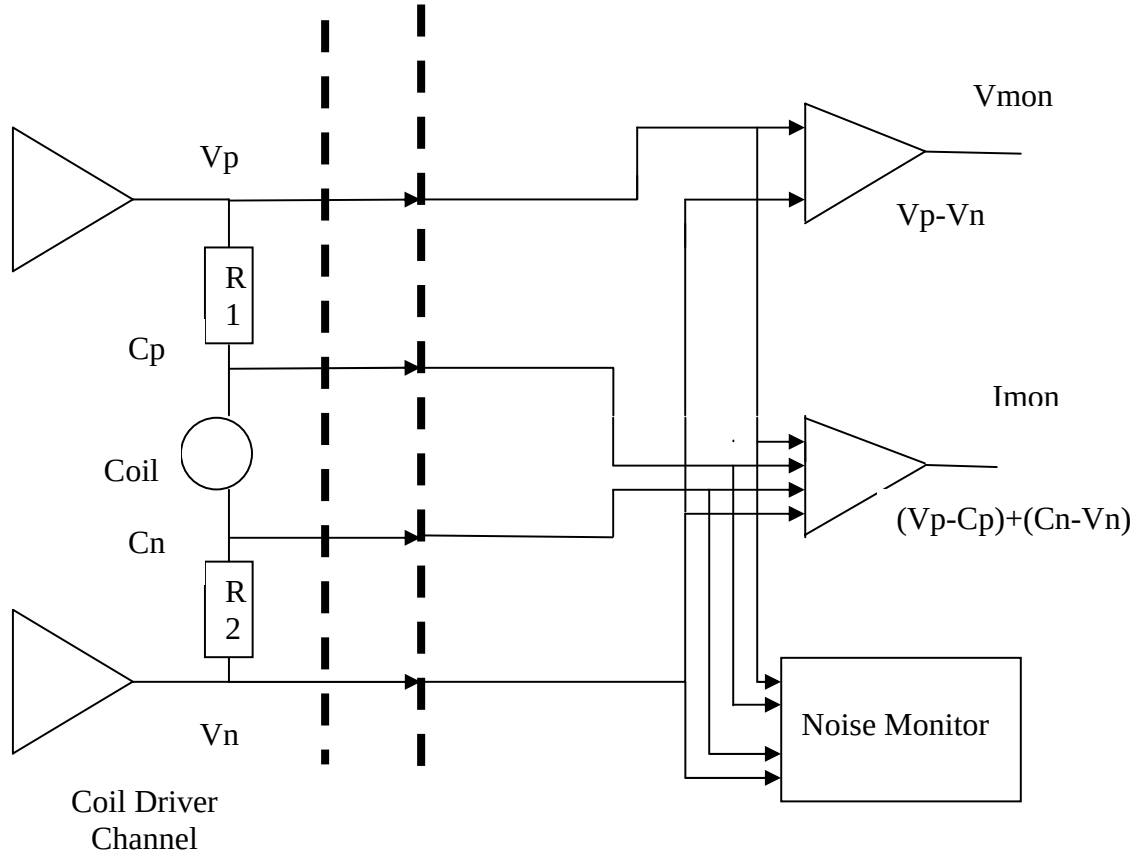
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon147……..
Test Engineer …Simon Pyatt…….
Date …11/11/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.89	√
-15V (TP6)	-15.03V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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Test Engineer …Simon Pyatt…….
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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.8V	**4.7V to 5.2V**	√
Ch2		4.8V	**4.7V to 5.2V**	√
Ch3		4.8V	**4.7V to 5.2V**	√
Ch4		4.8V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2.1	2.1
TP7	8	8	8	8	3.1	3.1	3.1	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.47	1.47	1.47	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.8V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.7V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.717V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.718V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.359V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.993V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.998V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.994V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.998V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.02V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.02V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon148……
Test Engineer…Simon Pyatt……
Date…11/11/09……

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1. Block diagram

2. Test equipment

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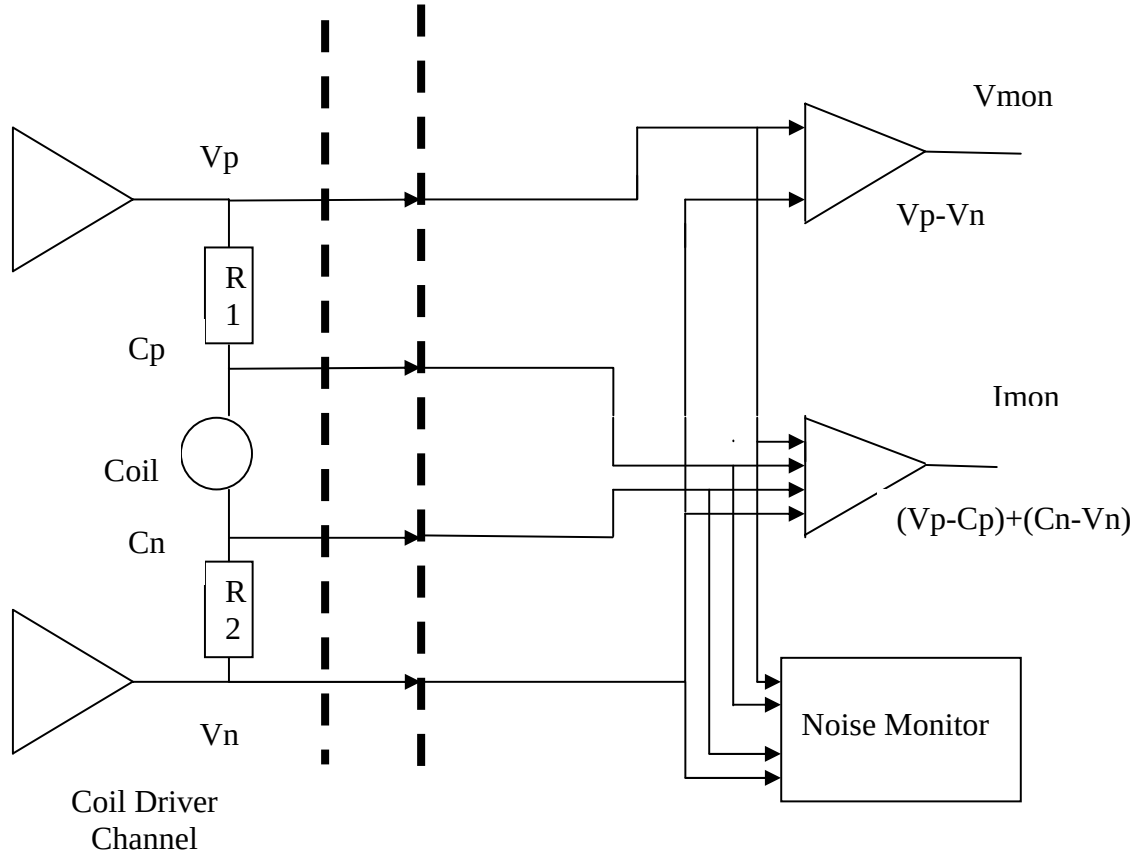
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

Serial No …mon148……..
Test Engineer …Simon Pyatt…….
Date …11/11/09……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon148……..
Test Engineer …Simon Pyatt…….
Date …11/11/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.99V	√
-15V (TP6)	-14.89V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mA	0.28A
-15v (TP6)	√	5mA	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.8V	**4.7V to 5.2V**	√
Ch2		4.8V	**4.7V to 5.2V**	√
Ch3		4.8V	**4.7V to 5.2V**	√
Ch4		4.8V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.5	1.4	1.4	1.4
TP6	4	4	4	4	2.2	2.1	2.1	2.1
TP7	8	8	8	8	3.2	3.2	3.1	3.2

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.5	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.46	1.4	1.4	1.4	
TP7/TP6	2	2	2	2	1.45	1.52	1.47	1.52	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.3V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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Test Engineer …Simon Pyatt…….
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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.718V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.715V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.361V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.99V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.989V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.994V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.991V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon149……
Test Engineer…Simon Pyatt……
Date…11/11/09……

Contents

1. Block diagram

2. Test equipment

3. Description

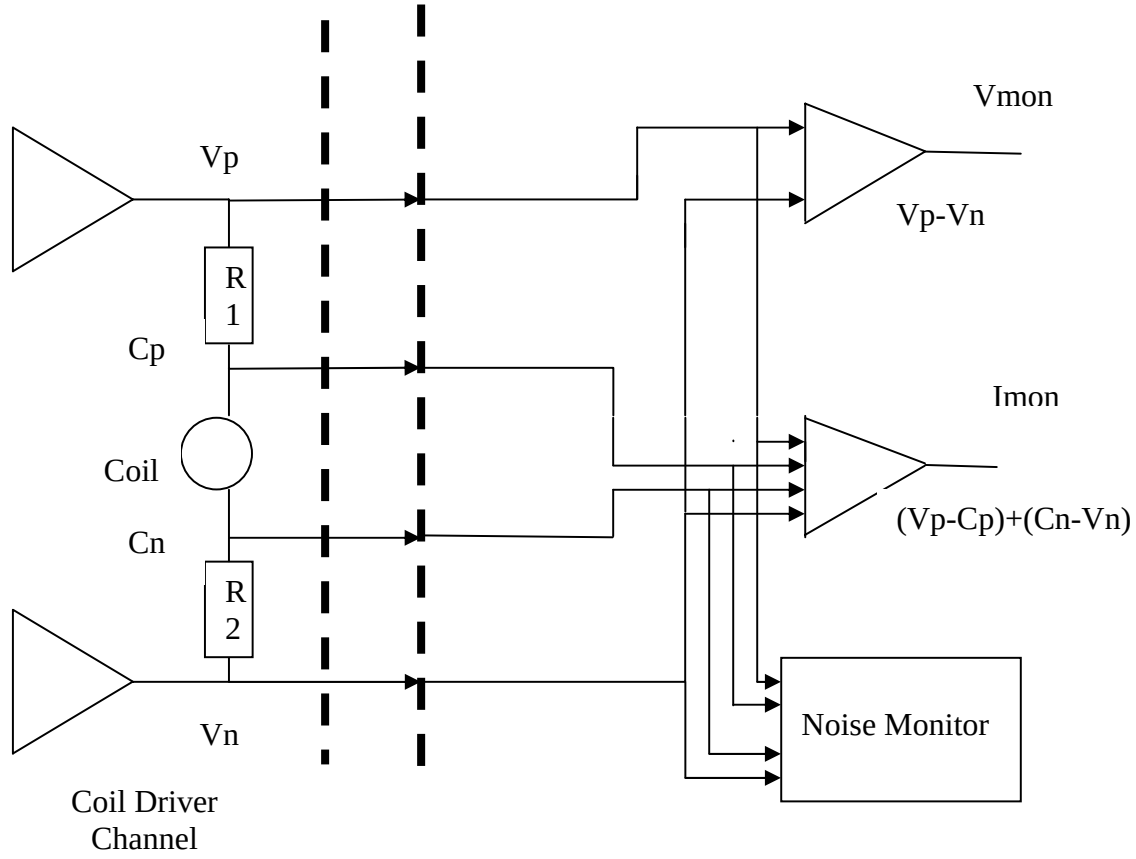
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon149……...
Test Engineer …Simon Pyatt…….
Date …11/11/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.82V	√
-15V (TP6)	-15.00V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mA	0.28A
-15v (TP6)	√	5mA	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.5V	**2.4V to 2.6V**	√
Ch2	100mV	2.5V	**2.4V to 2.6V**	√
Ch3	100mV	2.5V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2.1	2.1
TP7	8	8	8	8	3.1	3.1	3.1	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.47	1.47	1.47	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.9V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.8V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.8V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.8V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

Serial No …mon149……..
Test Engineer …Simon Pyatt…….
Date …11/11/09…….

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.710V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.716V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.359V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.989V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.994V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.991V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.994V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon150……
Test Engineer…Simon Pyatt……
Date…12/11/09……

Contents

1. Block diagram

2. Test equipment

3. Description

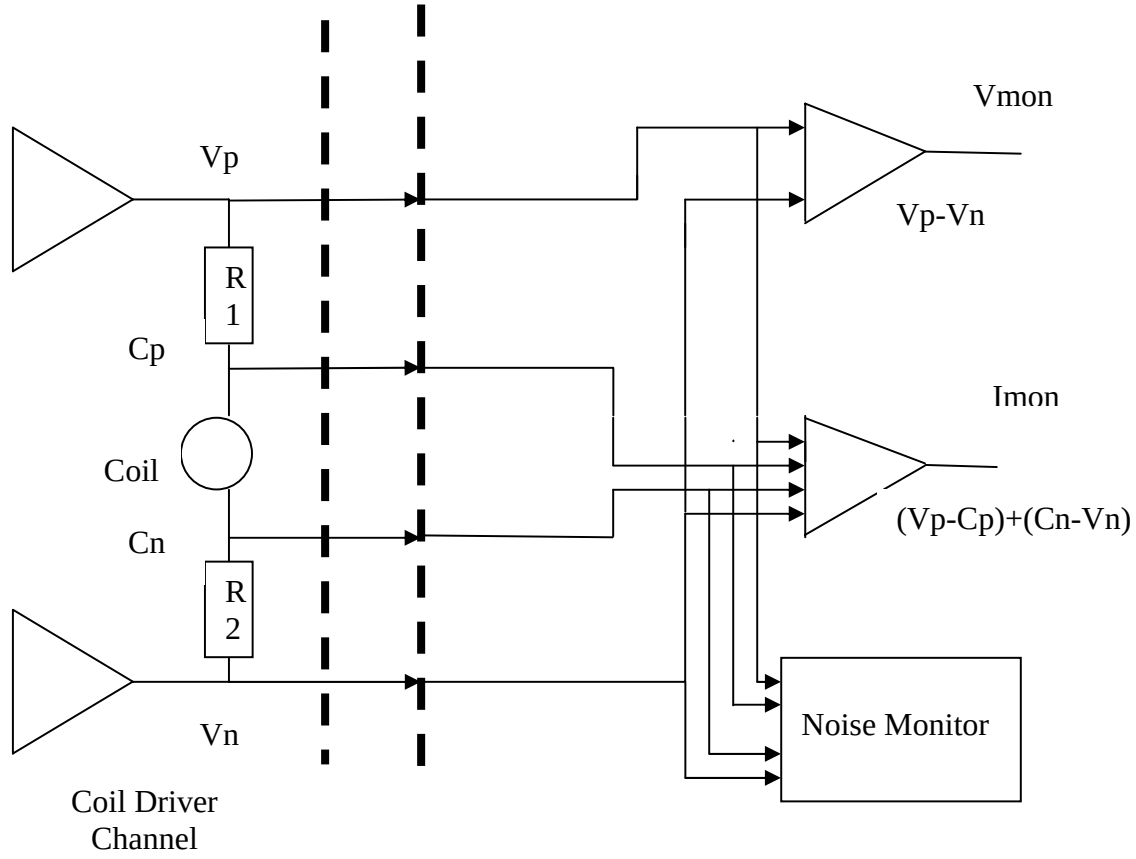
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

Serial No …mon150……..
Test Engineer …Simon Pyatt…….
Date …12/11/09……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon150……...
Test Engineer …Simon Pyatt…….
Date …12/11/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.79V	√
-15V (TP6)	-14.99V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mA	0.28A
-15v (TP6)	√	5mA	0.26A

Serial No …mon150……...
Test Engineer …Simon Pyatt…….
Date …12/11/09…….

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Test Engineer …Simon Pyatt…….
Date …12/11/09……

Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

Serial No …mon150……...
Test Engineer …Simon Pyatt……
Date …12/11/09……

Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.5	1.5	1.5	1.5
TP6	4	4	4	4	2.1	2.1	2.1	2.1
TP7	8	8	8	8	3.1	3.1	3.1	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.5	1.5	1.5	1.5	
TP6/TP4	2	2	2	2	1.4	1.4	1.4	1.4	
TP7/TP6	2	2	2	2	1.47	1.47	1.47	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√

Serial No …mon150……...
Test Engineer …Simon Pyatt…….
Date …12/11/09…….

6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

Serial No …mon150……...
Test Engineer …Simon Pyatt……
Date …12/11/09……

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.718V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.360V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.989V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.987V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.986V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.990V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon151……
Test Engineer…Simon Pyatt……
Date…12/11/09……

Contents

1. Block diagram

2. Test equipment

3. Description

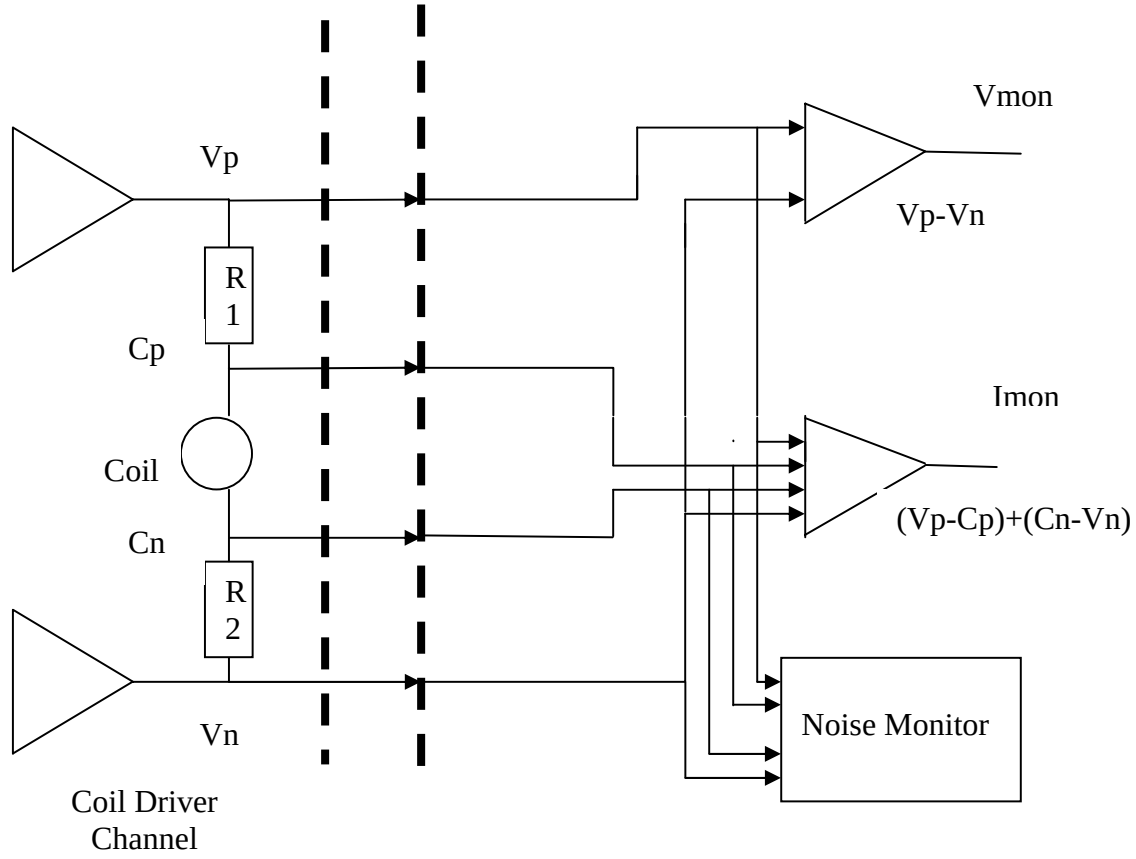
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

Serial No …mon151……..
Test Engineer …Simon Pyatt…….
Date …12/11/09……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon151……...
Test Engineer …Simon Pyatt…….
Date …12/11/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.95V	√
-15V (TP6)	-14.96V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mA	0.28A
-15v (TP6)	√	5mA	0.26A

Serial No …mon151……...
Test Engineer …Simon Pyatt…….
Date …12/11/09……

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

Serial No …mon151……...
Test Engineer …Simon Pyatt…….
Date …12/11/09……

Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.8V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.8V	**4.7V to 5.2V**	√

Serial No …mon151……...
Test Engineer …Simon Pyatt…….
Date …13/11/09……

Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.5	1.5
TP6	4	4	4	4	2.1	2.1	2.2	2.2
TP7	8	8	8	8	3.1	3.1	3.2	3.2

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.5	1.5	
TP6/TP4	2	2	2	2	1.5	1.5	1.46	1.46	
TP7/TP6	2	2	2	2	1.47	1.47	1.45	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.3V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√

Serial No …mon151……...
Test Engineer …Simon Pyatt…….
Date …13/11/09…….

6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

Serial No …mon151……...
Test Engineer …Simon Pyatt…….
Date …13/11/09…….

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.717V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.360V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.983V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.985V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.984V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.986V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.02V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon152……
Test Engineer…Simon Pyatt……
Date…13/11/09……

Contents

1. Block diagram

2. Test equipment

3. Description

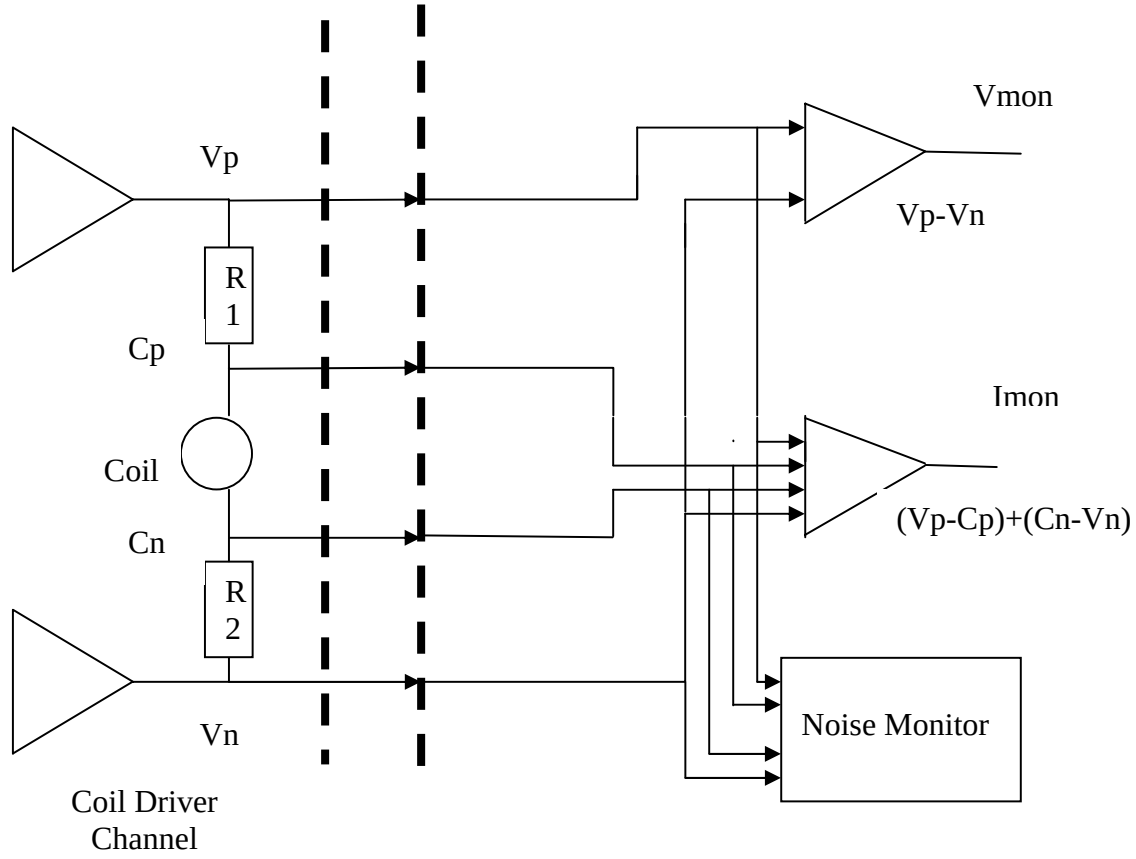
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon152……..
Test Engineer …Simon Pyatt…….
Date …13/11/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.99	√
-15V (TP6)	-14.89V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.8V	**4.7V to 5.2V**	√
Ch2		4.8V	**4.7V to 5.2V**	√
Ch3		4.8V	**4.7V to 5.2V**	√
Ch4		4.8V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2.1	2.1
TP7	8	8	8	8	3.1	3.1	3.1	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.47	1.47	1.47	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.8V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.717V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.716V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.360V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.359V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.996V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.992V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.989V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.994V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.02V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon153……
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Contents

1. Block diagram

2. Test equipment

3. Description

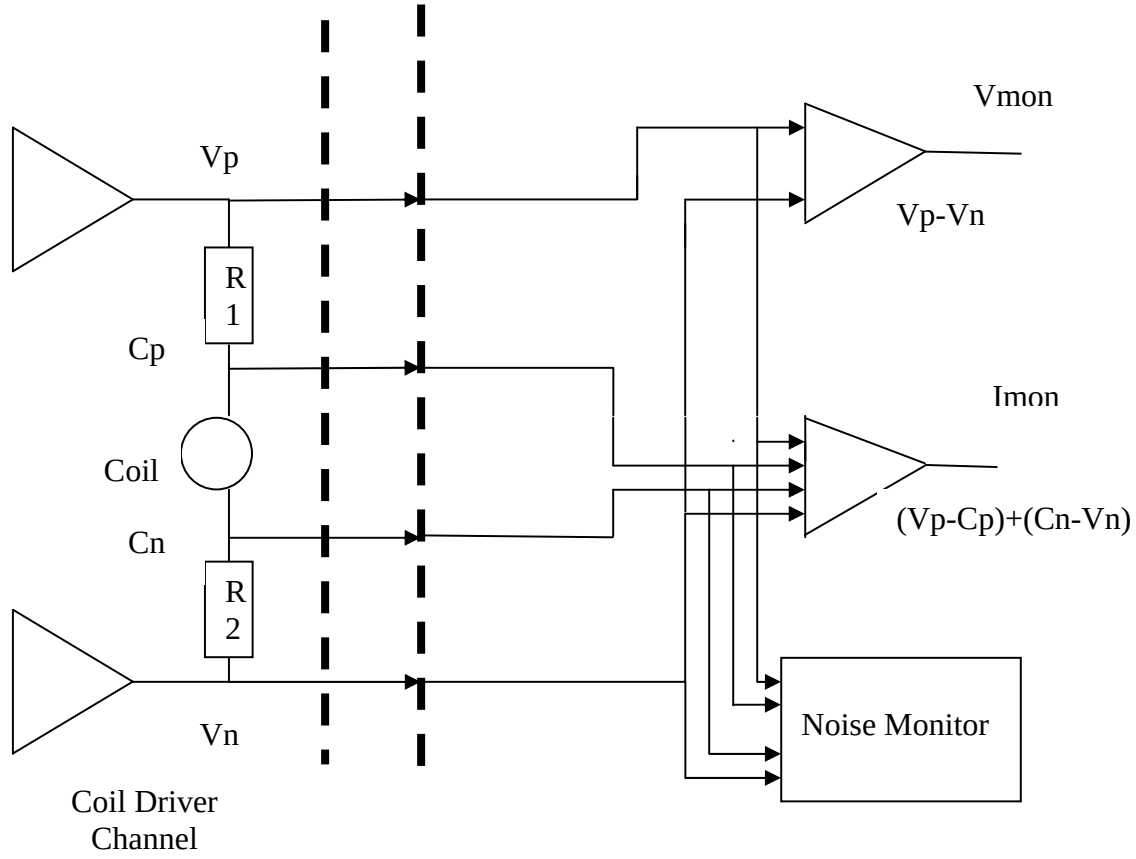
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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Date …16/11/09……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon153……...
Test Engineer …Simon Pyatt…….
Date …16/11/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.81V	√
-15V (TP6)	-14.91V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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Date …16/11/09……

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.5V	**2.4V to 2.6V**	√
Ch2	100mV	2.5V	**2.4V to 2.6V**	√
Ch3	100mV	2.5V	**2.4V to 2.6V**	√
Ch4	100mV	2.5V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2.1	2.1
TP7	8	8	8	8	3.1	3.1	3.1	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.47	1.47	1.47	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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Test Engineer …Simon Pyatt……
Date …16/11/09……

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.709V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.717V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.711V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.356V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.991V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.998V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.993V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.989V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon154……
Test Engineer…Simon Pyatt……
Date…16/11/09……

Contents

1. Block diagram

2. Test equipment

3. Description

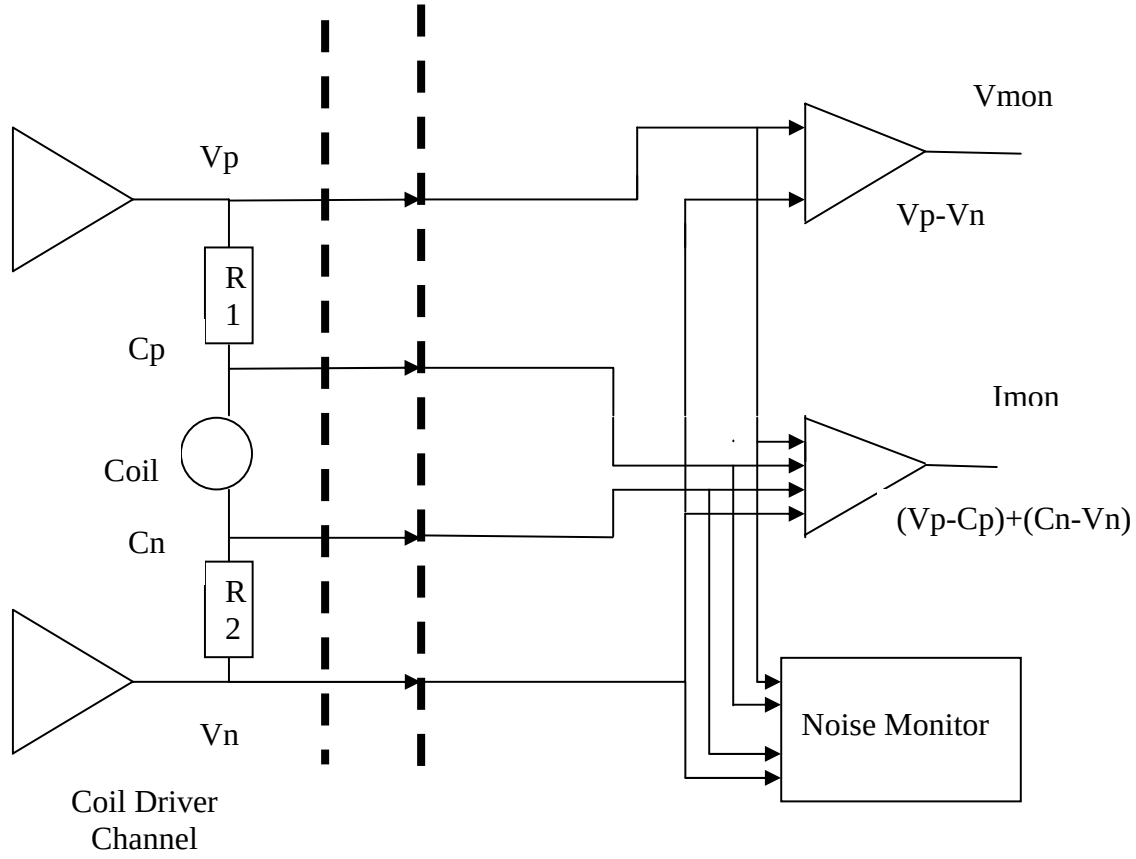
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon154……...
Test Engineer …Simon Pyatt…….
Date …16/11/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.95V	√
-15V (TP6)	-14.93V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Test Engineer …Simon Pyatt…….
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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2.1	2.1
TP7	8	8	8	8	3.1	3.1	3.1	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.47	1.47	1.47	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.8V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.710V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.709V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.354V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.355V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.992V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.989V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.990V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.985V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon155……
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Contents

1. Block diagram

2. Test equipment

3. Description

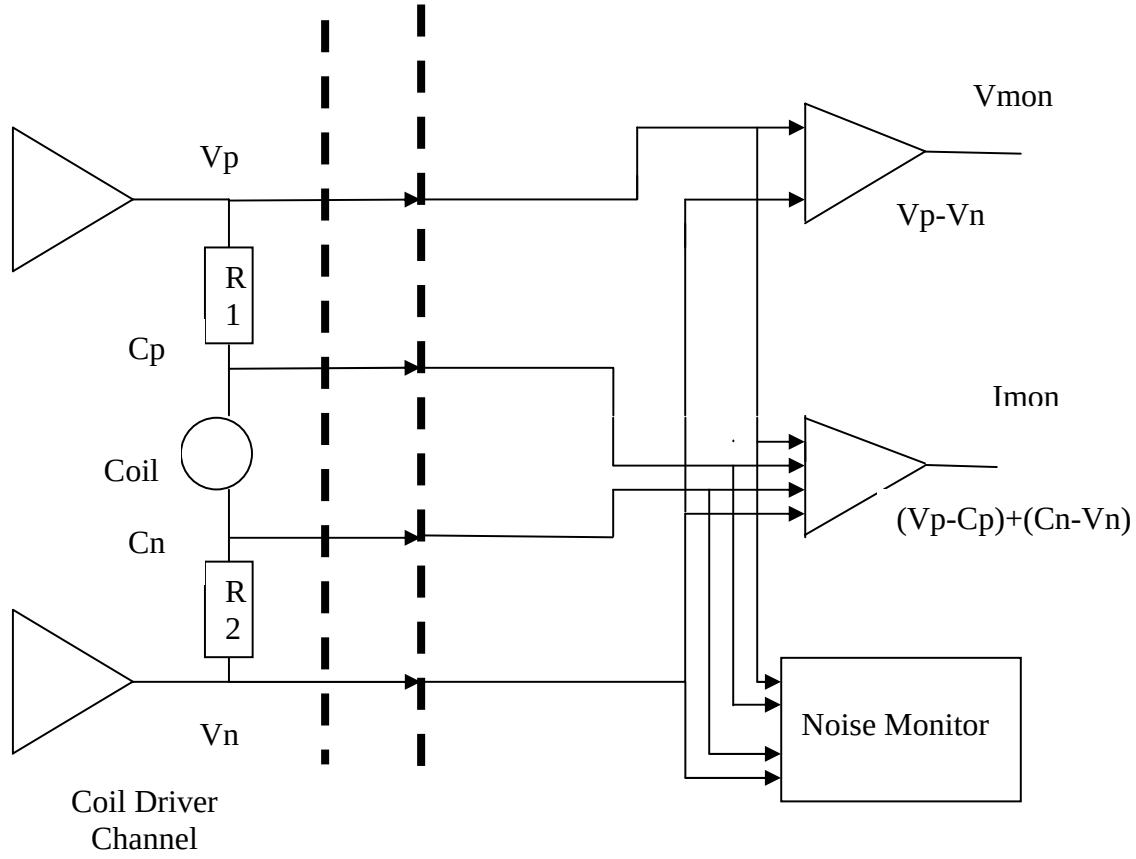
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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Test Engineer …Simon Pyatt…….
Date …16/11/09……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon155……...
Test Engineer …Simon Pyatt…….
Date …16/11/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.80V	√
-15V (TP6)	-15.00V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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Test Engineer …Simon Pyatt…….
Date …16/11/09……

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.5V	**2.4V to 2.6V**	√
Ch2	100mV	2.5V	**2.4V to 2.6V**	√
Ch3	100mV	2.5V	**2.4V to 2.6V**	√
Ch4	100mV	2.5V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.5	1.4	1.4	1.4
TP6	4	4	4	4	2.2	2.1	2.1	2.1
TP7	8	8	8	8	3.1	3.1	3.1	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.5	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.46	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.4	1.47	1.47	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.7V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

Serial No …mon155……...
Test Engineer …Simon Pyatt……
Date …16/11/09……

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.717V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.710V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.360V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.355V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.992V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.998V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.995V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.988V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.02V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon156……
Test Engineer…Simon Pyatt……
Date…16/11/09……

Contents

1. Block diagram

2. Test equipment

3. Description

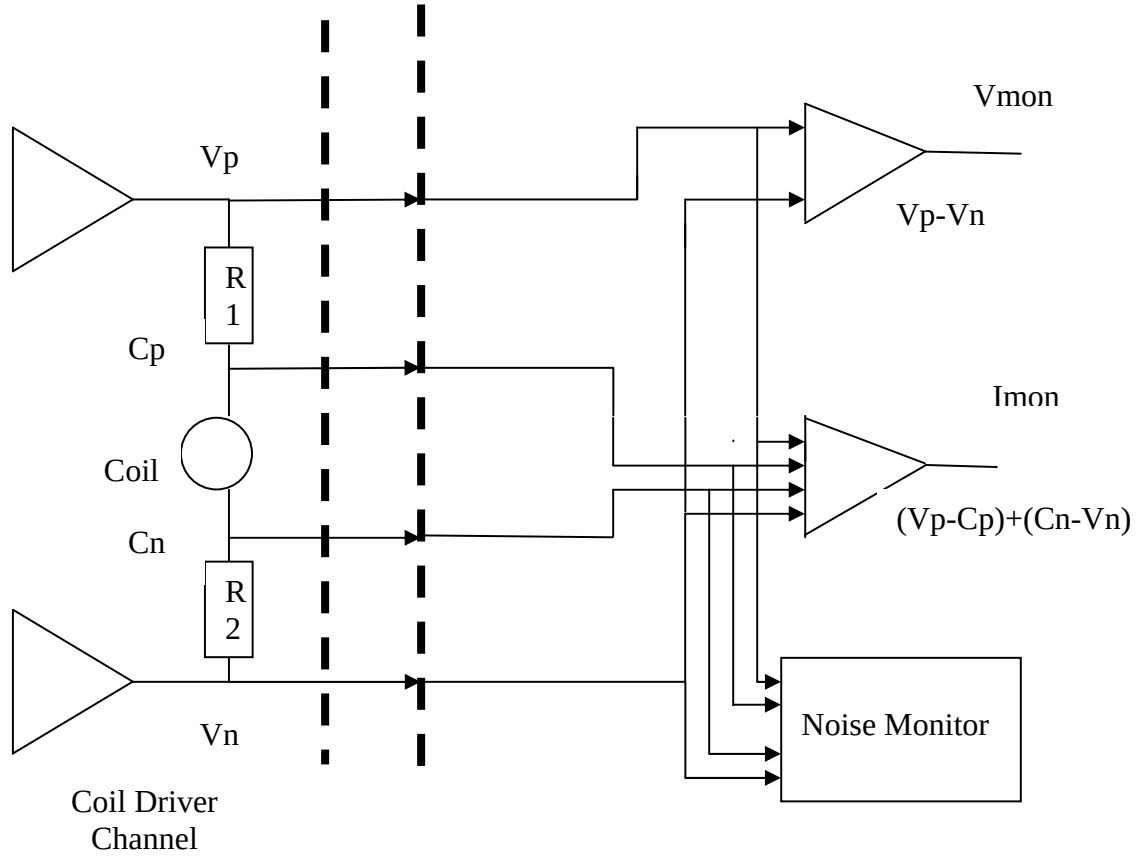
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

Serial No …mon156……..
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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon156……...
Test Engineer …Simon Pyatt…….
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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.87V	√
-15V (TP6)	-15.00V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Test Engineer …Simon Pyatt…….
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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2.1	2
TP7	8	8	8	8	2.9	2.9	3	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.5	1.42	
TP7/TP6	2	2	2	2	1.45	1.45	1.42	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.7V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.7V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.7V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

Serial No …mon156……...
Test Engineer …Simon Pyatt…….
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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.709V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.354V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.986V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.989V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.983V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.980V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon157……
Test Engineer…Simon Pyatt……
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1. Block diagram

2. Test equipment

3. Description

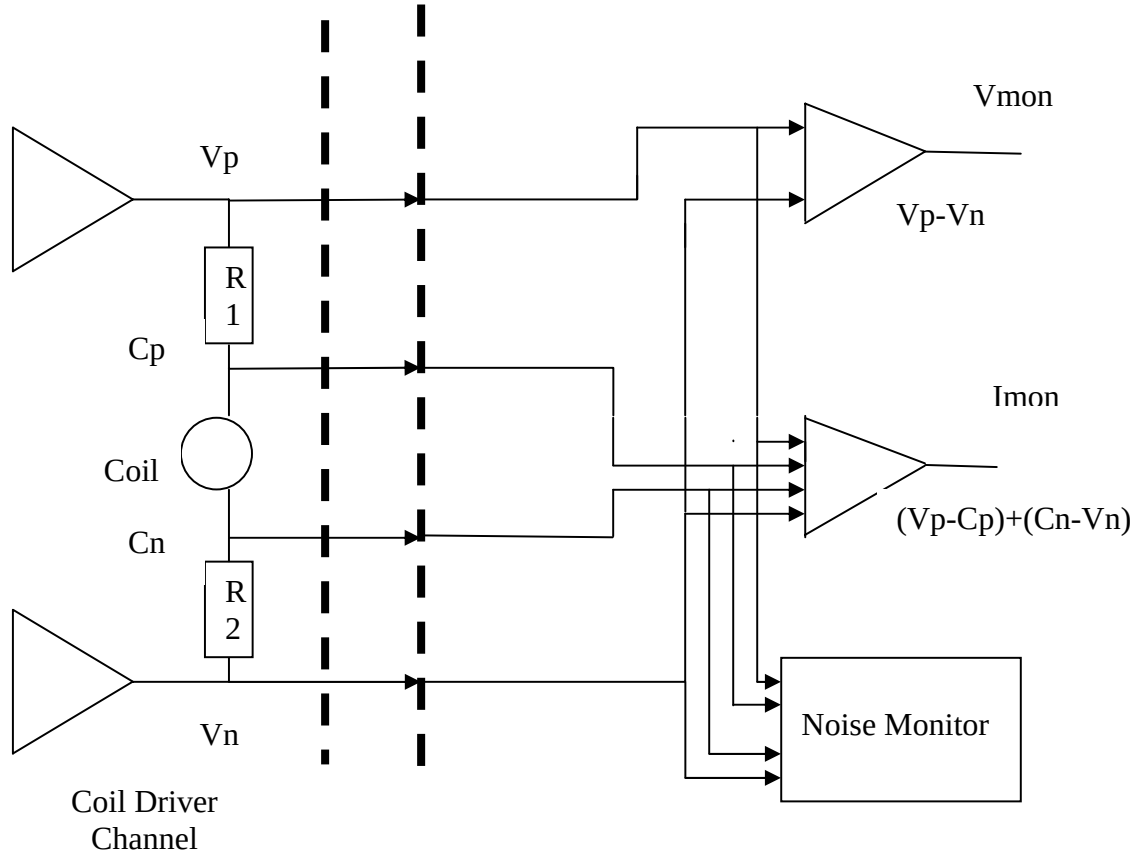
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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Test Engineer …Simon Pyatt…….
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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK? DS1 slightly off board**

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon157……...
Test Engineer …Simon Pyatt…….
Date …17/11/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.94V	√
-15V (TP6)	-15.02V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon157……...
Test Engineer …Simon Pyatt…….
Date …17/11/09……

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.5V	**2.4V to 2.6V**	√
Ch2	100mV	2.5V	**2.4V to 2.6V**	√
Ch3	100mV	2.5V	**2.4V to 2.6V**	√
Ch4	100mV	2.5V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

Serial No …mon157……...
Test Engineer …Simon Pyatt…….
Date …17/11/09……

Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2.1	2.1
TP7	8	8	8	8	3.1	3.1	3.1	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.47	1.47	1.47	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.2V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.3V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.713V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.356V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.982V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.980V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.978V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.980V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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Contents

1. Block diagram

2. Test equipment

3. Description

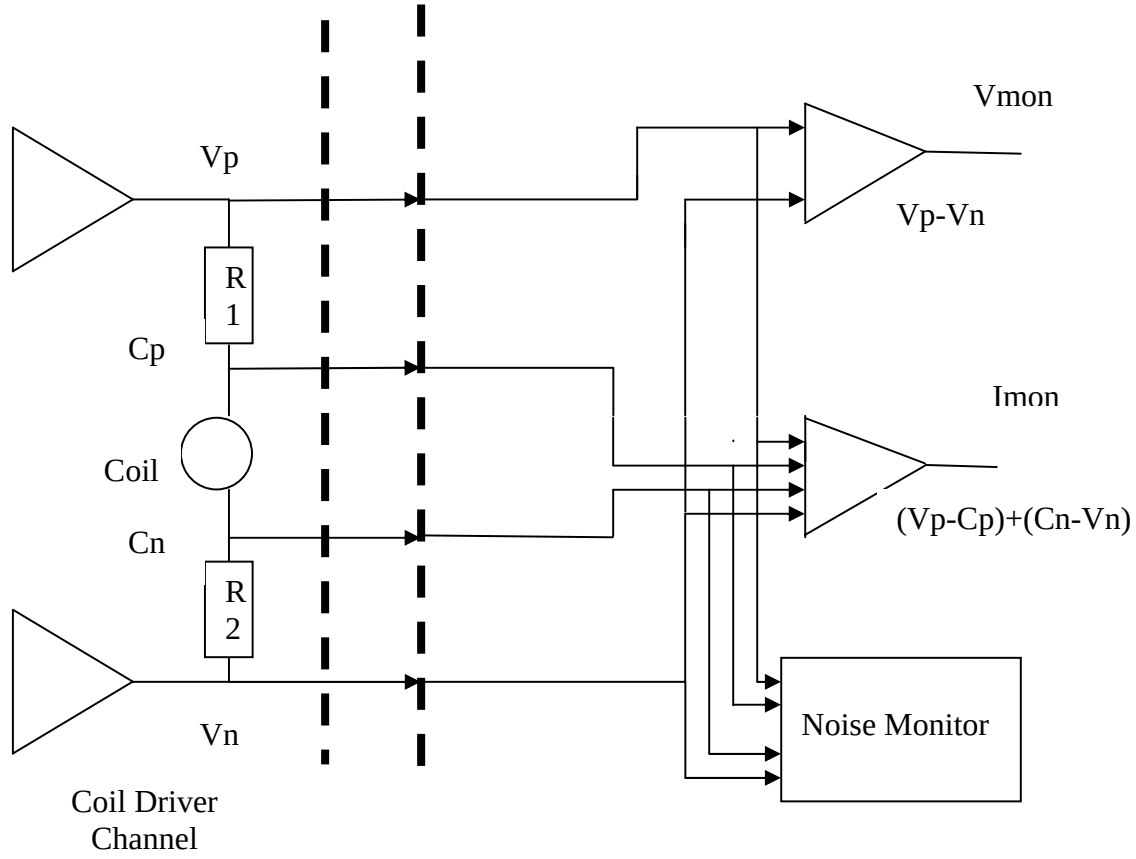
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

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Test Engineer ……
Date ……

NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.92V	√
-15V (TP6)	-15.05V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.6V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.6V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.9	2.7	2.8	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.45	1.35	1.4	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.709V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.353V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.99V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.985V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.987V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.980V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.02V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.02V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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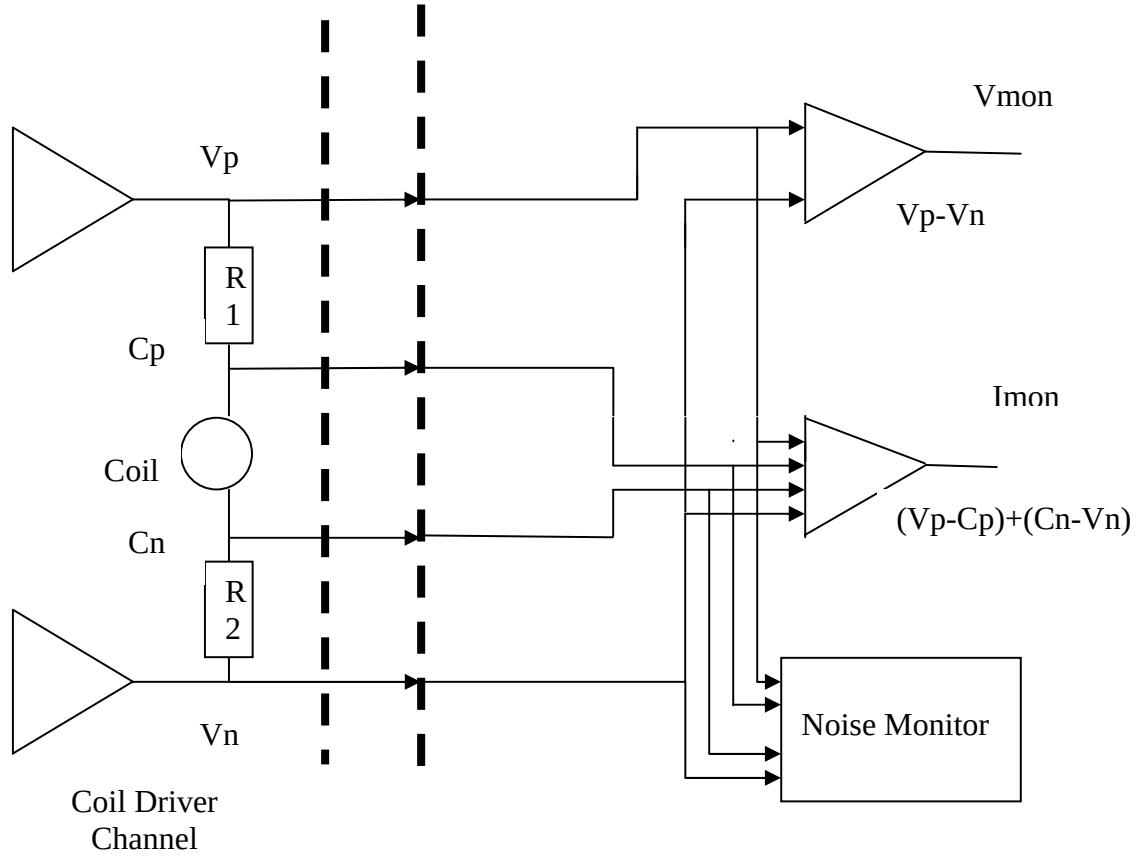
6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon159……...
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Date …17/11/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.82V	√
-15V (TP6)	-14.92V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.25A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.5V	**2.4V to 2.6V**	√
Ch2	100mV	2.5V	**2.4V to 2.6V**	√
Ch3	100mV	2.5V	**2.4V to 2.6V**	√
Ch4	100mV	2.5V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.6V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	3	2.9	2.9	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.5	1.45	1.45	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.7V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.2V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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Test Engineer …Simon Pyatt……
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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.711V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.360V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.356V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.984V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.982V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.980V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.976V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon160……
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1. Block diagram

2. Test equipment

3. Description

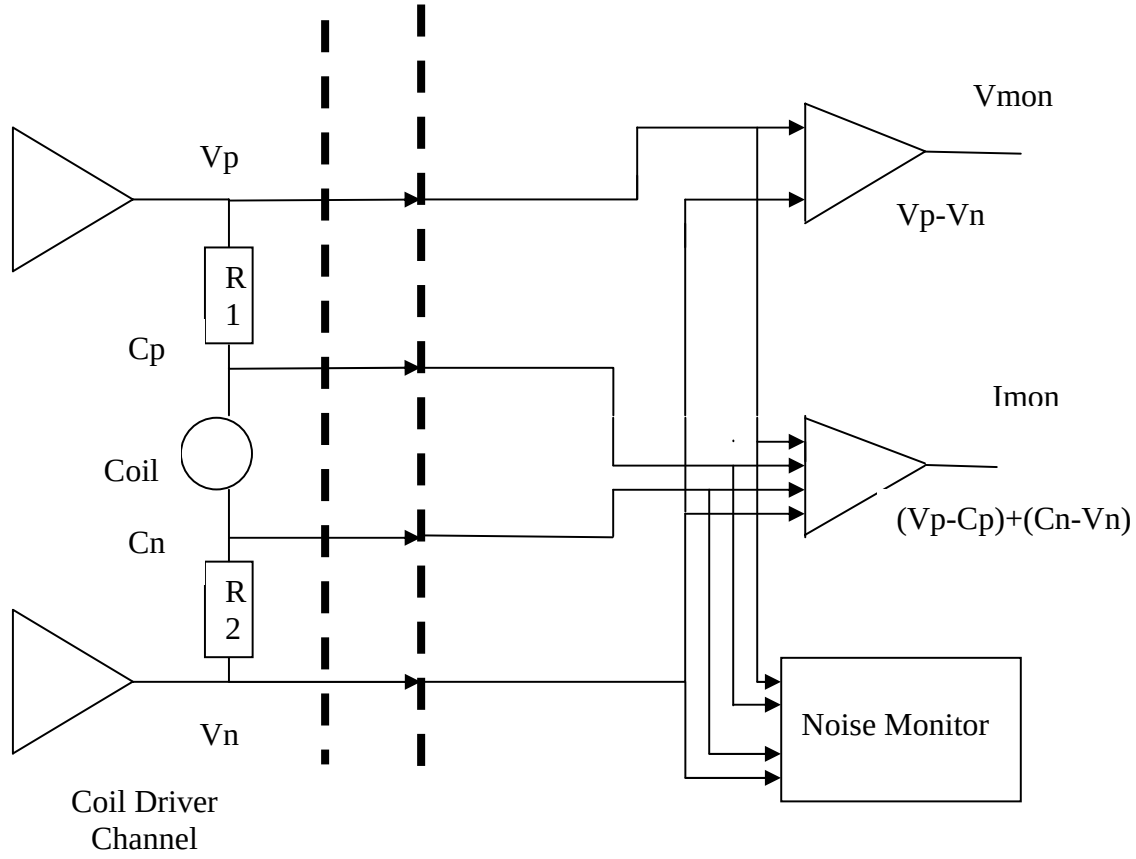
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.89V	√
-15V (TP6)	-15.00V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.9	2.9	2.9	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.45	1.45	1.45	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.8V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.8V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.710V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.709V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.708V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.715V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.354V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.353V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.982V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.979V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.976V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.984V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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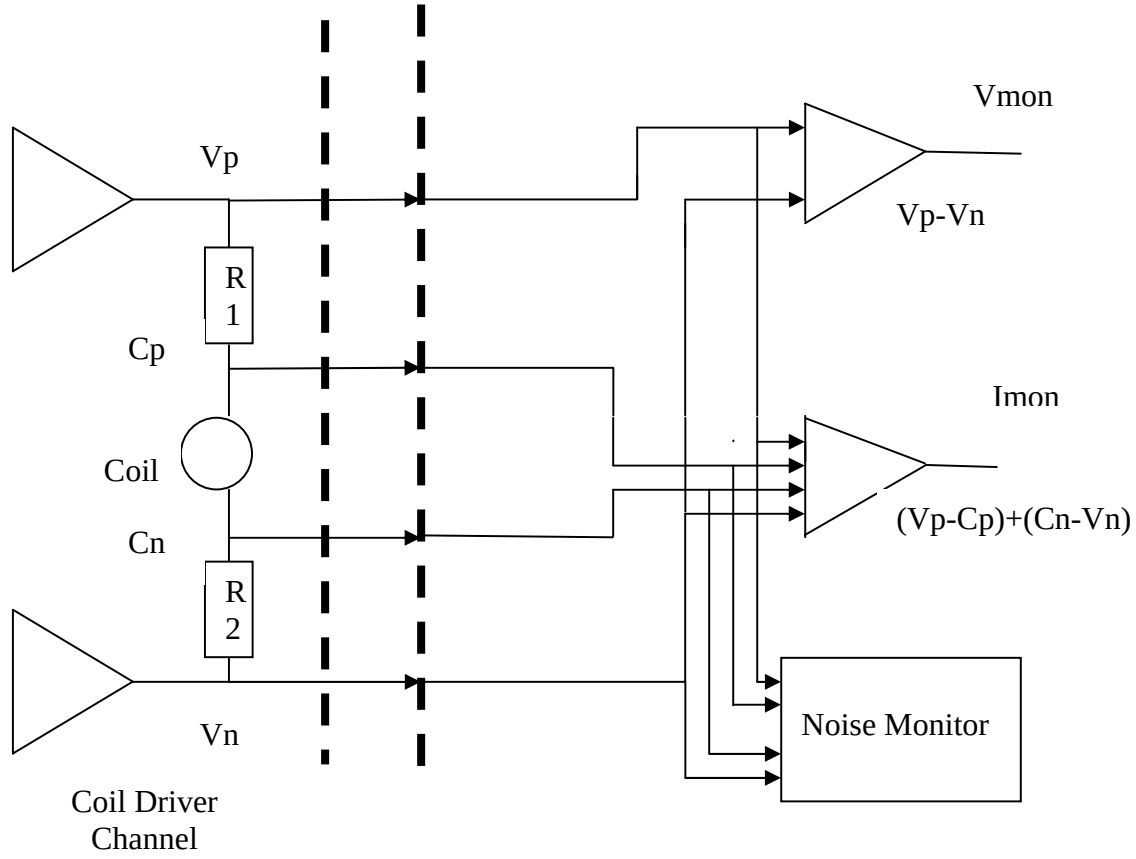
5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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Test Engineer …Simon Pyatt…….
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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon161……..
Test Engineer …Simon Pyatt…….
Date …18/11/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.91V	√
-15V (TP6)	-15.01V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon161……...
Test Engineer …Simon Pyatt…….
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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.6V	**1.6V to 1.9V**	√
Ch2	100mV	1.6V	**1.6V to 1.9V**	√
Ch3	100mV	1.6V	**1.6V to 1.9V**	√
Ch4	100mV	1.6V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.9	2.9	2.9	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.45	1.45	1.45	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.714V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.988V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.989V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.991V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.990V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon162……
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1. Block diagram

2. Test equipment

3. Description

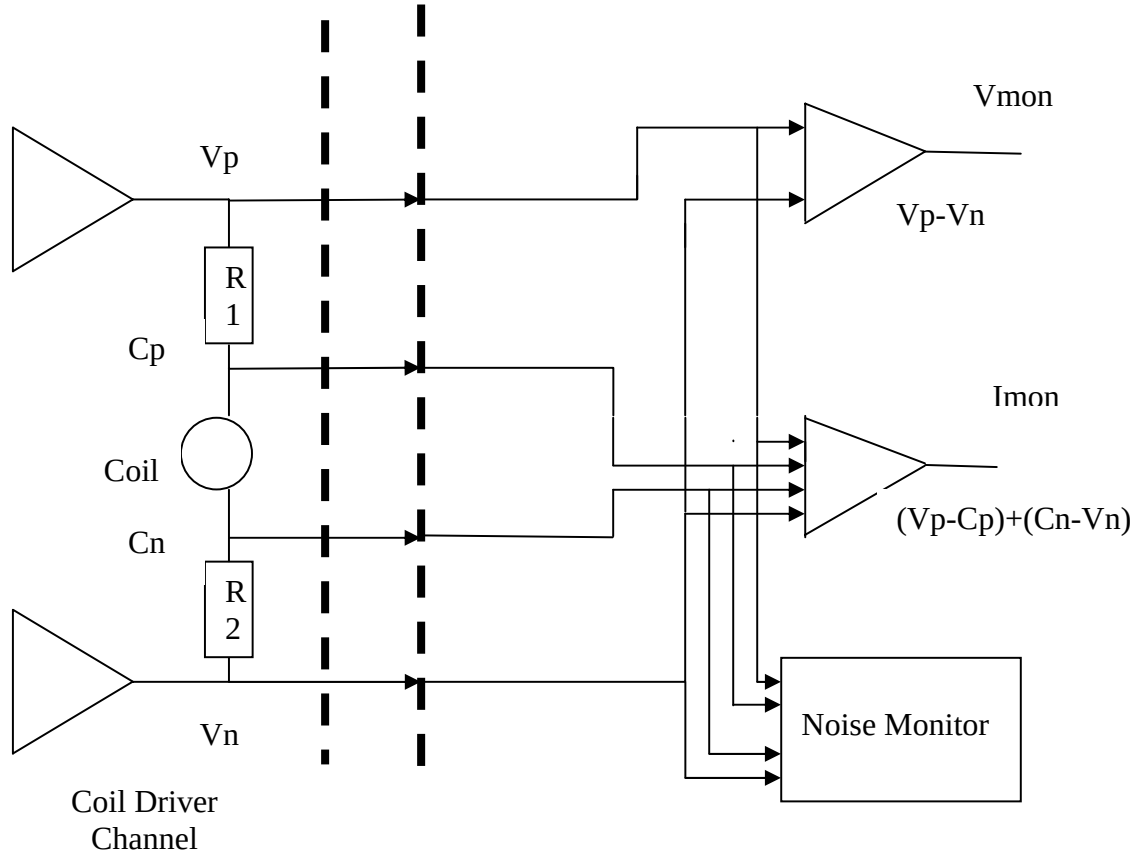
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.92V	√
-15V (TP6)	-14.96V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.6V	**1.6V to 1.9V**	√
Ch3	100mV	1.6V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.9	2.9	2.9	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.45	1.45	1.45	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.5	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.6	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.7	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.3	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.709V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.711V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.354V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.355V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.986V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.990V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.990V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.986V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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1. Block diagram

2. Test equipment

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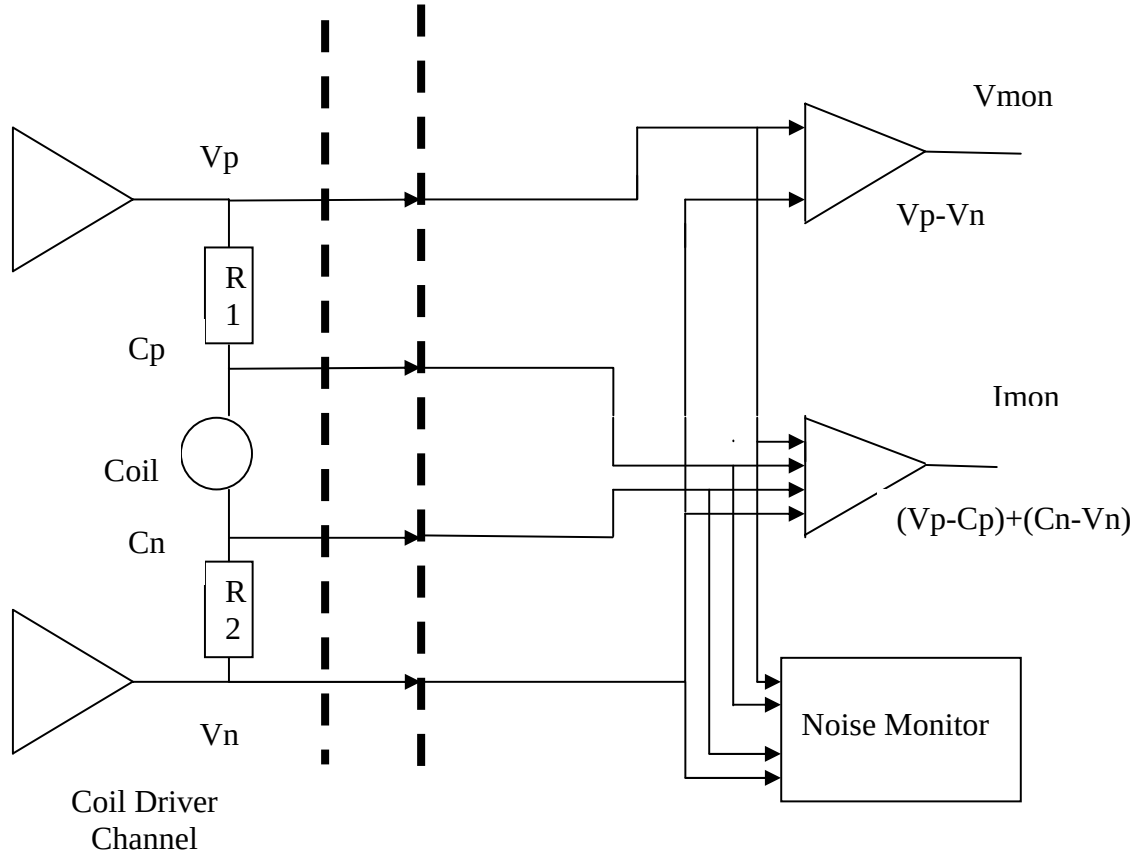
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon163……...
Test Engineer …Simon Pyatt…….
Date …18/11/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.82V	√
-15V (TP6)	-15.02V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon163……...
Test Engineer …Simon Pyatt…….
Date …18/11/09……

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.6V	**1.6V to 1.9V**	√
Ch2	100mV	1.6V	**1.6V to 1.9V**	√
Ch3	100mV	1.6V	**1.6V to 1.9V**	√
Ch4	100mV	1.6V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.9	2.9	2.9	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.45	1.45	1.45	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.5	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.2	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.8	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.5	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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Test Engineer …Simon Pyatt……
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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.714V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.986V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.989V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.990V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.986V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.03V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.02V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.03V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon164……
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Contents

1. Block diagram

2. Test equipment

3. Description

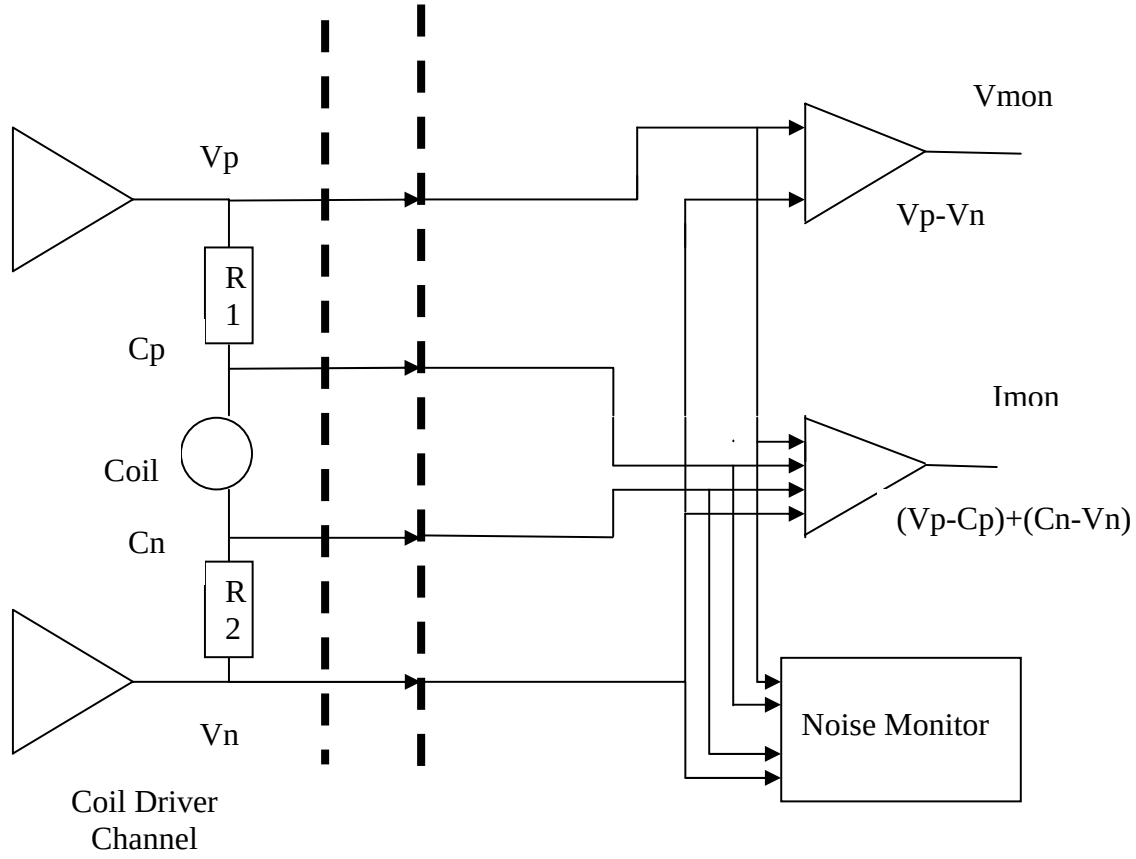
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.91V	√
-15V (TP6)	-15.00V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.5V	**2.4V to 2.6V**	√
Ch2	100mV	2.5V	**2.4V to 2.6V**	√
Ch3	100mV	2.5V	**2.4V to 2.6V**	√
Ch4	100mV	2.5V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Test Engineer …Simon Pyatt…….
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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.6V	**1.6V to 1.9V**	√
Ch3	100mV	1.6V	**1.6V to 1.9V**	√
Ch4	100mV	1.6V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.8	2.9	2.8	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.4	1.45	1.4	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.7V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.2V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

Serial No …mon164……..
Test Engineer …Simon Pyatt…….
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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.710V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.713V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.354V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	987V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	980V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	981V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	983V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.02V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.03V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon165……
Test Engineer…Simon Pyatt……
Date…19/11/09……

Contents

1. Block diagram

2. Test equipment

3. Description

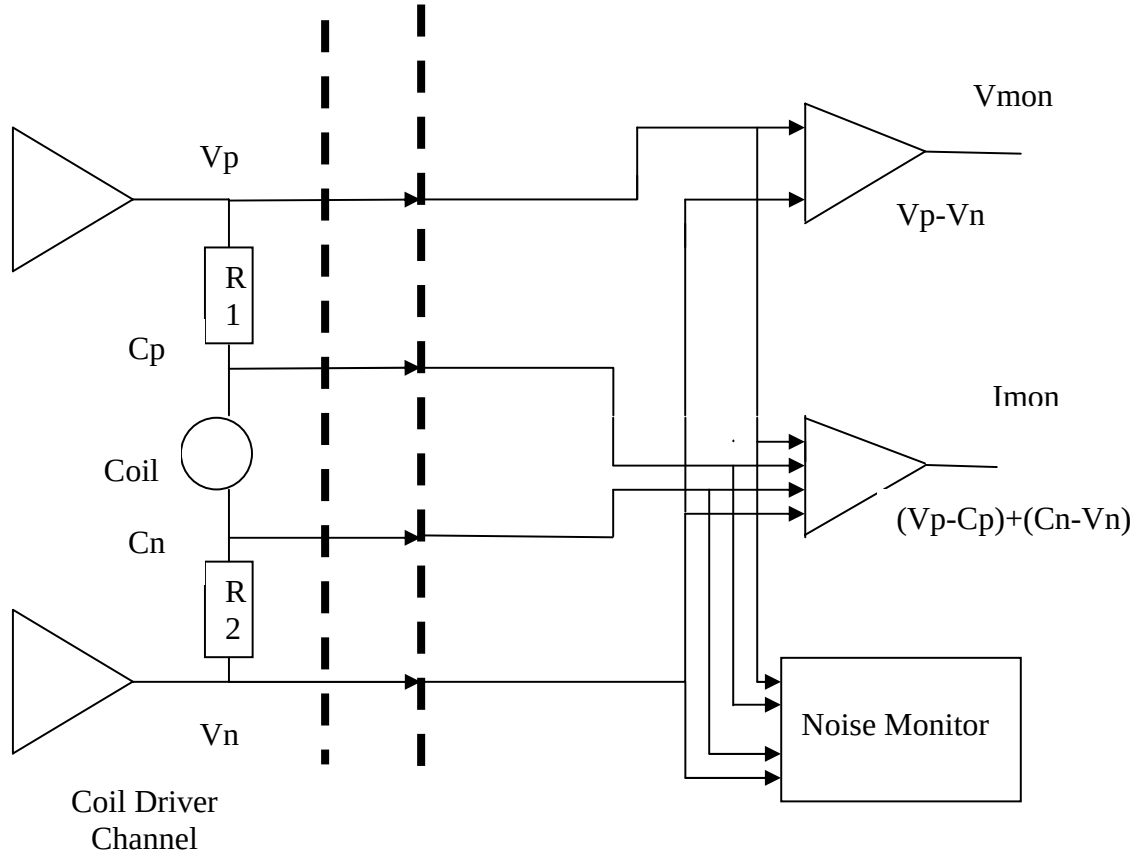
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon165……...
Test Engineer …Simon Pyatt…….
Date …19/11/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.87V	√
-15V (TP6)	-14.86V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.5V	**2.4V to 2.6V**	√
Ch2	100mV	2.5V	**2.4V to 2.6V**	√
Ch3	100mV	2.5V	**2.4V to 2.6V**	√
Ch4	100mV	2.5V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.6V	**1.6V to 1.9V**	√
Ch2	100mV	1.6V	**1.6V to 1.9V**	√
Ch3	100mV	1.6V	**1.6V to 1.9V**	√
Ch4	100mV	1.6V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.9	3	2.8	2.8

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.45	1.5	1.4	1.4	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.6V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.708V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.709V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.713V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.354V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.353V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.976V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.982V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.974V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.978V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.02V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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Contents

1. Block diagram

2. Test equipment

3. Description

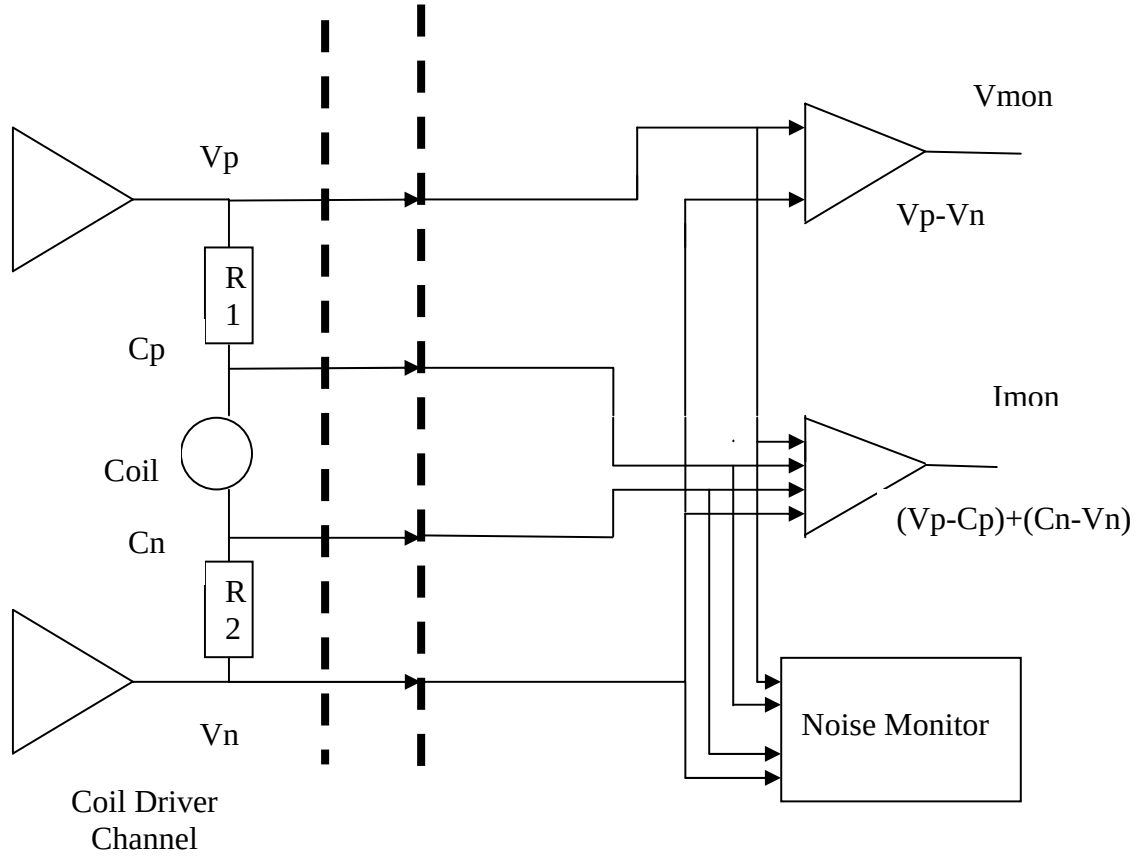
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

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NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.92V	√
-15V (TP6)	-14.92V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.5V	**2.4V to 2.6V**	√
Ch2	100mV	2.5V	**2.4V to 2.6V**	√
Ch3	100mV	2.5V	**2.4V to 2.6V**	√
Ch4	100mV	2.5V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.9	3	2.9	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.45	1.5	1.45	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.2V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.6V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.2V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.8V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.714V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.978V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.982V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.980V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.981V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.02V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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1. Block diagram

2. Test equipment

3. Description

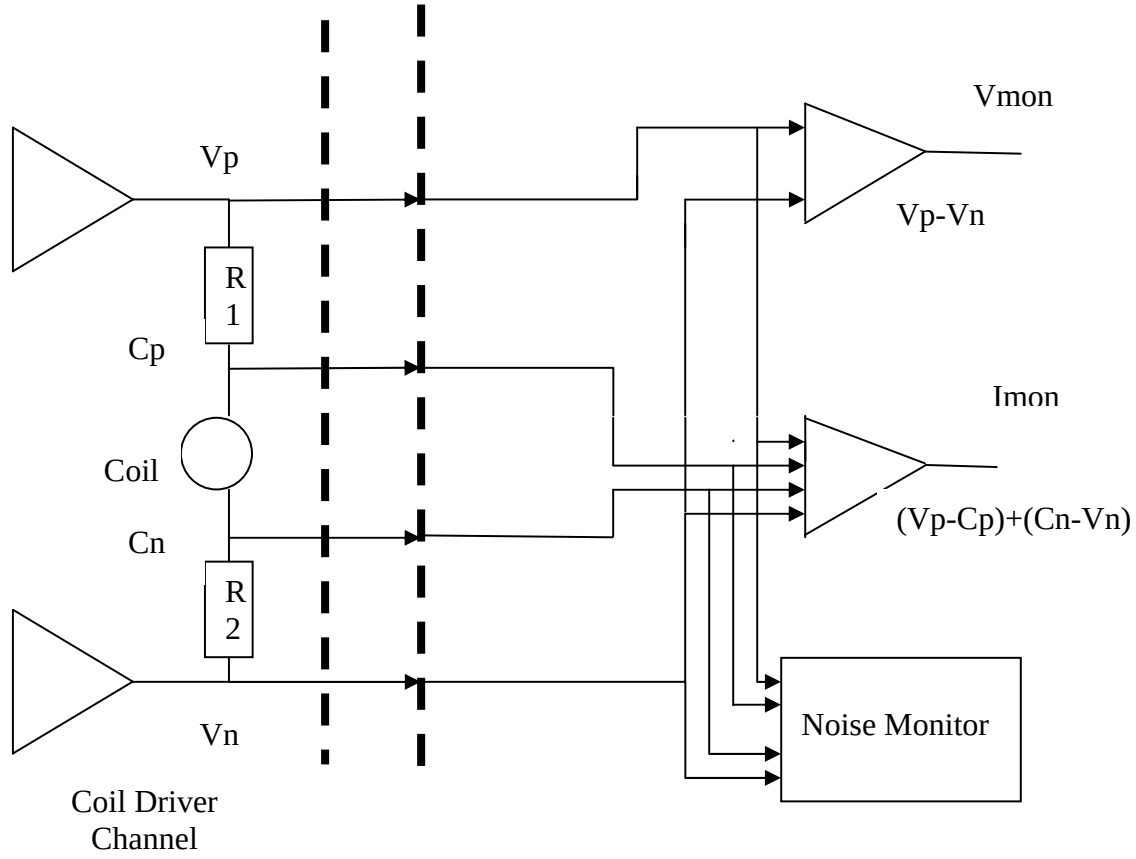
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon167……...
Test Engineer …Simon Pyatt…….
Date …23/11/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.84V	√
-15V (TP6)	-15.02V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon167……...
Test Engineer …Simon Pyatt…….
Date …23/11/09……

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.5V	**2.4V to 2.6V**	√
Ch2	100mV	2.5V	**2.4V to 2.6V**	√
Ch3	100mV	2.5V	**2.4V to 2.6V**	√
Ch4	100mV	2.5V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Test Engineer …Simon Pyatt…….
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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.6V	**1.6V to 1.9V**	√
Ch2	100mV	1.6V	**1.6V to 1.9V**	√
Ch3	100mV	1.6V	**1.6V to 1.9V**	√
Ch4	100mV	1.6V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.8	2.9	2.9	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.4	1.45	1.45	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.3V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.6V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.7V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.708V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.714V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.354V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.984V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.979V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.982V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.983V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon168……
Test Engineer…Simon Pyatt……
Date…23/11/09……

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2. Test equipment

3. Description

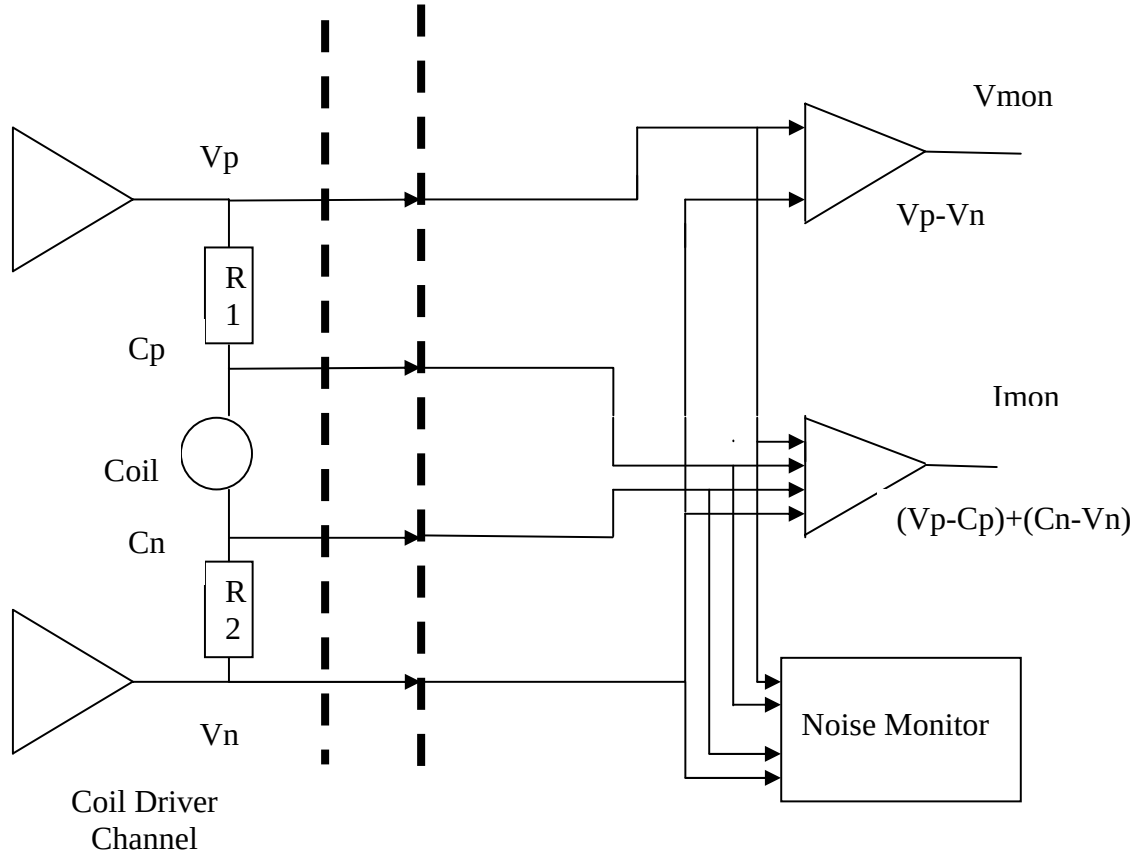
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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Test Engineer …Simon Pyatt…….
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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon168……...
Test Engineer …Simon Pyatt…….
Date …23/11/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.92V	√
-15V (TP6)	-14.93V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon168……...
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Date …23/11/09……

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.5V	**2.4V to 2.6V**	√
Ch2	100mV	2.5V	**2.4V to 2.6V**	√
Ch3	100mV	2.5V	**2.4V to 2.6V**	√
Ch4	100mV	2.5V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.6V	**1.6V to 1.9V**	√
Ch2	100mV	1.6V	**1.6V to 1.9V**	√
Ch3	100mV	1.6V	**1.6V to 1.9V**	√
Ch4	100mV	1.6V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.8	2.9	2.9	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.4	1.45	1.45	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.2V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.3V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.3V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.710V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.708V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.711V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.354V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.355V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.986V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.979V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.974V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.977V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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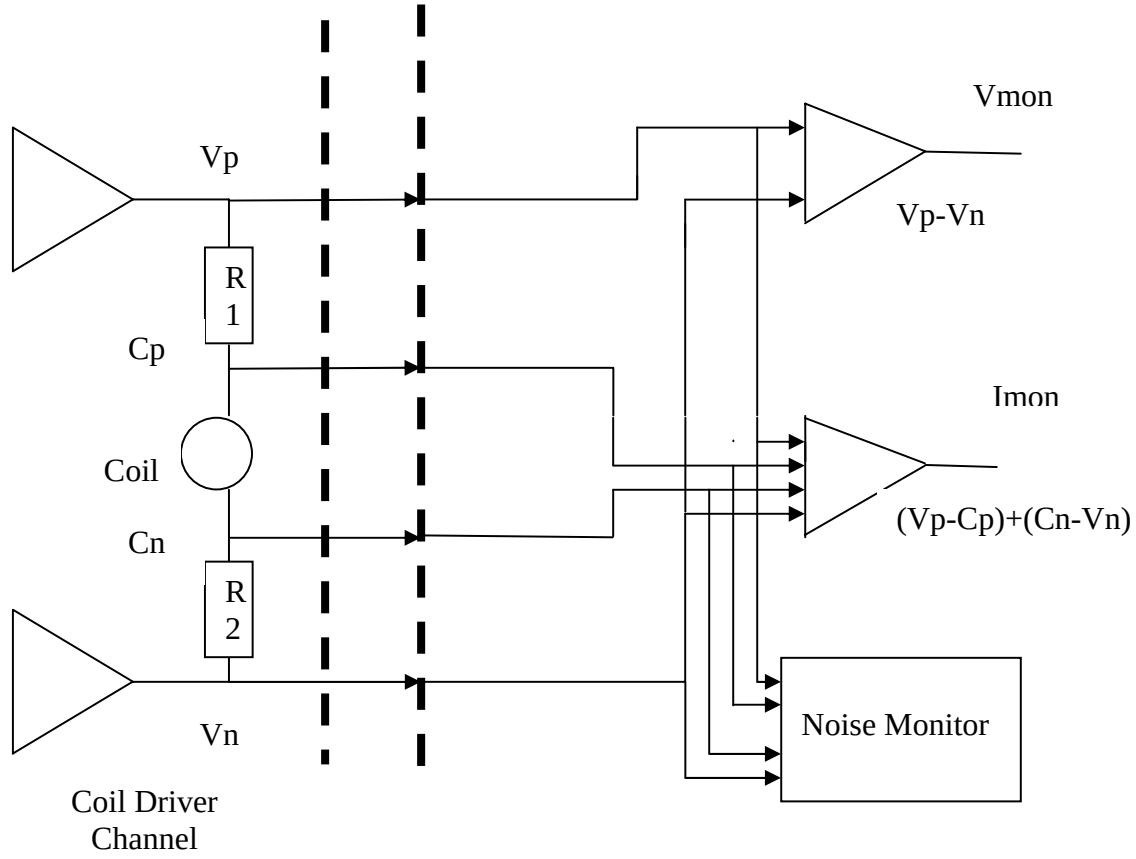
6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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Test Engineer …Simon Pyatt…….
Date …23/11/09……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK? IC10's on channels 1,2 and 3 are crooked.**

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon169……...
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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.89V	√
-15V (TP6)	-15.03V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.5V	**2.4V to 2.6V**	√
Ch2	100mV	2.5V	**2.4V to 2.6V**	√
Ch3	100mV	2.5V	**2.4V to 2.6V**	√
Ch4	100mV	2.5V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2.1	2
TP7	8	8	8	8	2.9	2.9	3	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.5	1.42	
TP7/TP6	2	2	2	2	1.45	1.45	1.42	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.6V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.6V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.717V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.713V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.360V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.361V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.989V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.986V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.989V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.983V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon170……
Test Engineer…Simon Pyatt……
Date…24/11/09……

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2. Test equipment

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5. Power

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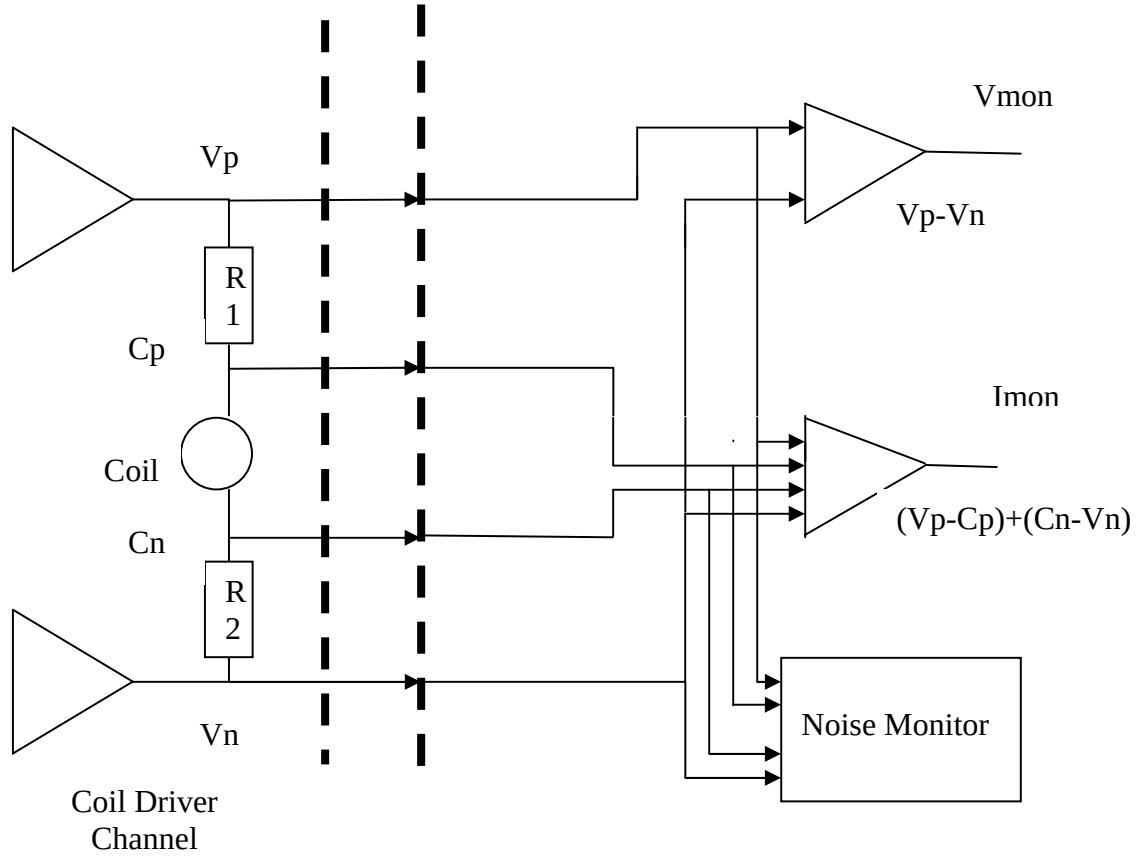
6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √ **C32 Ch 4. Cap on Ch3. Poor positioning**

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.90V	√
-15V (TP6)	-14.93V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.5V	**2.4V to 2.6V**	√
Ch2	100mV	2.5V	**2.4V to 2.6V**	√
Ch3	100mV	2.5V	**2.4V to 2.6V**	√
Ch4	100mV	2.5V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	1.9	2	2
TP7	8	8	8	8	2.9	2.8	2.8	2.8

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.45	1.47	1.4	1.4	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.2V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.3V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.2V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.708V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.716V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.354V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.977V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.980V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.982V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.986V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon171……
Test Engineer…Simon Pyatt……
Date…03/12/09……

Contents

1. Block diagram

2. Test equipment

3. Description

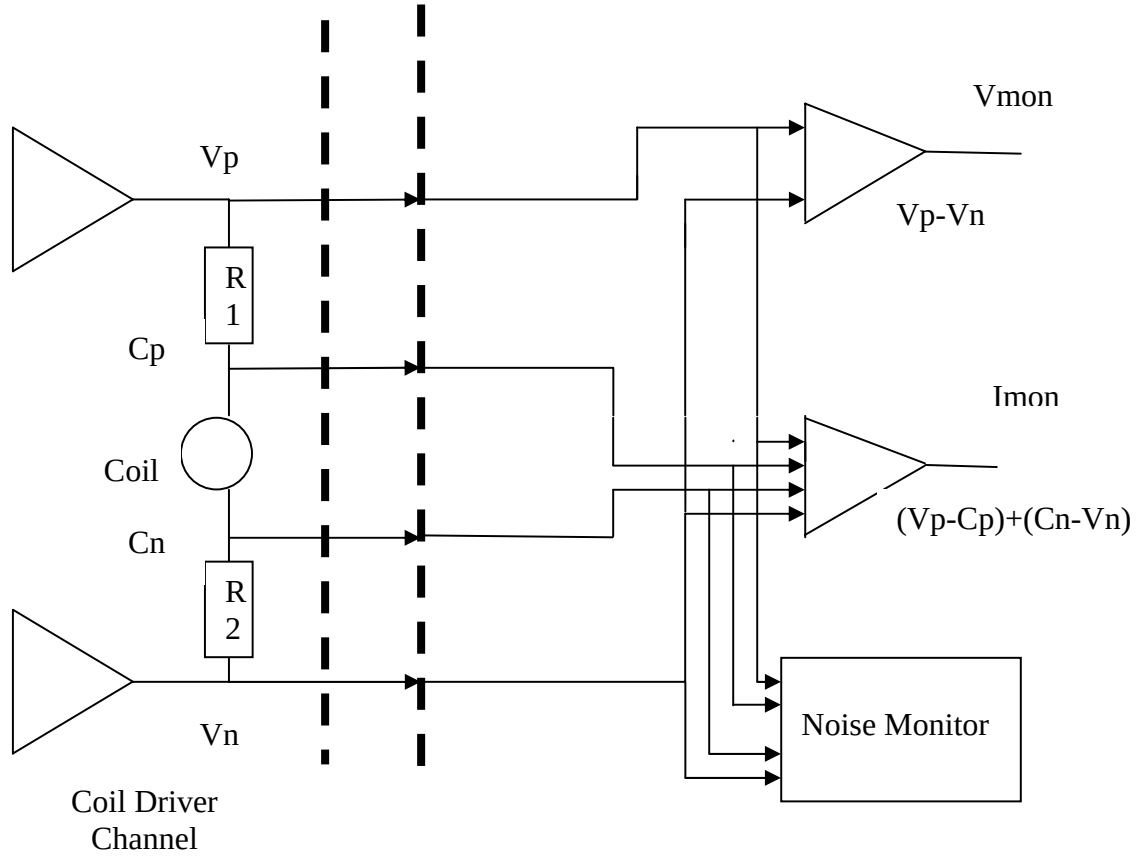
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon171……..
Test Engineer …Simon Pyatt…….
Date …03/12/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.94V	√
-15V (TP6)	-15.06V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.25A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.6V	**1.6V to 1.9V**	√
Ch2	100mV	1.6V	**1.6V to 1.9V**	√
Ch3	100mV	1.6V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Test Engineer …Simon Pyatt…….
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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.6V	**1.6V to 1.9V**	√
Ch2	100mV	1.6V	**1.6V to 1.9V**	√
Ch3	100mV	1.6V	**1.6V to 1.9V**	√
Ch4	100mV	1.6V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Test Engineer …Simon Pyatt…….
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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.8	2.9	2.8	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.4	1.45	1.4	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.7V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.2V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.710V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.717V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.353V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.359V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.977V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.982V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.976V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.984V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon172……
Test Engineer…Simon Pyatt……
Date…03/12/09……

Contents

1. Block diagram

2. Test equipment

3. Description

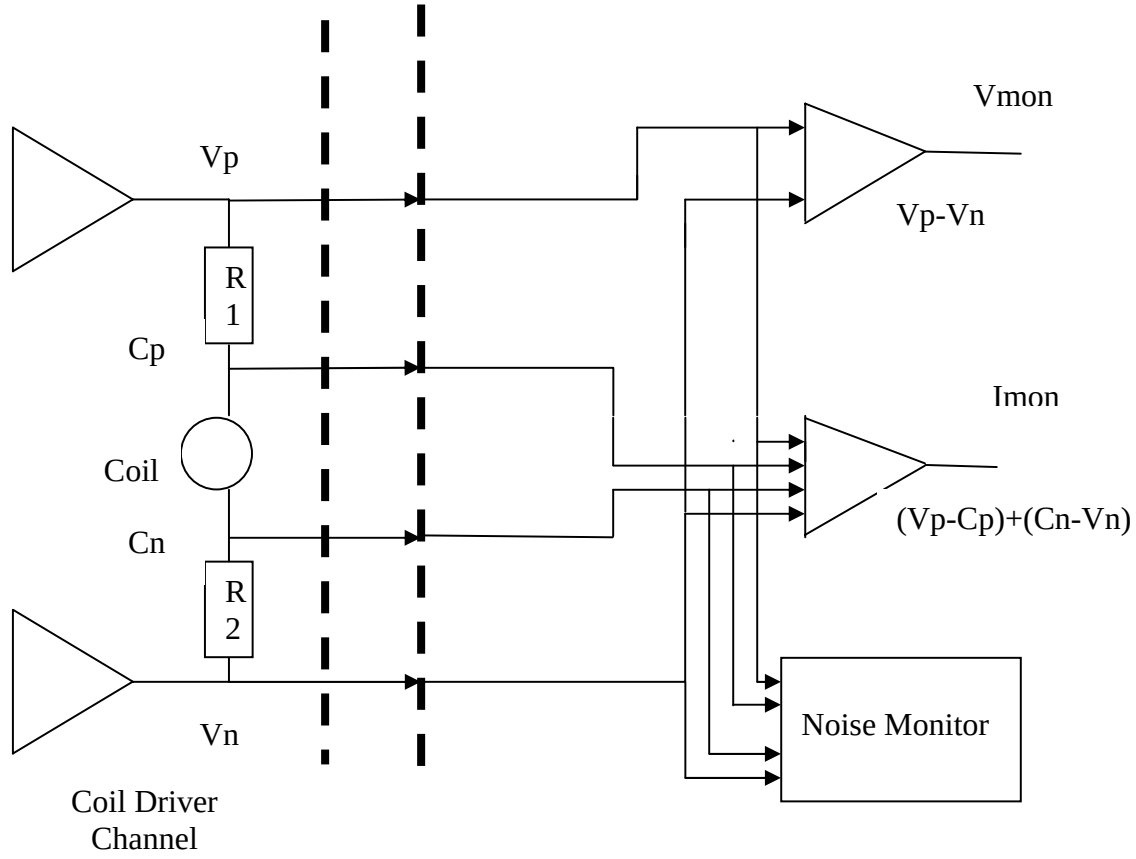
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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Test Engineer …Simon Pyatt…….
Date …03/12/09……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon172……..
Test Engineer …Simon Pyatt…….
Date …03/12/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.83V	√
-15V (TP6)	-14.92V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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Test Engineer …Simon Pyatt…….
Date …03/12/09……

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

Serial No …mon172……..
Test Engineer …Simon Pyatt…….
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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.5	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2.1	2.1
TP7	8	8	8	8	3.1	3.1	3.2	3.2

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.5	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.4	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.47	1.47	1.52	1.52	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.3V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.710V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.712V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.356V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.983V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.986V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.984V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.982V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon173……
Test Engineer…Simon Pyatt……
Date…03/12/09……

Contents

1. Block diagram

2. Test equipment

3. Description

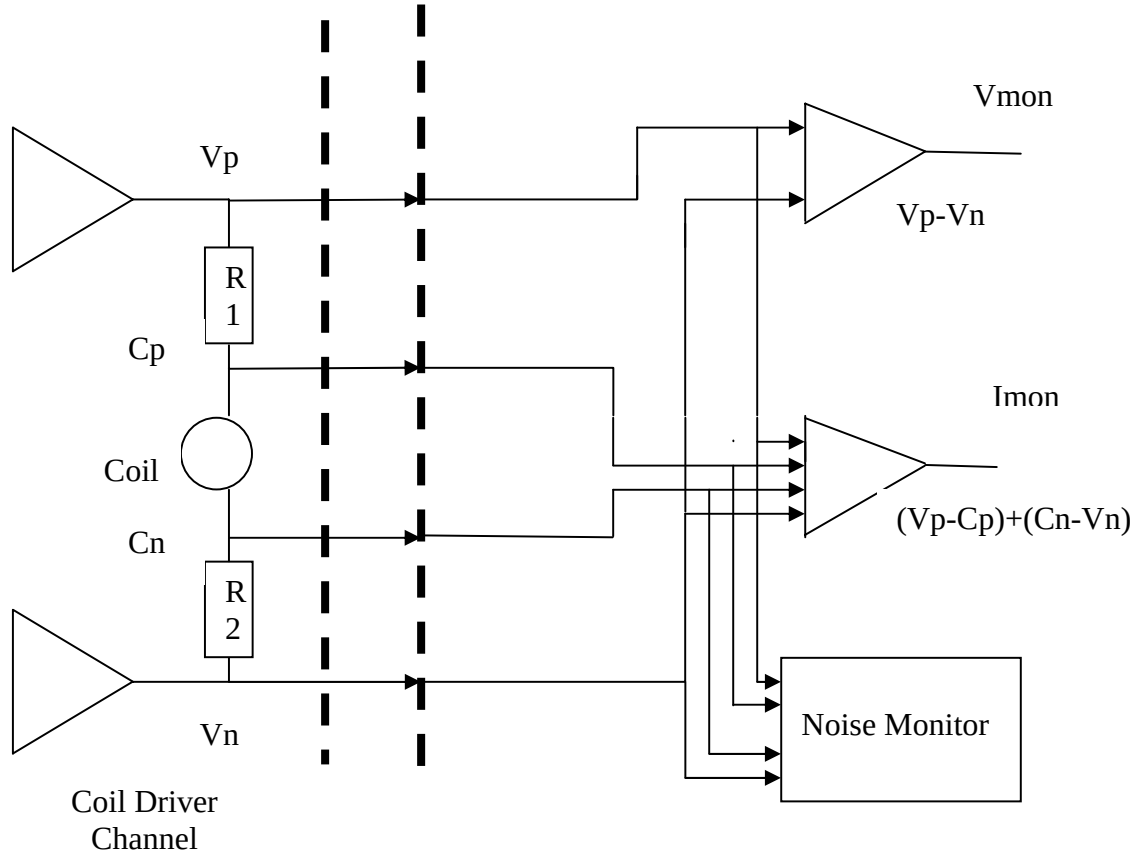
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

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Test Engineer …Simon Pyatt…….
Date …03/12/09……

NOTES

Serial No …mon173……...
Test Engineer …Simon Pyatt…….
Date …03/12/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	15.00V	√
-15V (TP6)	-14.94V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.6V	**1.6V to 1.9V**	√
Ch2	100mV	1.6V	**1.6V to 1.9V**	√
Ch3	100mV	1.6V	**1.6V to 1.9V**	√
Ch4	100mV	1.6V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	2	2	2	2	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	2	2	2	2	2	2	2	2
TP7	2	2	2	2	2.8	2.8	2.8	2.8

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.4	1.4	1.4	1.4	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.3V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.708V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.719V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.362V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.979V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.984V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.988V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.990V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon174……
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1. Block diagram

2. Test equipment

3. Description

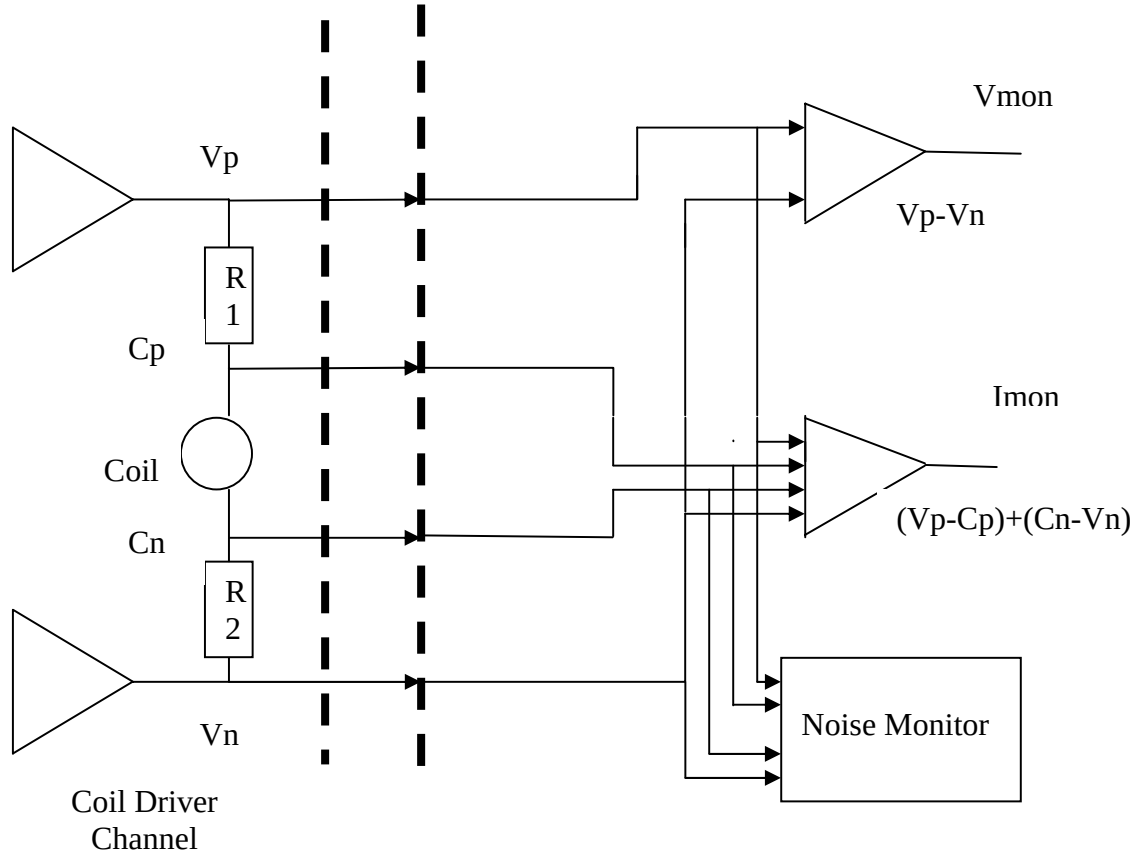
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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Test Engineer …Simon Pyatt…….
Date …03/12/09……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon174……..
Test Engineer …Simon Pyatt…….
Date …03/12/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.84V	√
-15V (TP6)	-14.94V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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Test Engineer …Simon Pyatt…….
Date …03/12/09……

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1		1.7V	**1.6V to 1.9V**	√
Ch2		1.7V	**1.6V to 1.9V**	√
Ch3		1.7V	**1.6V to 1.9V**	√
Ch4		1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	1.9	2	2
TP7	8	8	8	8	2.8	2.8	2.8	2.8

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.35	1.42	1.42	
TP7/TP6	2	2	2	2	1.4	1.47	1.4	1.4	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.2V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.8V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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Test Engineer …Simon Pyatt…….
Date …03/12/09……

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.719V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.713V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.361V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.994V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.993V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.996V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.989V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon175……
Test Engineer…Simon Pyatt……
Date…04/12/09……

Contents

1. Block diagram

2. Test equipment

3. Description

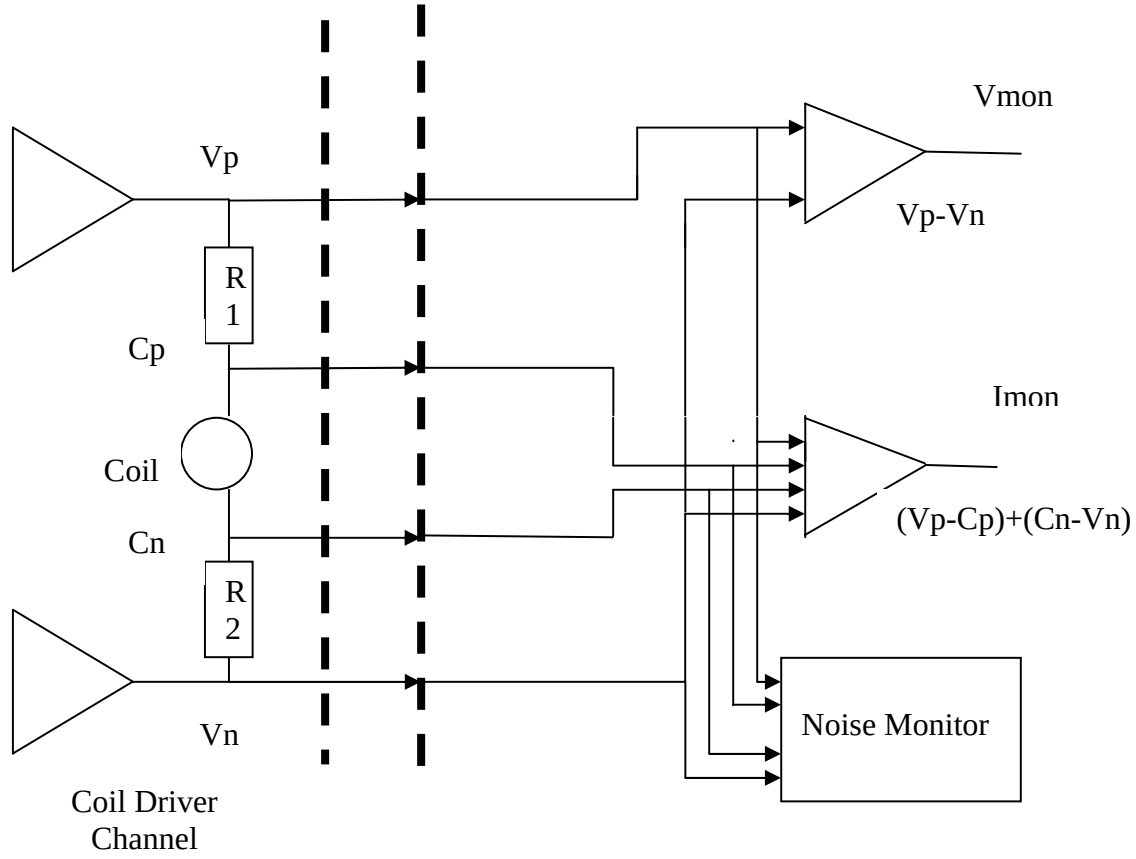
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

Serial No …mon175……..
Test Engineer …Simon Pyatt…….
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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK? C9 C10 Ch1 Mounted lifted off board**

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon175……...
Test Engineer …Simon Pyatt…….
Date …04/12/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.96V	√
-15V (TP6)	-14.88V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Test Engineer …Simon Pyatt…….
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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.6V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.6V	**1.6V to 1.9V**	√
Ch4	100mV	1.6V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Test Engineer …Simon Pyatt…….
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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	1.9	1.9	2
TP7	8	8	8	8	2.8	2.8	2.8	2.8

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.35	1.35	1.42	
TP7/TP6	2	2	2	2	1.4	1.47	1.47	1.4	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.2V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.2V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.7V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.2V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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Test Engineer …Simon Pyatt…….
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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.719V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.362V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.986V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.989V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.991V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.994V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	996V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon176……
Test Engineer…Simon Pyatt……
Date…04/12/09……

Contents

1. Block diagram

2. Test equipment

3. Description

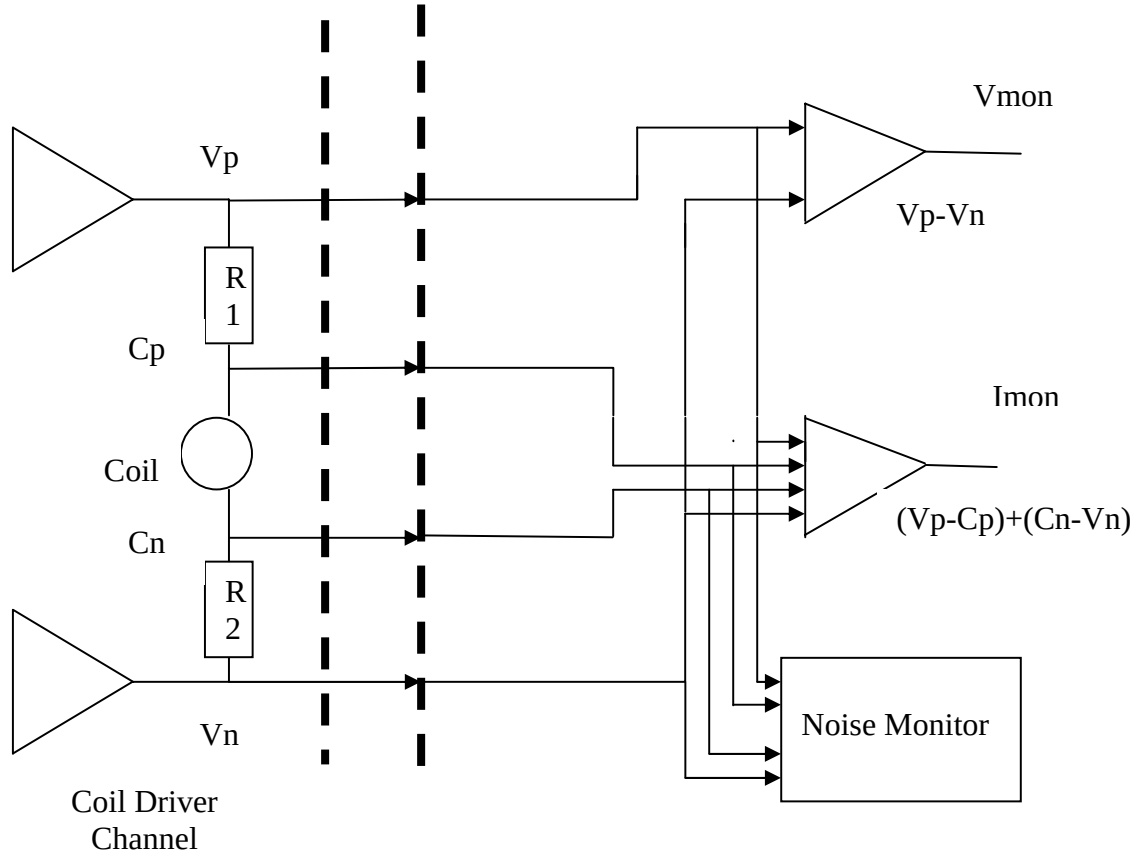
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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Test Engineer …Simon Pyatt…….
Date …04/12/09……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon176……...
Test Engineer …Simon Pyatt…….
Date …04/12/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.97V	√
-15V (TP6)	-14.93V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon176……...
Test Engineer …Simon Pyatt…….
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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Test Engineer …Simon Pyatt…….
Date …04/12/09……

Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1	100mV	4.7V	**4.7V to 5.2V**	√
Ch2	100mV	4.7V	**4.7V to 5.2V**	√
Ch3	100mV	4.7V	**4.7V to 5.2V**	√
Ch4	100mV	4.7V	**4.7V to 5.2V**	√

Serial No …mon176……...
Test Engineer …Simon Pyatt…….
Date …04/12/09……

Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	2	2	2	2	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	2	2	2	2	2	2	2	1.9
TP7	2	2	2	2	2.8	2.8	2.8	2.7

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.35	
TP7/TP6	2	2	2	2	1.4	1.4	1.4	1.42	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.3V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.2V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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Date …04/12/09……

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.709V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.712V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.354V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.356V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.994V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.989V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.995V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.992V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon177……
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Contents

1. Block diagram

2. Test equipment

3. Description

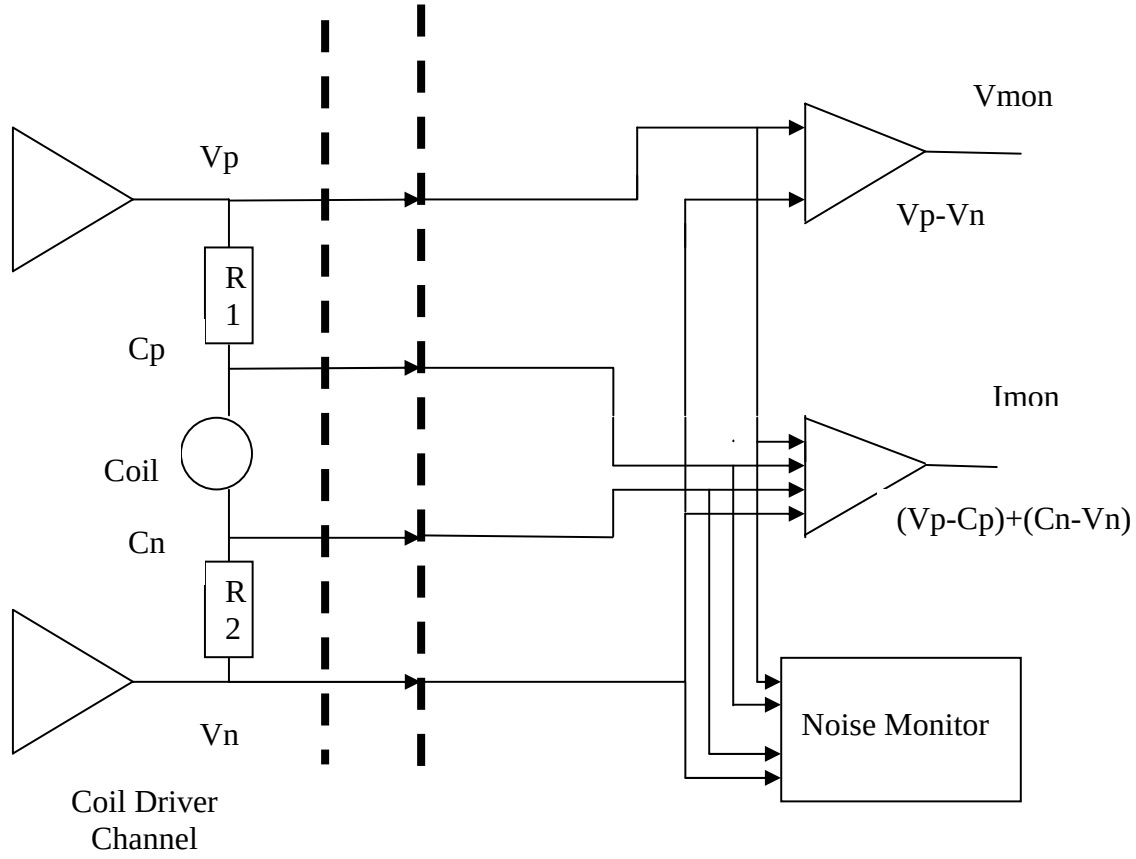
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Solder had filled up one of the mounting holes. I have removed it.

Serial No ……...
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Date ……

NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.84V	√
-15V (TP6)	-15.00V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.5V	**2.4V to 2.6V**	√
Ch2	100mV	2.5V	**2.4V to 2.6V**	√
Ch3	100mV	2.5V	**2.4V to 2.6V**	√
Ch4	100mV	2.5V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2	2
TP7	8	8	8	8	3.1	3.1	3	3

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.42	1.42	
TP7/TP6	2	2	2	2	1.47	1.47	1.5	1.5	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.6V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.717V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.360V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.360V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.996V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.995V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.989V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.995V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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1. Block diagram

2. Test equipment

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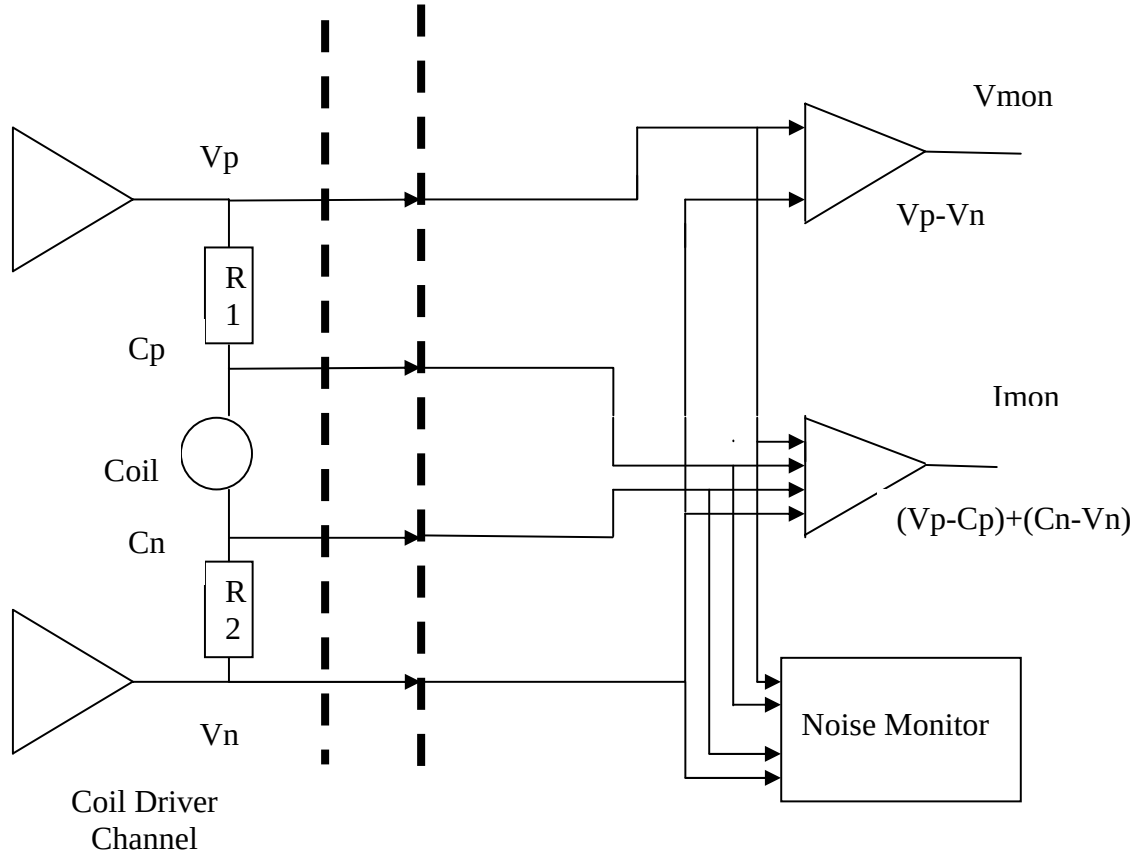
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon178……...
Test Engineer …Simon Pyatt…….
Date …14/12/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.96V	√
-15V (TP6)	-15.02V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1	100mV	4.7V	**4.7V to 5.2V**	√
Ch2	100mV	4.7V	**4.7V to 5.2V**	√
Ch3	100mV	4.7V	**4.7V to 5.2V**	√
Ch4	100mV	4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.5	1.4
TP6	4	4	4	4	2.1	2.1	2.1	2.1
TP7	8	8	8	8	3.1	3	3.1	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.5	1.4	√
TP6/TP4	2	2	2	2	1.5	1.5	1.4	1.5	√
TP7/TP6	2	2	2	2	1.47	1.42	1.47	1.47	√

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.6V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.9V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.2V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.2V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

Serial No …mon178……..
Test Engineer …Simon Pyatt…….
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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.717V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.714V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.360V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.992V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.990V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.996V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.991V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon179……
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Contents

1. Block diagram

2. Test equipment

3. Description

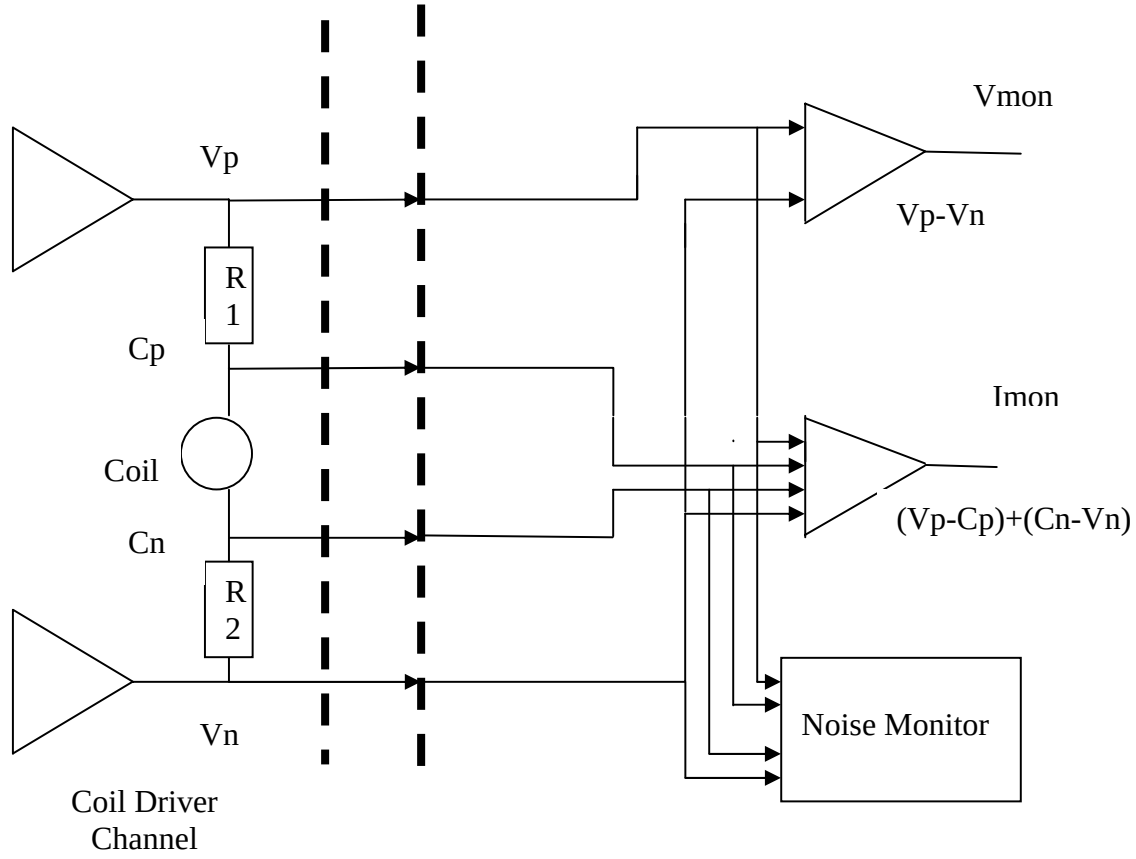
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.82V	√
-15V (TP6)	-14.95V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	1.9	2.1	2	2
TP7	8	8	8	8	2.8	2.9	2.8	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.35	1.5	1.42	1.42	
TP7/TP6	2	2	2	2	1.47	1.38	1.4	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.8V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.713V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.356V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.991V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.988V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.986V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.987V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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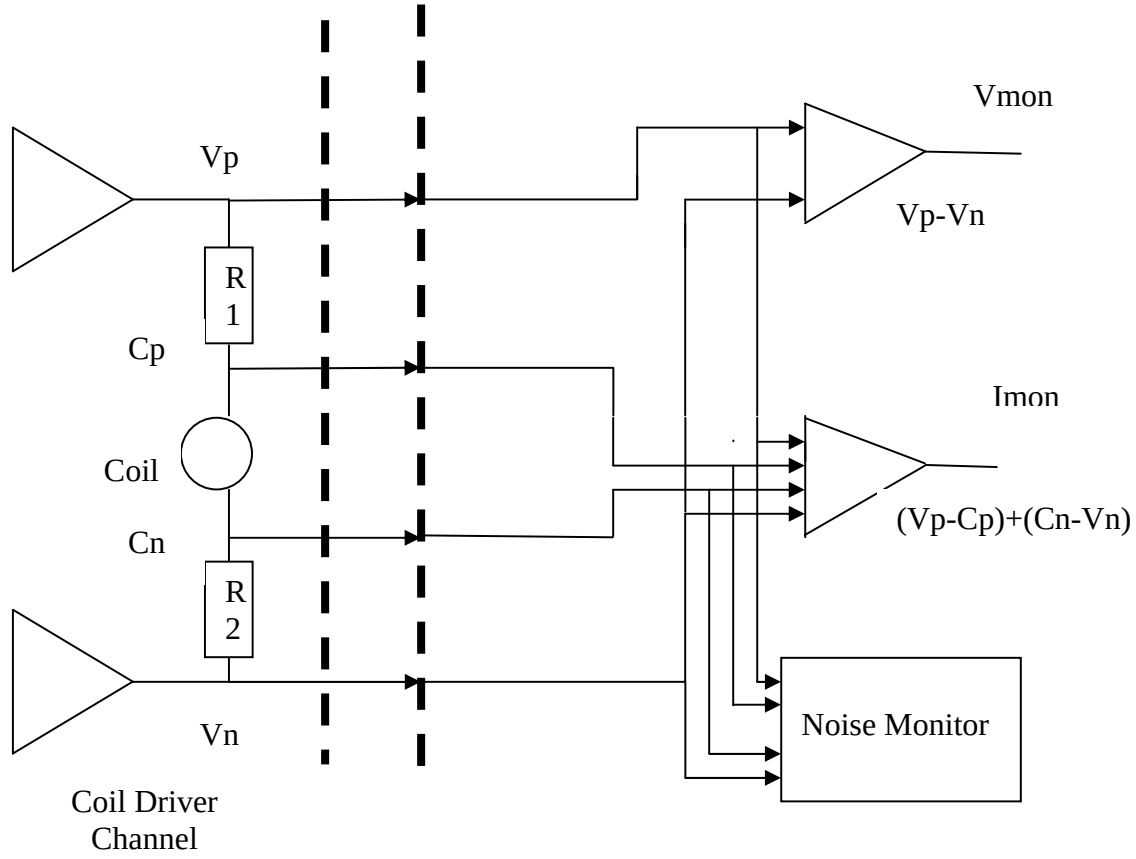
5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon180……..
Test Engineer …Simon Pyatt…….
Date …15/12/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.86V	√
-15V (TP6)	-14.97V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon180……...
Test Engineer …Simon Pyatt…….
Date …15/12/09……

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.8	2.9	2.8	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.4	1.45	1.4	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.6V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

Serial No …mon180……..
Test Engineer …Simon Pyatt…….
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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.719V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.710V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.362V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.354V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.992V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.988V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.995V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.985V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon181……
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1. Block diagram

2. Test equipment

3. Description

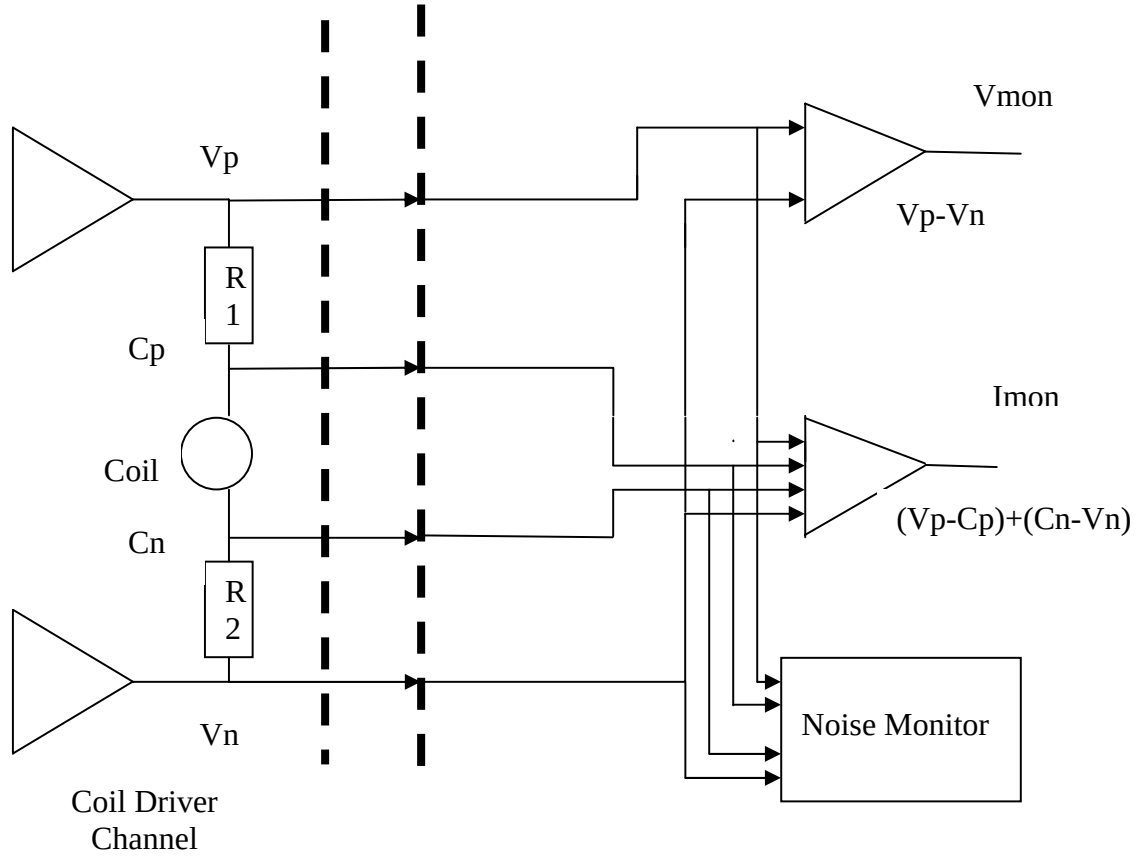
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon181……...
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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.92V	√
-15V (TP6)	-14.94V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.8	2.8	2.8	2.8

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.4	1.4	1.4	1.4	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.709V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.354V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.990V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.984V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.988V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.981V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon182……
Test Engineer…Simon Pyatt……
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2. Test equipment

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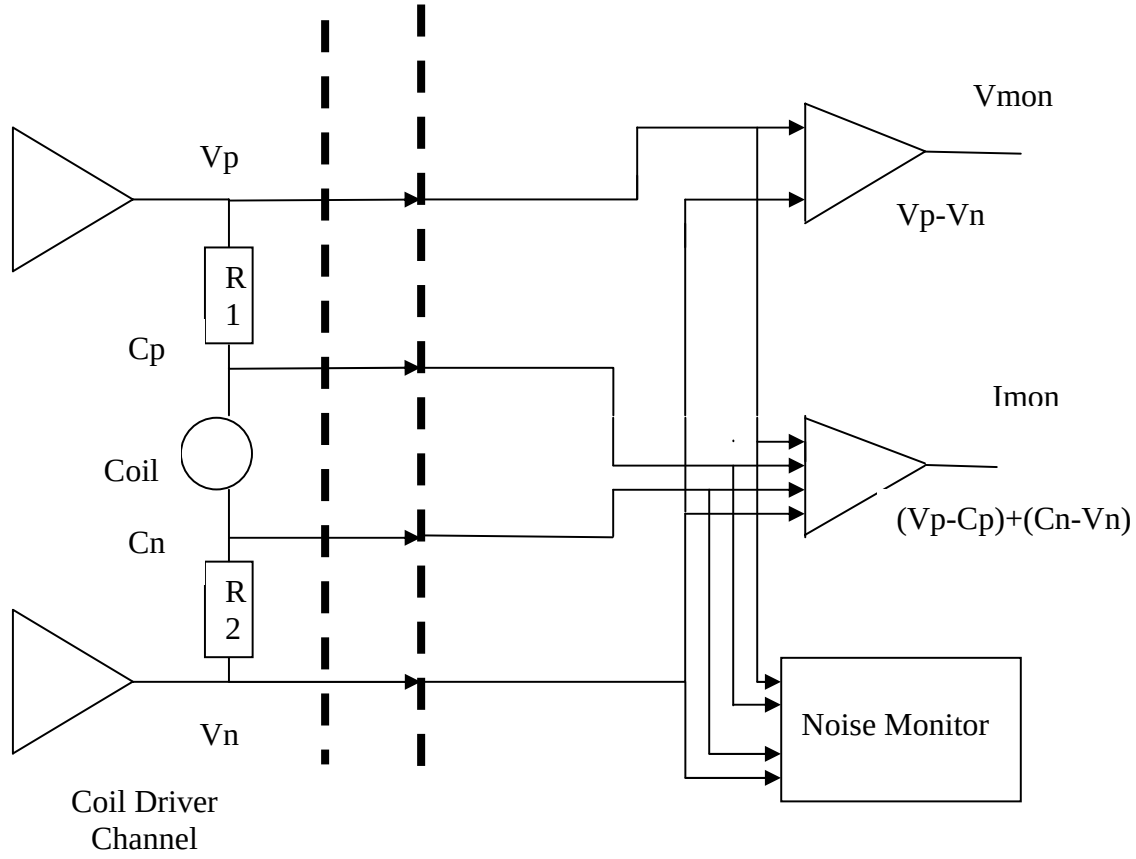
6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon182……..
Test Engineer …Simon Pyatt…….
Date …16/12/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.90V	√
-15V (TP6)	-15.02V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon182……...
Test Engineer …Simon Pyatt…….
Date …16/12/09……

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.9	2.8	2.8	2.8

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.45	1.4	1.4	1.4	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.9V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.707V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.714V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.354V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.990V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.989V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.979V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.987V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon183……
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Contents

1. Block diagram

2. Test equipment

3. Description

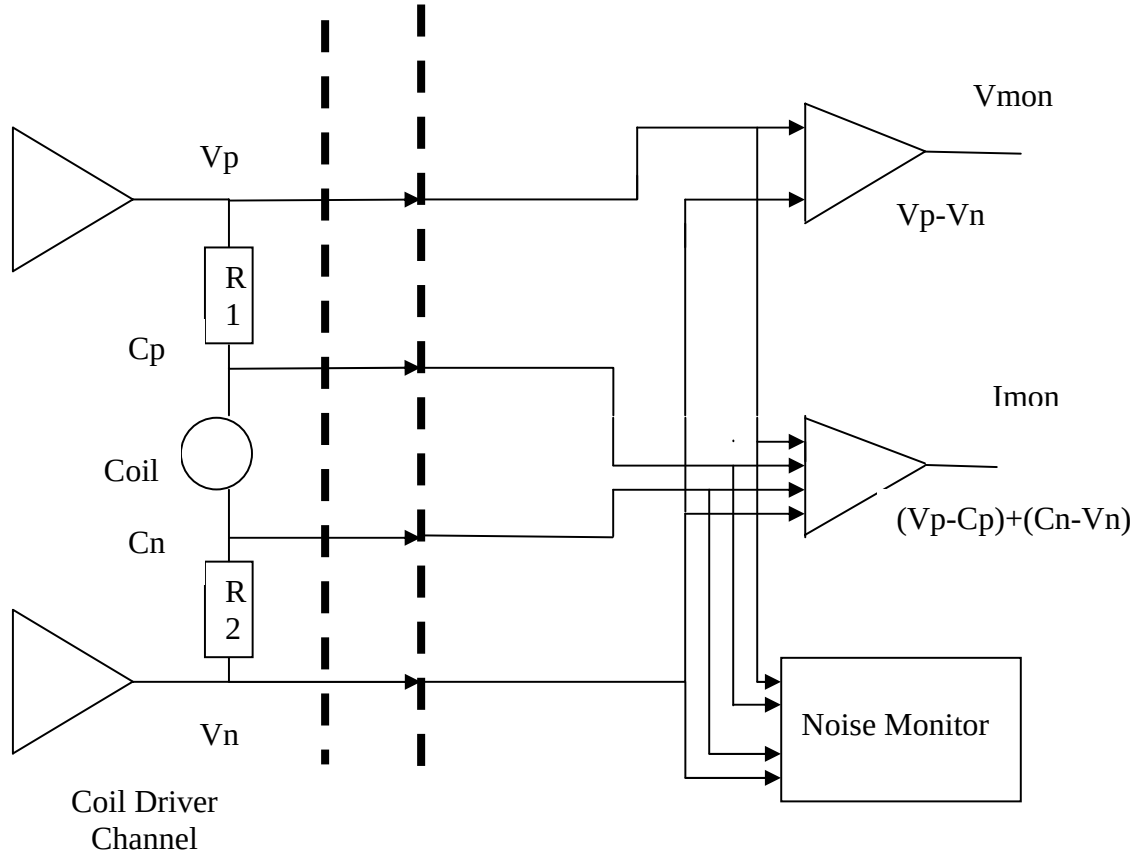
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.92V	√
-15V (TP6)	-14.91V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2	2	2
TP7	8	8	8	8	3	2.9	2.9	3

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.42	1.45	1.45	1.5	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.9V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.6V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.8V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.714V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.360V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.354V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.990V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.987V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.986V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.990V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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1. Block diagram

2. Test equipment

3. Description

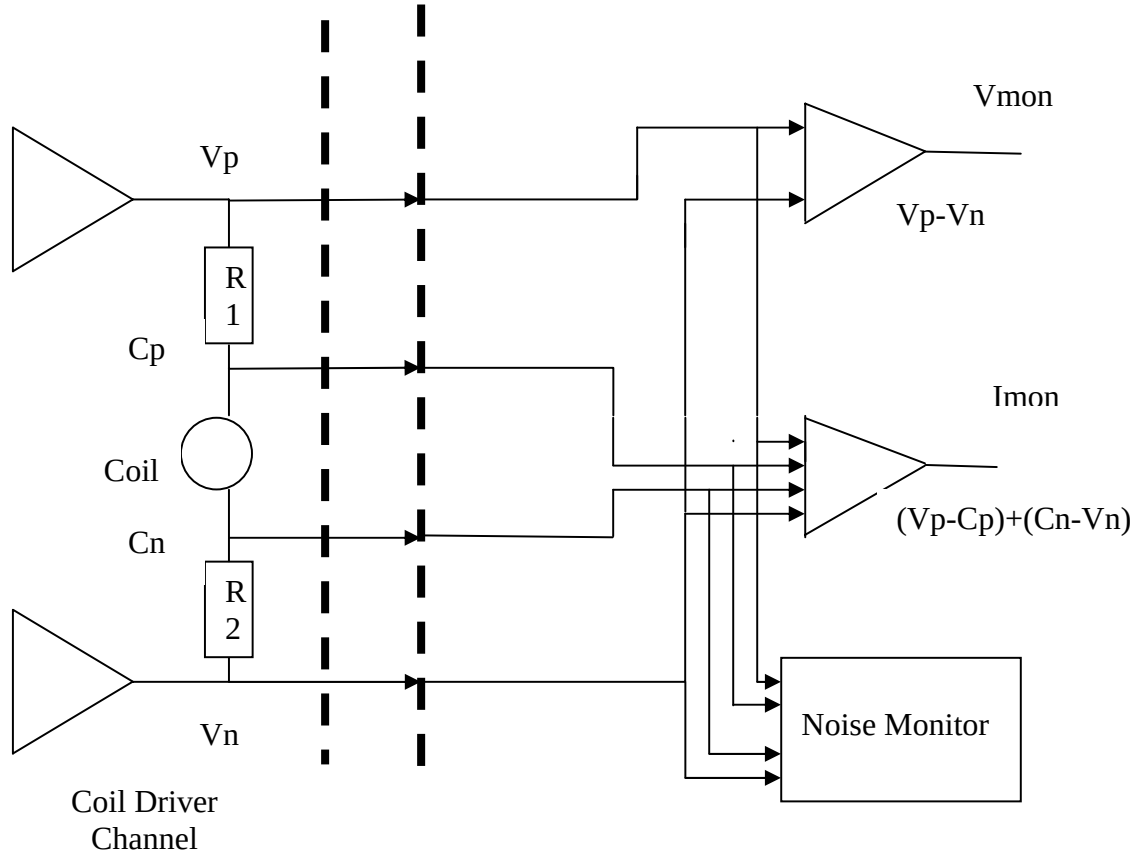
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK? √**
Comments

Visual overall check **OK? √**
Solder joint **OK? √**
Placement **OK? Poor positioning of all board components**

Modifications

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NOTES

Alignment assembly of this board is generally very poor throughout for SM components.

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.92V	√
-15V (TP6)	-15.01V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.6V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.6V	**1.6V to 1.9V**	√
Ch2	100mV	1.6V	**1.6V to 1.9V**	√
Ch3	100mV	1.6V	**1.6V to 1.9V**	√
Ch4	100mV	1.6V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.9	2.8	2.8	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.45	1.4	1.4	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.3V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.3V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.713V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.356V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.984V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.985V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.981V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.982V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon185……
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Contents

1. Block diagram

2. Test equipment

3. Description

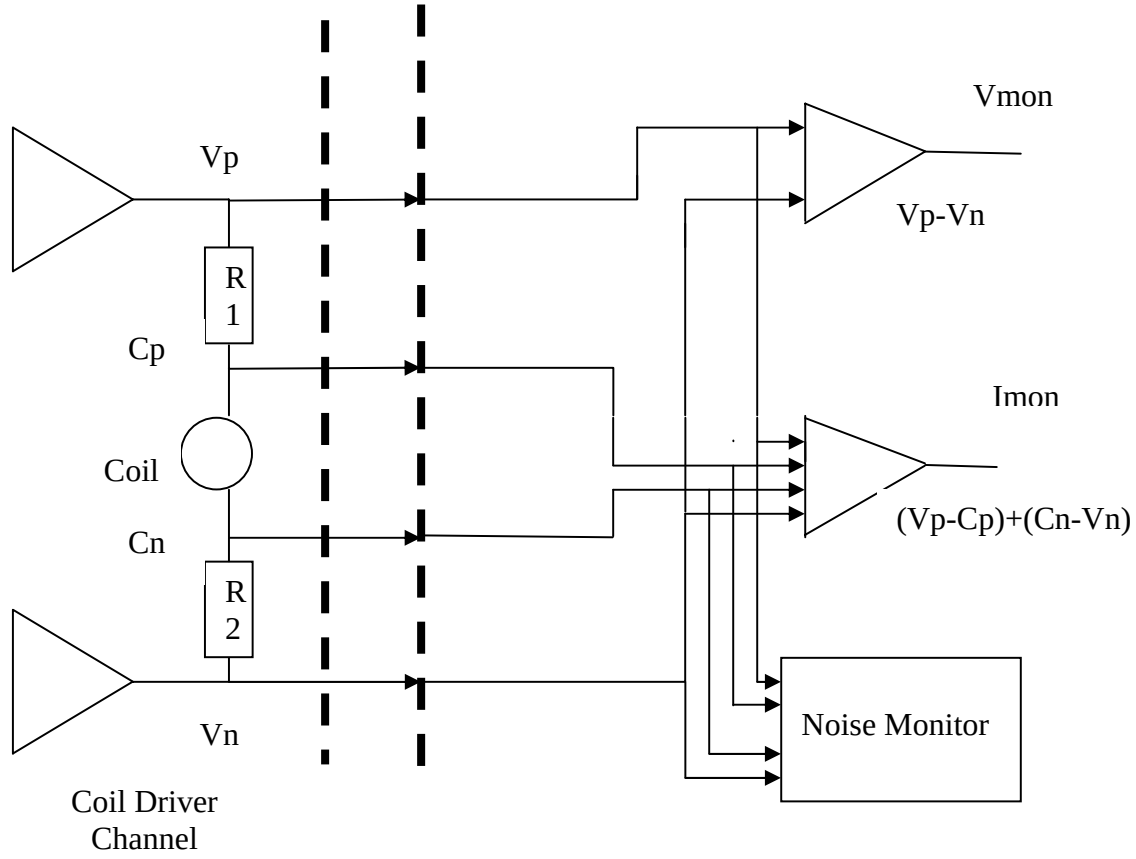
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
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Date ……

NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.94V	√
-15V (TP6)	-15.02V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.8	2.8	2.8	2.8

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.4	1.4	1.4	1.4	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.6V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.2V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.6V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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Test Engineer …Simon Pyatt…….
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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.709V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.354V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.985V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.986V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.981V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.977V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon186……
Test Engineer…Simon Pyatt……
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Contents

1. Block diagram

2. Test equipment

3. Description

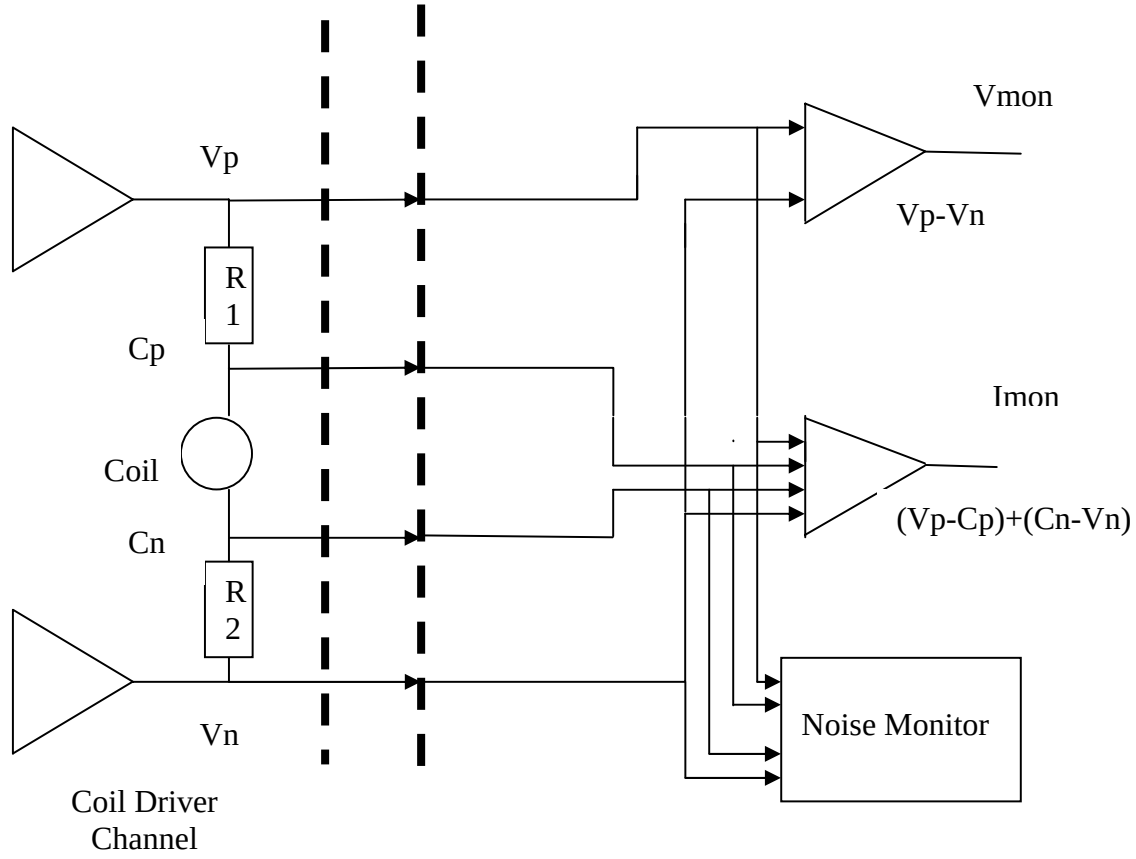
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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Test Engineer …Simon Pyatt…….
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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon186……..
Test Engineer …Simon Pyatt…….
Date …17/12/09…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.91V	√
-15V (TP6)	-14.98V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2.1	2.1
TP7	8	8	8	8	3.1	3.1	3.1	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.47	1.47	1.47	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.7V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.3V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.3V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.718V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.709V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.360V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.354V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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Contents

1. Block diagram

2. Test equipment

3. Description

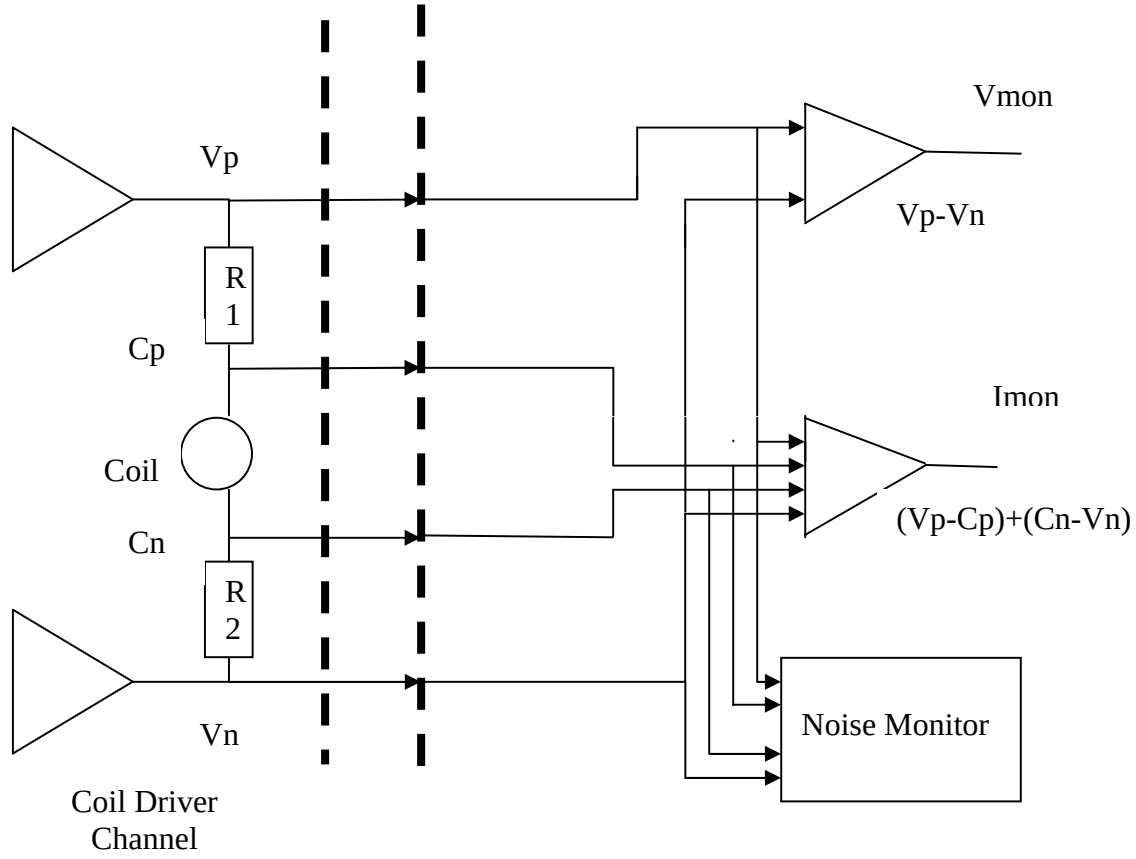
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

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NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.90V	√
-15V (TP6)	-15.01V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.25A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.5V	**2.4V to 2.6V**	√
Ch2	100mV	2.5V	**2.4V to 2.6V**	√
Ch3	100mV	2.5V	**2.4V to 2.6V**	√
Ch4	100mV	2.5V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2.1	2.1	2.1
TP7	8	8	8	8	3	3.1	3.1	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.5	1.47	1.47	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.7V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.716V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.359V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.991V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.991V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.991V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.991V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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1. Block diagram

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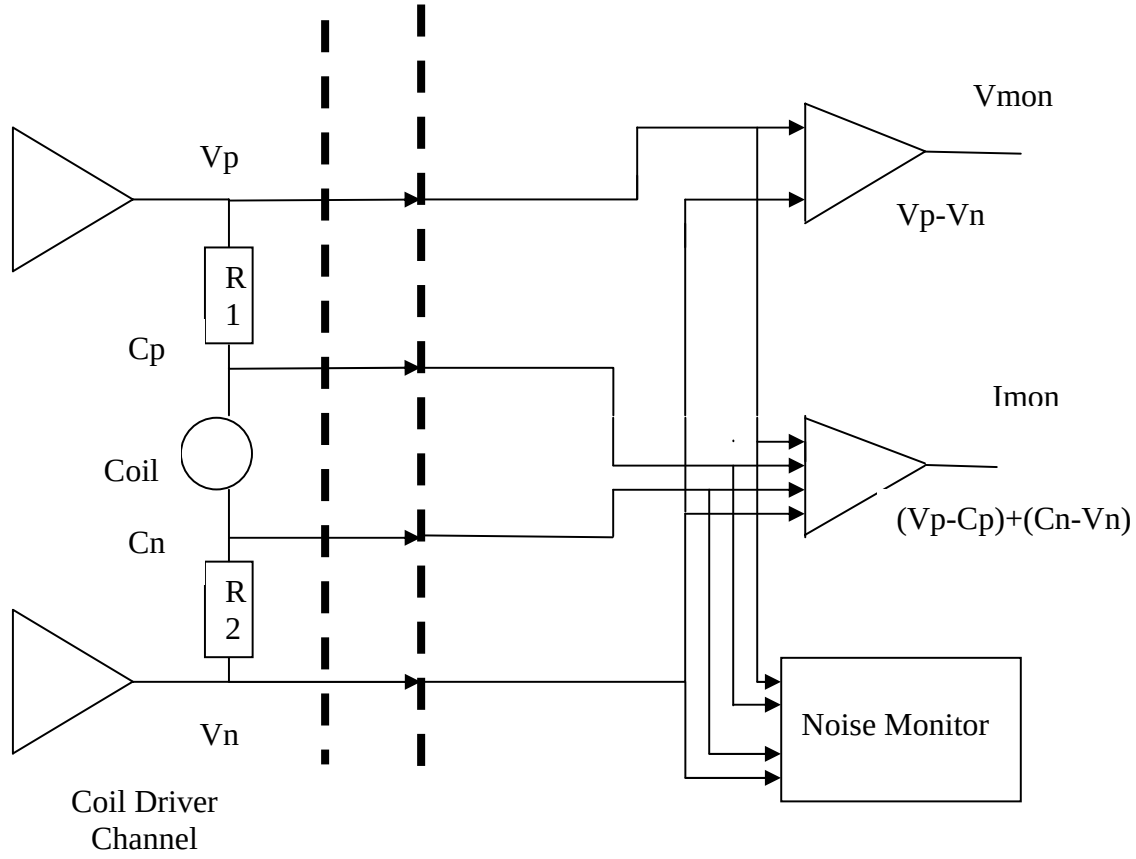
6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon188……...
Test Engineer …Simon Pyatt…….
Date …19/01/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.91V	√
-15V (TP6)	-14.93V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2.1	2	2
TP7	8	8	8	8	2.9	3	2.9	2.8

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.5	1.42	1.42	
TP7/TP6	2	2	2	2	1.45	1.42	1.45	1.4	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.8V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.7V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.717V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.714V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.361V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.985V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.985V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.984V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.982V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.02V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon189……
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2. Test equipment

3. Description

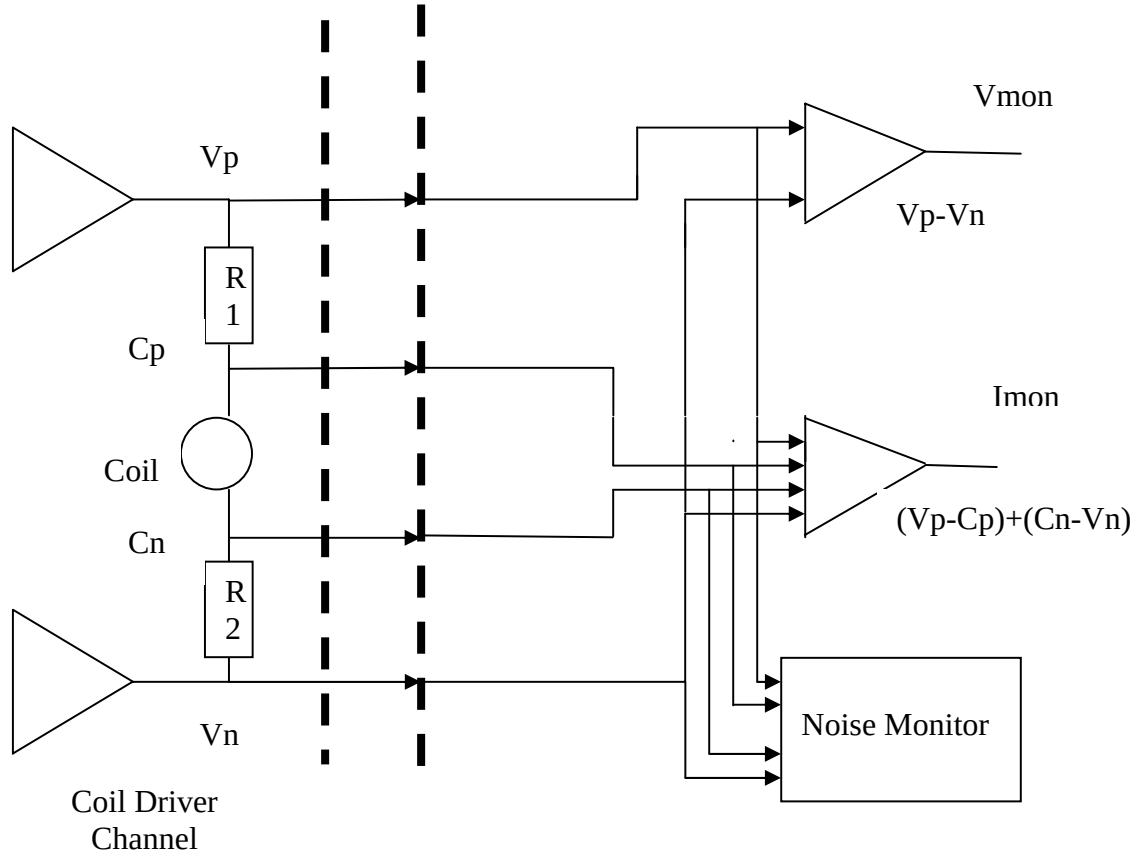
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon189……...
Test Engineer …Simon Pyatt…….
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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.91V	√
-15V (TP6)	-15.02V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.5V	**2.4V to 2.6V**	√
Ch2	100mV	2.5V	**2.4V to 2.6V**	√
Ch3	100mV	2.5V	**2.4V to 2.6V**	√
Ch4	100mV	2.5V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2	1.9	2
TP7	8	8	8	8	3.1	2.9	2.8	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.42	1.35	1.42	
TP7/TP6	2	2	2	2	1.47	1.45	1.47	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.717V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.359V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.99V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.984V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.989V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.991V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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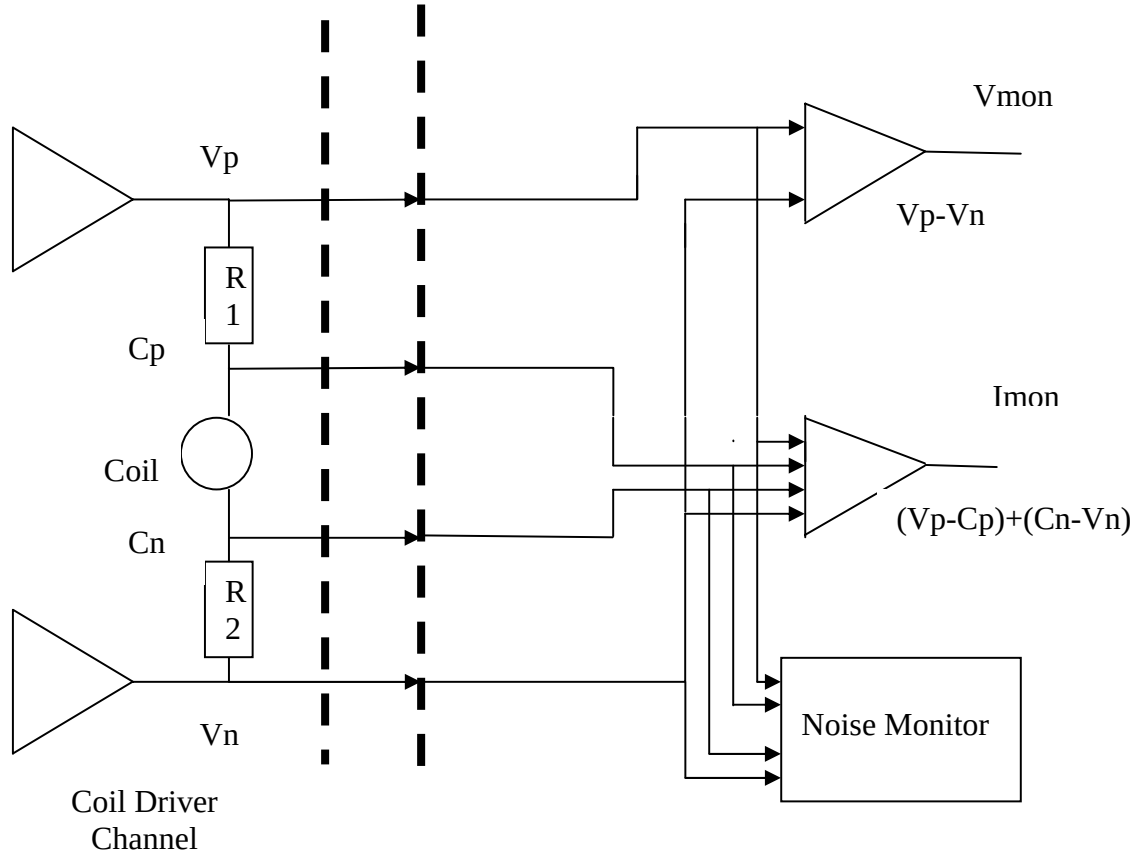
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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Test Engineer …Simon Pyatt…….
Date …20/01/10……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon190……...
Test Engineer …Simon Pyatt…….
Date …20/01/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.85V	√
-15V (TP6)	-14.97V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Test Engineer …Simon Pyatt…….
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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2	2	2.1
TP7	8	8	8	8	3.1	3	3	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.42	1.42	1.5	
TP7/TP6	2	2	2	2	1.47	1.5	1.5	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.8V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.2V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.709V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.713V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.354V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.355V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.992V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.995V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.995V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.993V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon191……
Test Engineer…Simon Pyatt……
Date…20/01/10……

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1. Block diagram

2. Test equipment

3. Description

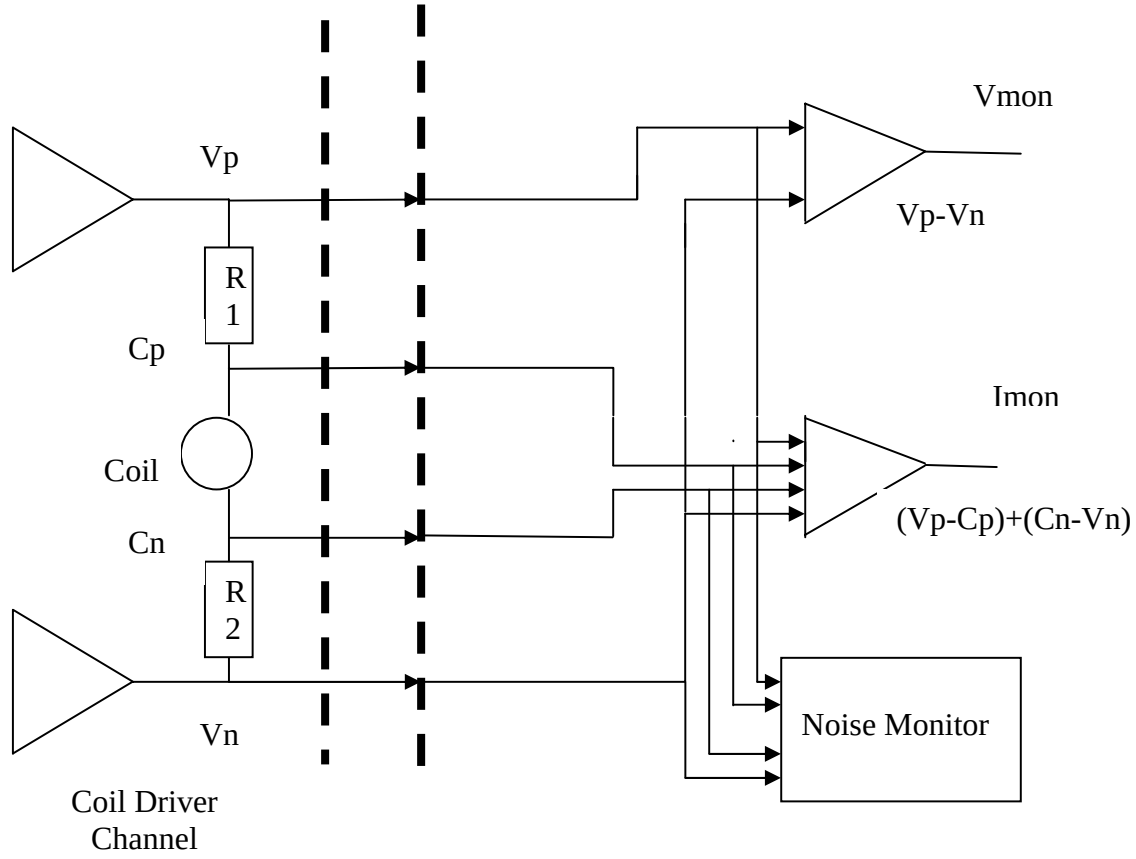
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon191……..
Test Engineer …Simon Pyatt…….
Date …20/01/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.99V	√
-15V (TP6)	-14.96V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon191……...
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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Test Engineer …Simon Pyatt…….
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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2	2.1	2
TP7	8	8	8	8	3.1	3	3.1	3

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.42	1.5	1.42	
TP7/TP6	2	2	2	2	1.47	1.5	1.47	1.5	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.6V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.9V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

Serial No …mon191……..
Test Engineer …Simon Pyatt…….
Date …21/01/10…….

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.710V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.724V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.365V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.997V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.03V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon192……
Test Engineer…Simon Pyatt……
Date…21/01/10……

Contents

1. Block diagram

2. Test equipment

3. Description

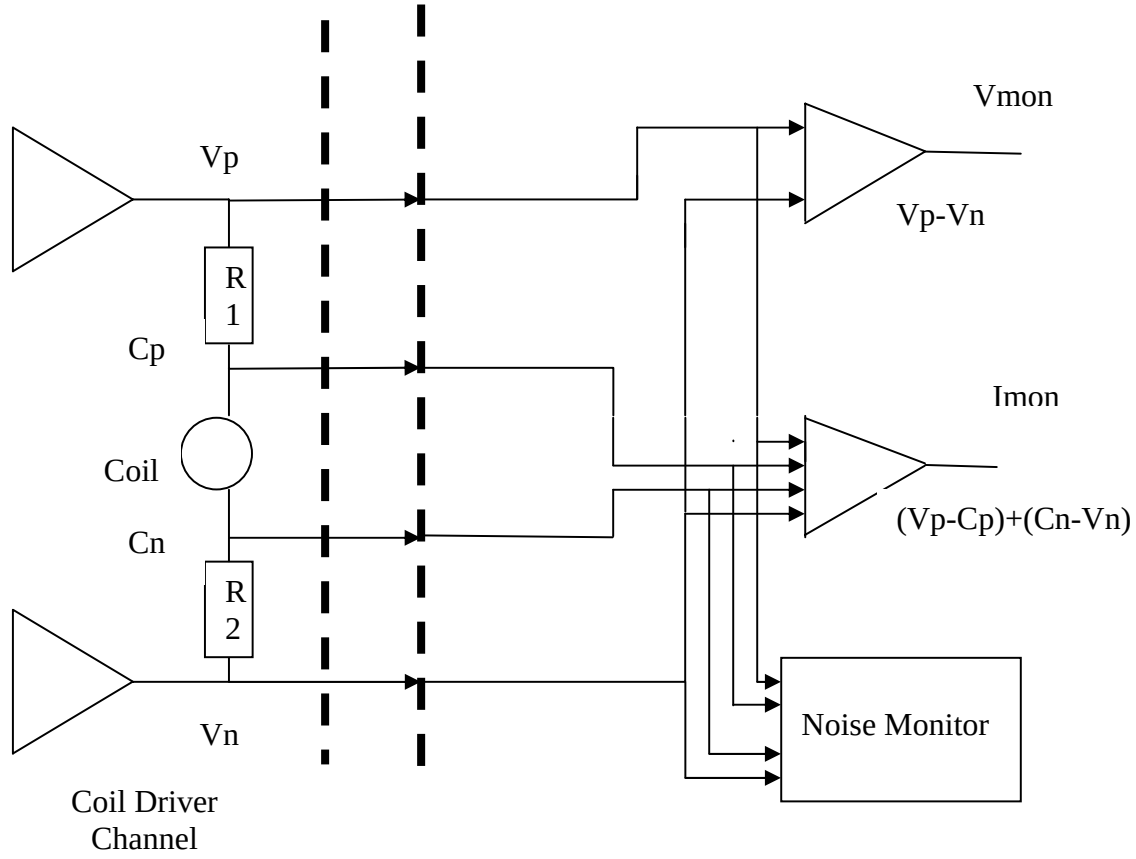
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon192……...
Test Engineer …Simon Pyatt…….
Date …21/01/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.89V	√
-15V (TP6)	-14.92V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon192……...
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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.6V	**1.6V to 1.9V**	√
Ch2	100mV	1.6V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.6V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.9	2.8	2.9	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.45	1.4	1.45	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.708V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.714V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.354V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.359V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon193……
Test Engineer…Simon Pyatt……
Date…21/01/10……

Contents

1. Block diagram

2. Test equipment

3. Description

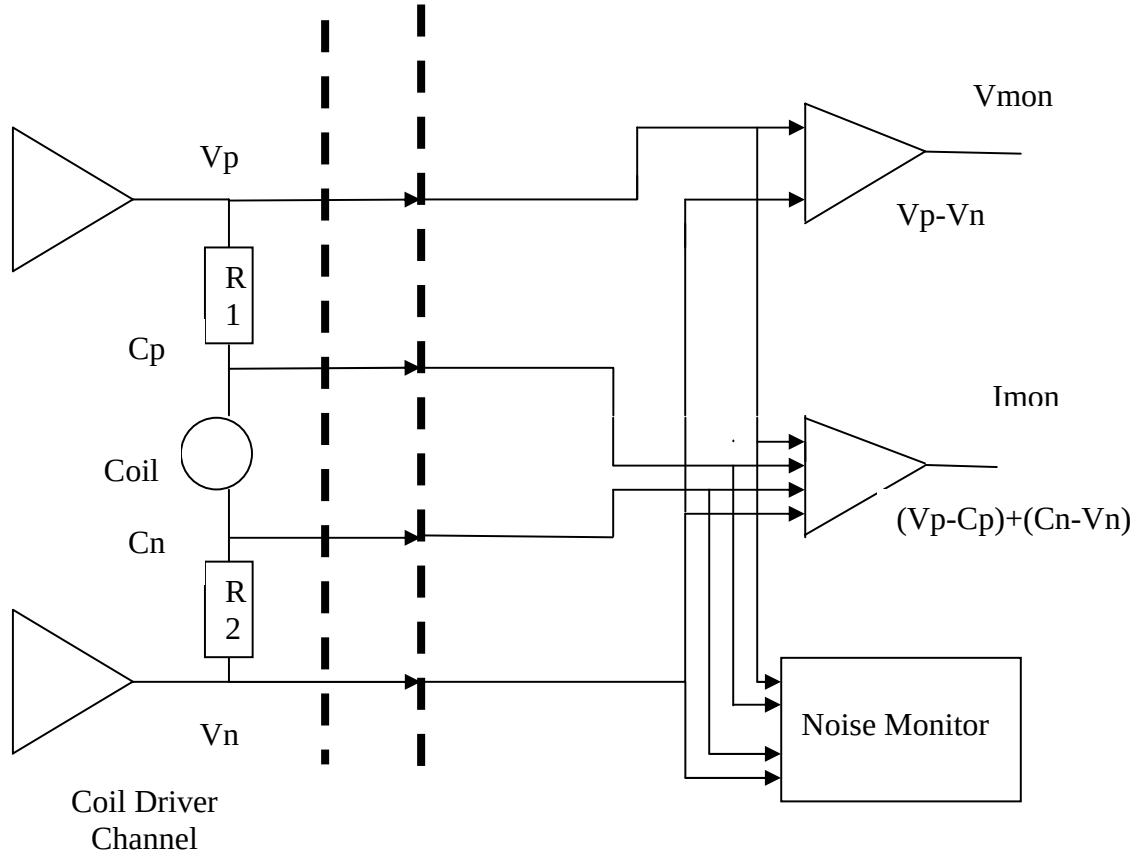
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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Test Engineer …Simon Pyatt…….
Date …21/01/10……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon193……...
Test Engineer …Simon Pyatt…….
Date …21/01/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.94V	√
-15V (TP6)	-15.02V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon193……...
Test Engineer …Simon Pyatt…….
Date …21/01/10……

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	1.9	1.9
TP7	8	8	8	8	2.8	2.9	2.7	2.7

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.35	1.35	
TP7/TP6	2	2	2	2	1.4	1.45	1.42	1.42	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.710V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.710V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.714V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.984V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.988V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.982V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.987V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon194……
Test Engineer…Simon Pyatt……
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Contents

1. Block diagram

2. Test equipment

3. Description

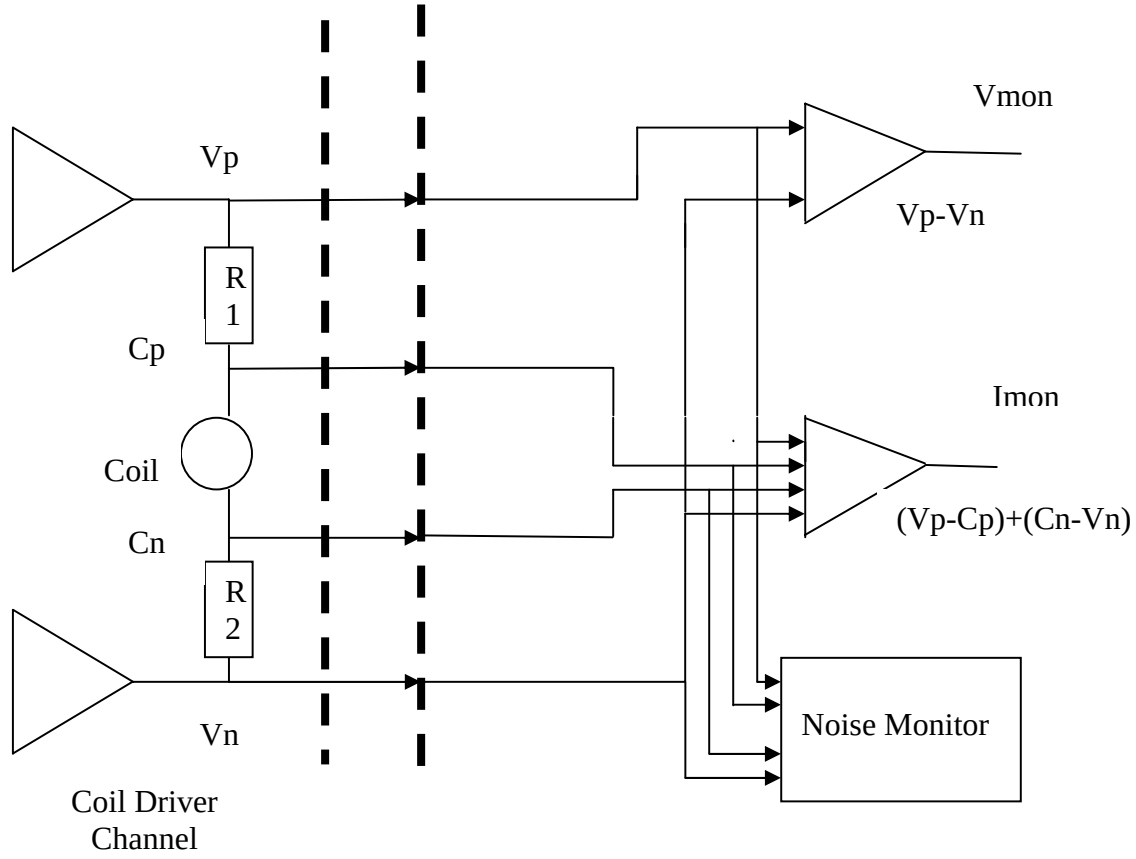
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

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Test Engineer ……
Date ……

NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.89V	√
-15V (TP6)	-14.95V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.8	2.7	2.8	2.7

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.4	1.35	1.4	1.35	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.7V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.7V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.717V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.715V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.362V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.991V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.995V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.991V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.992V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

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1. Block diagram

2. Test equipment

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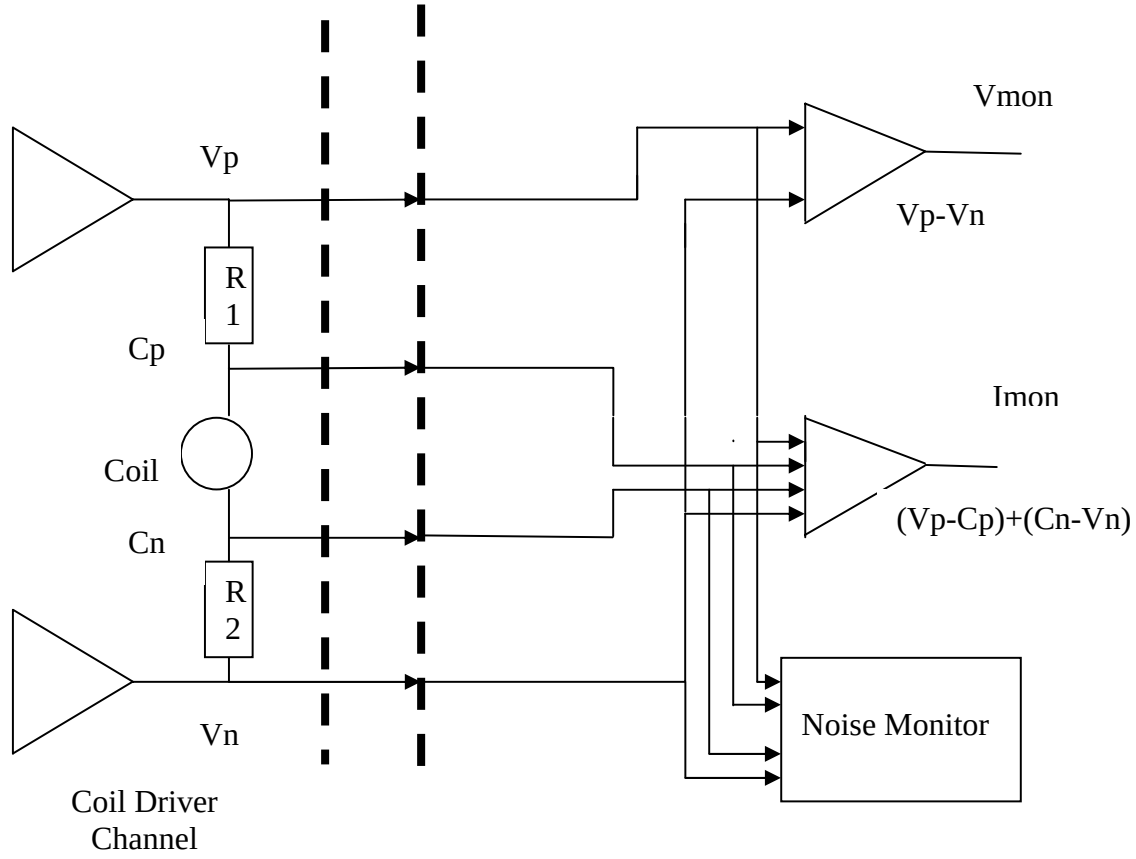
6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

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Test Engineer …Simon Pyatt…….
Date …21/01/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.90V	√
-15V (TP6)	-14.99V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.8	2.8	2.8	2.8

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.4	1.4	1.4	1.4	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.8V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.712V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.355V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.995V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.993V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.990V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.991V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon196……
Test Engineer…Simon Pyatt……
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Contents

1. Block diagram

2. Test equipment

3. Description

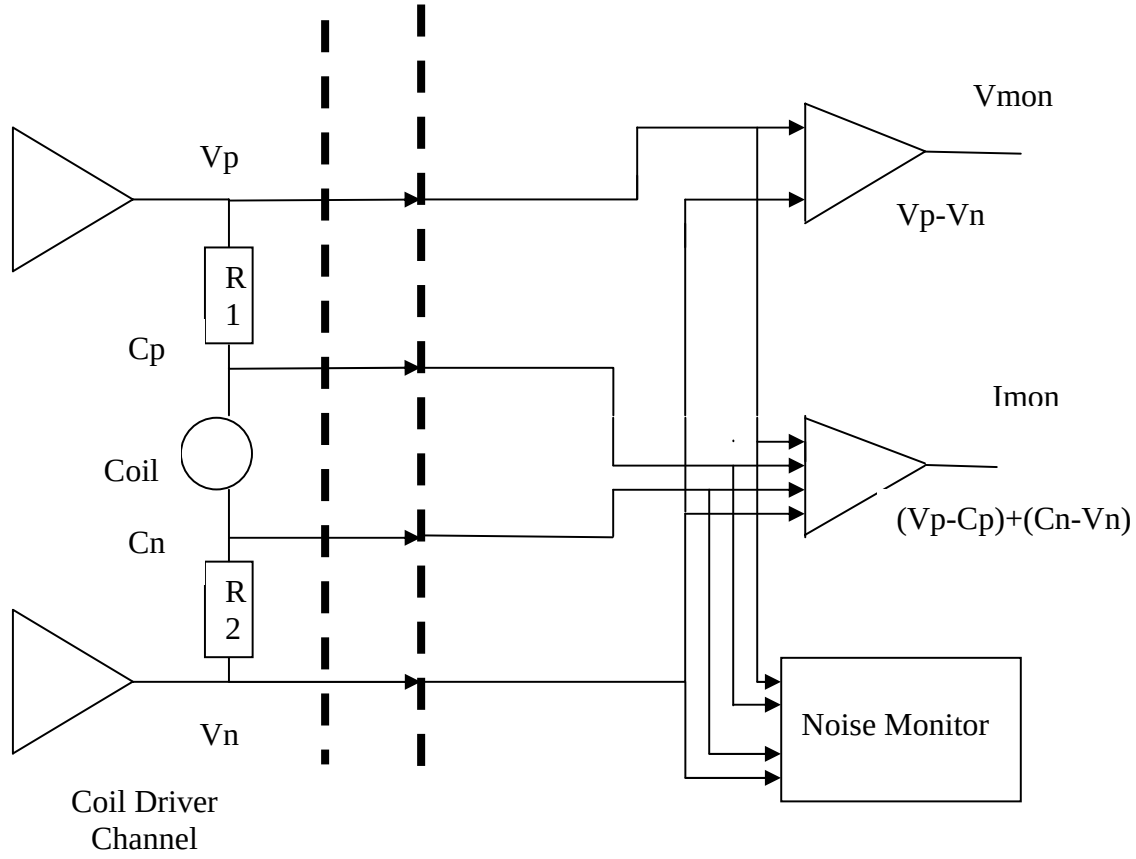
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon196……...
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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.98V	√
-15V (TP6)	-14.97V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.8	2.7	2.8	2.7

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.4	1.35	1.4	1.35	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.719V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.717V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.716V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.363V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.993V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.997V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.995V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.02V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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1. Block diagram

2. Test equipment

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4. Inspection

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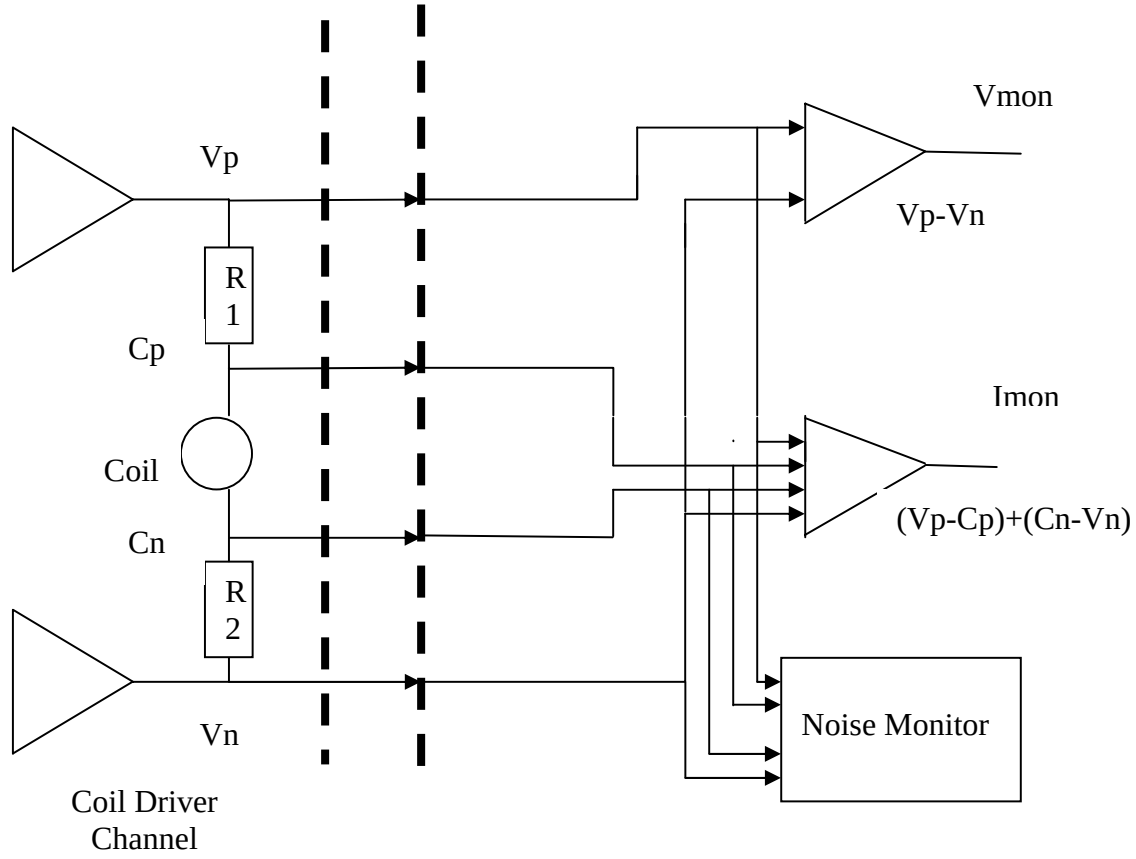
6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon197……...
Test Engineer …Simon Pyatt…….
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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.87V	√
-15V (TP6)	-14.99V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.6V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.8	2.8	2.8	2.8

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.4	1.4	1.4	1.4	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.6V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.722V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.718V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.360V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.364V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.360V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.997V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.992V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.999V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon198……
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Contents

1. Block diagram

2. Test equipment

3. Description

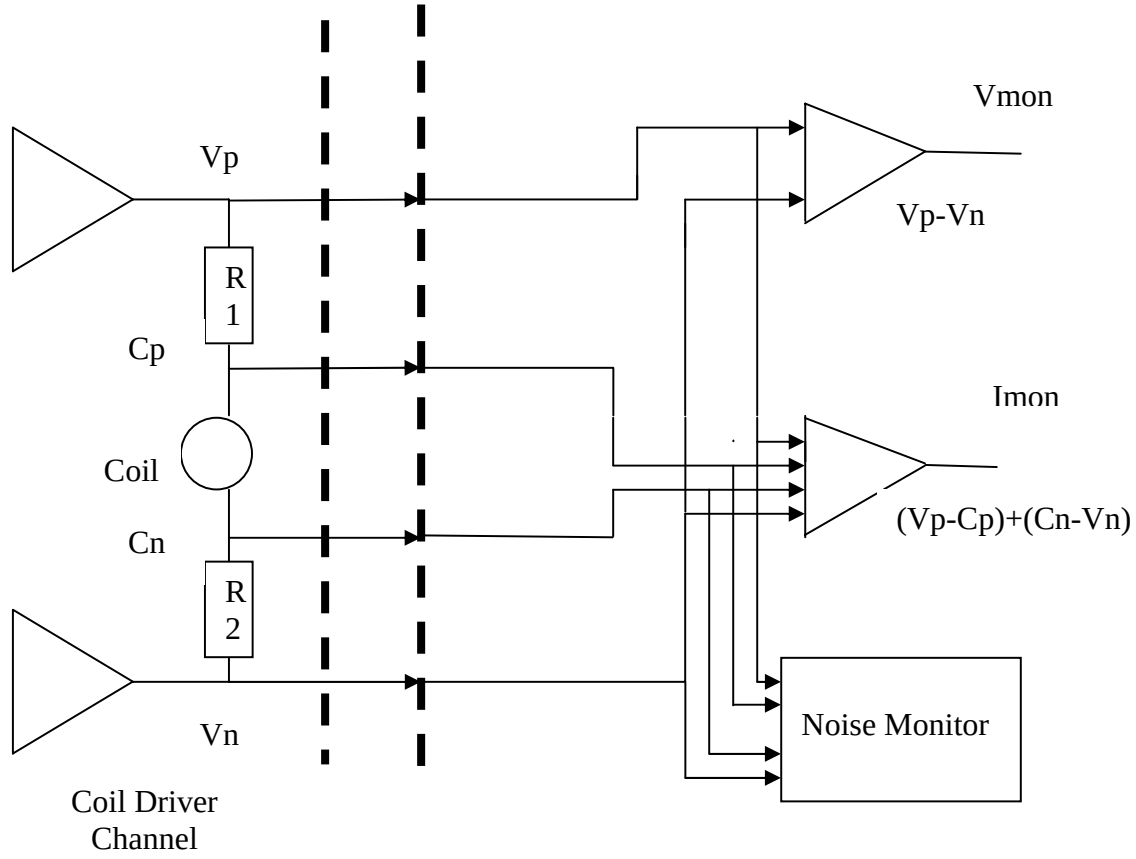
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon198……...
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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.84V	√
-15V (TP6)	-14.96V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2	2.1	2
TP7	8	8	8	8	3.1	3	3.1	3

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.47	1.5	1.47	1.5	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.6V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.8V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.6V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.712V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.356V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.991V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.984V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.991V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.986V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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1. Block diagram

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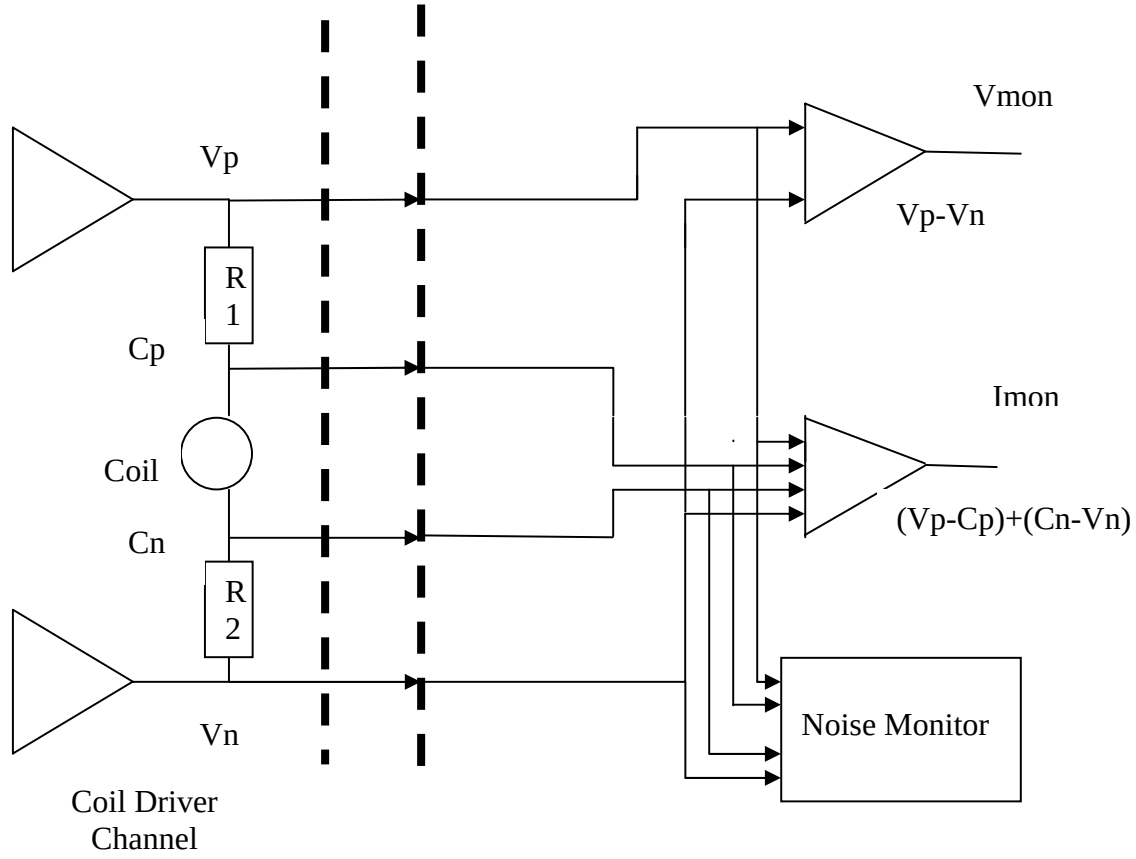
6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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Test Engineer …Simon Pyatt…….
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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon199……...
Test Engineer …Simon Pyatt…….
Date …25/01/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.80V	√
-15V (TP6)	-15.00V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon199……...
Test Engineer …Simon Pyatt…….
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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2.1	2.1
TP7	8	8	8	8	3.1	3.1	3.1	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.47	1.47	1.47	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.9V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.8V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√

Serial No …mon199……...
Test Engineer …Simon Pyatt…….
Date …25/01/10…….

6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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Test Engineer …Simon Pyatt…….
Date …26/01/10…….

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.714V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.04V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon200……
Test Engineer…Simon Pyatt……
Date…02/03/10……

Contents

1. Block diagram

2. Test equipment

3. Description

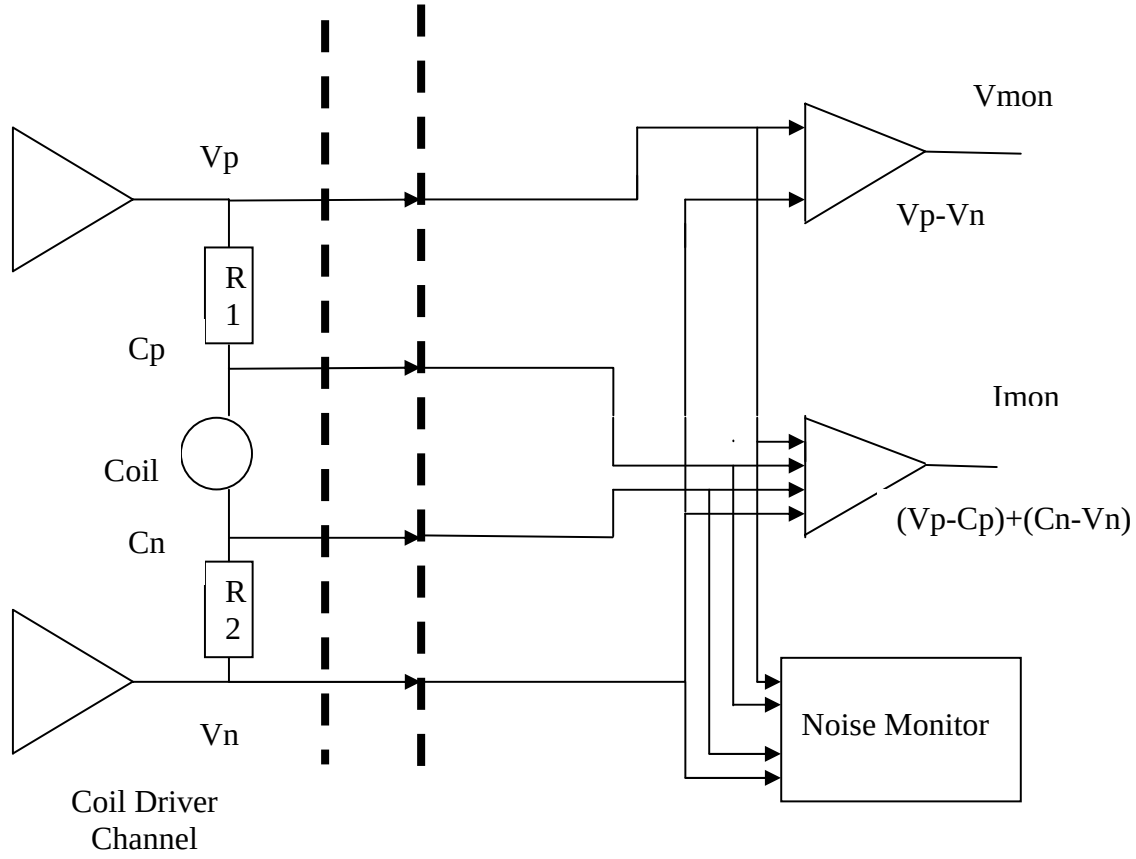
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

Serial No …mon200……..
Test Engineer …Simon Pyatt……
Date …02/03/10……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

RMS to DC converter (736JRZ) replaced. Original was faulty.

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon200……...
Test Engineer …Simon Pyatt…….
Date …02/03/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.86V	√
-15V (TP6)	-14.98V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon200……...
Test Engineer …Simon Pyatt…….
Date …02/03/10…….

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

Serial No …mon200……...
Test Engineer …Simon Pyatt…….
Date …02/03/10…….

Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Test Engineer …Simon Pyatt…….
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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.9	3	2.9	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.45	1.5	1.45	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.8V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.9V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	5V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.8V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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Test Engineer …Simon Pyatt…….
Date …03/03/10…….

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.710V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.713V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.356V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.982V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.987V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.987V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.985V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon201……
Test Engineer…Simon Pyatt……
Date…03/03/10……

Contents

1. Block diagram

2. Test equipment

3. Description

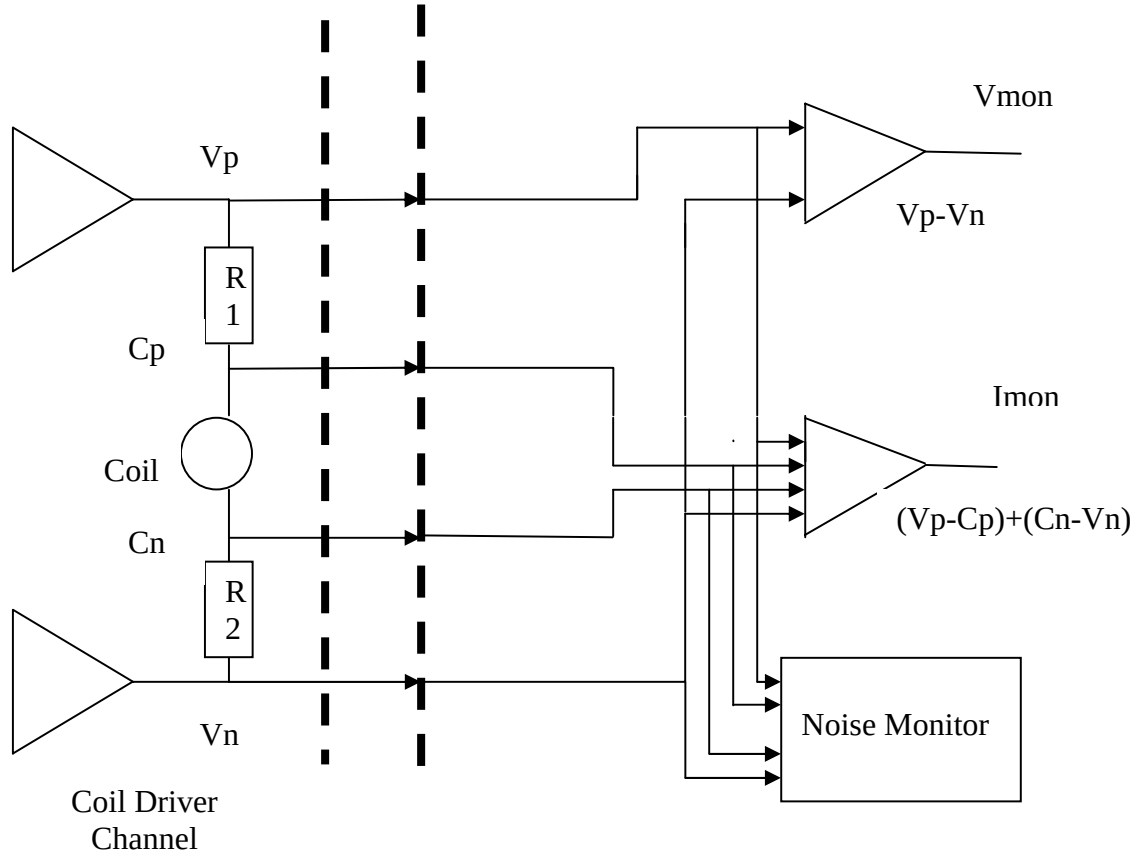
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

Serial No …mon201……..
Test Engineer …Simon Pyatt…….
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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon201……...
Test Engineer …Simon Pyatt…….
Date …03/03/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.88V	√
-15V (TP6)	-14.84V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon201……...
Test Engineer …Simon Pyatt…….
Date …03/03/10……

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

Serial No …mon201……...
Test Engineer …Simon Pyatt…….
Date …03/03/10……

Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

Serial No …mon201……..
Test Engineer …Simon Pyatt…….
Date …03/03/10……

Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.8	2.8	2.9	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.4	1.4	1.45	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.6V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√

Serial No …mon201……...
Test Engineer …Simon Pyatt…….
Date …03/03/10…….

6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

Serial No …mon201……..
Test Engineer …Simon Pyatt…….
Date …03/03/10…….

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.718V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.715V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.361V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.359V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.981V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.981V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.986V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.981V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon202……
Test Engineer…Simon Pyatt……
Date…03/03/10……

Contents

1. Block diagram

2. Test equipment

3. Description

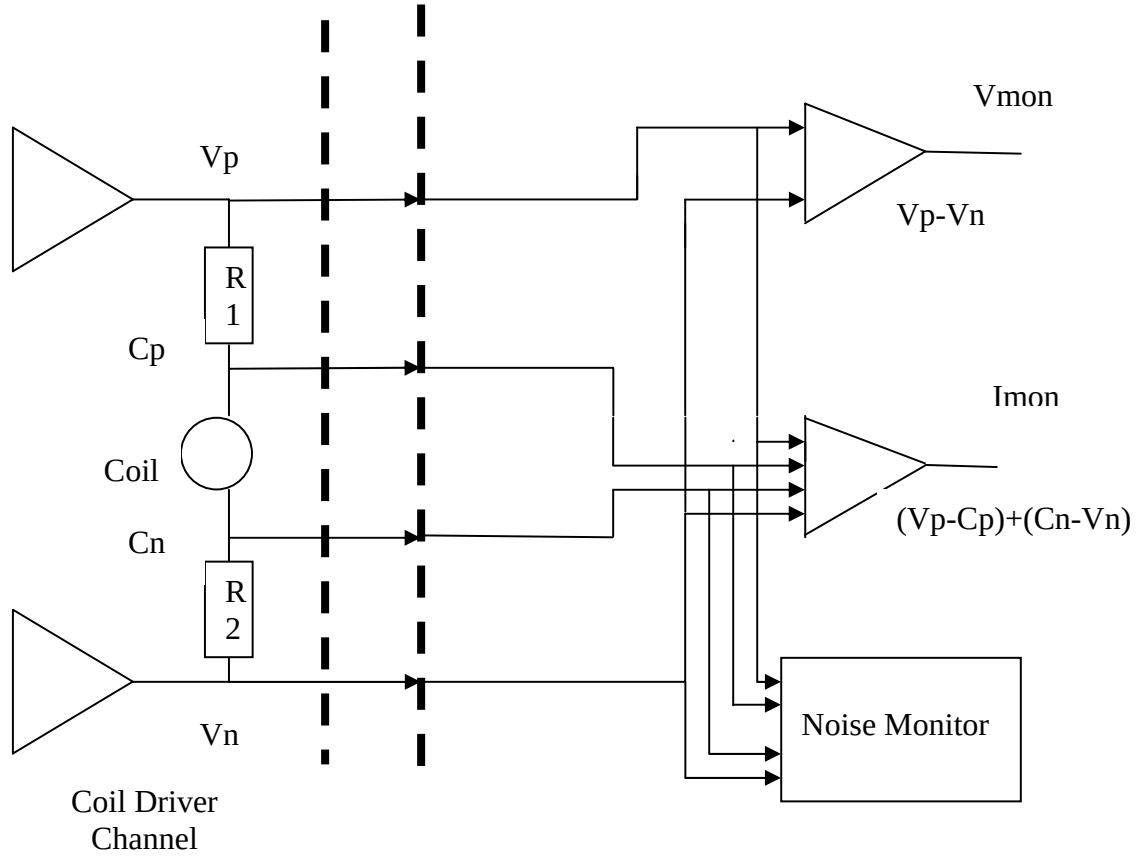
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

Serial No …mon202……..
Test Engineer …Simon Pyatt…….
Date …03/03/10……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Positive regulator (LM2940CS) replaced. Original was faulty.

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon202……..
Test Engineer …Simon Pyatt…….
Date …03/03/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.86V	√
-15V (TP6)	-15.00V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon202……...
Test Engineer …Simon Pyatt…….
Date …03/03/10……

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Test Engineer …Simon Pyatt…….
Date …03/03/10……

Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

Serial No …mon202……..
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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.8	2.8	2.9	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.4	1.4	1.45	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√

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Test Engineer …Simon Pyatt…….
Date …03/03/10…….

6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

Serial No …mon202……...
Test Engineer …Simon Pyatt…….
Date …03/03/10……

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.717V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.712V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.356V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon203……
Test Engineer…Simon Pyatt……
Date…03/03/10……

Contents

1. Block diagram

2. Test equipment

3. Description

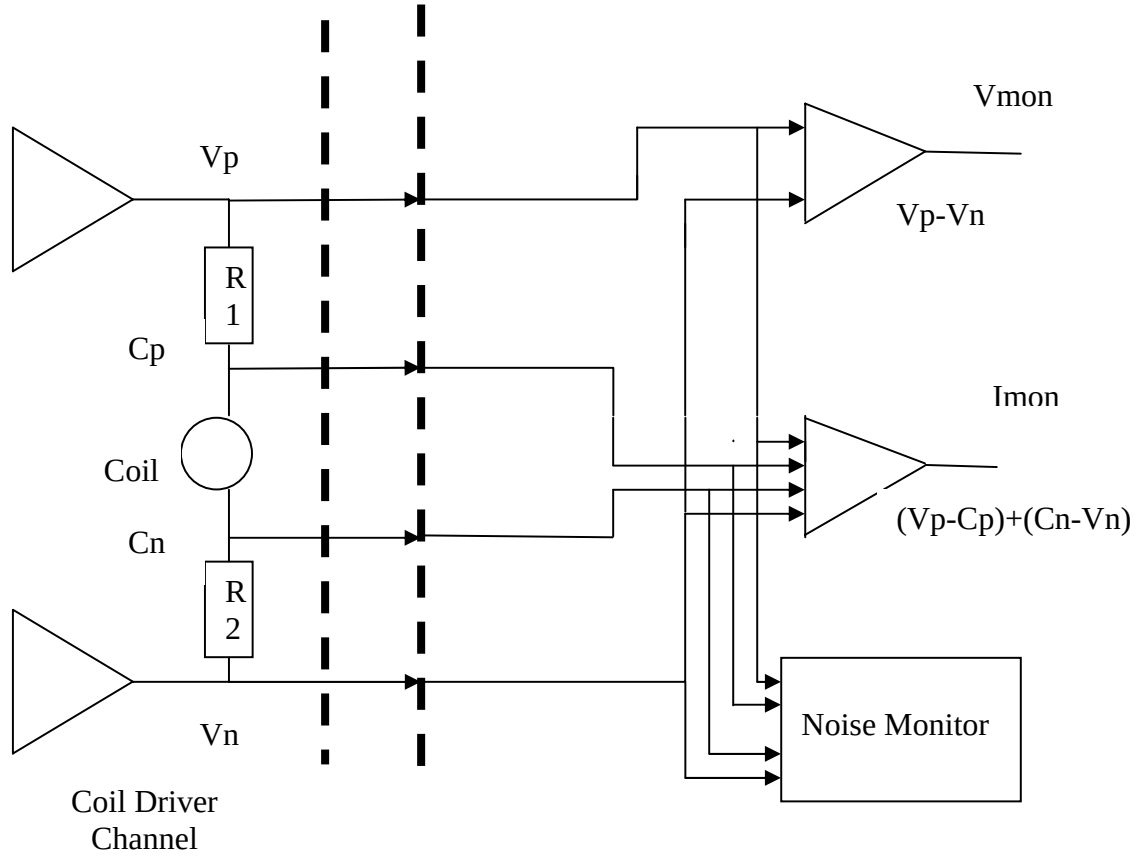
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

Serial No …mon203……..
Test Engineer …Simon Pyatt…….
Date …03/03/10……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Positive regulator (LM2940CS) replaced. Original was faulty.

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon203……..
Test Engineer …Simon Pyatt…….
Date …03/03/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.92V	√
-15V (TP6)	-14.98V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon203……...
Test Engineer …Simon Pyatt…….
Date …03/03/10…….

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

Serial No …mon203……...
Test Engineer …Simon Pyatt…….
Date …03/03/10…….

Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

Serial No …mon203……..
Test Engineer …Simon Pyatt…….
Date …03/03/10……

Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.8	2.9	2.9	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.4	1.45	1.45	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.7V	4 to 5.5V	√

Serial No …mon203……...
Test Engineer …Simon Pyatt…….
Date …03/03/10…….

6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

Serial No …mon203……...
Test Engineer …Simon Pyatt…….
Date …03/03/10…….

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.710V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.712V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.982V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.984V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.984V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.981V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon204……
Test Engineer…Simon Pyatt……
Date…04/03/10……

Contents

1. Block diagram

2. Test equipment

3. Description

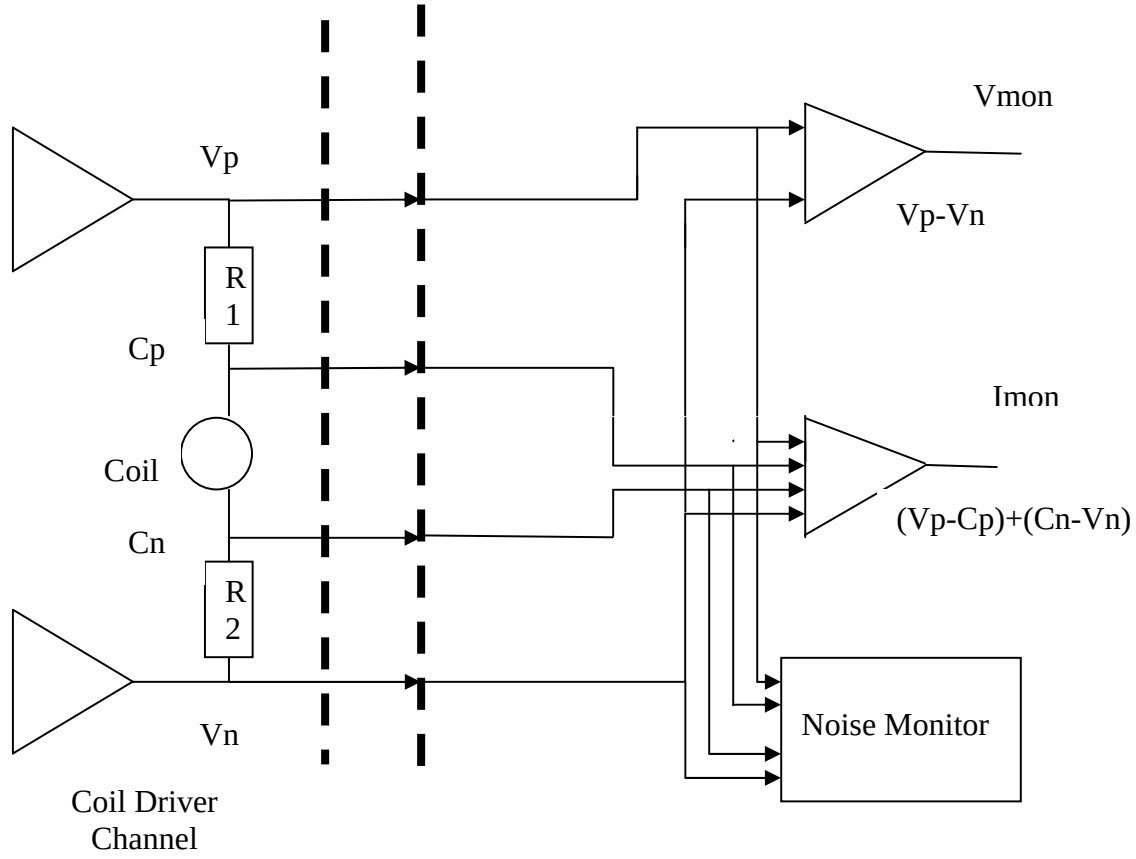
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

Serial No …mon204……..
Test Engineer …Simon Pyatt…….
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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Positive regulator (LM2940CS) replaced. Original was faulty.

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon204……..
Test Engineer …Simon Pyatt…….
Date …04/03/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.92V	√
-15V (TP6)	-15.07V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon204……...
Test Engineer …Simon Pyatt…….
Date …04/03/10…….

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Test Engineer …Simon Pyatt…….
Date …04/03/10…….

Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Test Engineer …Simon Pyatt…….
Date …04/03/10……

Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	3	2.8	2.8	2.8

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.5	1.4	1.4	1.4	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.9V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.8V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√

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Date …04/03/10…….

6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

Serial No …mon204……..
Test Engineer …Simon Pyatt…….
Date …04/03/10…….

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.709V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.714V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.353V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.989V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.986V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.980V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.986V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon205……
Test Engineer…Simon Pyatt……
Date…04/03/10……

Contents

1. Block diagram

2. Test equipment

3. Description

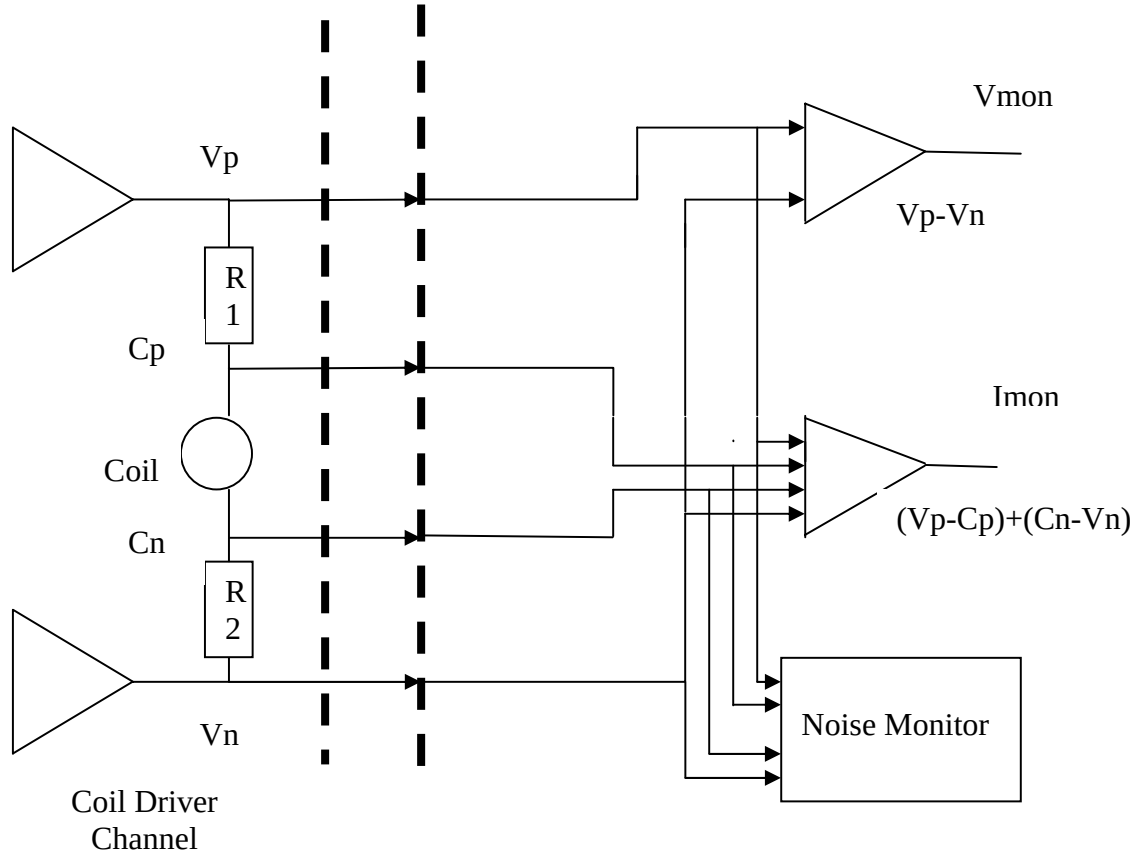
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

Serial No …mon205……..
Test Engineer …Simon Pyatt…….
Date …04/03/10……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Positive regulator (LM2940CS) replaced. Original was faulty.

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon205……..
Test Engineer …Simon Pyatt…….
Date …04/03/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.85V	√
-15V (TP6)	-14.94V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon205……...
Test Engineer …Simon Pyatt…….
Date …04/03/10…….

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.8	2.8	2.9	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.4	1.4	1.45	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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Test Engineer …Simon Pyatt…….
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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.709V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.354V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.990V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.989V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.989V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.980V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon206……
Test Engineer…Simon Pyatt……
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Contents

1. Block diagram

2. Test equipment

3. Description

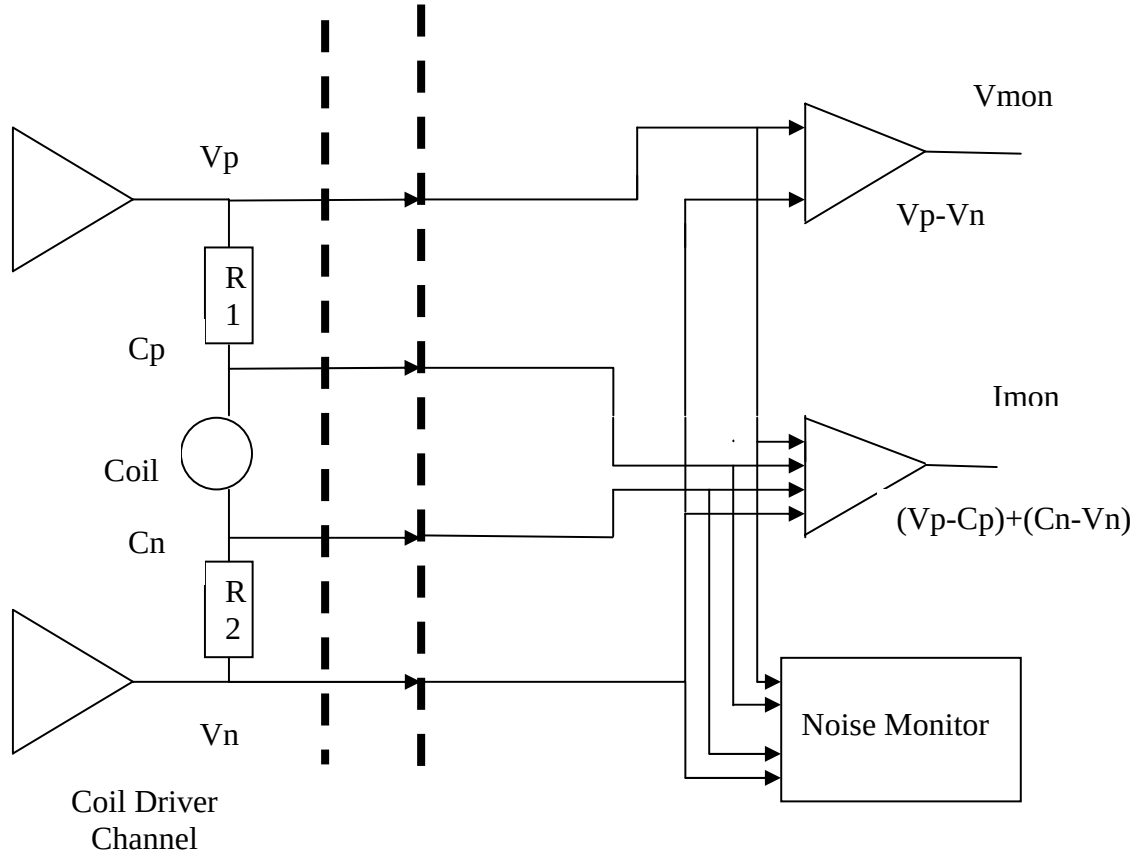
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

RMS to DC converter (736JRZ) Channel 4 replaced. Original was faulty.

Serial No ……...
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Date ……

NOTES

Serial No …mon206……..
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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.99V	√
-15V (TP6)	-15.03V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2.1	2.1
TP7	8	8	8	8	3.1	3.1	3.1	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.47	1.47	1.47	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.6V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.6V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.7V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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Test Engineer …Simon Pyatt…….
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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.715V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.02V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.02V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon207……
Test Engineer…Simon Pyatt……
Date…05/03/10……

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1. Block diagram

2. Test equipment

3. Description

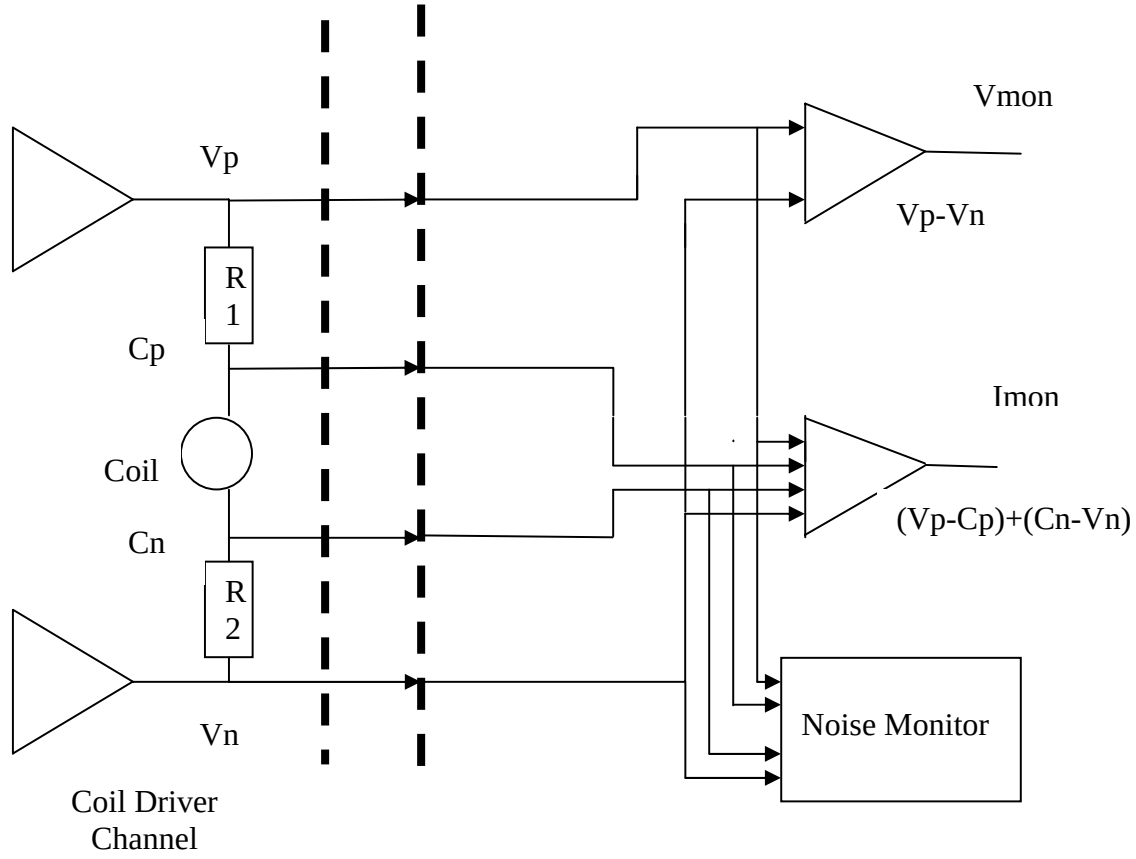
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

RMS to DC converter (736JRZ) replaced. Original was faulty.

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon207……..
Test Engineer …Simon Pyatt…….
Date …05/03/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.87V	√
-15V (TP6)	-15.07V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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Test Engineer …Simon Pyatt…….
Date …05/03/10……

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.9	2.8	2.9	2.8

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.45	1.4	1.45	1.4	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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Test Engineer …Simon Pyatt…….
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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.708V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.713V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.360V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.353V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.988V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.984V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.978V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.982V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon208……
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Contents

1. Block diagram

2. Test equipment

3. Description

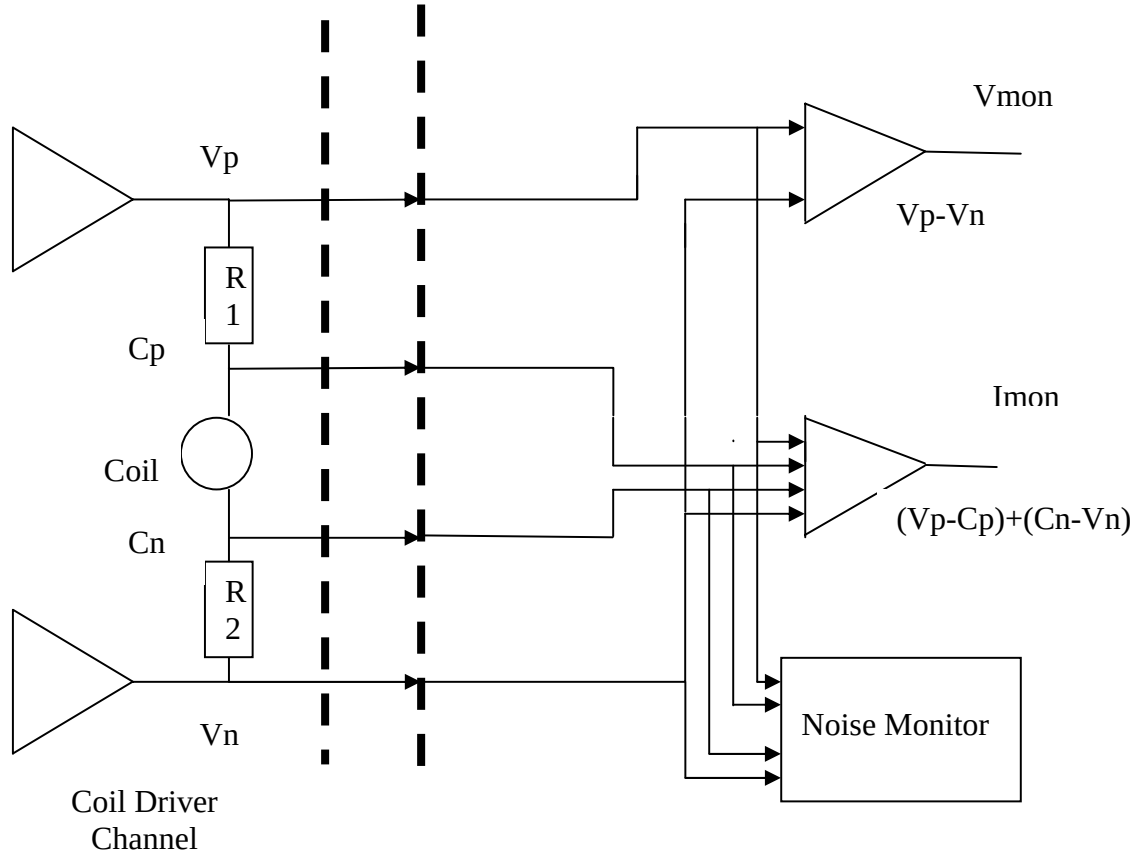
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

RMS to DC converter (736JRZ) channel 1 replaced. Original was faulty.

Serial No ……...
Test Engineer ……
Date ……

NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.88V	√
-15V (TP6)	-15.04V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2.1	2.1
TP7	8	8	8	8	3.1	3.1	3.1	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.47	1.47	1.47	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.718V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.717V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.361V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.359V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.987V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.991V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.985V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.988V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon209……
Test Engineer…Simon Pyatt……
Date…05/03/10……

Contents

1. Block diagram

2. Test equipment

3. Description

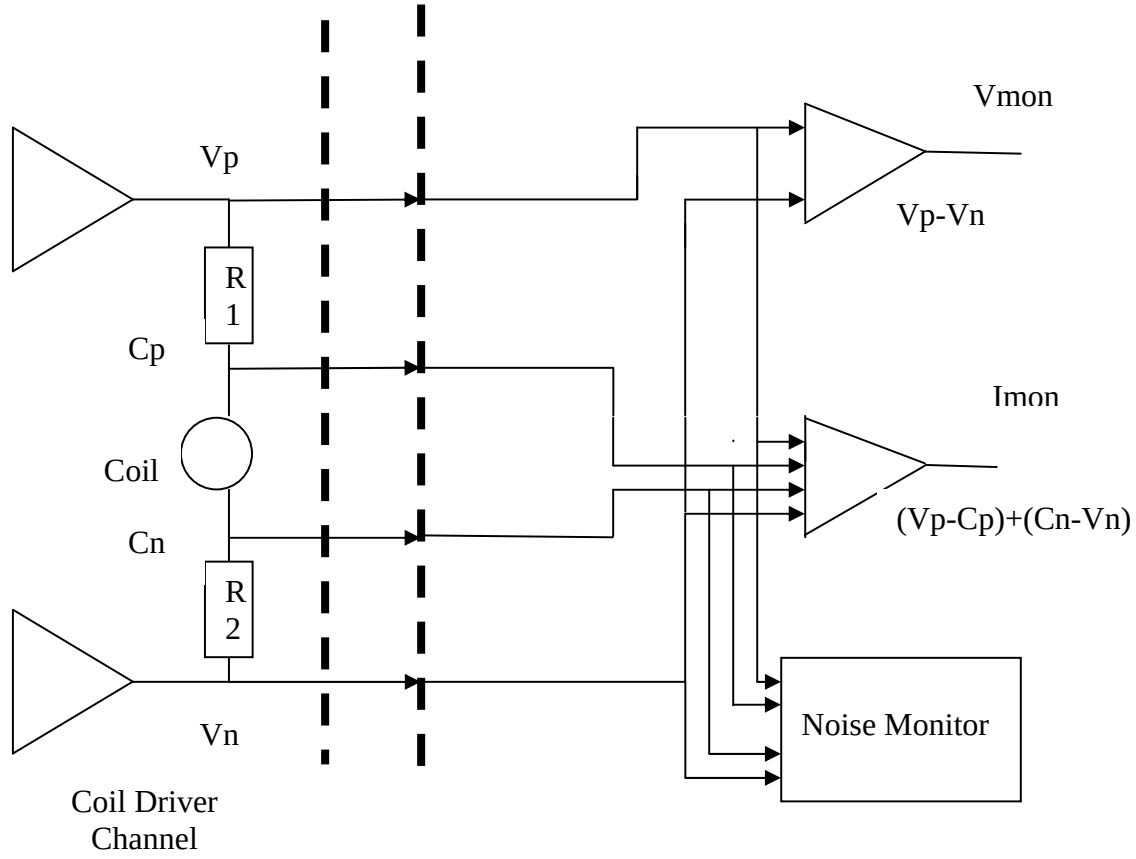
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

Serial No …mon209……..
Test Engineer …Simon Pyatt…….
Date …05/03/10……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Positive regulator (LM2940CS) replaced. Original was faulty.

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon209……..
Test Engineer …Simon Pyatt…….
Date …05/03/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.90V	√
-15V (TP6)	-14.99V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon209……...
Test Engineer …Simon Pyatt…….
Date …05/03/10…….

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

Serial No …mon209……..
Test Engineer …Simon Pyatt…….
Date …05/03/10…….

Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

Serial No …mon209……..
Test Engineer …Simon Pyatt…….
Date …05/03/10…….

Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.8	2.9	2.9	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.4	1.45	1.45	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.5	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.7	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.4	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.5	4 to 5.5V	√

Serial No …mon209……...
Test Engineer …Simon Pyatt…….
Date …05/03/10…….

6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

Serial No …mon209……..
Test Engineer …Simon Pyatt…….
Date …05/03/10…….

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.710V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.714V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon210……
Test Engineer…Simon Pyatt……
Date…05/03/10……

Contents

1. Block diagram

2. Test equipment

3. Description

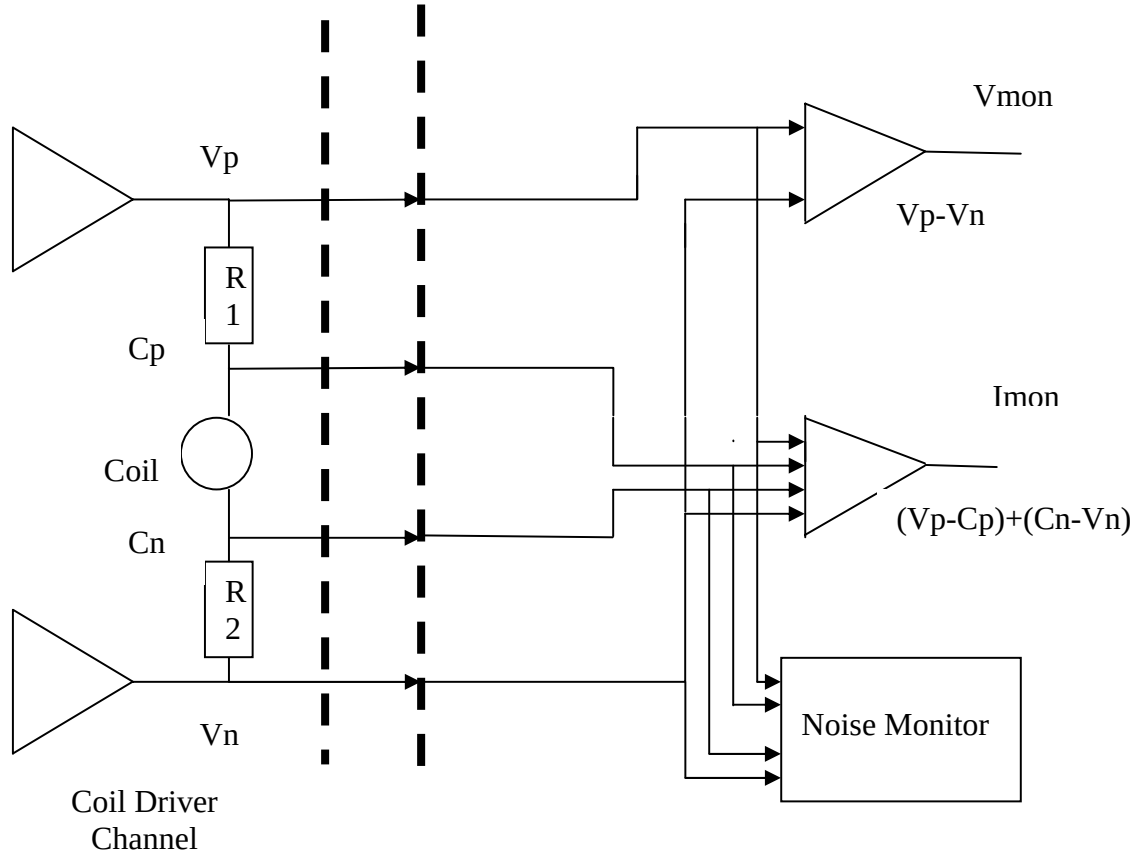
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

Serial No …mon210……..
Test Engineer …Simon Pyatt……
Date …05/03/10……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Positive regulator (LM2940CS) replaced. Original was faulty.

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon210……...
Test Engineer …Simon Pyatt…….
Date …05/03/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.88V	√
-15V (TP6)	-15.04V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon210……...
Test Engineer …Simon Pyatt…….
Date …05/03/10……

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

Serial No …mon210……..
Test Engineer …Simon Pyatt…….
Date …08/03/10…….

Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

Serial No …mon210……..
Test Engineer …Simon Pyatt…….
Date …08/03/10…….

Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2	2
TP7	8	8	8	8	3.1	3.1	2.9	3

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.42	1.42	
TP7/TP6	2	2	2	2	1.47	1.47	1.45	1.5	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.6V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.8V	4 to 5.5V	√

Serial No …mon210……...
Test Engineer …Simon Pyatt…….
Date …08/03/10…….

6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

Serial No …mon210……..
Test Engineer …Simon Pyatt…….
Date …08/03/10…….

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.722V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.711V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.364V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.355V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.997V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.985V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.986V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.983V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.02V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon211……
Test Engineer…Simon Pyatt……
Date…09/03/10……

Contents

1. Block diagram

2. Test equipment

3. Description

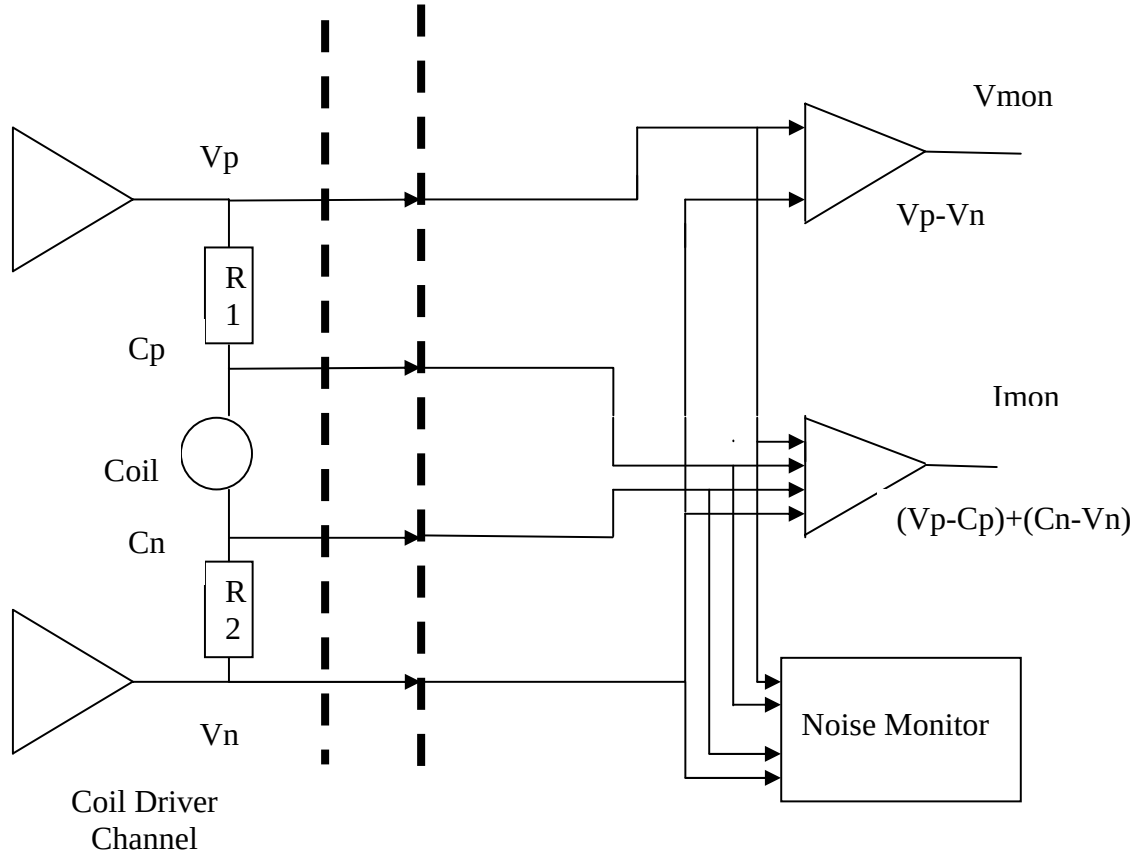
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Positive regulator (LM2940CS) replaced. Original was faulty.

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NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.91V	√
-15V (TP6)	-14.93V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.8V	**4.7V to 5.2V**	√
Ch2		4.8V	**4.7V to 5.2V**	√
Ch3		4.8V	**4.7V to 5.2V**	√
Ch4		4.8V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2.1	2.1
TP7	8	8	8	8	3.1	3.1	3.1	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.47	1.47	1.47	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.6V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.6V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.714V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.994V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.994V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.988V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.991V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon212……
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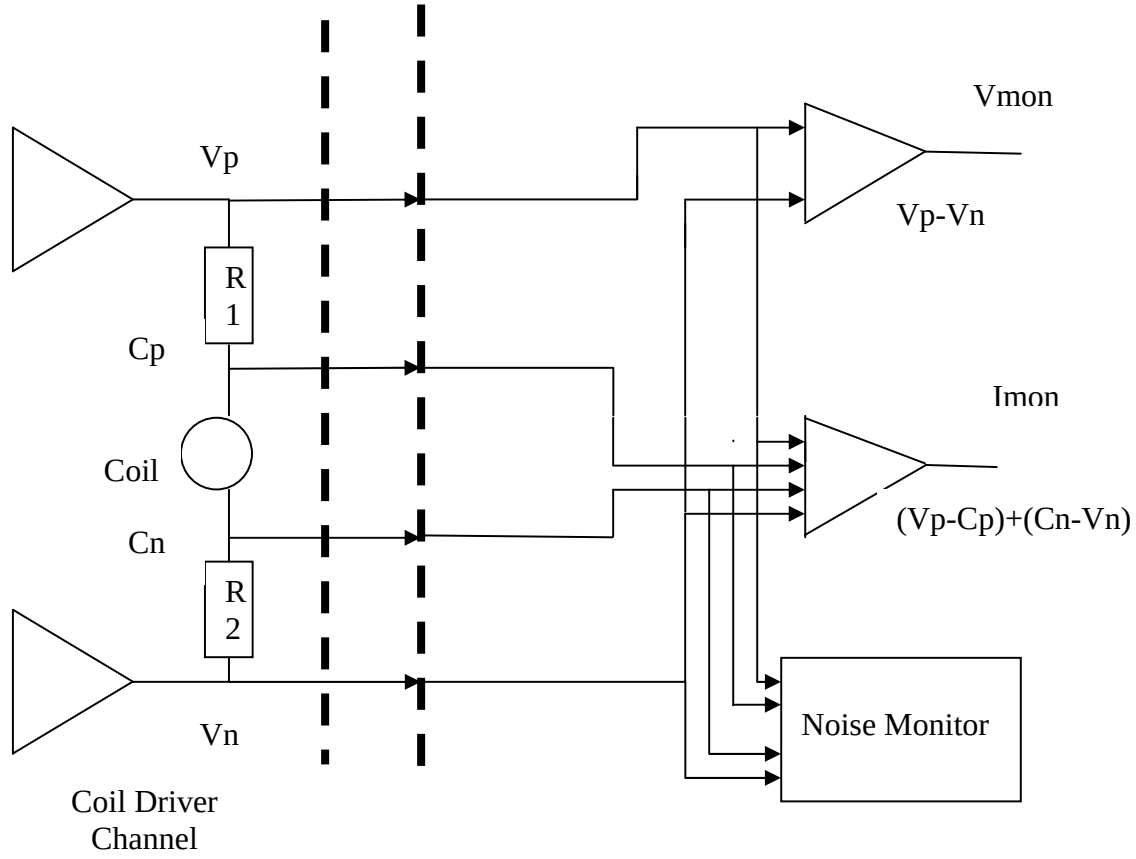
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

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Date ……

NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.97V	√
-15V (TP6)	-15.03V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.9	3	2.9	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.45	1.5	1.45	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.3V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.6V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.717V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.717V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.360V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.359V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.02V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.02V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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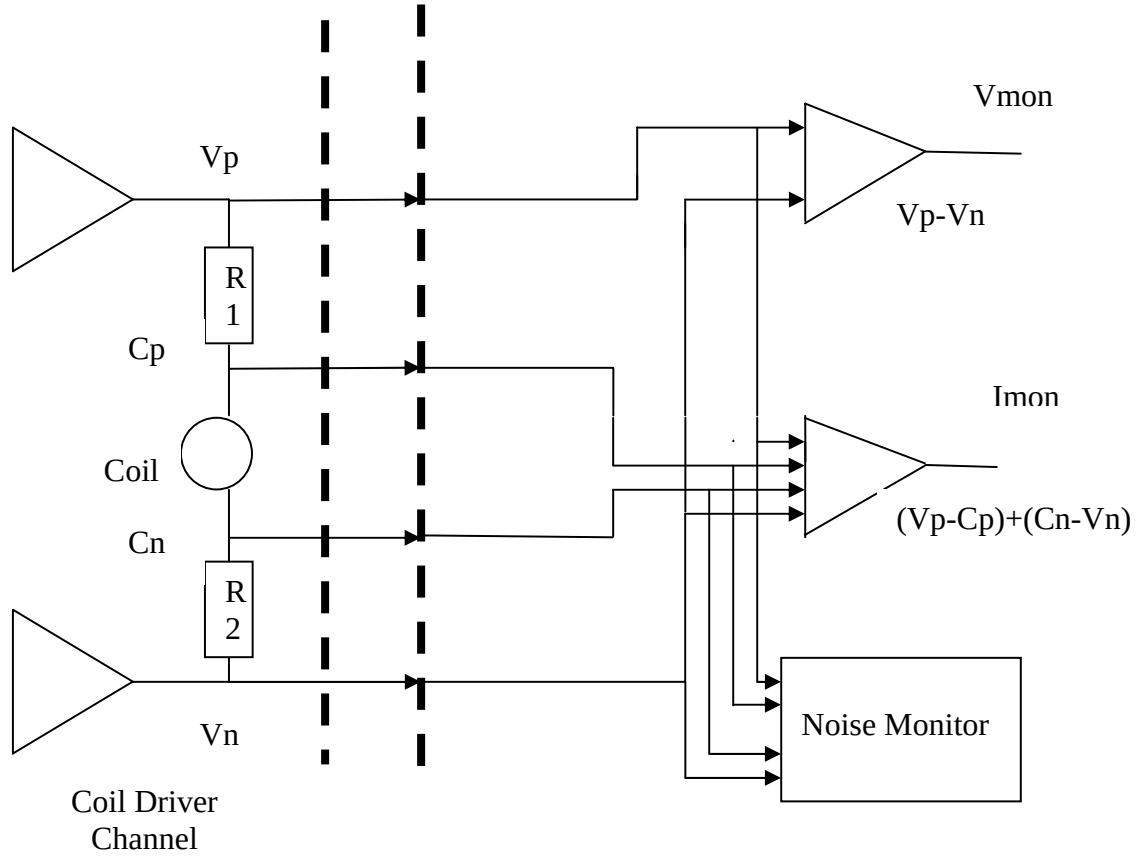
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

Serial No …mon213……..
Test Engineer …Simon Pyatt…….
Date …10/03/10……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Positive regulator (LM2940CS) replaced. Original was faulty.

Serial No ……...
Test Engineer ……
Date ……

NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.89V	√
-15V (TP6)	-14.96V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Test Engineer …Simon Pyatt…….
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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.8V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	3.9	3.9	3.9	3.9	2	2.1	2.1	2.1
TP7	7.8	7.8	7.8	7.8	3	3.1	3.1	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	1.95	1.95	1.95	1.95	1.42	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.5	1.47	1.47	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.8V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.716V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.359V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.988V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.991V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.984V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.988V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.02V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon214……
Test Engineer…Simon Pyatt……
Date…10/03/10……

Contents

1. Block diagram

2. Test equipment

3. Description

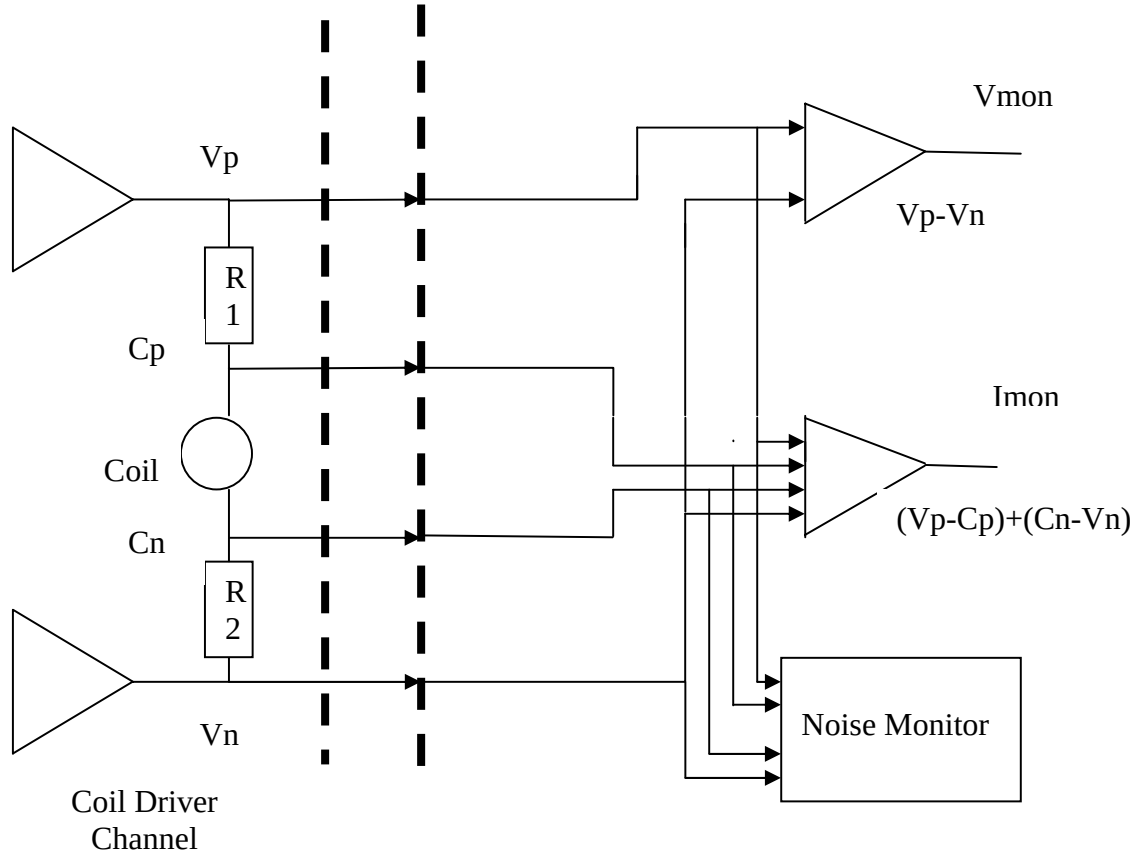
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Removed trapped metal debris caught under IC8 which was shorting pins causing it to malfunction.

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Test Engineer ……
Date ……

NOTES

Serial No …mon214……..
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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.88V	√
-15V (TP6)	-15.00V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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Test Engineer …Simon Pyatt…….
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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.8	2.8	2.9	2.8

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.4	1.4	1.45	1.4	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

Serial No …mon214……..
Test Engineer …Simon Pyatt…….
Date …10/03/10…….

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.711V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.356V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.992V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.987V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.988V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.985V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon215……
Test Engineer…Simon Pyatt……
Date…10/03/10……

Contents

1. Block diagram

2. Test equipment

3. Description

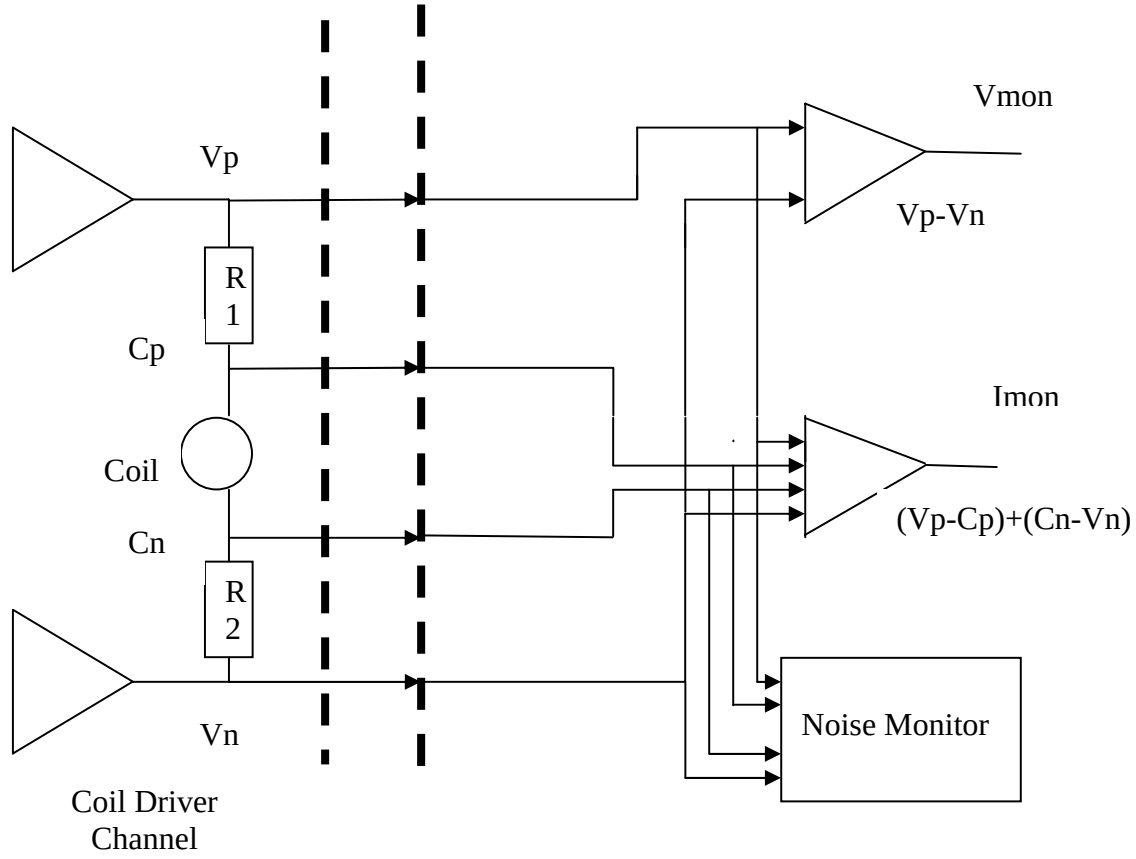
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK? Slightly smeared silk screen**
Solder joint **OK?** √
Placement **OK?** √

Modifications

Channel 1 RMS to DC (736JRZ) converter replaced. Original was faulty.

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon215……..
Test Engineer …Simon Pyatt…….
Date …10/03/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.83V	√
-15V (TP6)	-14.97V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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Test Engineer …Simon Pyatt…….
Date …10/03/10……

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Test Engineer …Simon Pyatt…….
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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.6V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2.1	2	2
TP7	8	8	8	8	2.8	3.1	2.9	2.8

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.5	1.42	1.42	
TP7/TP6	2	2	2	2	1.4	1.47	1.45	1.4	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.6V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.713V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.356V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.986V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.983V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.982V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.983V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.02V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon216……
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Date…10/03/10……

Contents

1. Block diagram

2. Test equipment

3. Description

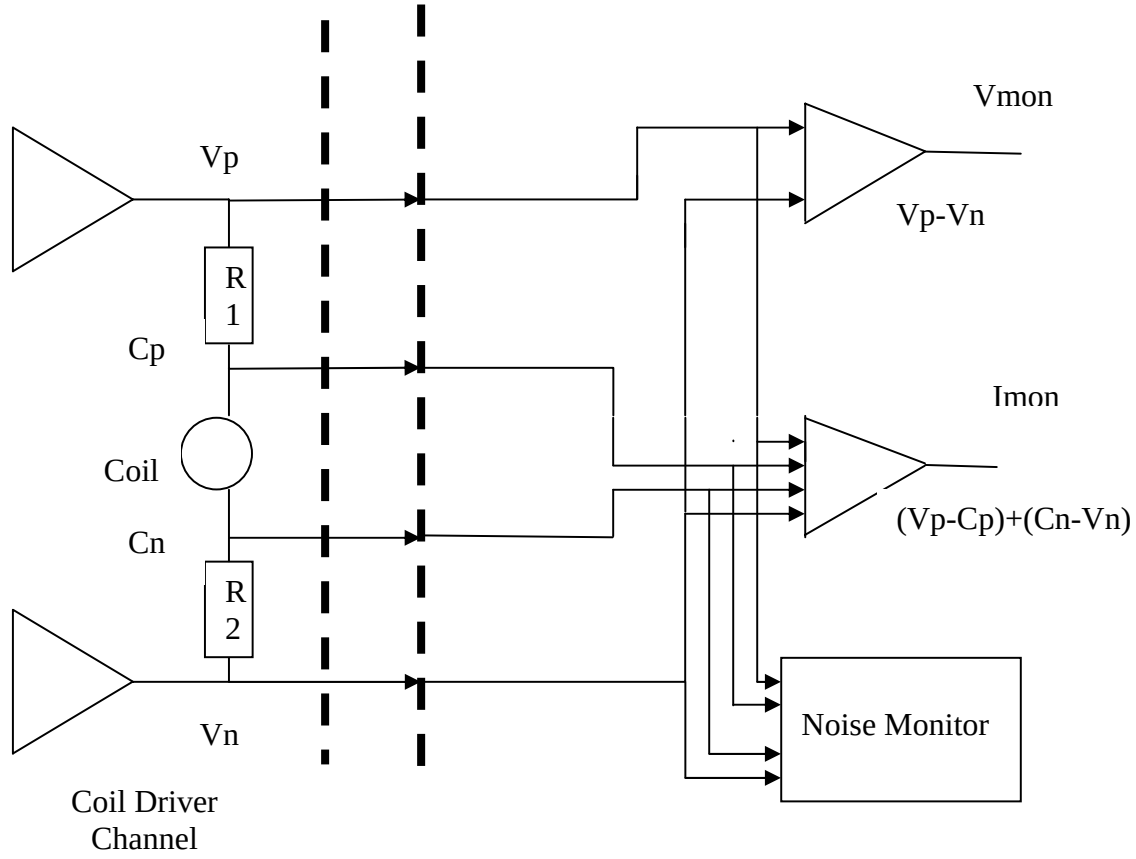
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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Test Engineer …Simon Pyatt…….
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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Channel 3 RMS to DC (736JRZ) replaced. Original was faulty.

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon216……..
Test Engineer …Simon Pyatt…….
Date …10/03/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	15.01V	√
-15V (TP6)	-14.96V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon216……...
Test Engineer …Simon Pyatt…….
Date …10/03/10…….

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Test Engineer …Simon Pyatt…….
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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.5	1.4	1.4	1.4
TP6	4	4	4	4	2.2	2.1	2.1	2.1
TP7	8	8	8	8	3.2	3.1	3.2	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.5	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.46	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.45	1.47	1.52	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.6V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.6V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.6V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√

Serial No …mon216……...
Test Engineer …Simon Pyatt…….
Date …11/03/10…….

6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.716V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.998V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.998V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.991V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.998V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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Contents

1. Block diagram

2. Test equipment

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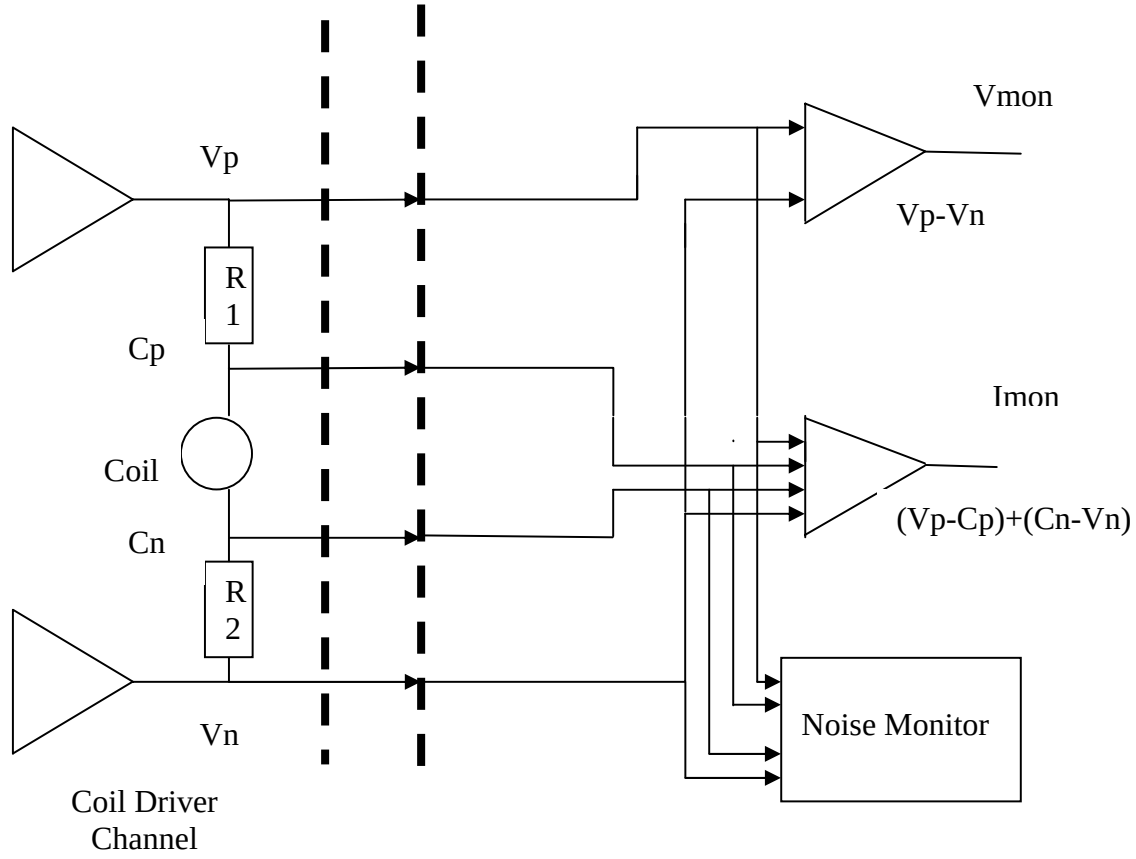
5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Channel 4 RMS to DC (736JRZ) replaced. Original was faulty.

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.89V	√
-15V (TP6)	-15.00V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2.1	2.1
TP7	8	8	8	8	3.1	3.1	3.1	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.47	1.47	1.47	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.8V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.6V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.6V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.720V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.710V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.716V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.363V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.354V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.02V	**1V (0.9 to 1.1V)**	√

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1. Block diagram

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6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
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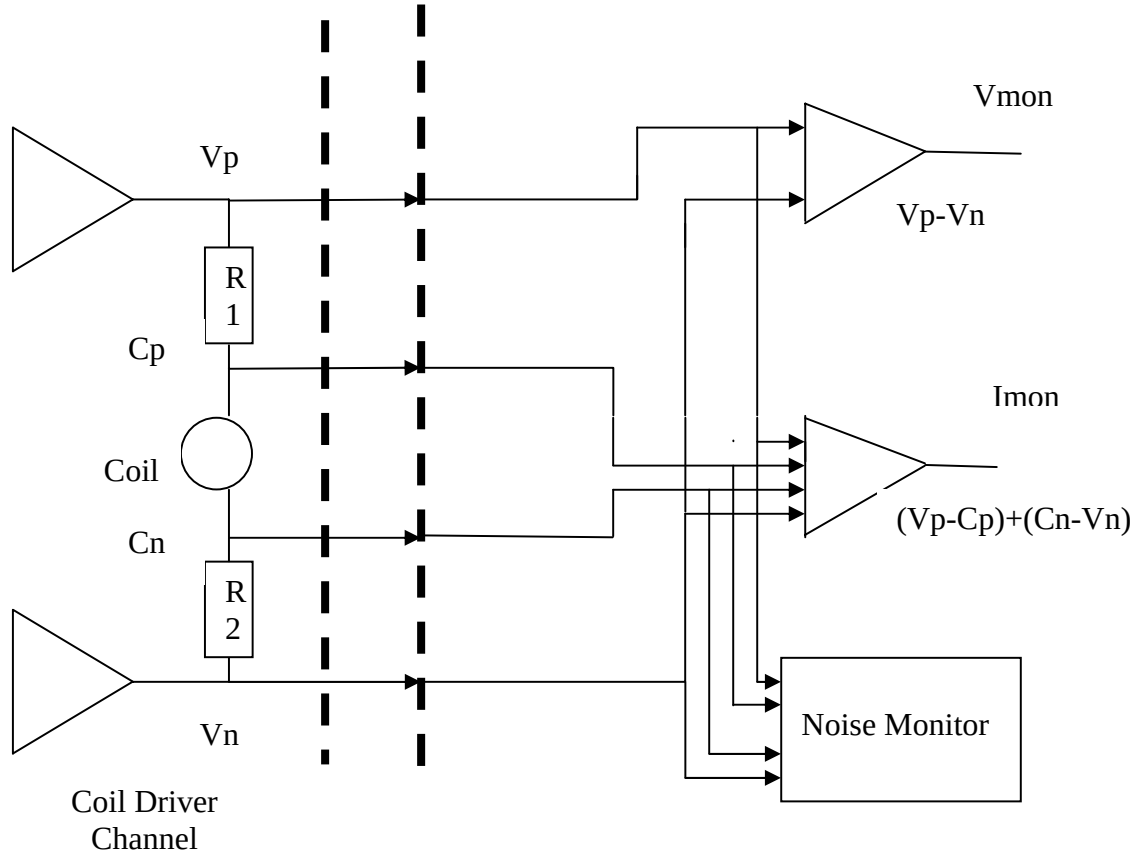
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Channel 1 RMS to DC (736JRZ) replaced. Original was faulty.

Blob of solder removed from one mounting hole.

Positive regulator (LM2940CS) replaced. Original was fluctuating in the mV range.

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.92V	√
-15V (TP6)	-14.94V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.6V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2	2
TP7	8	8	8	8	3.1	3.1	2.9	2.8

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.42	1.42	
TP7/TP6	2	2	2	2	1.47	1.47	1.45	1.4	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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Date …11/03/10……

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.718V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.361V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.992V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.994V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.995V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.998V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.993V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon219……
Test Engineer…Simon Pyatt……
Date…12/03/10……

Contents

1. Block diagram

2. Test equipment

3. Description

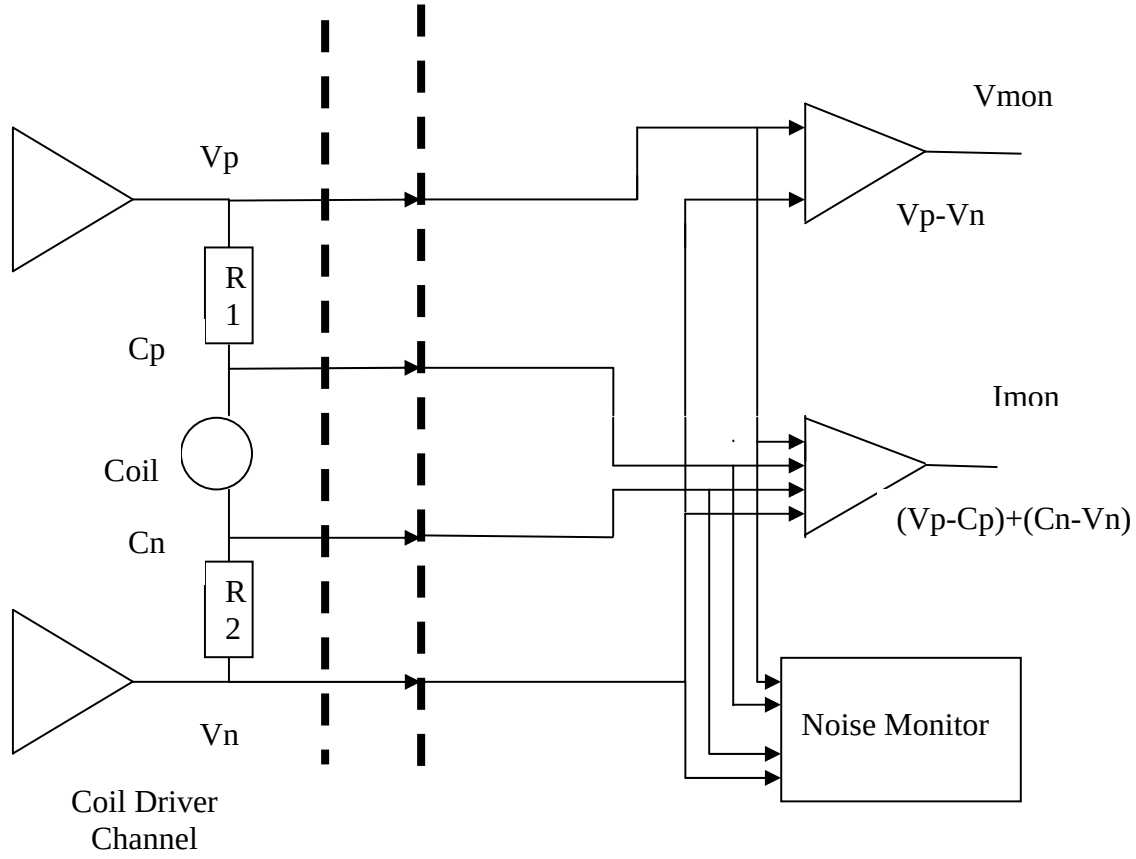
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Channel 3 RMS to DC converter circuit was giving out incorrect output. Faulty component was C27, however IC10 and IC11 were also replaced during diagnostic work.

Serial No ……...
Test Engineer ……
Date ……

NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.91V	√
-15V (TP6)	-14.90V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.8	2.9	2.9	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.4	1.45	1.45	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.3V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.8V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.718V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.714V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.987V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.987V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.991V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.986V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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1. Block diagram

2. Test equipment

3. Description

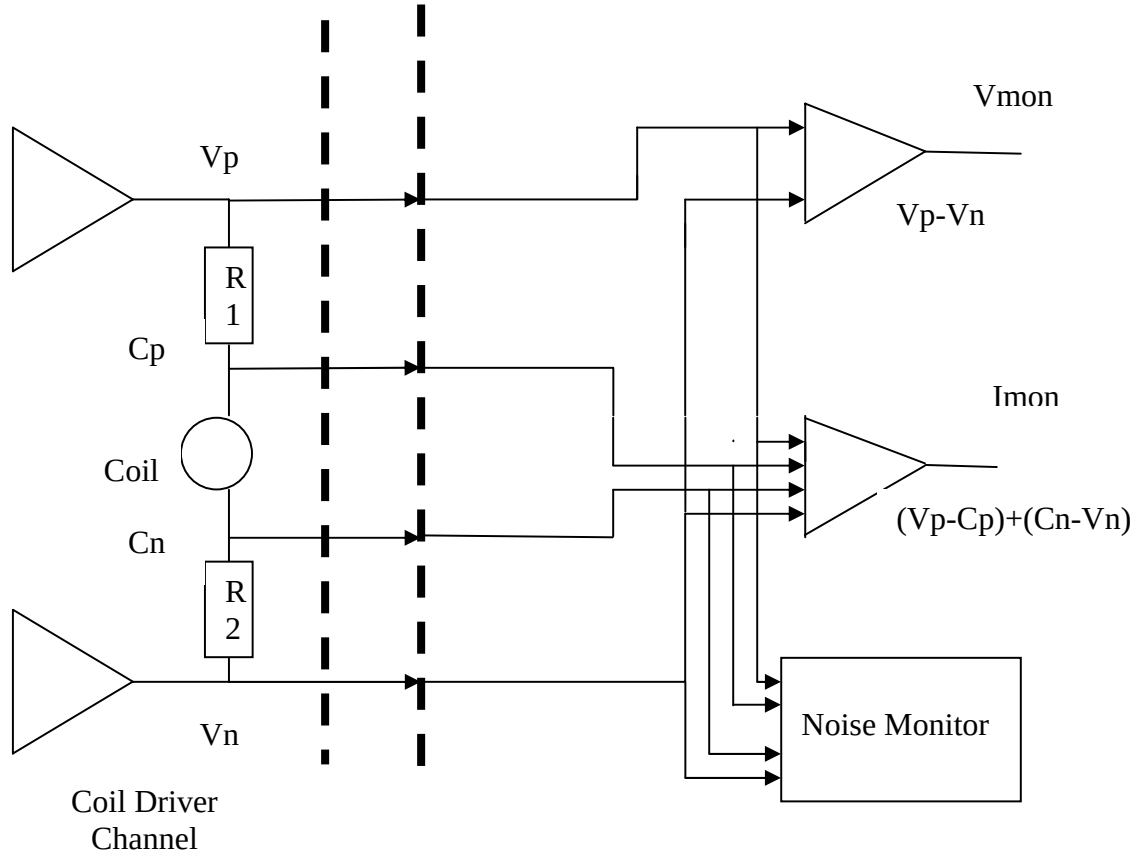
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Positive (LM2940CS) and negative (LM2990S) regulators both replaced. Originals were both faulty.

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Test Engineer ……
Date ……

NOTES

Serial No …mon220……...
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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.88V	√
-15V (TP6)	-14.85V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon220……...
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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Date …12/03/10……

Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.8	2.9	2.8	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.4	1.45	1.4	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.6V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.3V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.6V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.719V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.716V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.362V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.359V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	0.980V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	0.983V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	0.988V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	0.984V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon221……
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Contents

1. Block diagram

2. Test equipment

3. Description

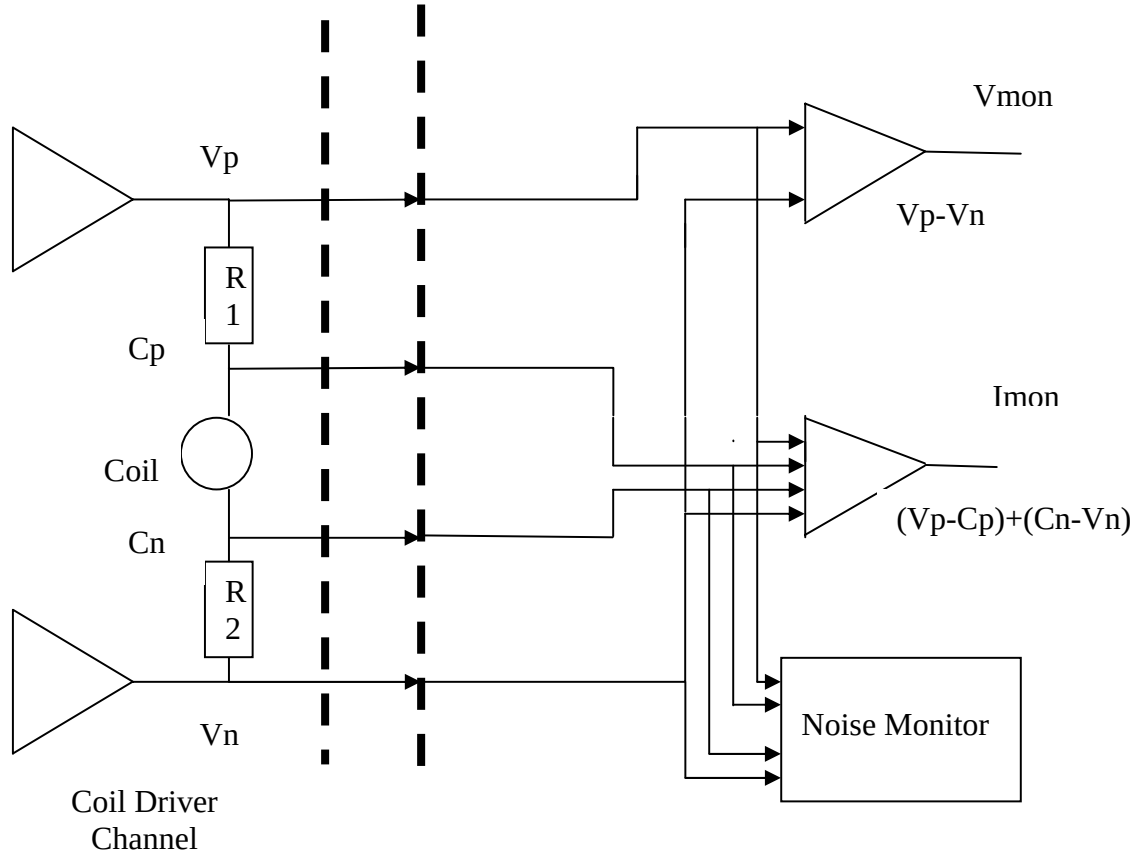
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

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NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.93V	√
-15V (TP6)	-14.89V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.29A
-15v (TP6)	√	5mV	0.27A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1	100mV	4.7V	**4.7V to 5.2V**	√
Ch2	100mV	4.7V	**4.7V to 5.2V**	√
Ch3	100mV	4.7V	**4.7V to 5.2V**	√
Ch4	100mV	4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2	2.1
TP7	8	8	8	8	3	3.1	3	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.42	1.47	1.5	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	9.9V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch2	TP10	9.9V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch3	TP10	9.9V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch4	TP10	9.9V	9.7 to 10V	√	4.4V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.711V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.356V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.03V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.03V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.03V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.03V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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1. Block diagram

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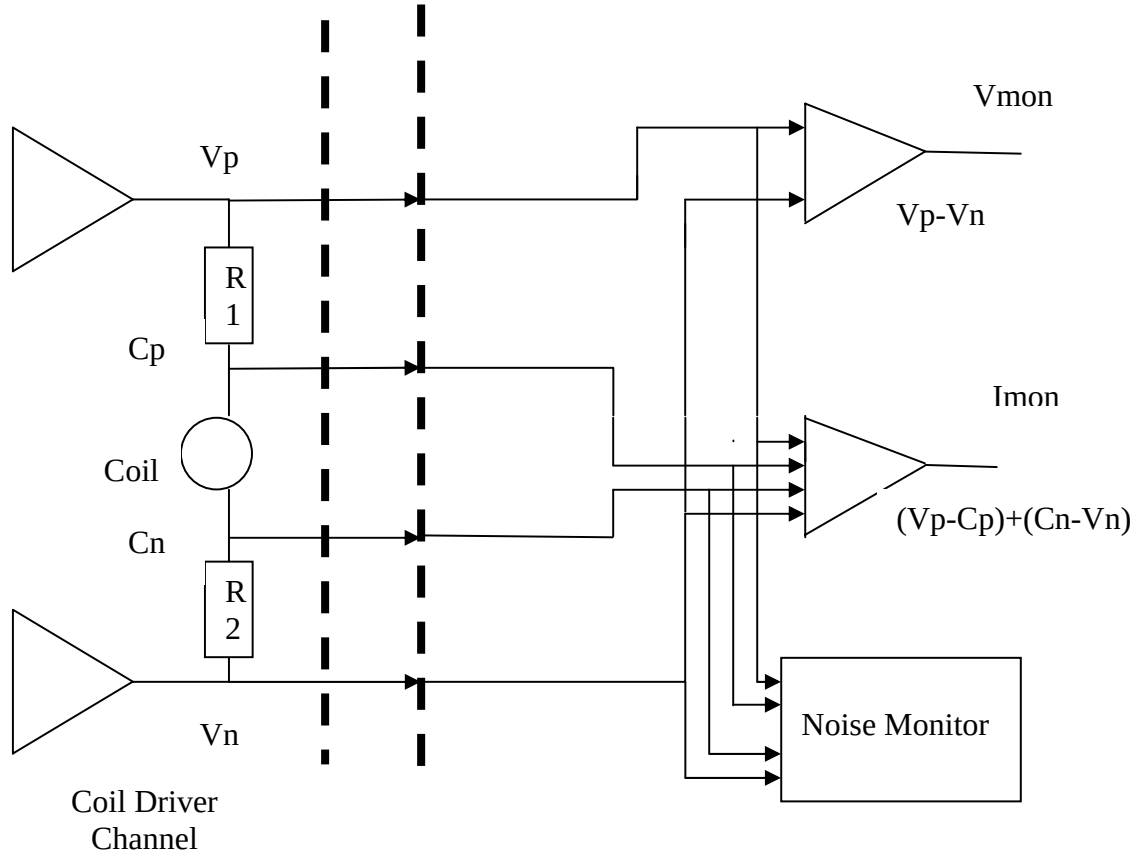
6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

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Test Engineer …Simon Pyatt…….
Date …05/08/10……

NOTES

Serial No …mon222……...
Test Engineer …Simon Pyatt…….
Date …05/08/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.93V	√
-15V (TP6)	-15.00V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28V
-15v (TP6)	√	5mV	0.26V

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.5V	**2.4V to 2.6V**	√
Ch2	100mV	2.5V	**2.4V to 2.6V**	√
Ch3	100mV	2.5V	**2.4V to 2.6V**	√
Ch4	100mV	2.5V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2.1
TP7	8	8	8	8	3	2.9	2.9	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.5	
TP7/TP6	2	2	2	2	1.5	1.45	1.45	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.7V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.9V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.8V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

Serial No …mon222……..
Test Engineer …Simon Pyatt…….
Date …05/08/10…….

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.714V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.04V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.04V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.04V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.04V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon223……
Test Engineer…Simon Pyatt……
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Contents

1. Block diagram

2. Test equipment

3. Description

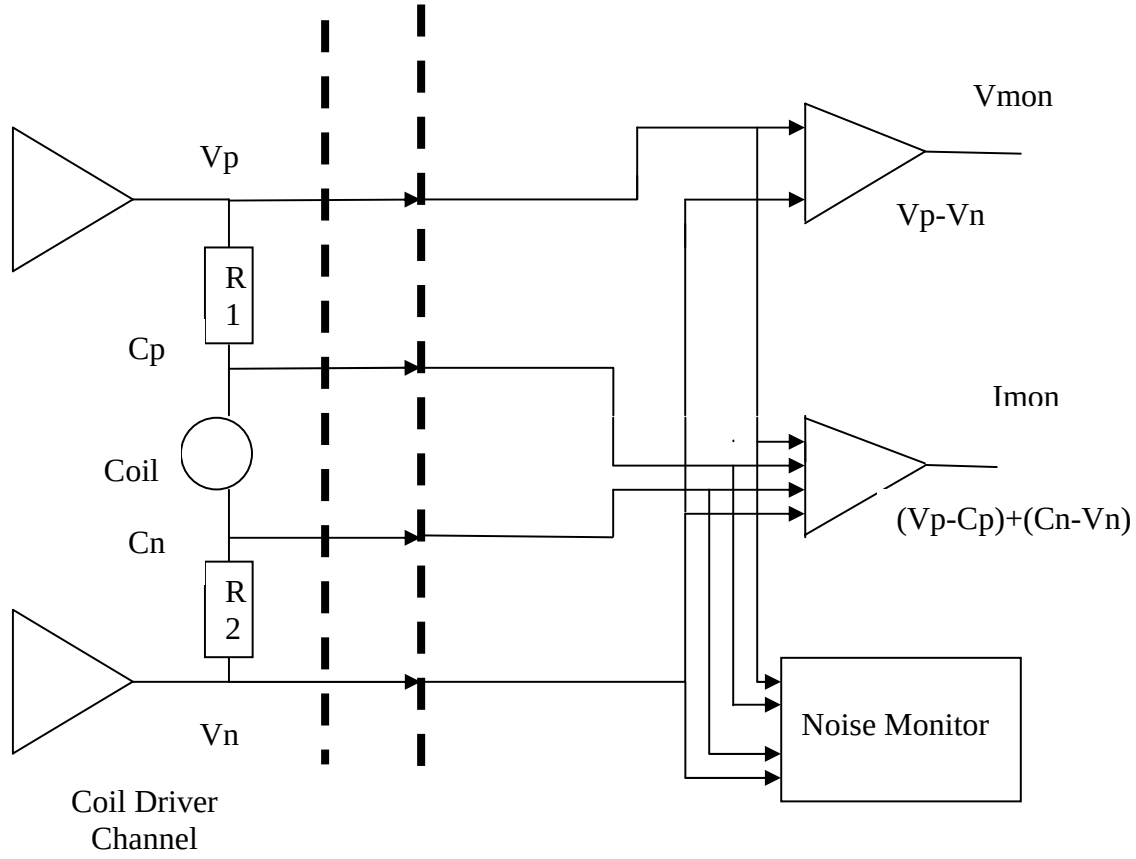
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon223……..
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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.91V	√
-15V (TP6)	-15.02V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2.1	2.1
TP7	8	8	8	8	3.1	3.1	3	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.47	1.47	1.42	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.3V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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Test Engineer …Simon Pyatt……
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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.717V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.717V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.361V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.360V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.03V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.03V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.02V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.03V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon224……
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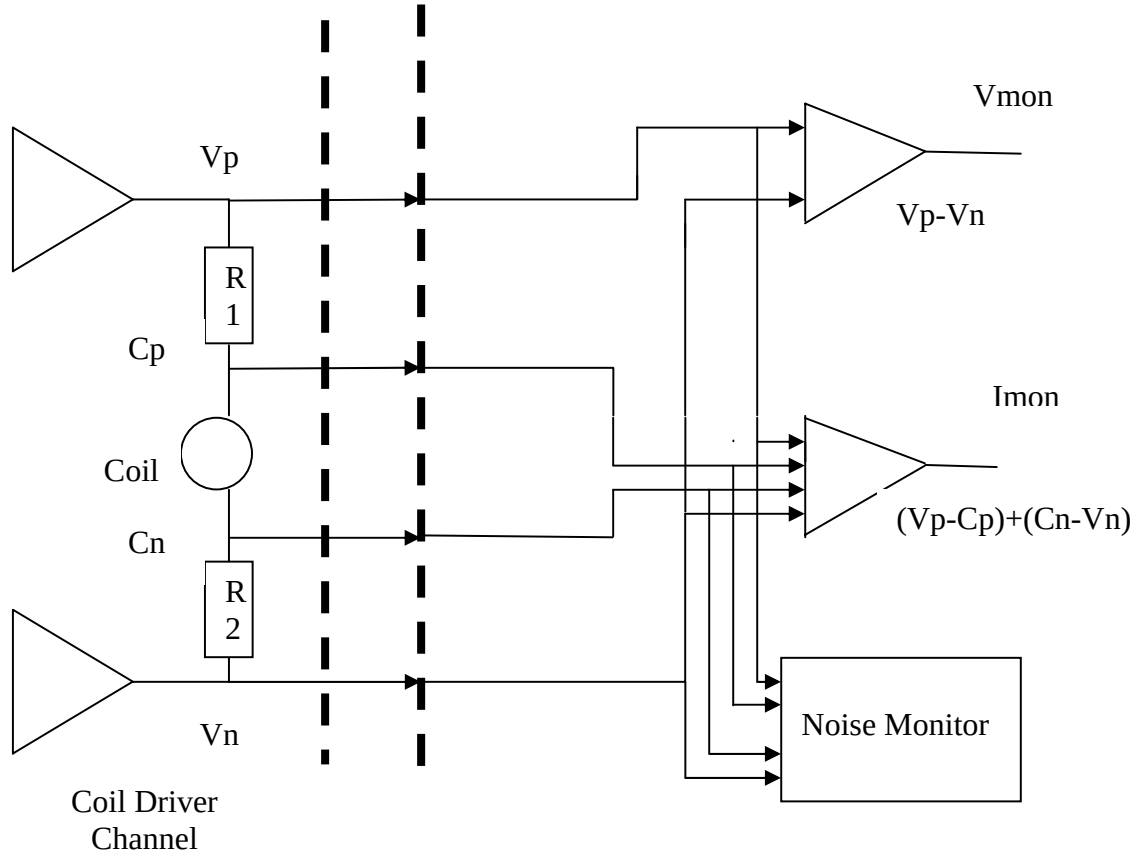
6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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Test Engineer …Simon Pyatt…….
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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon224……..
Test Engineer …Simon Pyatt…….
Date …06/08/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.98V	√
-15V (TP6)	-15.17V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon224……...
Test Engineer …Simon Pyatt…….
Date …06/08/10…….

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

Serial No …mon224……...
Test Engineer …Simon Pyatt…….
Date …06/08/10…….

Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

Serial No …mon224……..
Test Engineer …Simon Pyatt…….
Date …06/08/10…….

Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2	2	2
TP7	8	8	8	8	3	3	2.9	3

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.42	1.5	1.45	1.5	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.6V	4 to 5.5V	√

Serial No …mon224……...
Test Engineer …Simon Pyatt…….
Date …09/08/10…….

6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

Serial No …mon224……..
Test Engineer …Simon Pyatt…….
Date …09/08/10…….

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.710V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.715V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.02V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon225……
Test Engineer…Simon Pyatt……
Date…09/08/10……

Contents

1. Block diagram

2. Test equipment

3. Description

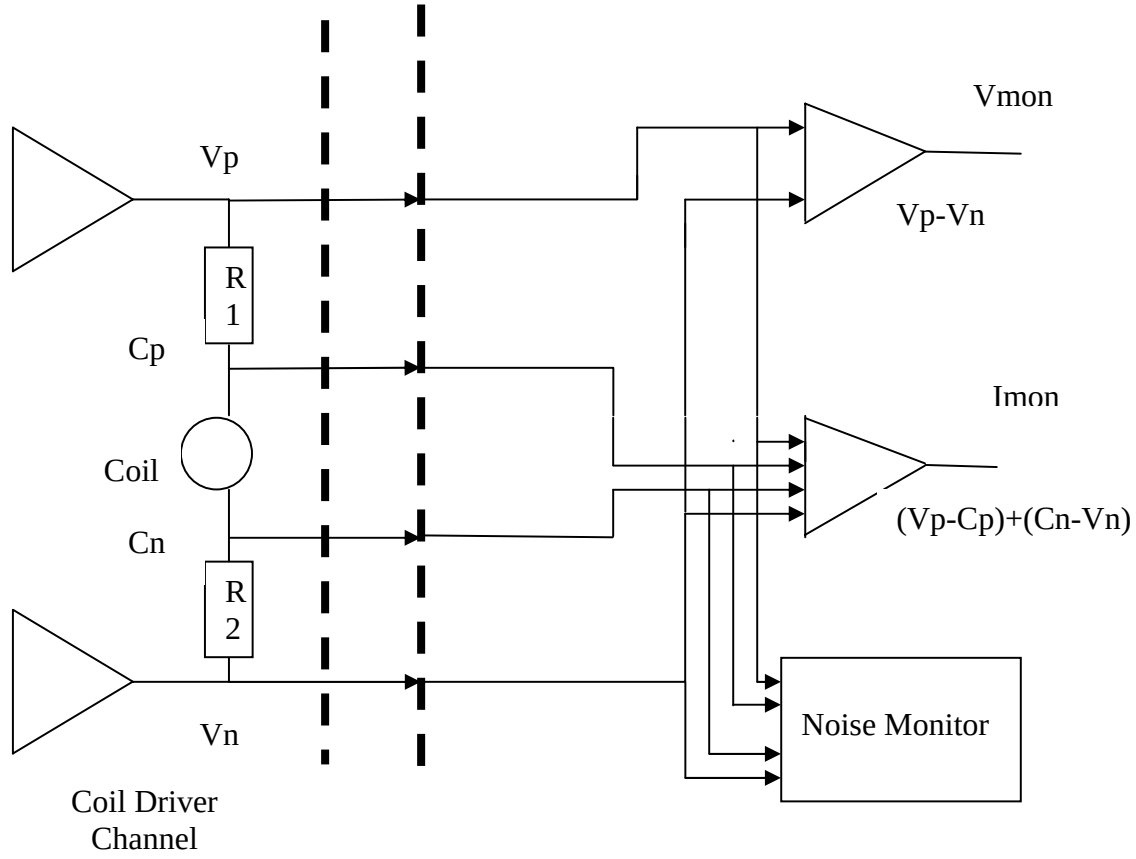
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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Test Engineer…Simon Pyatt……
Date…09/08/10……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon225……...
Test Engineer …Simon Pyatt…….
Date …09/08/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.94V	√
-15V (TP6)	-14.92V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	1mV	√	0.28A
-15v (TP6)	5mV	√	0.26A

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Test Engineer …Simon Pyatt…….
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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Test Engineer …Simon Pyatt…….
Date …09/08/10…….

Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Test Engineer …Simon Pyatt…….
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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2	2.1	2.1
TP7	8	8	8	8	3	2.9	3	3

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.42	1.5	1.5	
TP7/TP6	2	2	2	2	1.42	1.45	1.42	1.42	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.6V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.3V	4 to 5.5V	√

Serial No …mon225……...
Test Engineer …Simon Pyatt…….
Date …09/08/10…….

6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

Serial No …mon225……...
Test Engineer …Simon Pyatt……
Date …09/08/10……

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.713V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.356V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.02V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.02V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon226……
Test Engineer…Simon Pyatt……
Date…09/08/10……

Contents

1. Block diagram

2. Test equipment

3. Description

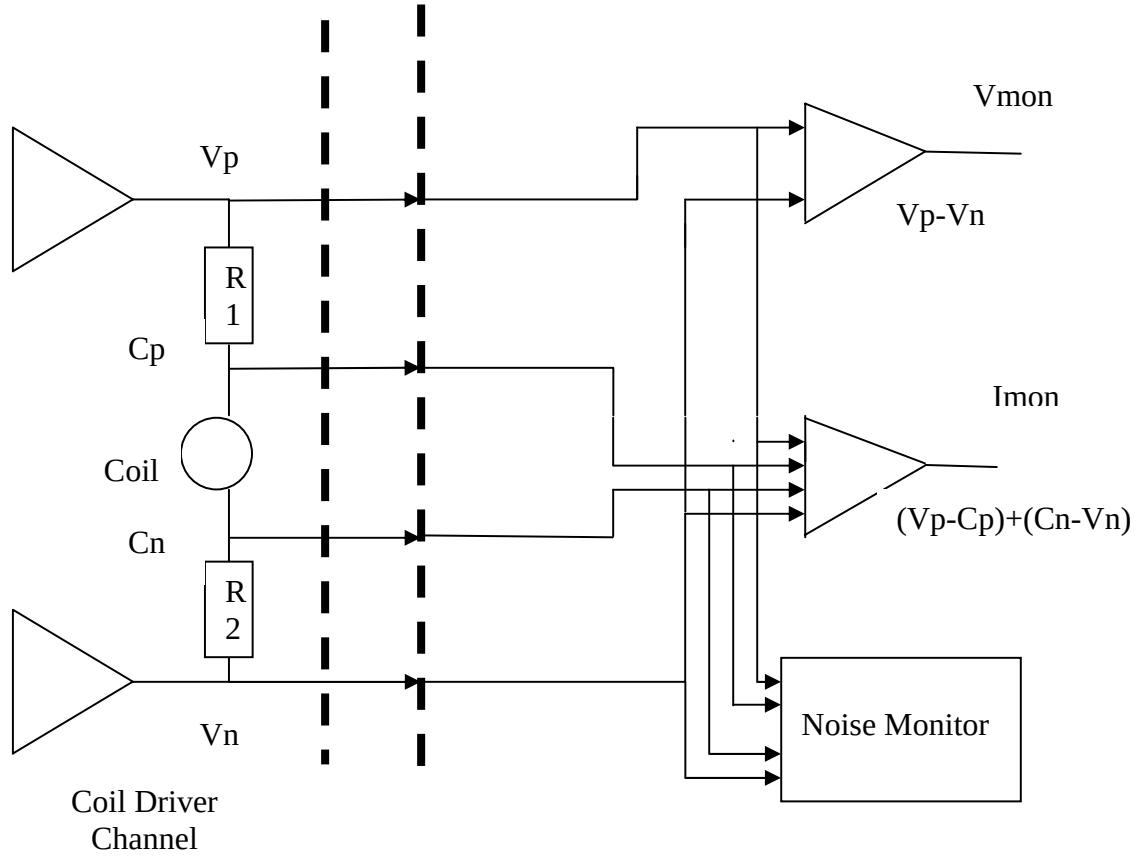
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

Serial No…mon226……
Test Engineer…Simon Pyatt……
Date…09/08/10……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon226……..
Test Engineer …Simon Pyatt…….
Date …09/08/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.89V	√
-15V (TP6)	-14.96V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon226……...
Test Engineer …Simon Pyatt…….
Date …09/08/10……

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2.1	2.1	2.1
TP7	8	8	8	8	3	3.1	3	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.5	1.47	1.42	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.3V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.713V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.356V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.02V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.02V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon227……
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Contents

1. Block diagram

2. Test equipment

3. Description

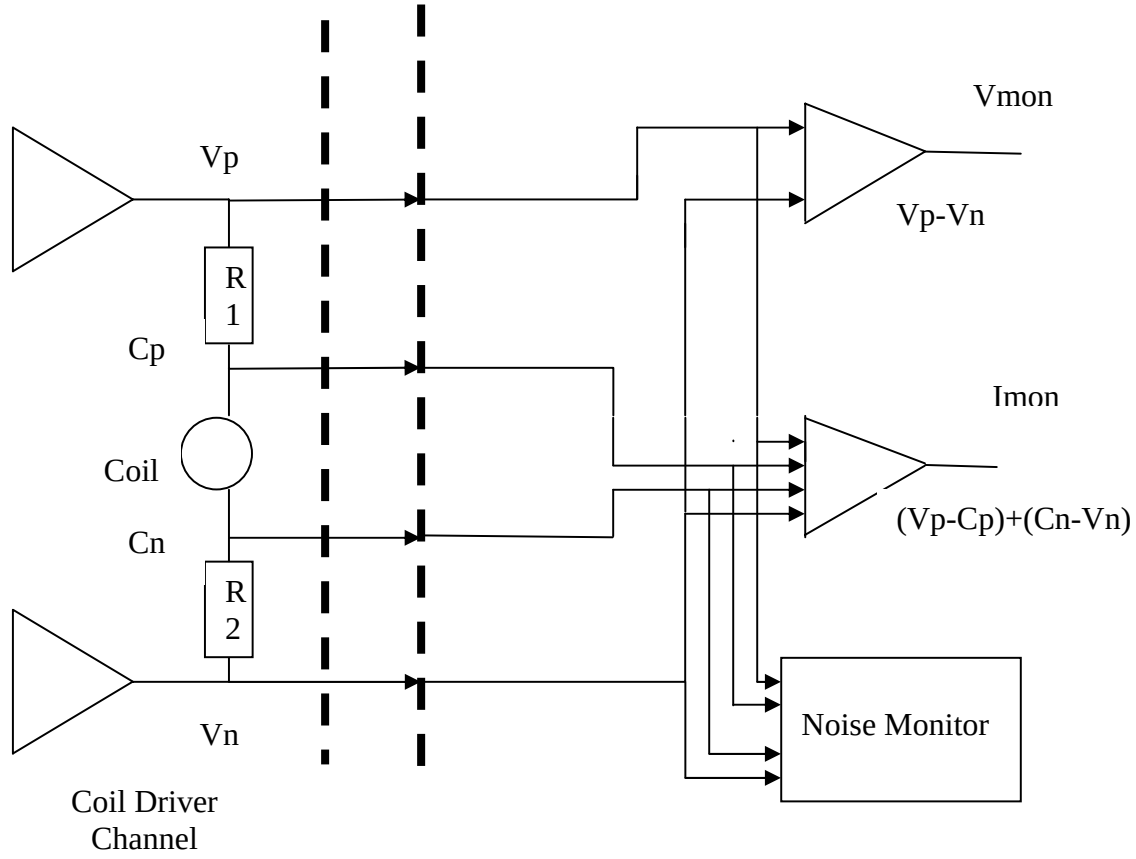
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.95V	√
-15V (TP6)	-15.13V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2.1	2.1
TP7	8	8	8	8	3.1	3	3.1	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.47	1.42	1.47	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.7V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.7V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.2V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.6V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.713V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.02V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.02V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.02V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

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1. Block diagram

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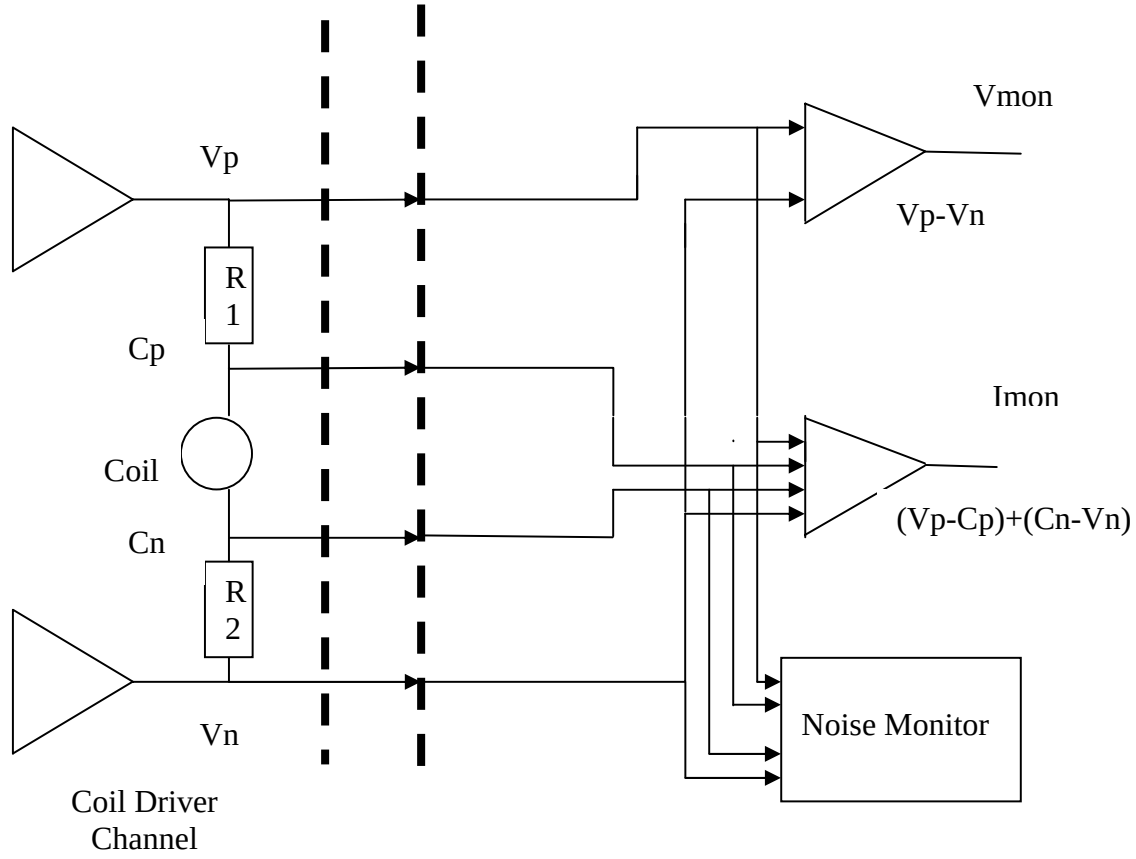
6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon228……...
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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.94V	√
-15V (TP6)	-14.98V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1Mv	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2.1	2.1
TP7	8	8	8	8	3	3.1	3.1	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.42	1.47	1.47	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.3V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.3V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.8V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.9V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.710V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.715V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.353V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.02V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.02V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.02V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.02V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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1. Block diagram

2. Test equipment

3. Description

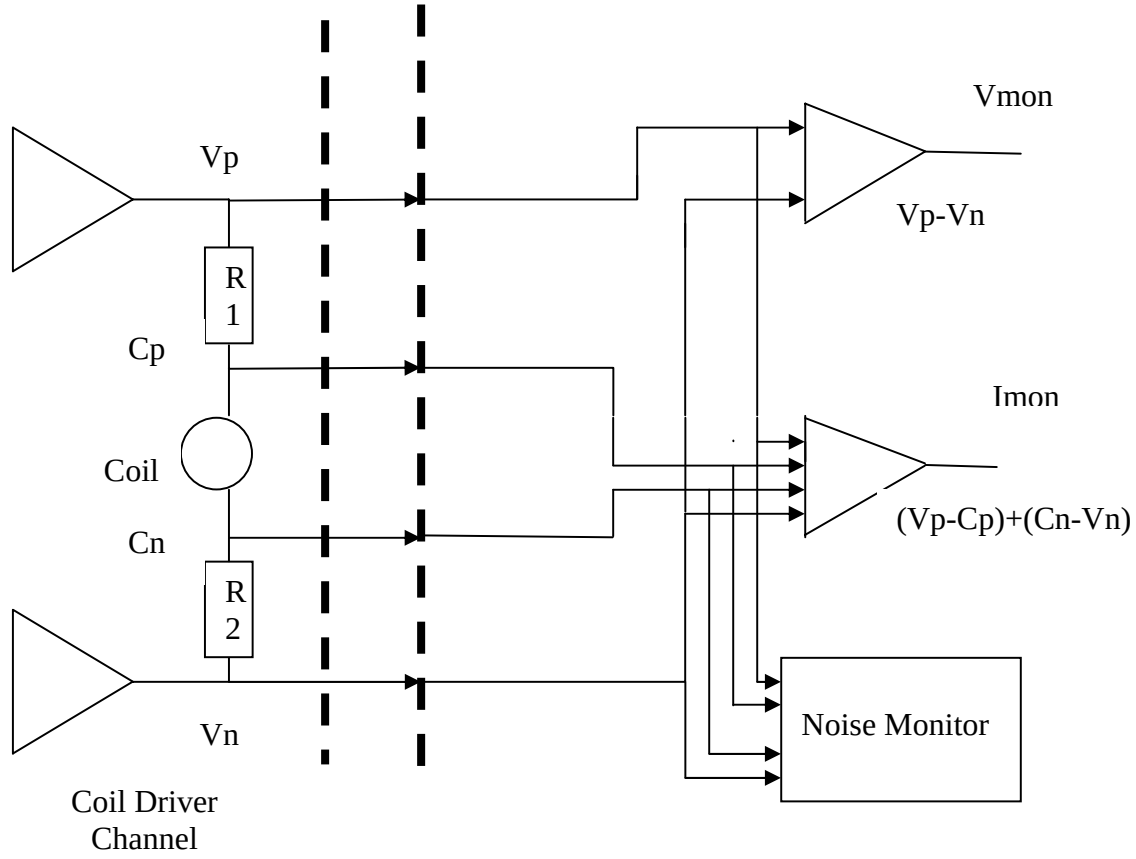
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

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NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	15.02V	√
-15V (TP6)	-15.15V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2	2.1
TP7	8	8	8	8	3.1	3.1	3	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.42	1.5	
TP7/TP6	2	2	2	2	1.47	1.47	1.5	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.3V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.6V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.713V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.02V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.02V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.02V	**1V (0.9 to 1.1V)**	√

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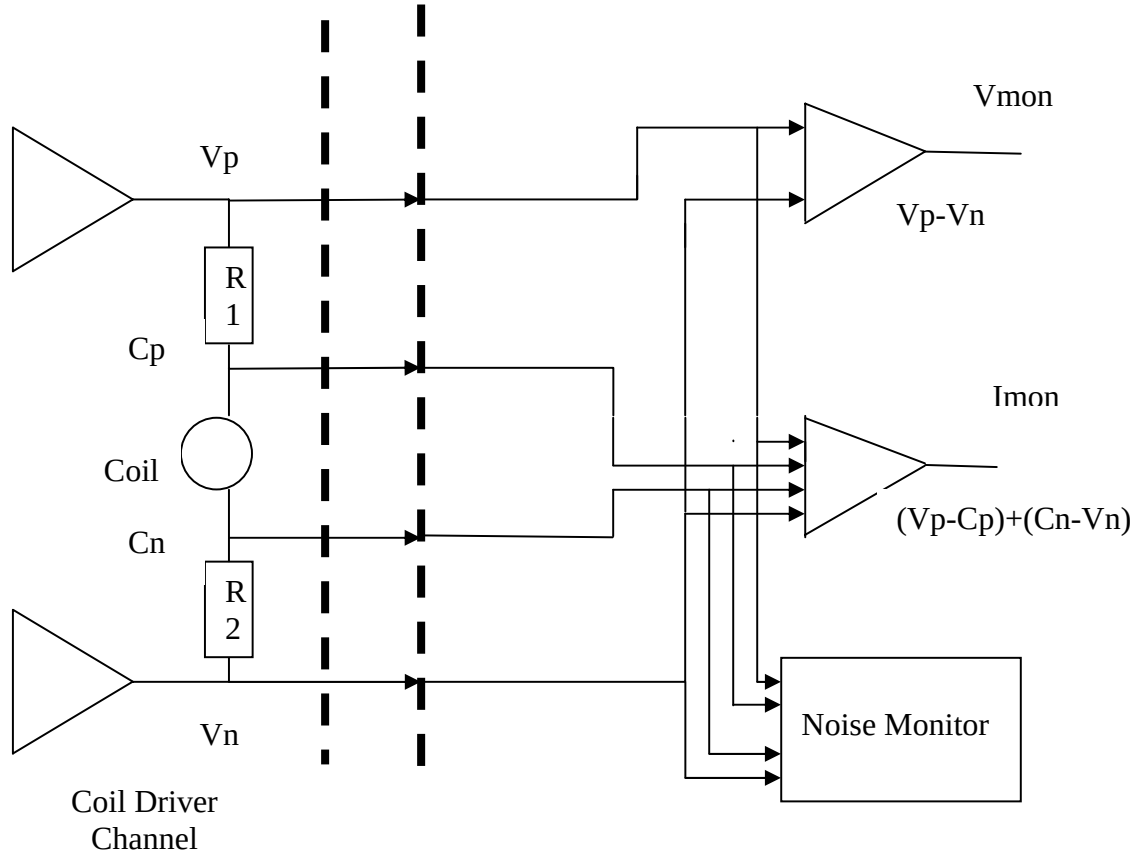
6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

Serial No…mon230……
Test Engineer…Simon Pyatt……
Date…13/08/10……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon230……..
Test Engineer …Simon Pyatt…….
Date …13/08/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.96V	√
-15V (TP6)	-15.03V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

Serial No …mon230……...
Test Engineer …Simon Pyatt…….
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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

Serial No …mon230……..
Test Engineer …Simon Pyatt…….
Date …13/08/10…….

Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2.1
TP7	8	8	8	8	2.9	2.8	2.9	3

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.5	
TP7/TP6	2	2	2	2	1.45	1.4	1.45	1.42	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.7V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.6V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.3V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.6V	**4 to 5.5V**	√

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Test Engineer …Simon Pyatt…….
Date …13/08/10…….

6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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Test Engineer …Simon Pyatt…….
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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.713V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.02V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.02V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon231……
Test Engineer…Simon Pyatt……
Date…17/08/10……

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1. Block diagram

2. Test equipment

3. Description

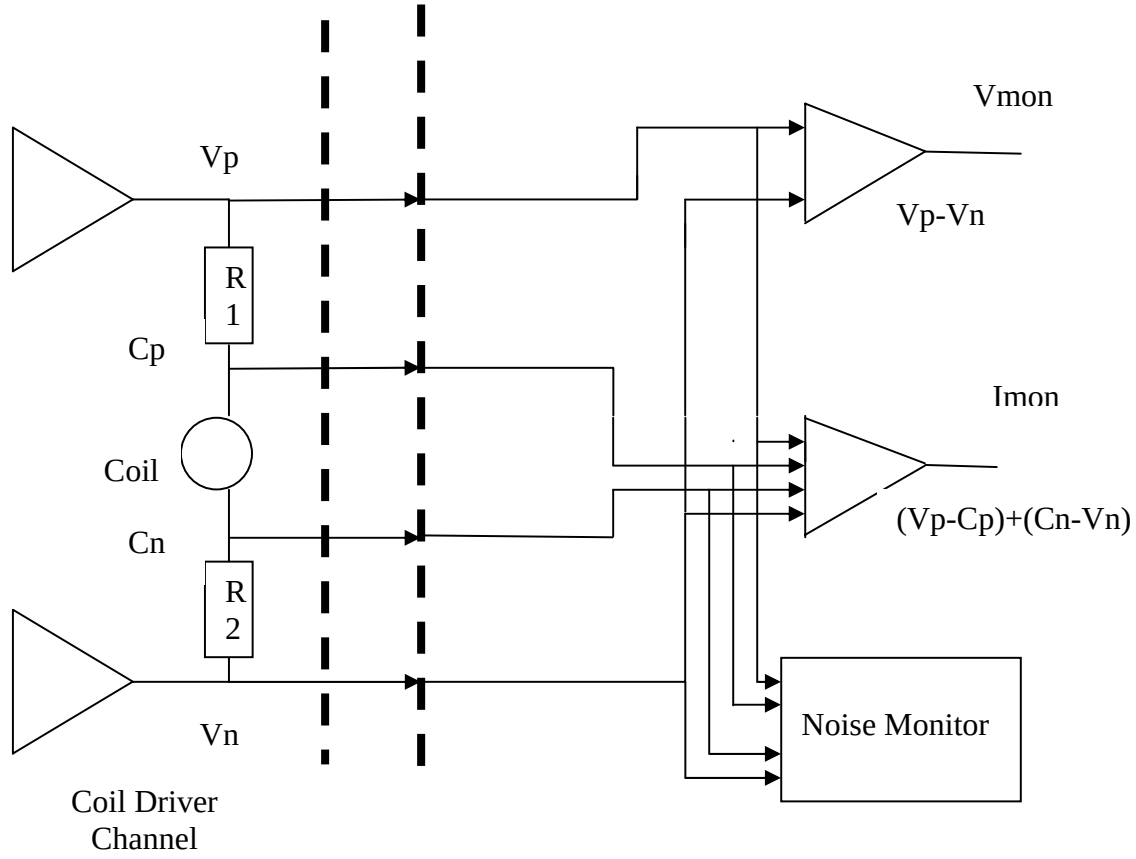
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

Serial No …mon231……..
Test Engineer …Simon Pyatt…….
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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon231……..
Test Engineer …Simon Pyatt…….
Date …17/08/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	15.06V	√
-15V (TP6)	-15.09V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon231……...
Test Engineer …Simon Pyatt…….
Date …17/08/10……

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Test Engineer …Simon Pyatt…….
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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.9	2.9	2.8	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.45	1.45	1.4	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.2V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.3V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.3V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

Serial No …mon231……..
Test Engineer …Simon Pyatt…….
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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.713V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.02V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon232……
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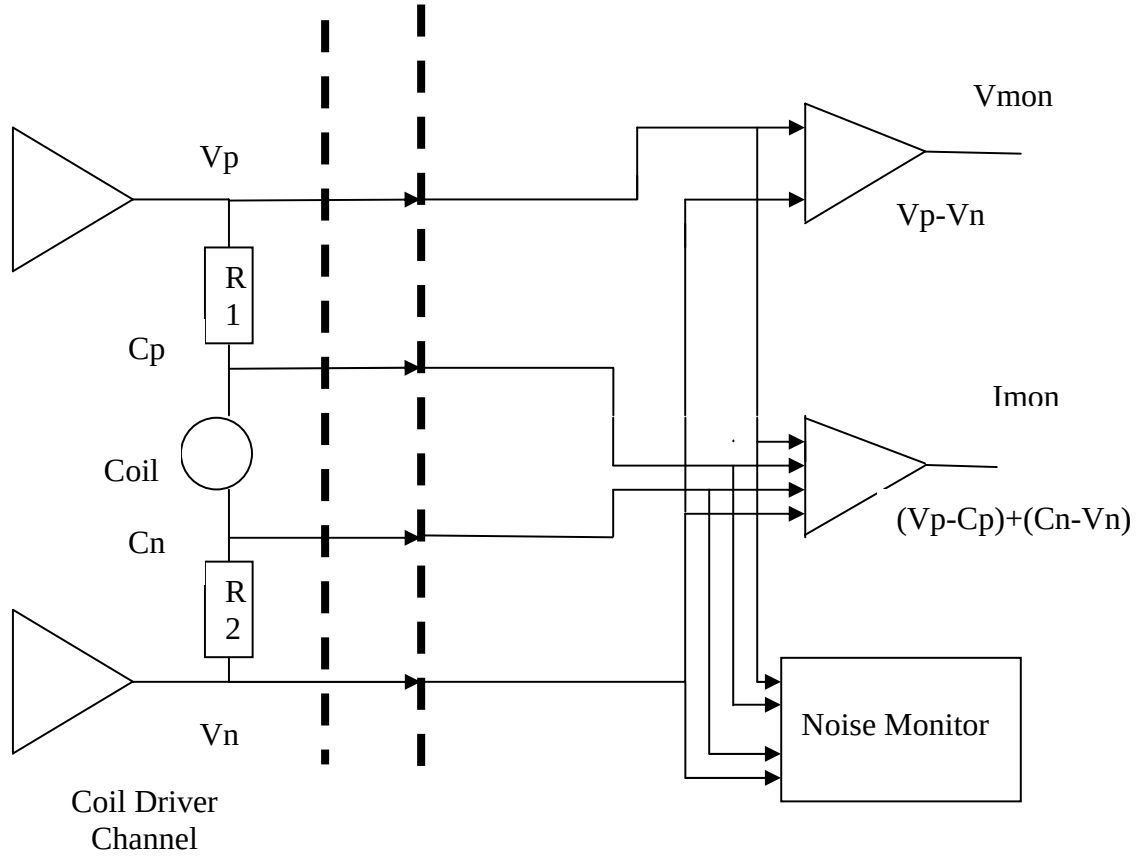
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon232……..
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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	15.07V	√
-15V (TP6)	-15.01V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.8V	**4.7V to 5.2V**	√
Ch2		4.8V	**4.7V to 5.2V**	√
Ch3		4.8V	**4.7V to 5.2V**	√
Ch4		4.8V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2.1	2.1
TP7	8	8	8	8	3.1	3.1	3.1	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.47	1.47	1.47	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.7V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.8V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.720V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.360V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.363V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.02V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon233……
Test Engineer…Simon Pyatt……
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Contents

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2. Test equipment

3. Description

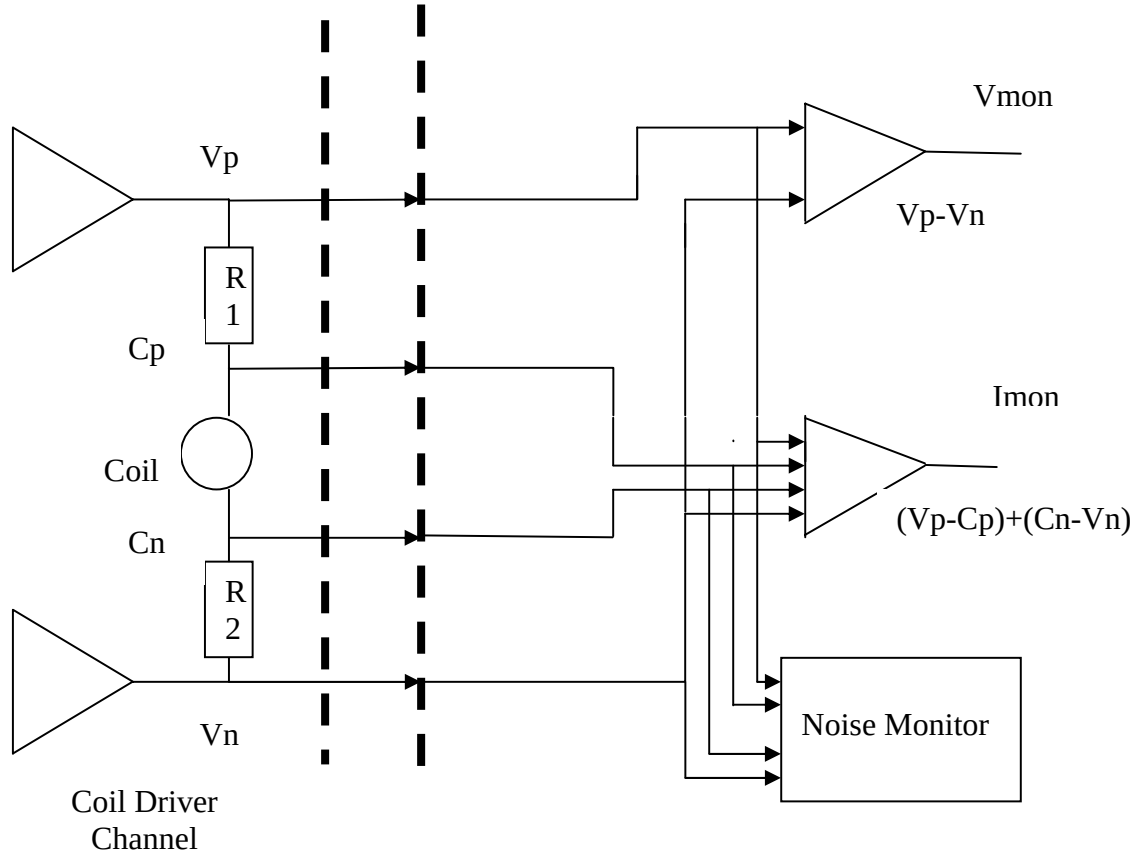
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon233……...
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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.86V	√
-15V (TP6)	-15.00V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2	2
TP7	8	8	8	8	3.1	3	3	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.42	1.42	
TP7/TP6	2	2	2	2	1.47	1.42	1.5	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.6V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.710V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.713V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.354V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.356V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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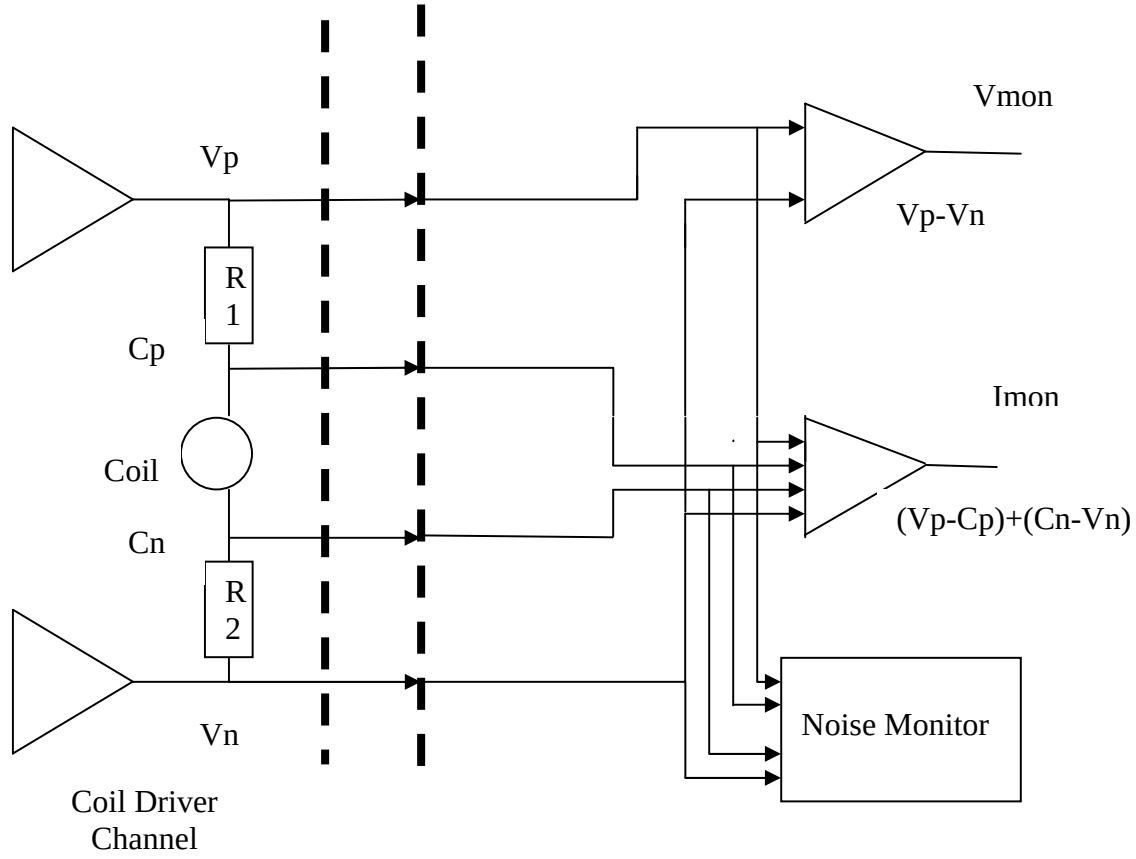
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

Serial No…mon234……
Test Engineer…Simon Pyatt……
Date…17/08/10……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon234……...
Test Engineer …Simon Pyatt…….
Date …17/08/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.94V	√
-15V (TP6)	-14.98V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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Test Engineer …Simon Pyatt…….
Date …17/08/10……

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Test Engineer …Simon Pyatt…….
Date …19/08/10……

Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.8V	**4.7V to 5.2V**	√
Ch2		4.8V	**4.7V to 5.2V**	√
Ch3		4.8V	**4.7V to 5.2V**	√
Ch4		4.8V	**4.7V to 5.2V**	√

Serial No …mon234……..
Test Engineer …Simon Pyatt…….
Date …19/08/10…….

Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2.1	2.1
TP7	8	8	8	8	3	3	3	3

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.42	1.42	1.42	1.42	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.6V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.6V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.6V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.6V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

Serial No …mon234……..
Test Engineer …Simon Pyatt…….
Date …19/08/10…….

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.713V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.356V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.02V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon235……
Test Engineer…Simon Pyatt……
Date…19/08/10……

Contents

1. Block diagram

2. Test equipment

3. Description

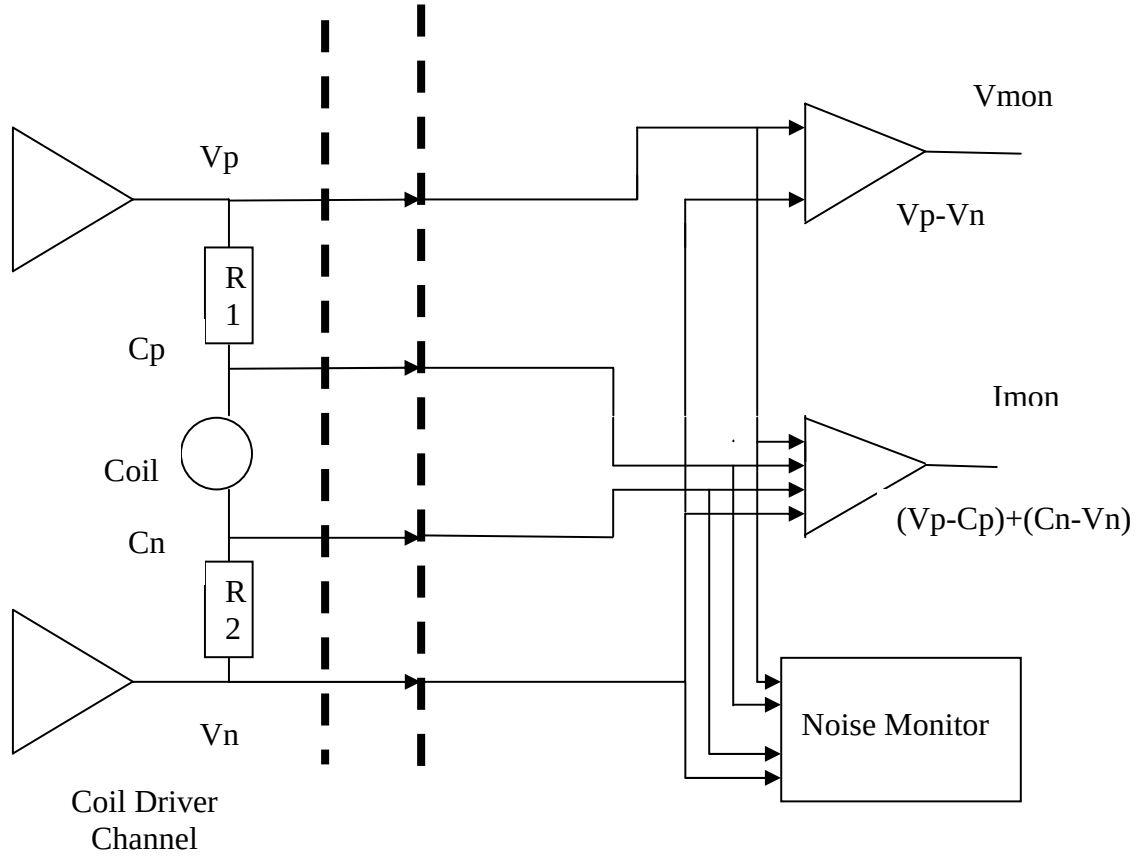
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

Serial No …mon235……..
Test Engineer …Simon Pyatt…….
Date …19/08/10……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon235……..
Test Engineer …Simon Pyatt…….
Date …19/08/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.89V	√
-15V (TP6)	-15.01V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon235……...
Test Engineer …Simon Pyatt…….
Date …19/08/10……

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

Serial No …mon235……...
Test Engineer …Simon Pyatt…….
Date …19/08/10……

Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

Serial No …mon235……..
Test Engineer …Simon Pyatt…….
Date …19/08/10……

Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2.1	2.1
TP7	8	8	8	8	3	3	3.1	3

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.42	1.42	1.47	1.42	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.2V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.3V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.2V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.6V	4 to 5.5V	√

Serial No …mon235……...
Test Engineer …Simon Pyatt…….
Date …19/08/10…….

6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

Serial No …mon235……..
Test Engineer …Simon Pyatt…….
Date …19/08/10…….

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.712V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.356V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon236……
Test Engineer…Simon Pyatt……
Date…25/08/10……

Contents

1. Block diagram

2. Test equipment

3. Description

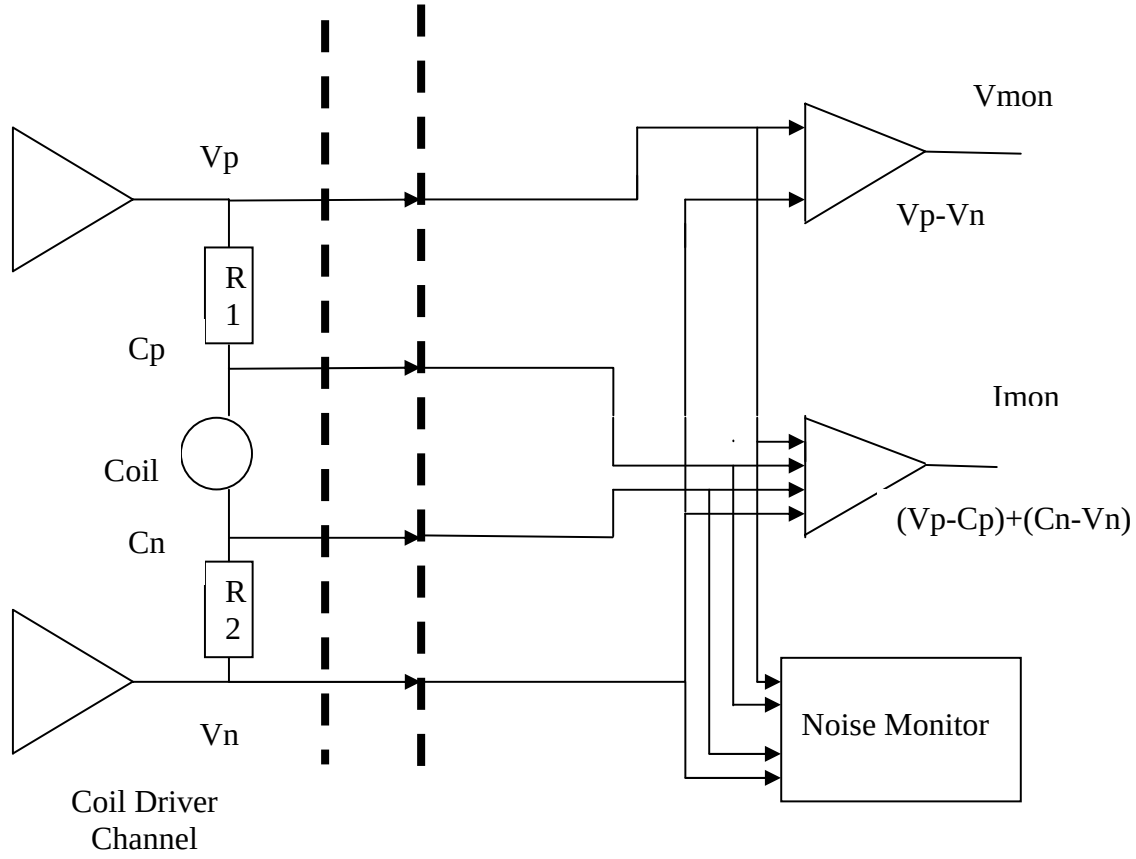
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.98V	√
-15V (TP6)	-15.02V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2.1	2.1
TP7	8	8	8	8	3	3	3	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.42	1.42	1.42	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.7V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.6V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.6V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.712V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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1. Block diagram

2. Test equipment

3. Description

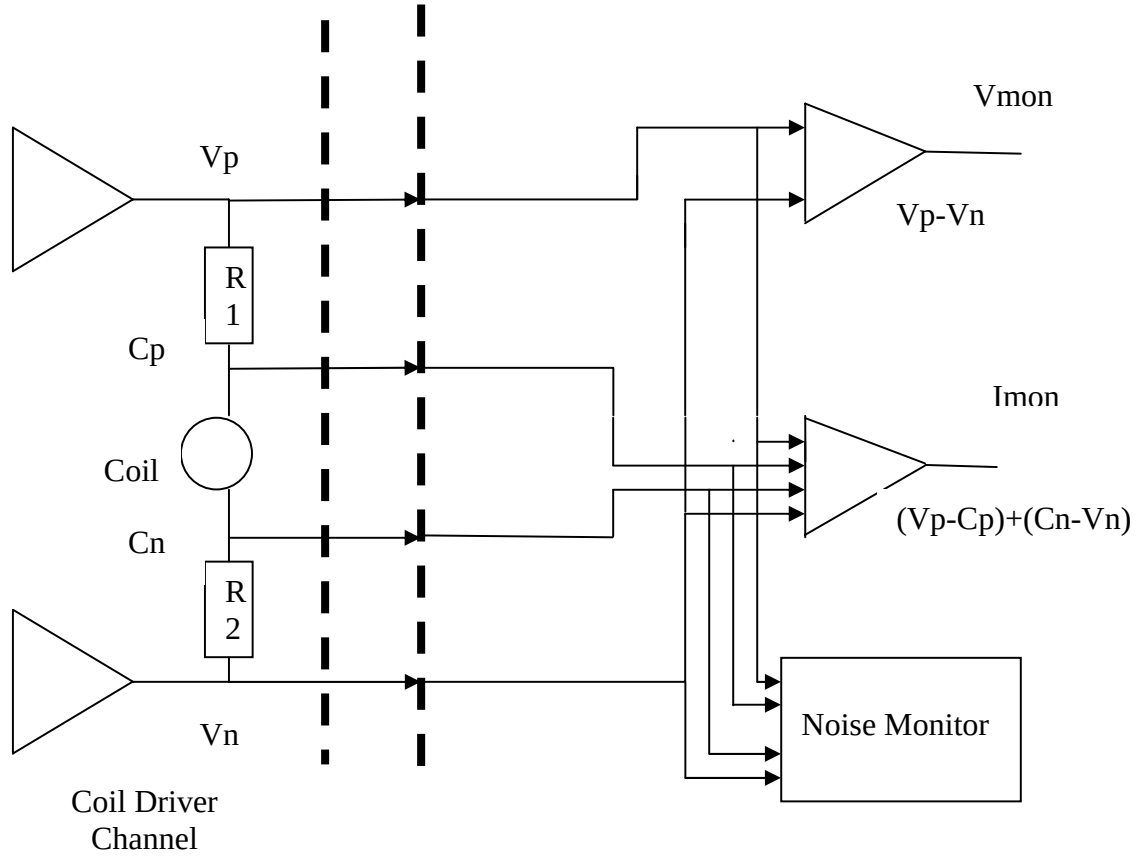
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon237……...
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Date …25/08/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.94V	√
-15V (TP6)	-15.00V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2	2
TP7	8	8	8	8	3	3	2.9	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.42	1.42	
TP7/TP6	2	2	2	2	1.42	1.42	1.45	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.3V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.3V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.8V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.3V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.711V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.36V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.355V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon238……
Test Engineer…Simon Pyatt……
Date…25/08/10……

Contents

1. Block diagram

2. Test equipment

3. Description

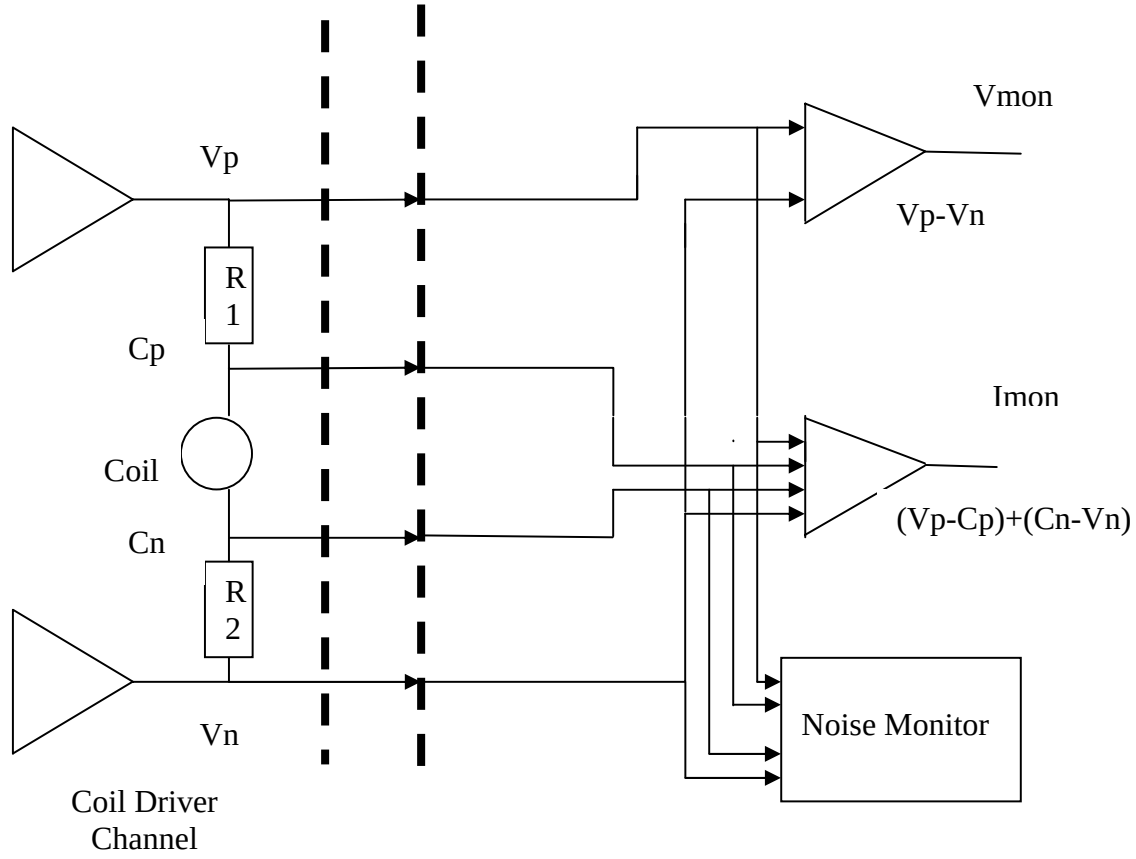
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon238……...
Test Engineer …Simon Pyatt…….
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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.86V	√
-15V (TP6)	-14.93V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.8V	**4.7V to 5.2V**	√
Ch2		4.8V	**4.7V to 5.2V**	√
Ch3		4.8V	**4.7V to 5.2V**	√
Ch4		4.8V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2	2.1	2
TP7	8	8	8	8	3.2	2.9	3	3

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.42	1.5	1.42	
TP7/TP6	2	2	2	2	1.52	1.45	1.42	1.5	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.8V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.7V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.3V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.714V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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1. Block diagram

2. Test equipment

3. Description

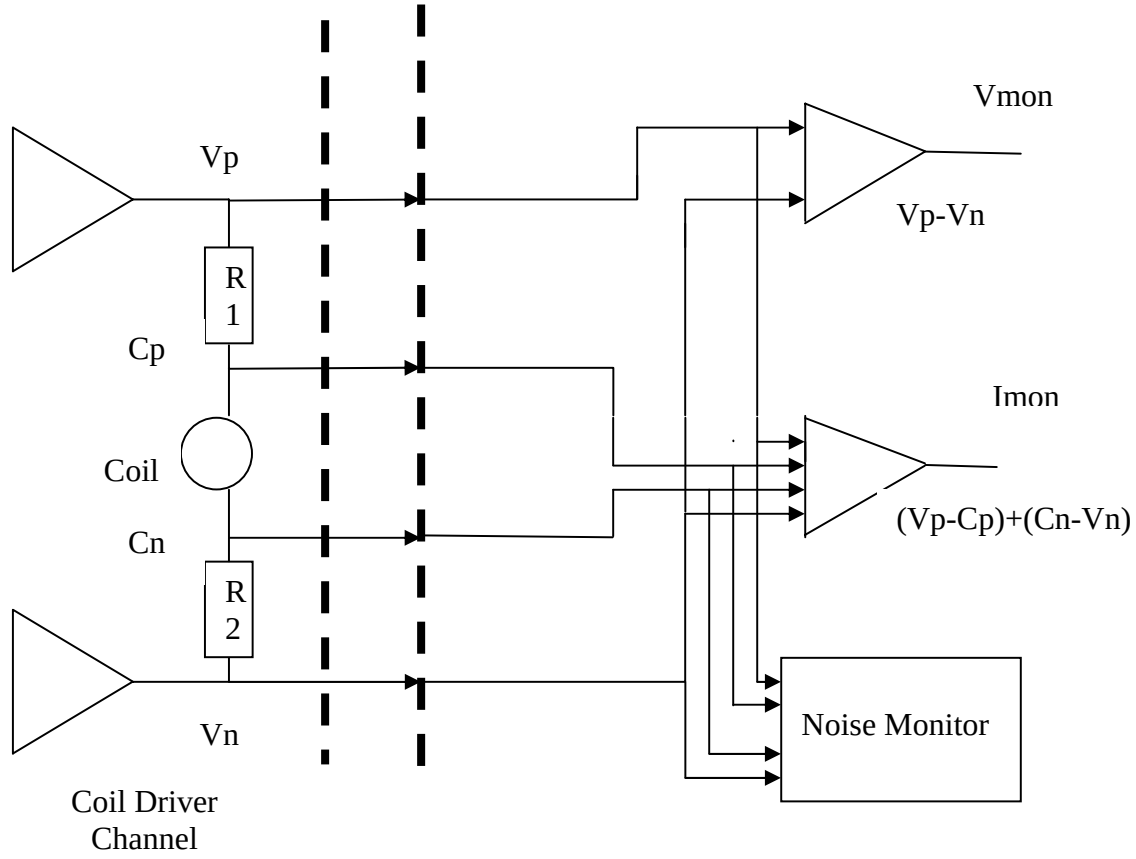
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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Date …27/08/10……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon239……...
Test Engineer …Simon Pyatt…….
Date …27/08/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.94V	√
-15V (TP6)	-14.98V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.8	2.9	2.9	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.4	1.45	1.45	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.8V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.8V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.3V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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Test Engineer …Simon Pyatt…….
Date …27/08/10…….

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.712V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.355V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon240……
Test Engineer…Simon Pyatt……
Date…27/08/10……

Contents

1. Block diagram

2. Test equipment

3. Description

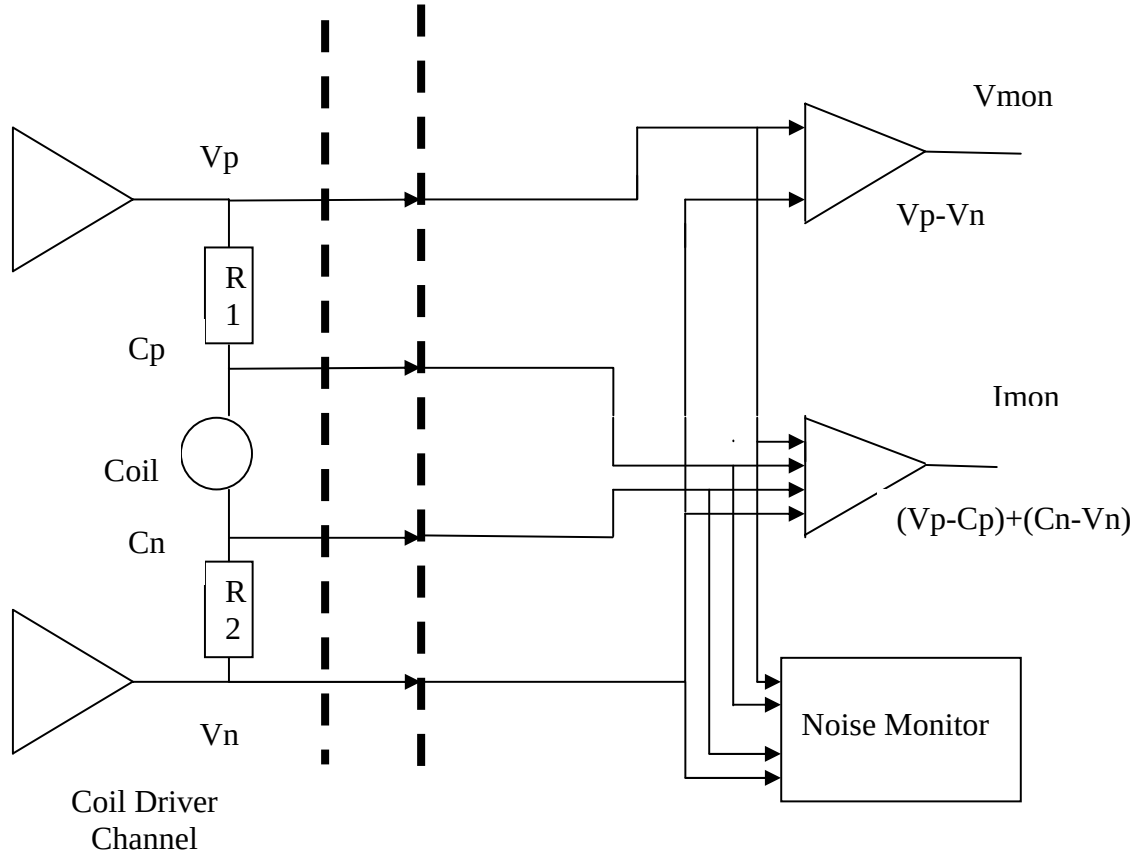
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

Serial No …mon240……..
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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon240……...
Test Engineer …Simon Pyatt…….
Date …27/08/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.94V	√
-15V (TP6)	-15.03V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.6V	**1.6V to 1.9V**	√
Ch3	100mV	1.6V	**1.6V to 1.9V**	√
Ch4	100mV	1.6V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2.1	2
TP7	8	8	8	8	2.8	2.9	2.9	2.8

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.5	1.42	
TP7/TP6	2	2	2	2	1.4	1.45	1.38	1.4	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.3V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.7V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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Test Engineer …Simon Pyatt…….
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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.718V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.710V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.361V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.361V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.354V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.02V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon241……
Test Engineer…Simon Pyatt……
Date…27/08/10……

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1. Block diagram

2. Test equipment

3. Description

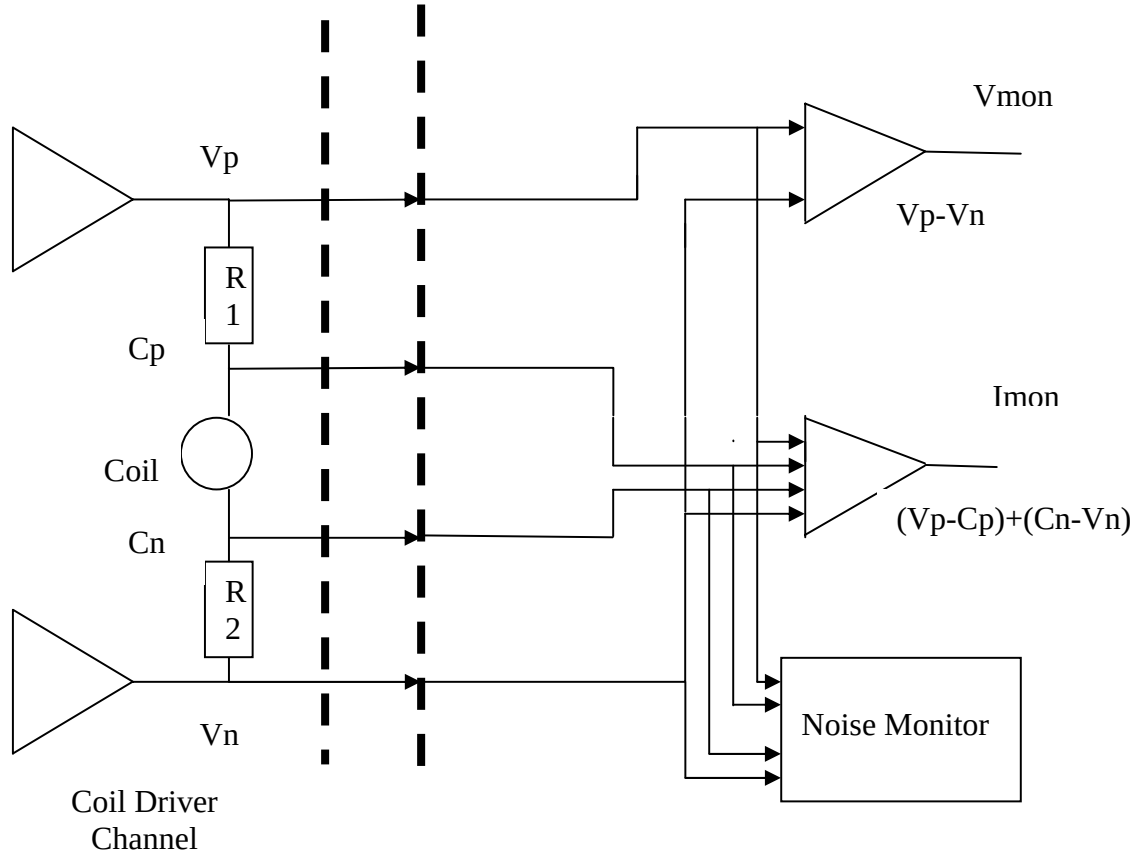
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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Test Engineer …Simon Pyatt…….
Date …27/08/10……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon241……..
Test Engineer …Simon Pyatt…….
Date …27/08/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.97V	√
-15V (TP6)	-14.94V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon241……...
Test Engineer …Simon Pyatt…….
Date …27/08/10……

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.5V	**2.4V to 2.6V**	√
Ch2	100mV	2.5V	**2.4V to 2.6V**	√
Ch3	100mV	2.5V	**2.4V to 2.6V**	√
Ch4	100mV	2.5V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Test Engineer …Simon Pyatt…….
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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

Serial No …mon241……..
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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.8	2.8	2.8	2.8

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.4	1.4	1.4	1.4	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.3V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.6V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.6V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

Serial No …mon241……..
Test Engineer …Simon Pyatt…….
Date …27/08/10…….

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.716V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.360V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.359V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon242……
Test Engineer…Simon Pyatt……
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Contents

1. Block diagram

2. Test equipment

3. Description

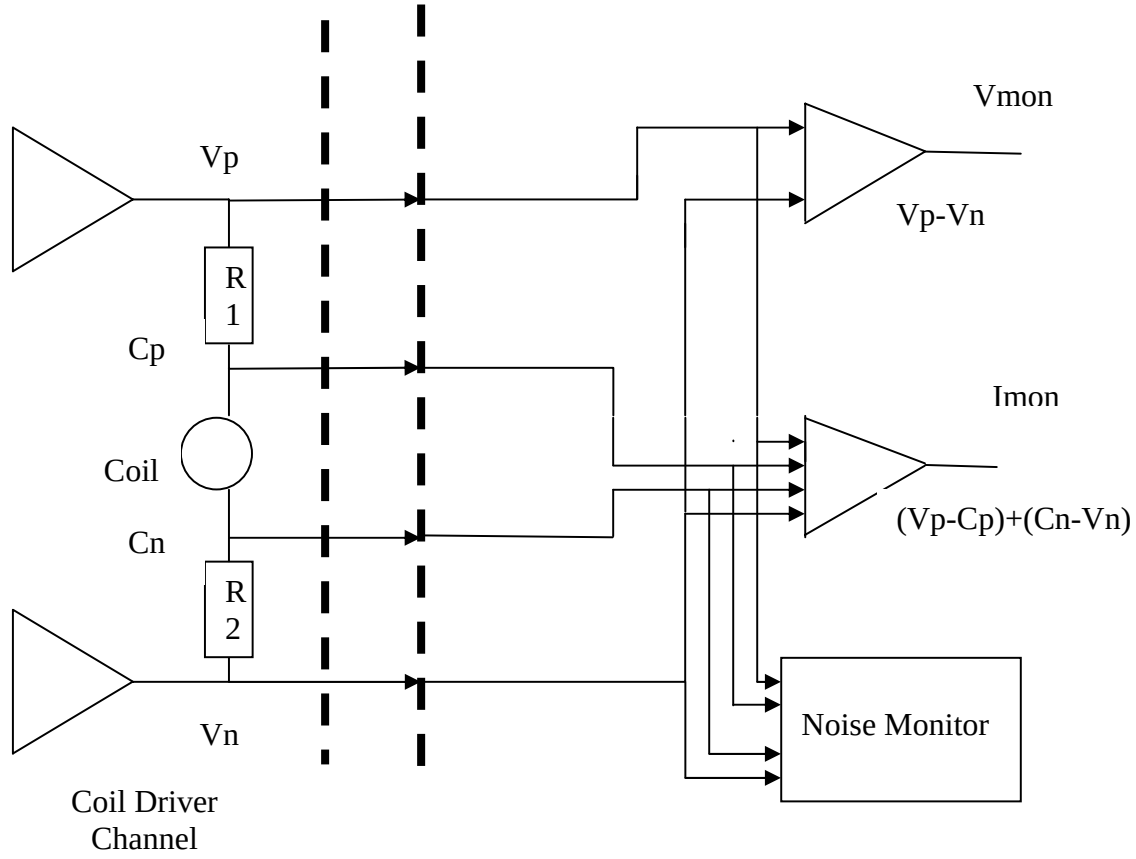
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.96V	√
-15V (TP6)	-14.92V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Test Engineer …Simon Pyatt…….
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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.8V	**4.7V to 5.2V**	√
Ch2		4.8V	**4.7V to 5.2V**	√
Ch3		4.8V	**4.7V to 5.2V**	√
Ch4		4.8V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2	2.1	2.1
TP7	8	8	8	8	3	2.9	3	3

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.45	1.5	1.5	
TP7/TP6	2	2	2	2	1.42	1.45	1.42	1.42	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.3V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.3V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.7V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.710V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.711V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.354V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.355V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon243……
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1. Block diagram

2. Test equipment

3. Description

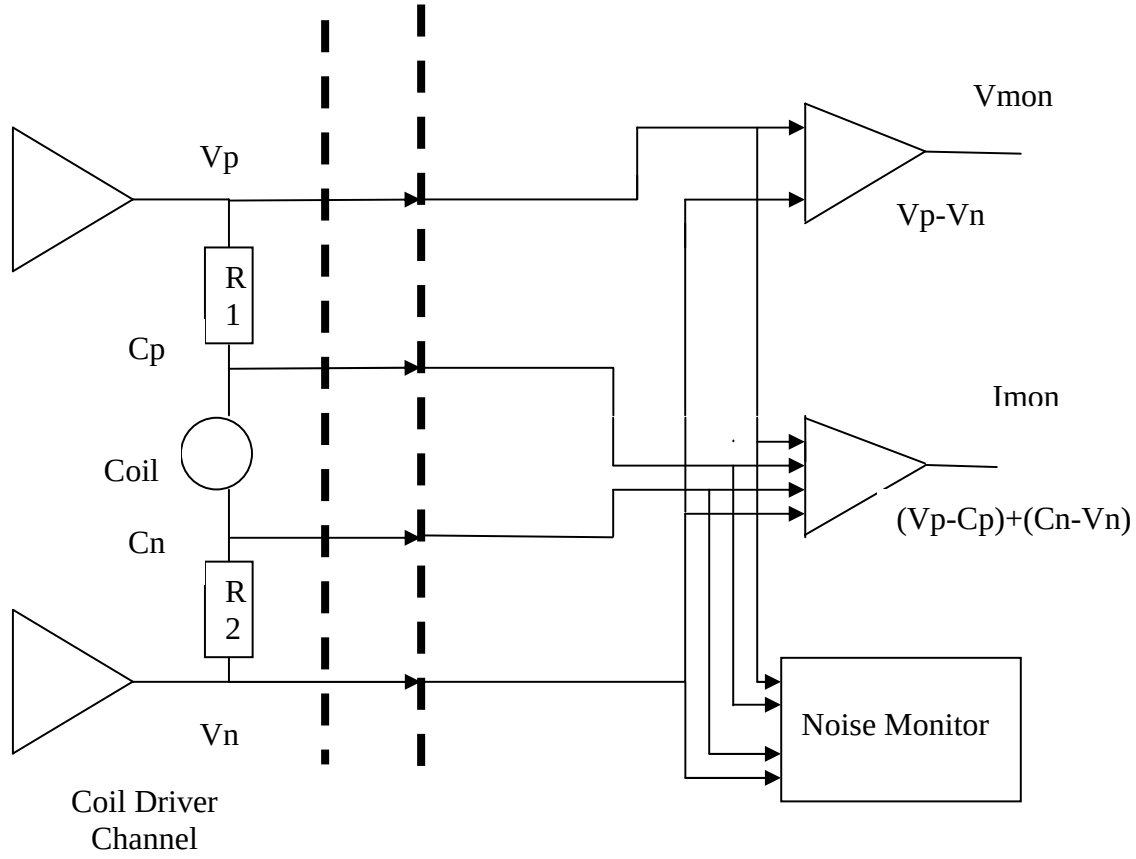
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon243……..
Test Engineer …Simon Pyatt…….
Date …01/09/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.96V	√
-15V (TP6)	-14.97V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon243……...
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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2.1
TP7	8	8	8	8	2.8	2.8	2.8	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.5	
TP7/TP6	2	2	2	2	1.4	1.4	1.4	1.38	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.3V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.8V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.6V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.6V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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Test Engineer …Simon Pyatt…….
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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.714V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon244……
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Contents

1. Block diagram

2. Test equipment

3. Description

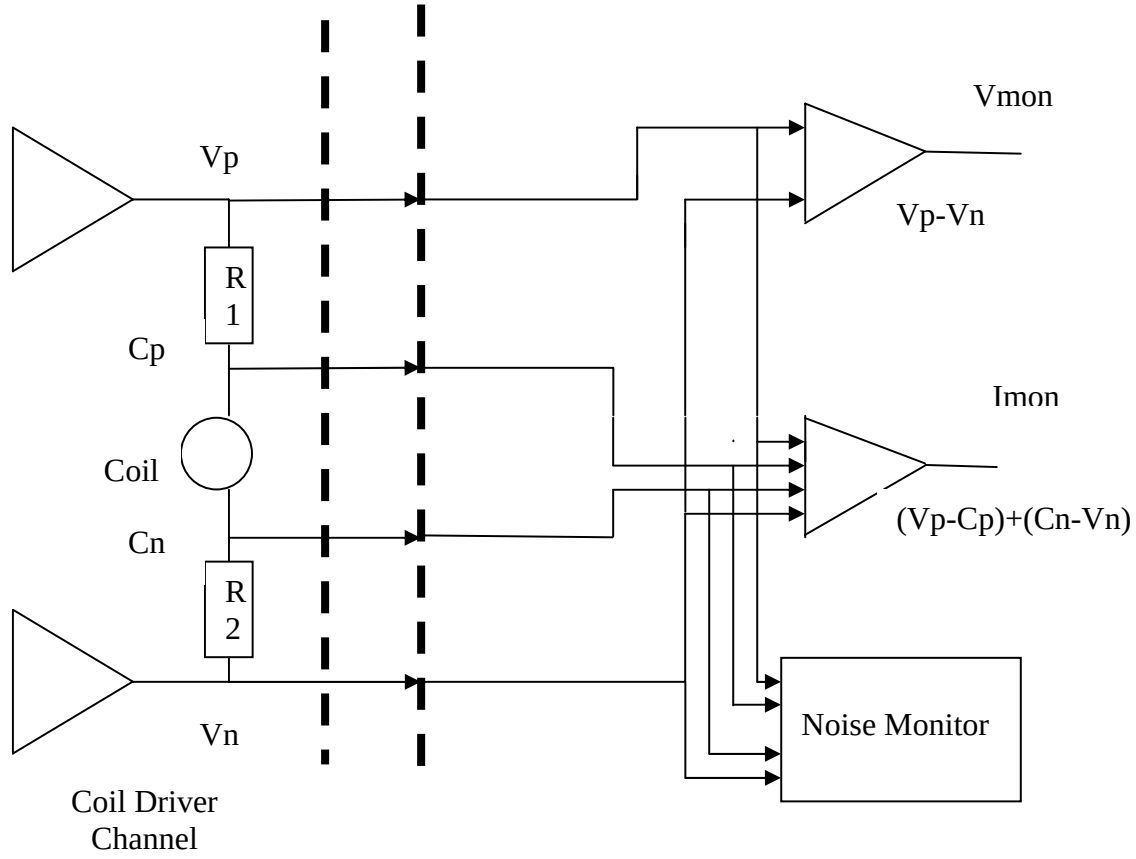
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
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Date ……

NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.91V	√
-15V (TP6)	-15.05V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.8	2.8	2.9	2.8

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.4	1.4	1.45	1.4	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.6V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.7V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.8V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.712V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.360V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.356V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

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1. Block diagram

2. Test equipment

3. Description

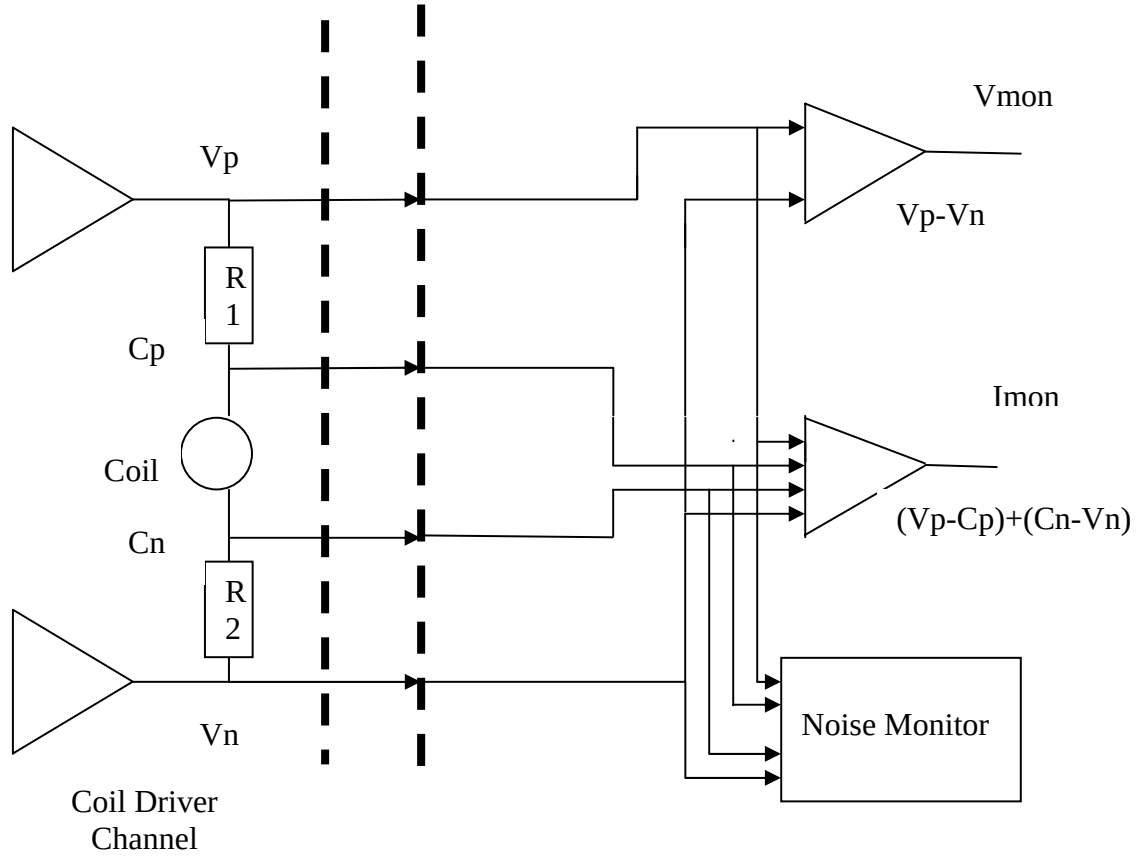
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon245……..
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Date …01/09/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	15.08V	√
-15V (TP6)	-14.99V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Test Engineer …Simon Pyatt…….
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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	1.9	1.9	1.9	1.9	1.4	1.4	1.4	1.4
TP6	3.8	3.8	3.8	3.8	2.1	2.1	2.1	2.1
TP7	7.5	7.5	7.5	7.5	3.1	3	3	3

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	1.9	1.9	1.9	1.9	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	
TP7/TP6	1.97	1.97	1.97	1.97	1.47	1.42	1.42	1.42	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.3V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.8V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.6V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.4V	4 to 5.5V	√

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Test Engineer …Simon Pyatt…….
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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

Serial No …mon245……...
Test Engineer …Simon Pyatt…….
Date …01/09/10…….

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.714V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.360V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.02V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon246……
Test Engineer…Simon Pyatt……
Date…01/09/10……

Contents

1. Block diagram

2. Test equipment

3. Description

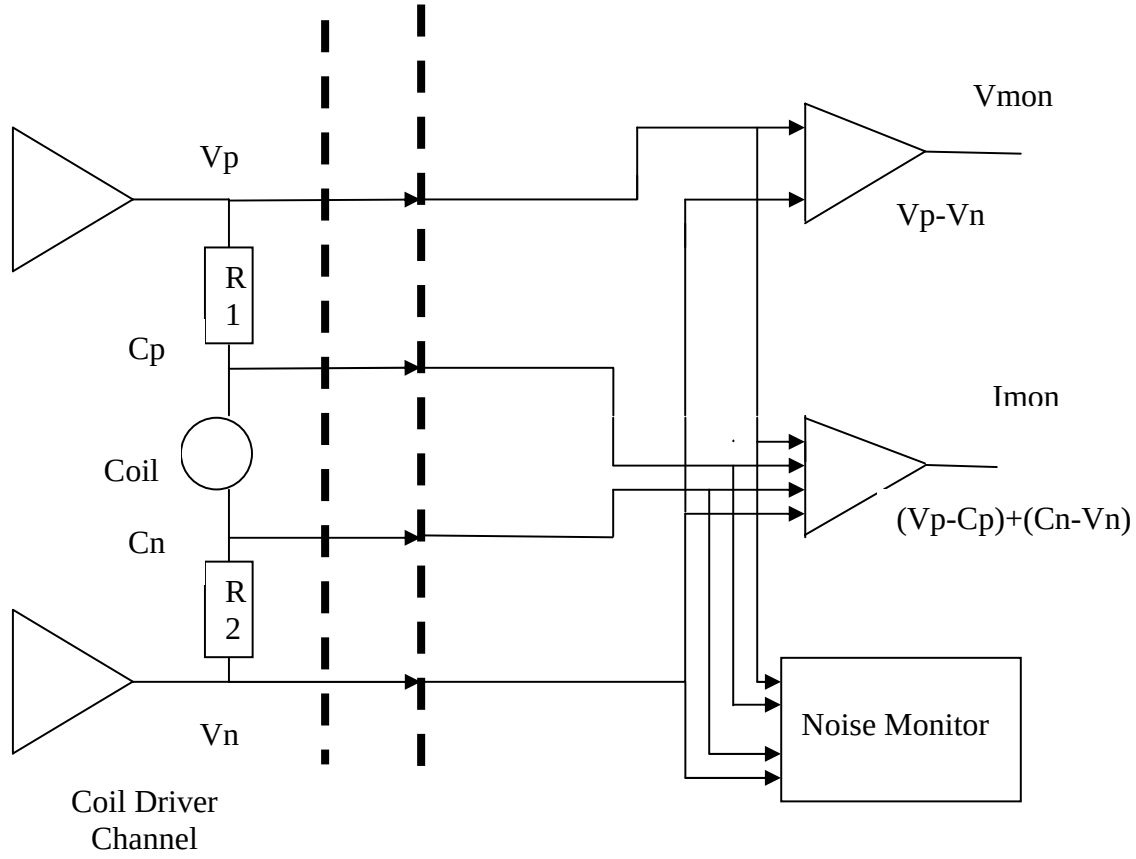
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon246……..
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Date …01/09/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.91V	√
-15V (TP6)	-15.05V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Test Engineer …Simon Pyatt…….
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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Test Engineer …Simon Pyatt…….
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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2.1	2.1
TP7	8	8	8	8	3.1	3.1	3.1	3

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.47	1.47	1.47	1.42	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.8V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.3V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.3V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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Test Engineer …Simon Pyatt……
Date …02/09/10……

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.717V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.718V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.360V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.361V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.02V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.02V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon247……
Test Engineer…Simon Pyatt……
Date…03/09/10……

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1. Block diagram

2. Test equipment

3. Description

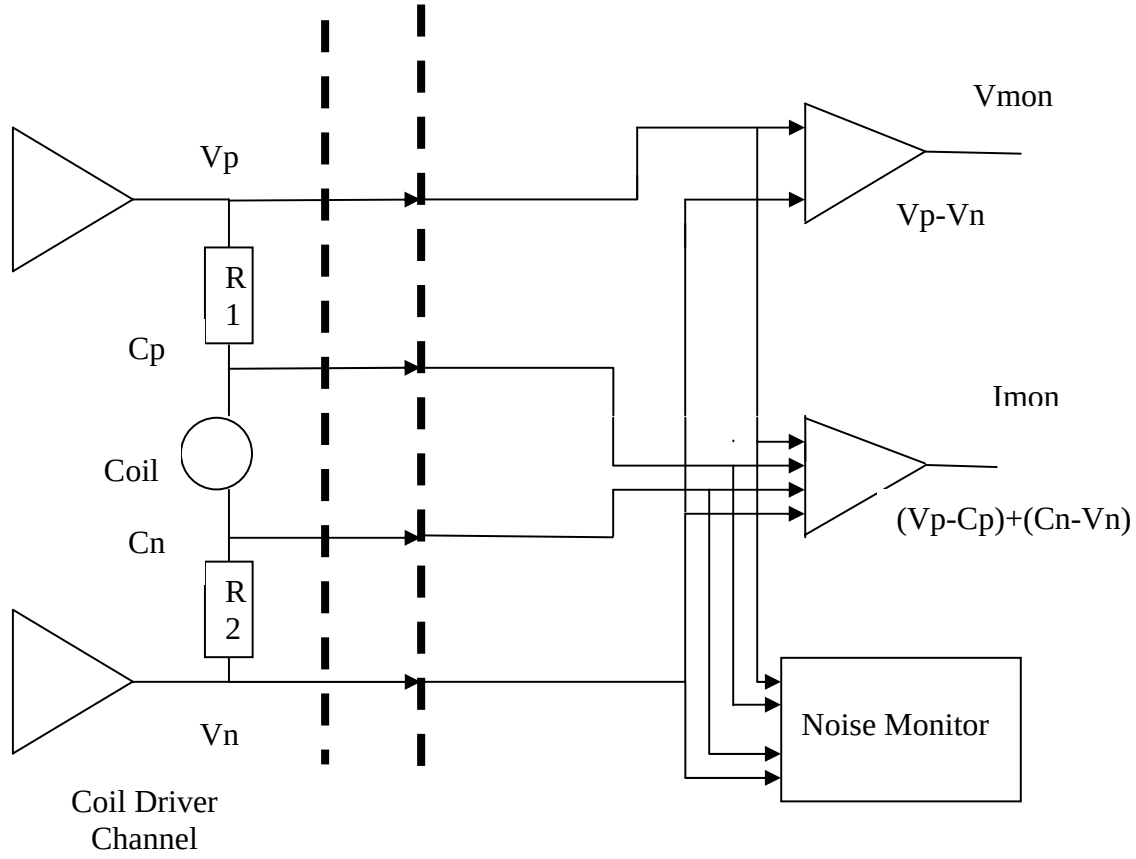
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

Serial No …mon247……..
Test Engineer …Simon Pyatt…….
Date …03/09/10……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon247……...
Test Engineer …Simon Pyatt…….
Date …03/09/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.90V	√
-15V (TP6)	-15.07V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon247……...
Test Engineer …Simon Pyatt…….
Date …03/09/10……

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2	1.9	2
TP7	8	8	8	8	2.9	2.9	2.8	2.8

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.42	1.35	1.42	
TP7/TP6	2	2	2	2	1.38	1.45	1.47	1.4	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.6V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.6V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.7V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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Date …03/09/10……

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.715V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.359V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon248……
Test Engineer…Simon Pyatt……
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1. Block diagram

2. Test equipment

3. Description

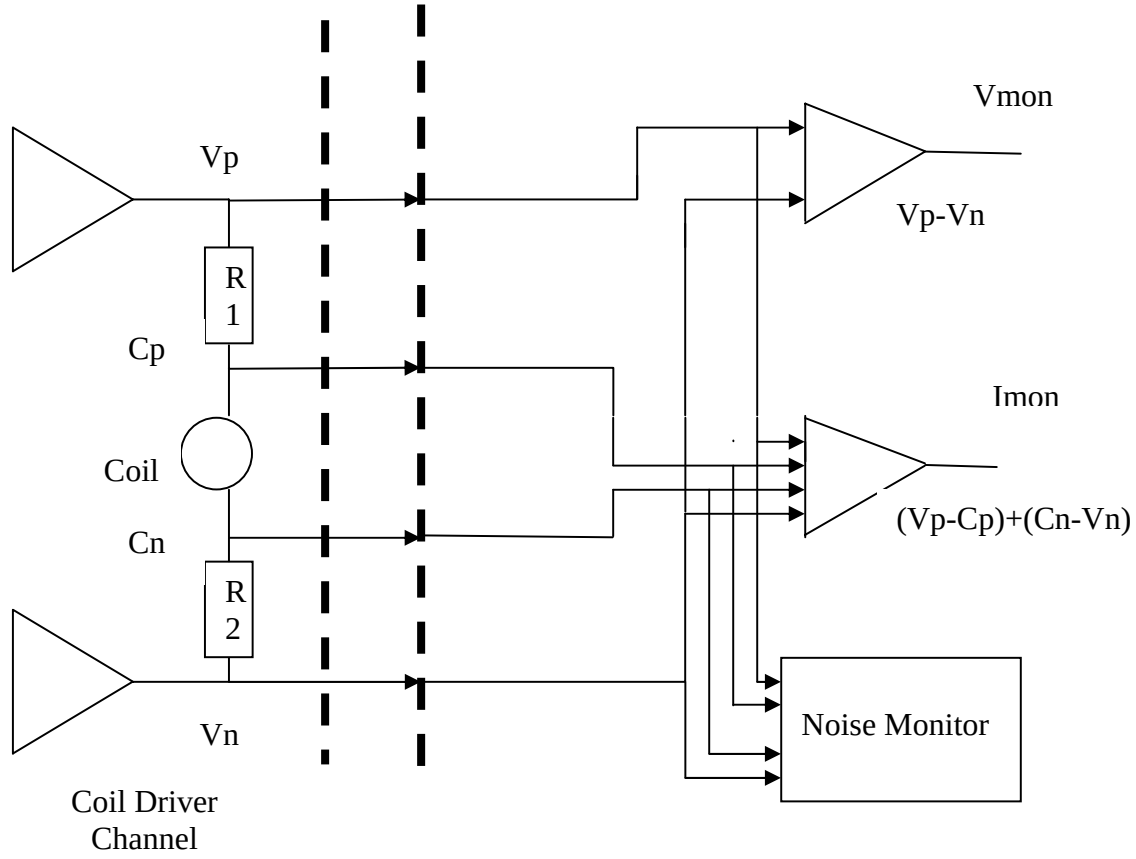
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon248……..
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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.89V	√
-15V (TP6)	-15.00V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2.1	2.1
TP7	8	8	8	8	3.1	3	3.1	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.47	1.42	1.47	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.7V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.7V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	√
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	√
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.717V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.715V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.361V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.360V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	
Ch3, TP13	1.02V	**1V (0.9 to 1.1V)**	
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	

MONITOR BOARD TEST PLAN

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1. Block diagram

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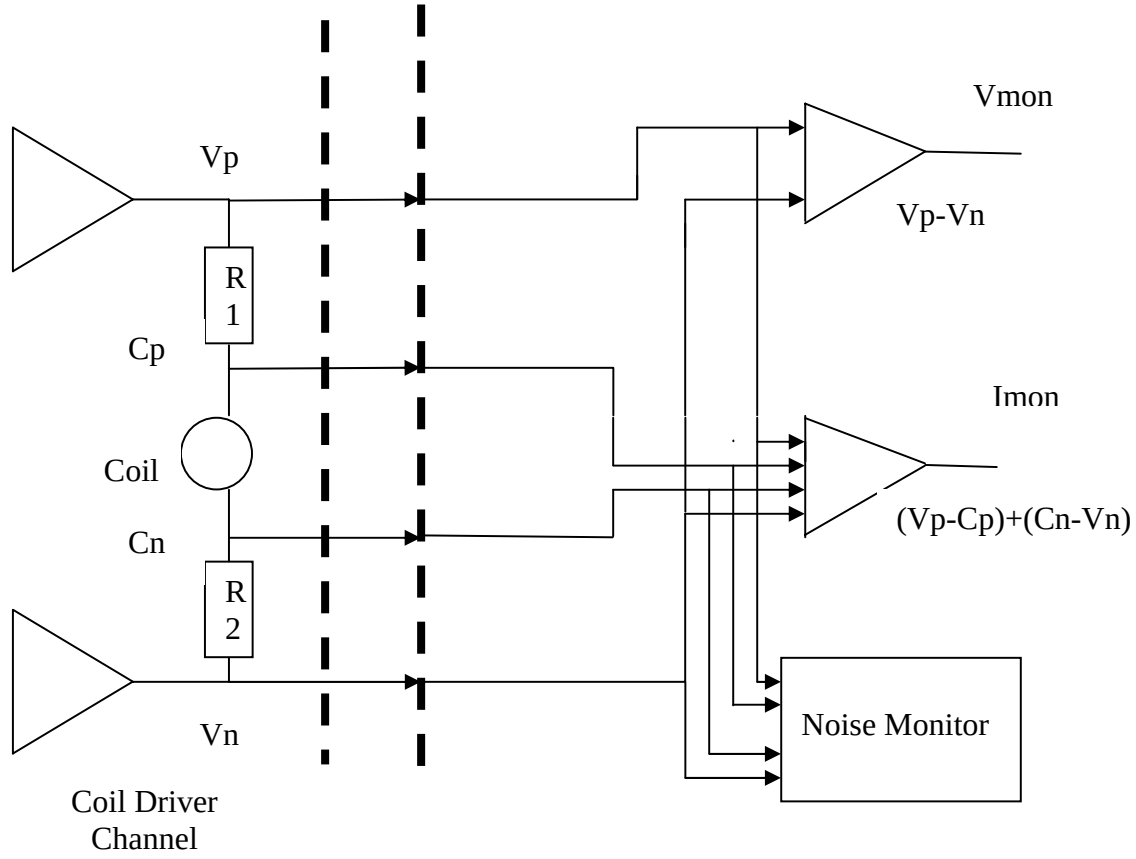
6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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Test Engineer …Simon Pyatt…….
Date …06/09/10……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon249……..
Test Engineer …Simon Pyatt…….
Date …06/09/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	15.04V	√
-15V (TP6)	-14.92V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon249……...
Test Engineer …Simon Pyatt…….
Date …06/09/10…….

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.8	2.8	2.8	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.4	1.4	1.4	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.3V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.3V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.6V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.714V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.02V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon250……
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Contents

1. Block diagram

2. Test equipment

3. Description

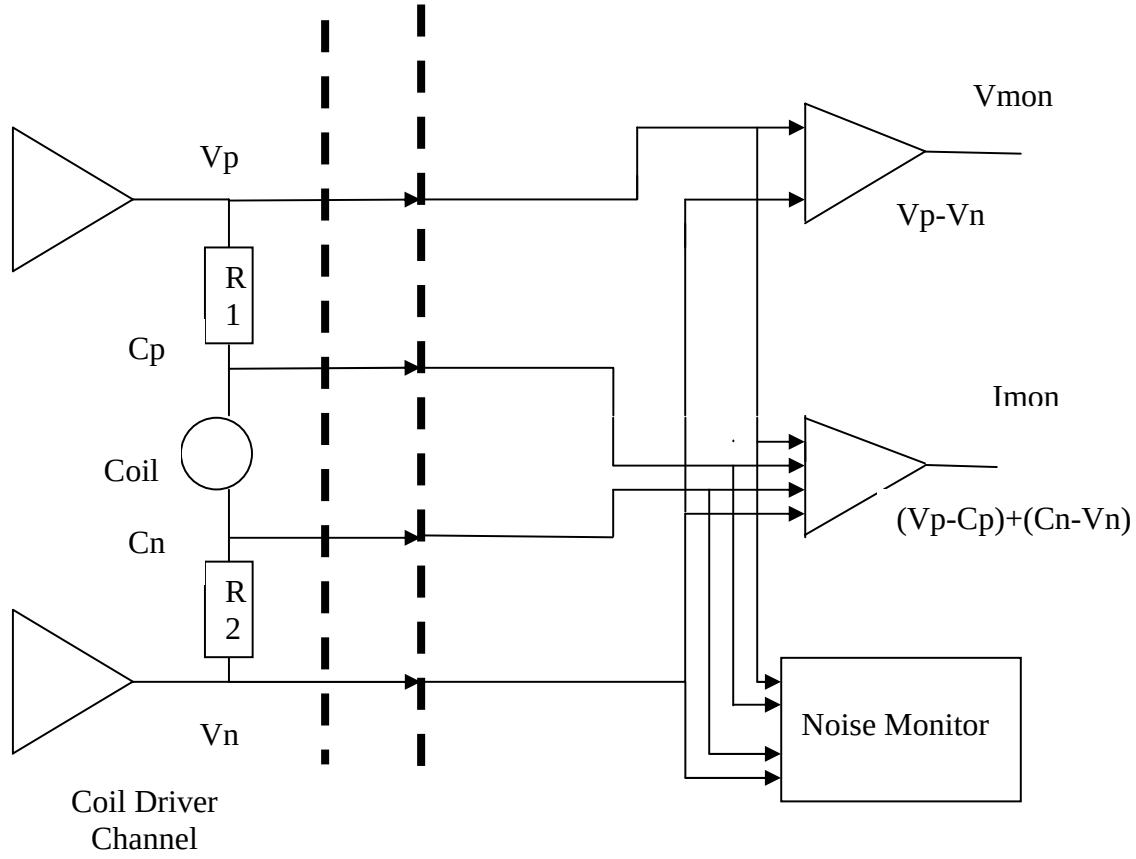
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.95V	√
-15V (TP6)	-15.00V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.8	2.9	2.9	2.8

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.4	1.45	1.45	1.4	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.6V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.713V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.356V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.02V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon251……
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1. Block diagram

2. Test equipment

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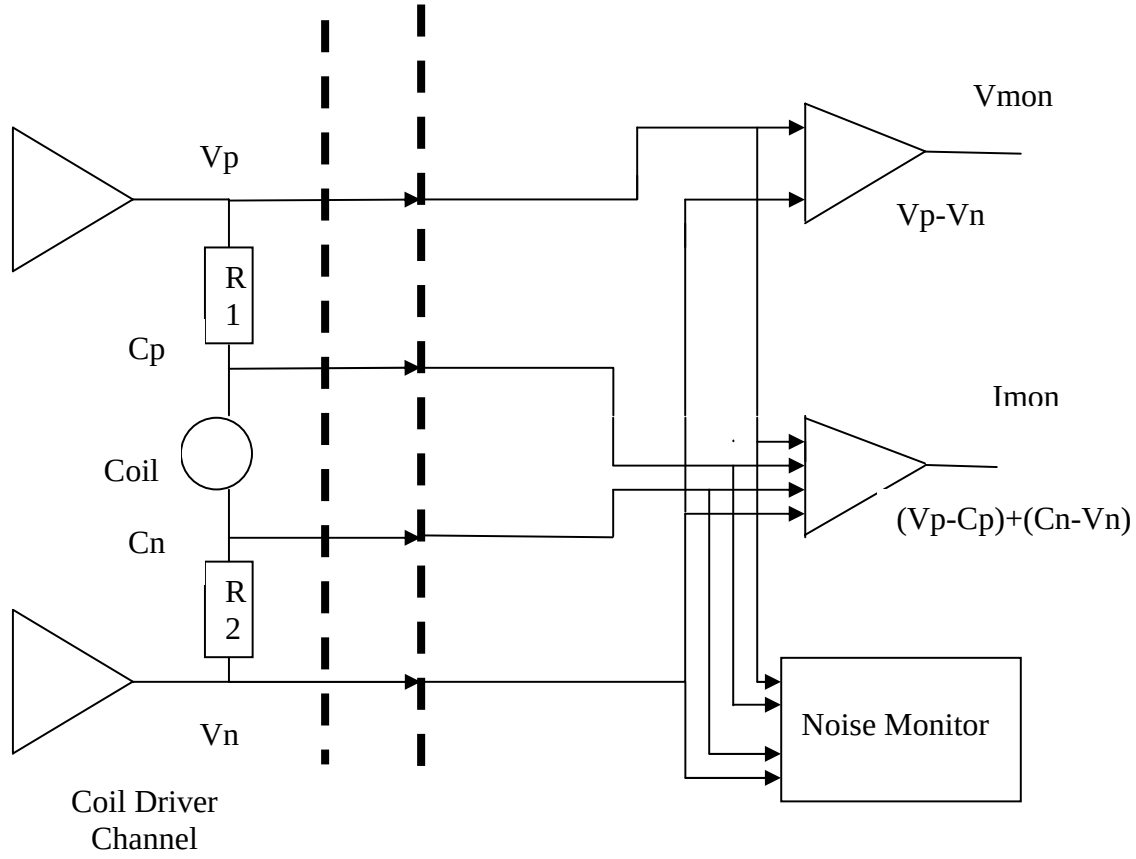
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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Date …06/09/10……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon251……...
Test Engineer …Simon Pyatt…….
Date …06/09/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.94V	√
-15V (TP6)	-15.04V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.8V	**4.7V to 5.2V**	√
Ch2		4.8V	**4.7V to 5.2V**	√
Ch3		4.8V	**4.7V to 5.2V**	√
Ch4		4.8V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2.1	2
TP7	8	8	8	8	2.9	2.9	2.9	2.8

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.42	
TP7/TP6	2	2	2	2	1.38	1.38	1.38	1.4	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.4V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.3V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.718V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.713V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.361V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.14V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.14V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.16V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.15V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon252……
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Contents

1. Block diagram

2. Test equipment

3. Description

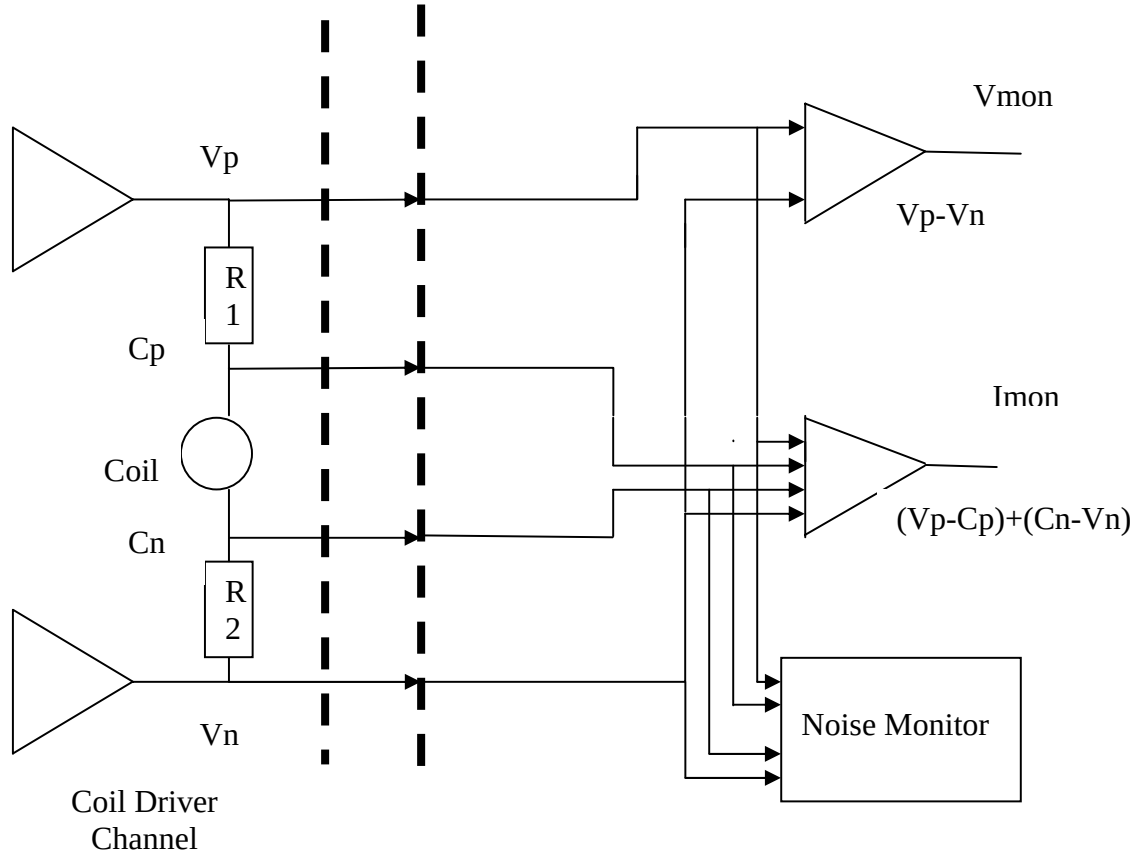
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

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NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.88V	√
-15V (TP6)	-15.06V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.8V	**4.7V to 5.2V**	√
Ch2		4.8V	**4.7V to 5.2V**	√
Ch3		4.8V	**4.7V to 5.2V**	√
Ch4		4.8V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2.1	2.1	2.1
TP7	8	8	8	8	3	3	3.1	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.42	1.42	1.47	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.6V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.8V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.8V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.714V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.02V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon253……
Test Engineer…Simon Pyatt……
Date…13/09/10……

Contents

1. Block diagram

2. Test equipment

3. Description

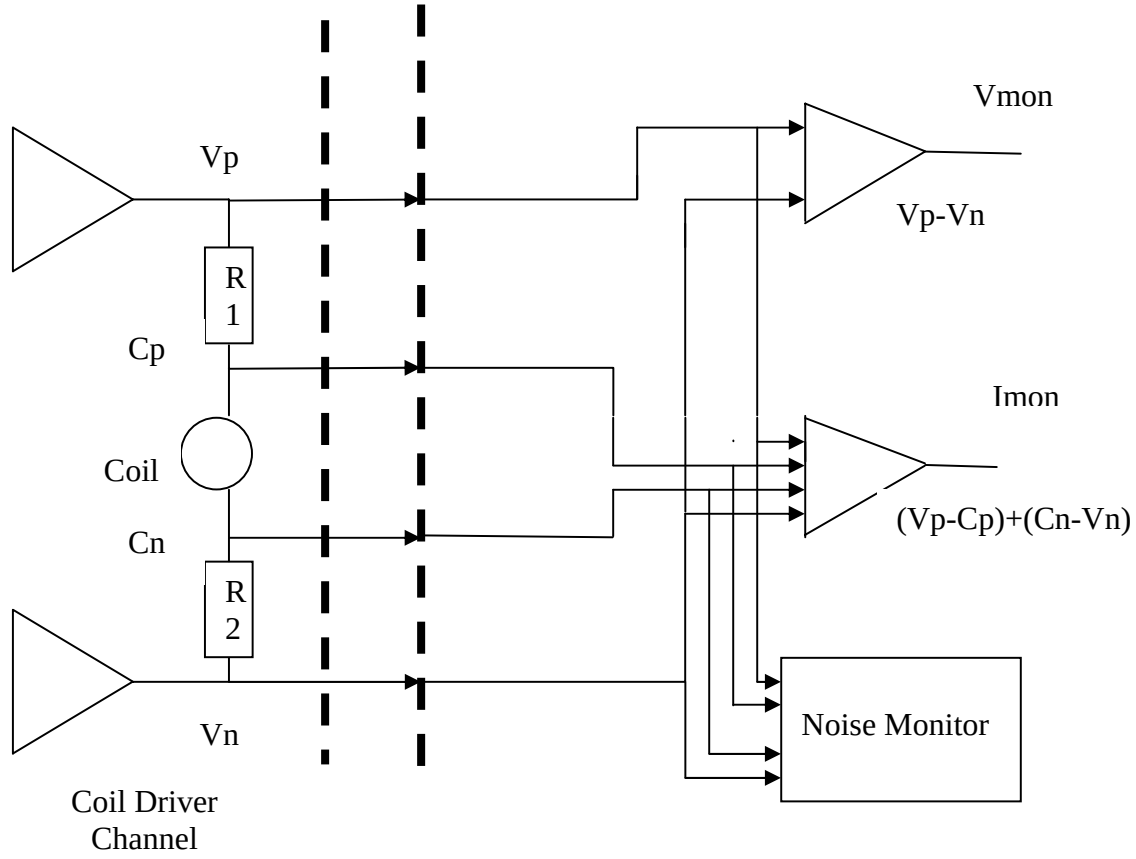
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

Serial No …mon253……..
Test Engineer …Simon Pyatt…….
Date …13/09/10……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon253……...
Test Engineer …Simon Pyatt…….
Date …13/09/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.84V	√
-15V (TP6)	-15.07V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon253……...
Test Engineer …Simon Pyatt…….
Date …13/09/10……

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

Serial No …mon253……..
Test Engineer …Simon Pyatt…….
Date …14/09/10……

Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1	100mV	4.7V	**4.7V to 5.2V**	√
Ch2	100mV	4.8V	**4.7V to 5.2V**	√
Ch3	100mV	4.8V	**4.7V to 5.2V**	√
Ch4	100mV	4.8V	**4.7V to 5.2V**	√

Serial No …mon253……..
Test Engineer …Simon Pyatt…….
Date …14/09/10…….

Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.8	2.8	2.9	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.4	1.4	1.45	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.7V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.8V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.6V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.8V	4 to 5.5V	√

Serial No …mon253……...
Test Engineer …Simon Pyatt…….
Date …14/09/10…….

6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

Serial No …mon253……...
Test Engineer …Simon Pyatt…….
Date …14/09/10…….

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.716V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.715V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.360V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.359V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.02V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon254……
Test Engineer…Simon Pyatt……
Date…14/09/10……

Contents

1. Block diagram

2. Test equipment

3. Description

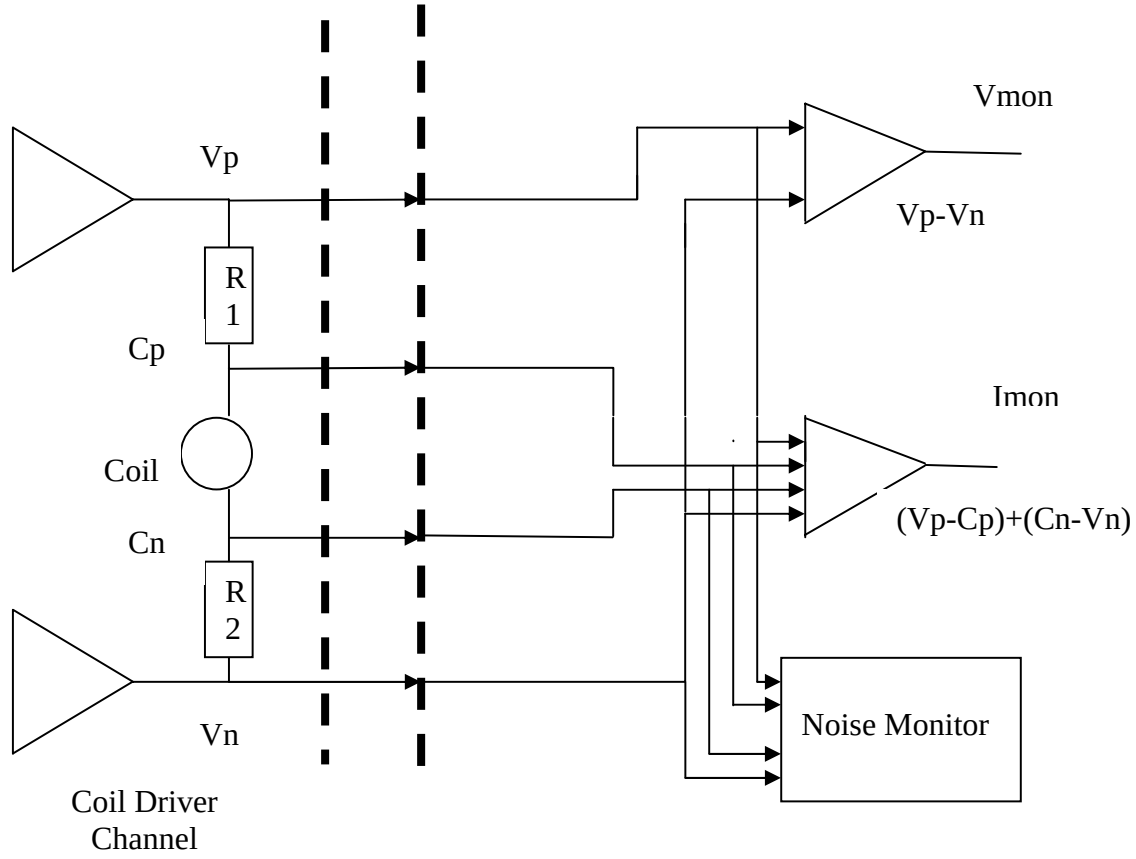
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

Serial No …mon254……..
Test Engineer …Simon Pyatt…….
Date …14/09/10……

4. Inspection

Workmanship

General **OK?** √
Comments

Board is slightly bowed.

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon254……..
Test Engineer …Simon Pyatt…….
Date …14/09/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.87V	√
-15V (TP6)	-15.04V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon254……...
Test Engineer …Simon Pyatt…….
Date …14/09/10……

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

Serial No …mon254……...
Test Engineer …Simon Pyatt…….
Date …14/09/10…….

Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

Serial No …mon254……..
Test Engineer …Simon Pyatt…….
Date …14/09/10…….

Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2.1	2	2.1	2.1
TP7	8	8	8	8	3.1	2.9	3.1	3

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.5	1.42	1.5	1.5	
TP7/TP6	2	2	2	2	1.47	1.45	1.47	1.42	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.3V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.8V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.7V	4 to 5.5V	√

Serial No …mon254……...
Test Engineer …Simon Pyatt…….
Date …14/09/10…….

6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

Serial No …mon254……..
Test Engineer …Simon Pyatt…….
Date …14/09/10…….

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.715V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon255……
Test Engineer…Simon Pyatt……
Date…14/09/10……

Contents

1. Block diagram

2. Test equipment

3. Description

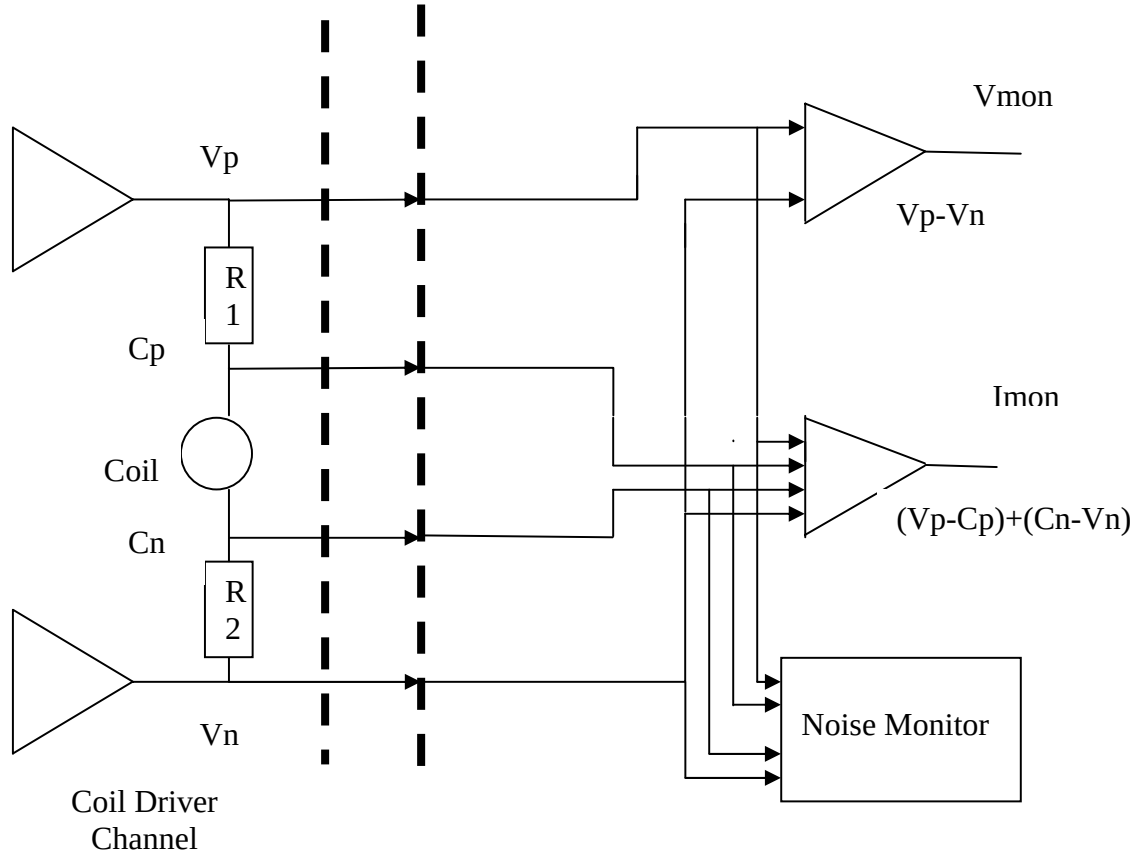
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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Test Engineer …Simon Pyatt…….
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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon255……..
Test Engineer …Simon Pyatt…….
Date …14/09/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.95V	√
-15V (TP6)	-15.02V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.9	2.9	2.9	2.8

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.45	1.45	1.45	1.4	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.6V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.8V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.712V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.356V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon256……
Test Engineer…Simon Pyatt……
Date…14/09/10……

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2. Test equipment

3. Description

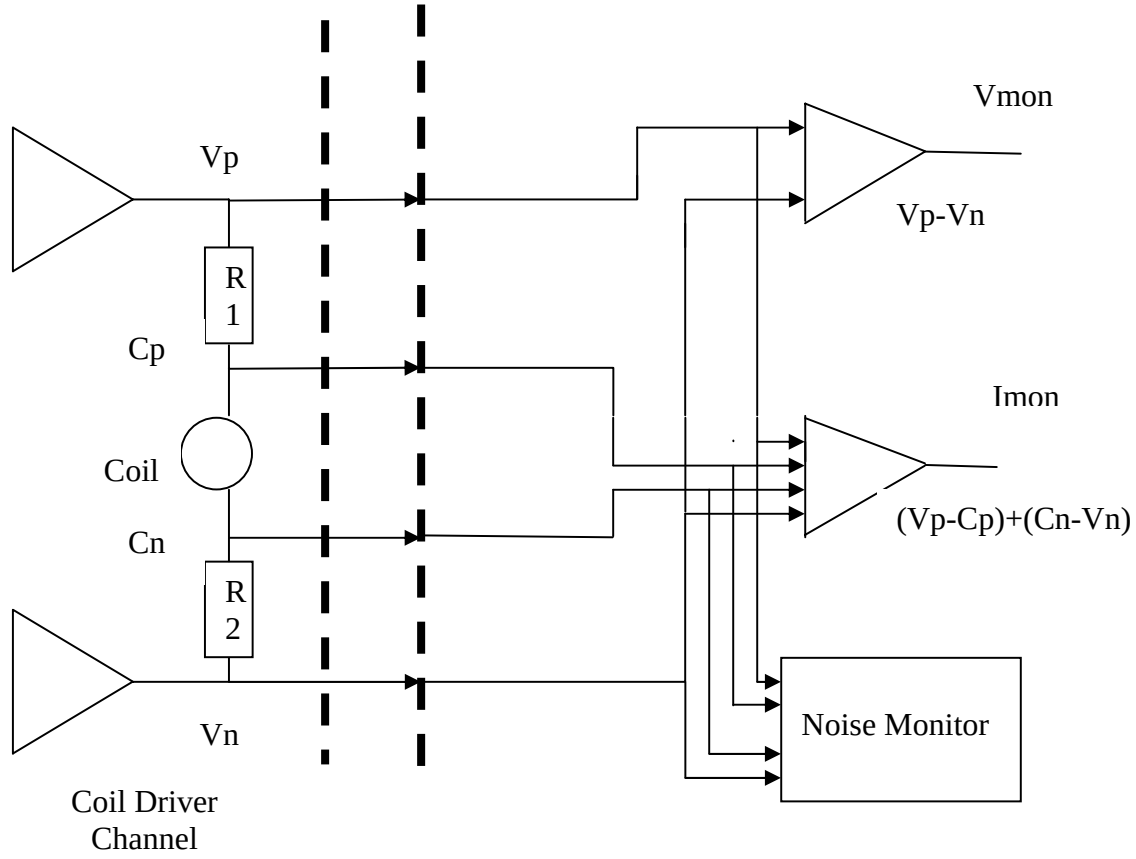
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon256……..
Test Engineer …Simon Pyatt…….
Date …14/09/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.94V	√
-15V (TP6)	-15.14V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.9	2.9	2.8	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.45	1.45	1.4	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.8V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.7V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.8V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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Test Engineer …Simon Pyatt…….
Date …14/09/10…….

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.714V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon257……
Test Engineer…Simon Pyatt……
Date…15/09/10……

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2. Test equipment

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4. Inspection

5. Power

6. Circuit operation

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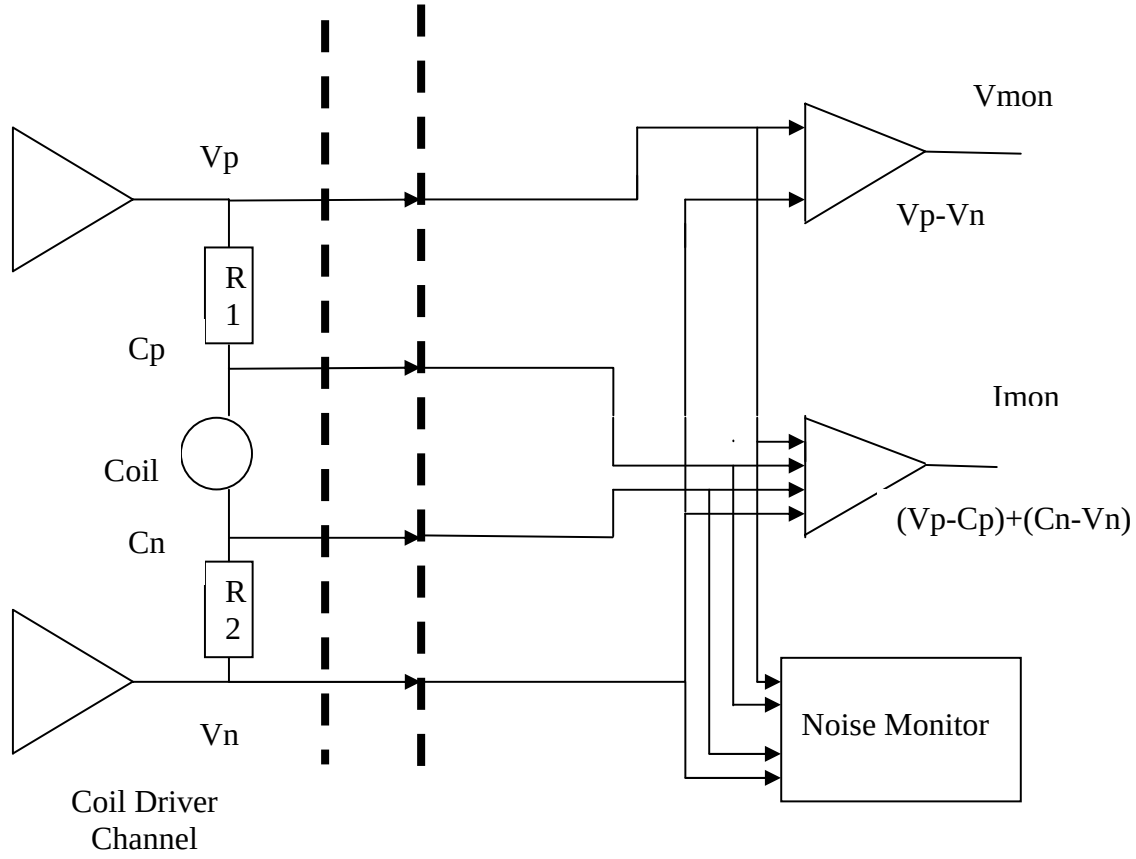
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon257……...
Test Engineer …Simon Pyatt…….
Date …15/09/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	15.04V	√
-15V (TP6)	-14.93V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Test Engineer …Simon Pyatt…….
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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.8V	**4.7V to 5.2V**	√
Ch2		4.8V	**4.7V to 5.2V**	√
Ch3		4.8V	**4.7V to 5.2V**	√
Ch4		4.8V	**4.7V to 5.2V**	√

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Test Engineer …Simon Pyatt…….
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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2.1	2.1	2.1
TP7	8	8	8	8	3.1	3.1	3.1	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.55	1.47	1.47	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.3V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.7V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.8V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.716V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.359V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon258……
Test Engineer…Simon Pyatt……
Date…15/09/10……

Contents

1. Block diagram

2. Test equipment

3. Description

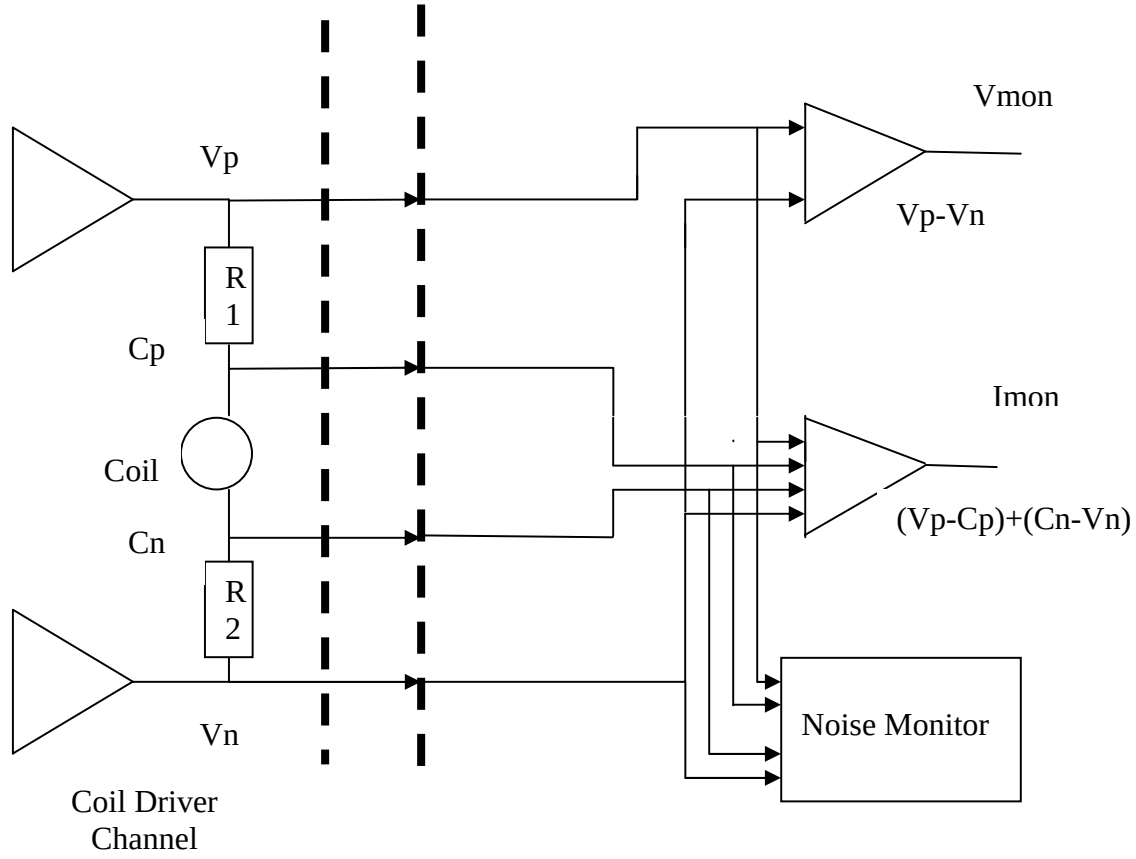
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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Test Engineer …Simon Pyatt…….
Date …15/09/10……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon258……..
Test Engineer …Simon Pyatt…….
Date …15/09/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.84V	√
-15V (TP6)	-15.01V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon258……...
Test Engineer …Simon Pyatt…….
Date …15/09/10……

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Test Engineer …Simon Pyatt…….
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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

Serial No …mon258……..
Test Engineer …Simon Pyatt…….
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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2.1	2.1	2.1
TP7	8	8	8	8	2.9	3.1	3.1	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.45	1.47	1.47	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.3V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.7V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.8V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.8V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

Serial No …mon258……..
Test Engineer …Simon Pyatt…….
Date …15/09/10…….

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.712V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.355V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon259……
Test Engineer…Simon Pyatt……
Date…15/09/10……

Contents

1. Block diagram

2. Test equipment

3. Description

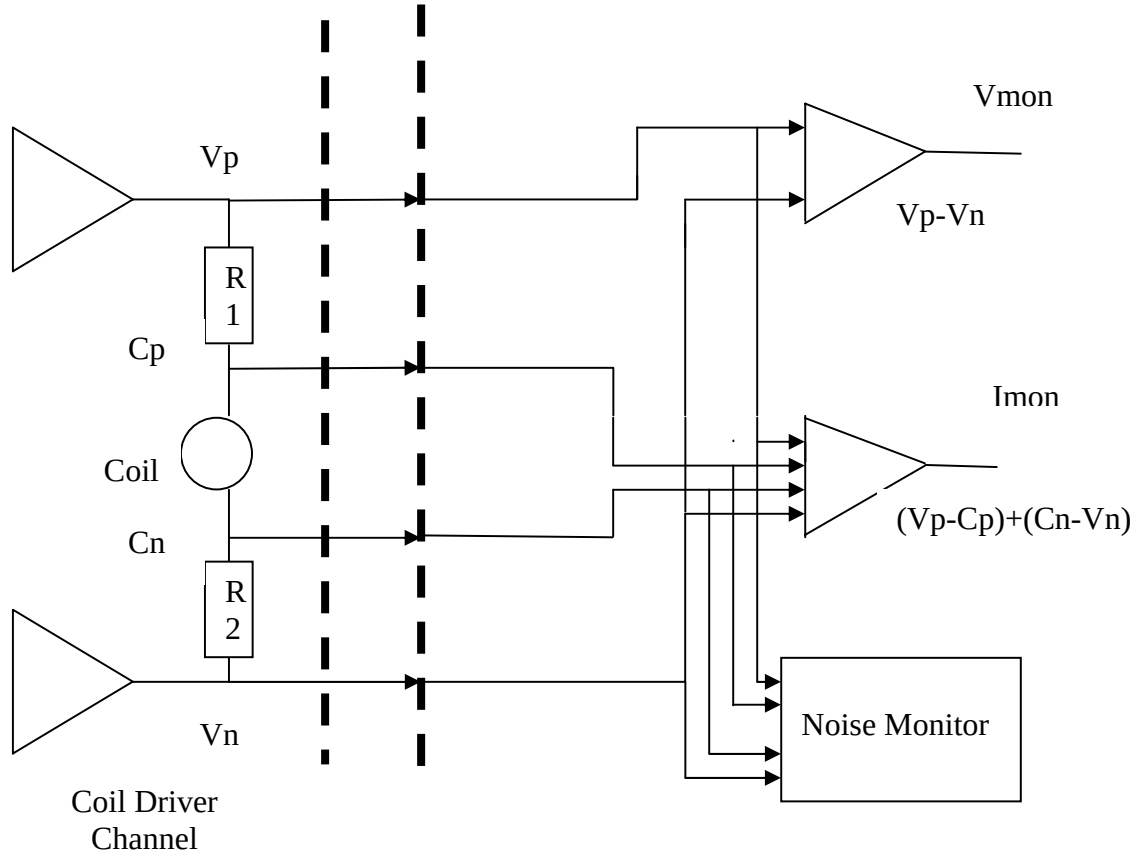
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon259……..
Test Engineer …Simon Pyatt…….
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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.93V	√
-15V (TP6)	-15.02V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2.1	2.1	2.1
TP7	8	8	8	8	3	3.1	3.1	3.1

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.5	1.5	1.5	
TP7/TP6	2	2	2	2	1.5	1.47	1.47	1.47	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.7V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.6V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.711V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.713V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.356V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon260……
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1. Block diagram

2. Test equipment

3. Description

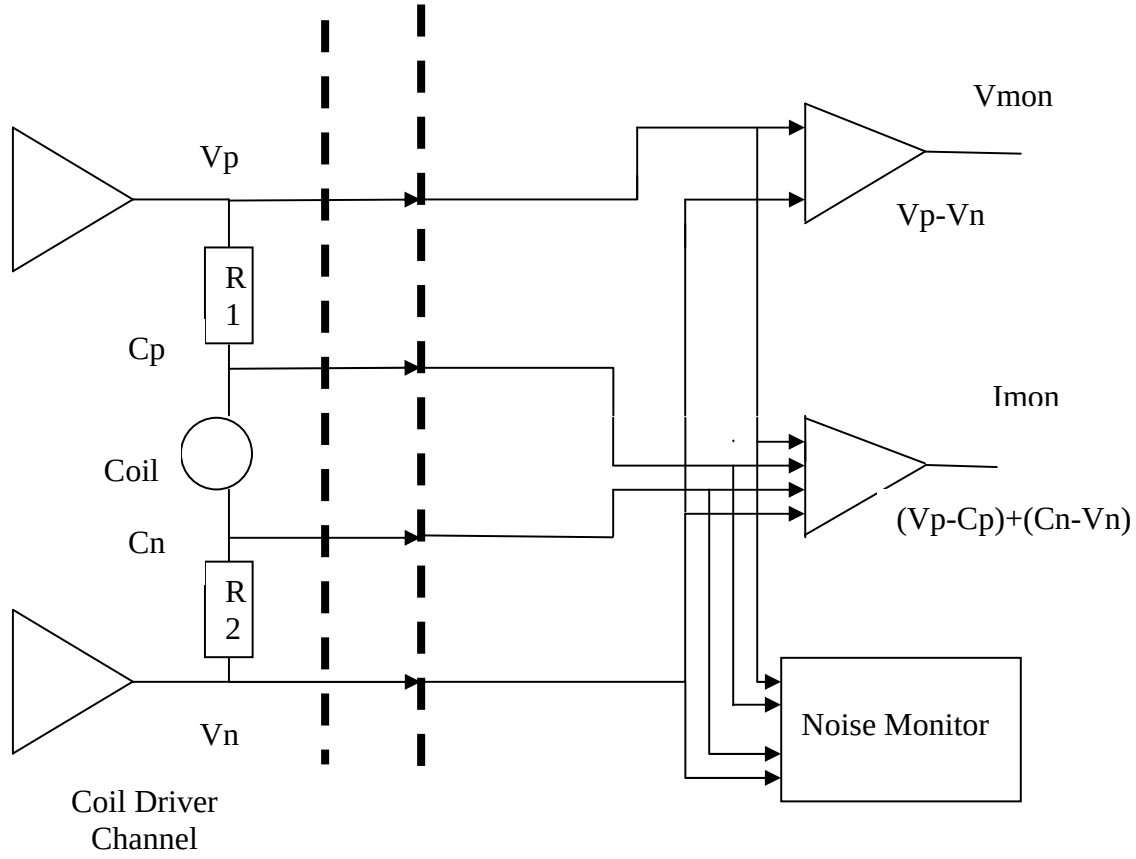
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon260……...
Test Engineer …Simon Pyatt…….
Date …15/09/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	15.02V	√
-15V (TP6)	-15.08V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

Serial No …mon260……...
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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.7V	**4.7V to 5.2V**	√
Ch2		4.7V	**4.7V to 5.2V**	√
Ch3		4.7V	**4.7V to 5.2V**	√
Ch4		4.7V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.9	2.9	2.8	2.8

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.45	1.45	1.4	1.4	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	TP10	10V	9.7 to 10V	√	4.6V	4 to 5.5V	√
Ch2	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√
Ch3	TP10	10V	9.7 to 10V	√	4.7V	4 to 5.5V	√
Ch4	TP10	10V	9.7 to 10V	√	4.5V	4 to 5.5V	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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Test Engineer …Simon Pyatt…….
Date …15/09/10…….

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.710V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.712V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.715V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.355V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.356V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon261……
Test Engineer…Simon Pyatt……
Date…16/09/10……

Contents

1. Block diagram

2. Test equipment

3. Description

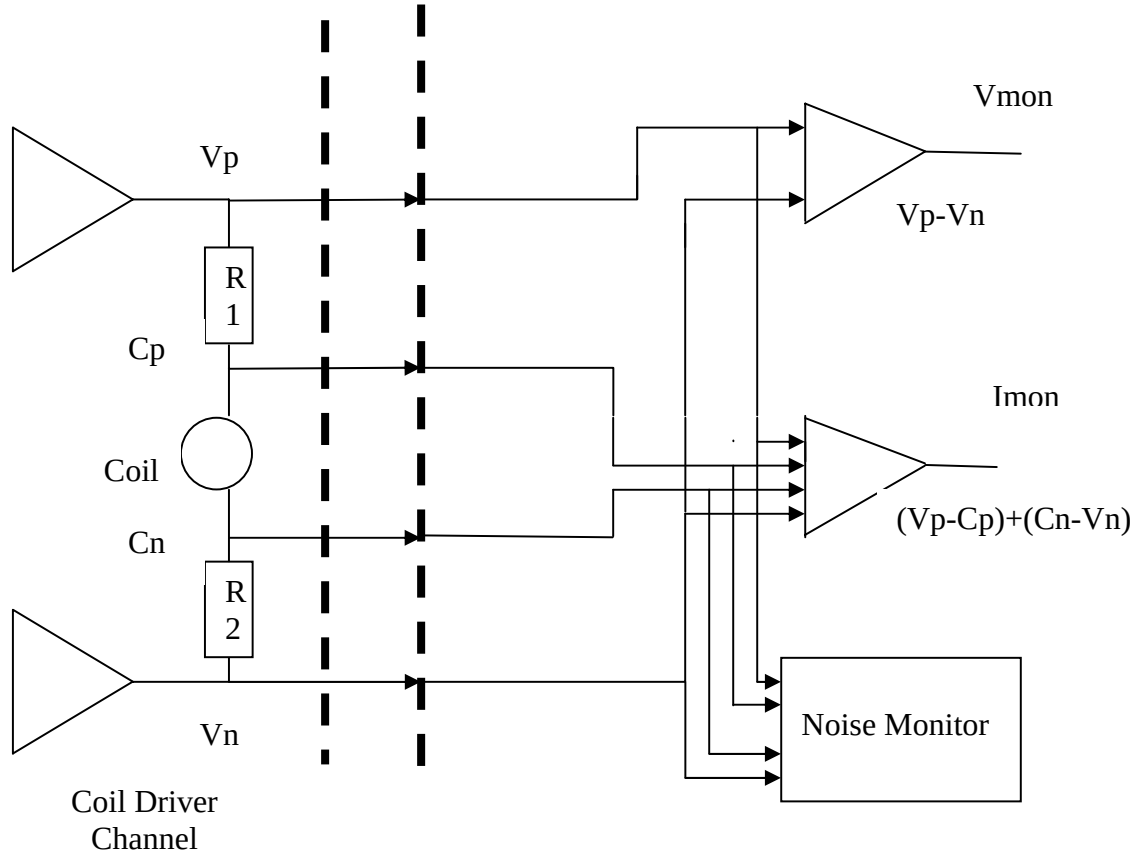
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon261……..
Test Engineer …Simon Pyatt…….
Date …16/09/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.96V	√
-15V (TP6)	-14.96V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.7V	**1.6V to 1.9V**	√

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Test Engineer …Simon Pyatt…….
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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.7V	**1.6V to 1.9V**	√
Ch2	100mV	1.7V	**1.6V to 1.9V**	√
Ch3	100mV	1.7V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.8V	**4.7V to 5.2V**	√
Ch2		4.8V	**4.7V to 5.2V**	√
Ch3		4.8V	**4.7V to 5.2V**	√
Ch4		4.8V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2
TP7	8	8	8	8	2.9	2.8	2.8	2.9

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.42	1.42	1.42	1.42	
TP7/TP6	2	2	2	2	1.45	1.4	1.4	1.45	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.6V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.9V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.713V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.715V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.359V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No…mon262……
Test Engineer…Simon Pyatt……
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Contents

1. Block diagram

2. Test equipment

3. Description

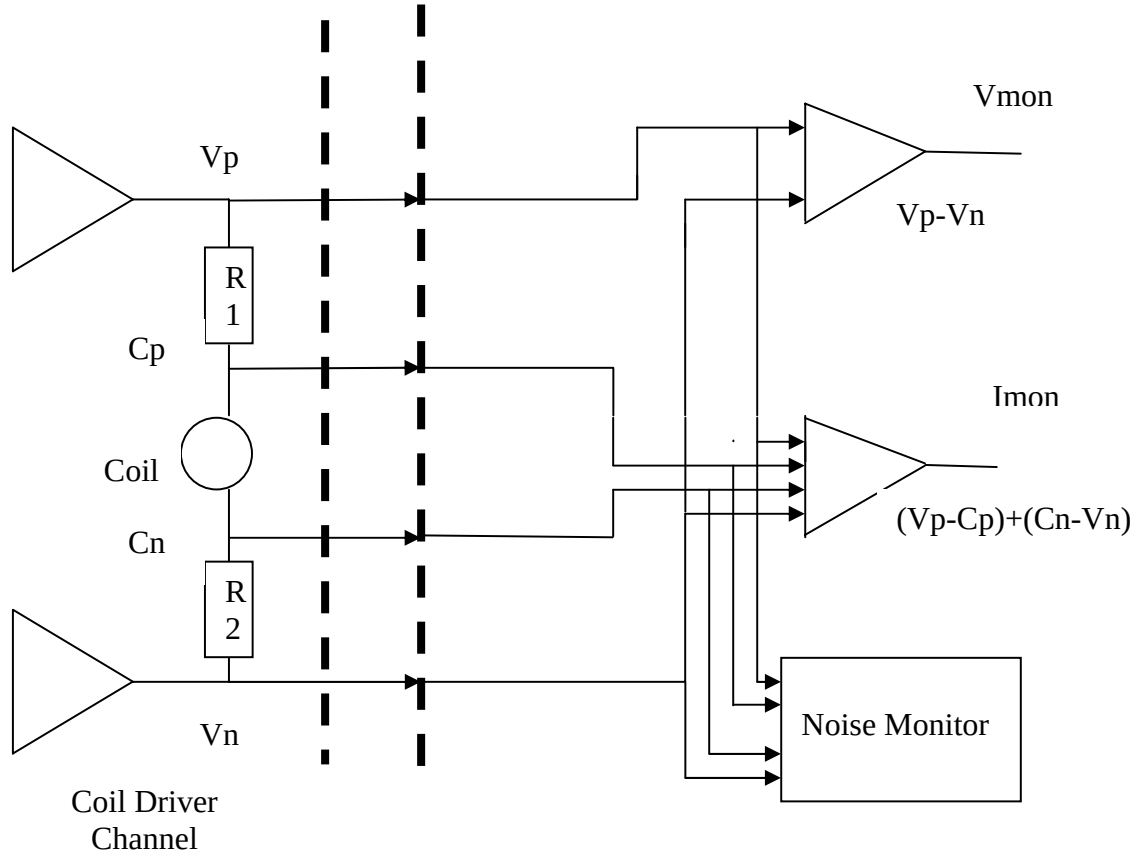
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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Date …16/09/10……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No …mon262……...
Test Engineer …Simon Pyatt…….
Date …16/09/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.99V	√
-15V (TP6)	-14.97V	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	0.28A
-15v (TP6)	√	5mV	0.26A

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1	100mV	2.4V	**2.4V to 2.6V**	√
Ch2	100mV	2.4V	**2.4V to 2.6V**	√
Ch3	100mV	2.4V	**2.4V to 2.6V**	√
Ch4	100mV	2.4V	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1	100mV	1.8V	**1.6V to 1.9V**	√
Ch2	100mV	1.8V	**1.6V to 1.9V**	√
Ch3	100mV	1.8V	**1.6V to 1.9V**	√
Ch4	100mV	1.8V	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.8V	**4.7V to 5.2V**	√
Ch2		4.8V	**4.7V to 5.2V**	√
Ch3		4.8V	**4.7V to 5.2V**	√
Ch4		4.8V	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.4	1.4	1.4	1.4
TP6	4	4	4	4	2	2	2	2.1
TP7	8	8	8	8	2.9	2.9	2.9	3

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.4	1.4	1.4	1.4	
TP6/TP4	2	2	2	2	1.4	1.4	1.4	1.5	
TP7/TP6	2	2	2	2	1.45	1.45	1.45	1.42	

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√
Ch2	**TP10**	10V	**9.7 to 10V**	√	4.3V	**4 to 5.5V**	√
Ch3	**TP10**	10V	**9.7 to 10V**	√	4.3V	**4 to 5.5V**	√
Ch4	**TP10**	10V	**9.7 to 10V**	√	4.5V	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		2V	**1.9 to 2.1V**	√
Ch2		2V	**1.9 to 2.1V**	√
Ch3		2V	**1.9 to 2.1V**	√
Ch4		2V	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0V	0V	0V	0V	
(2) 3V in	**1V +/- 0.1V**	1V	1V	1V	1V	
(3) 4.5V in	**1.5V +/- 0.1V**	1.5V	1.5V	1.5V	1.5V	
(4) 6V in	**2V +/- 0.1V**	2V	2V	2V	2V	

Serial No …mon262……..
Test Engineer …Simon Pyatt…….
Date …16/09/10…….

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.715V	**0.707 (0.68 to 0.72V)**	√
Ch2	0.714V	**0.707 (0.68 to 0.72V)**	√
Ch3	0.717V	**0.707 (0.68 to 0.72V)**	√
Ch4	0.715V	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch2	0.357V	**0.35V (0.33 to 0.37V)**	√
Ch3	0.360V	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358V	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01V	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01V	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No……..Mon263.....
Test Engineer…..Xen……
Date……..8/12/10..……

Contents

1. Block diagram

2. Test equipment

3. Description

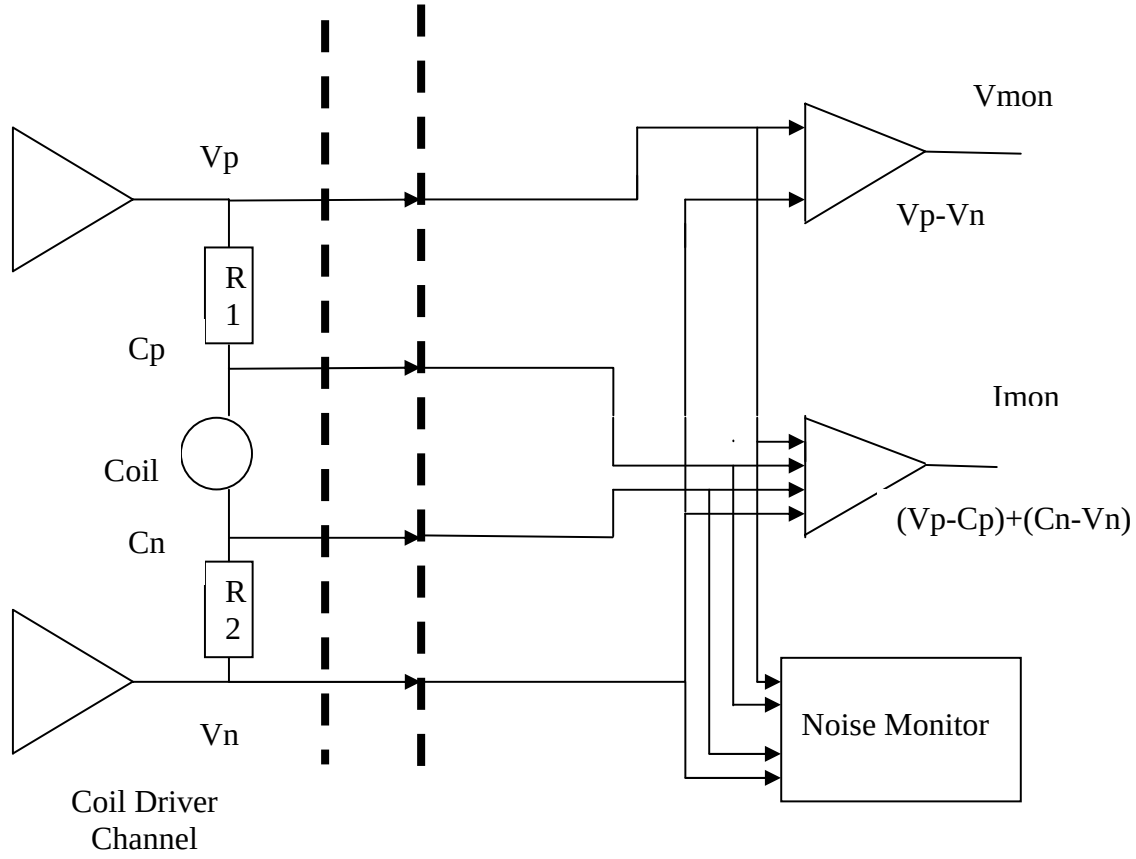
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



1. Block diagram of one channel of the monitor board.
Each board houses four such channels.

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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Test Engineer…..Xen……
Date……..8/12/10..……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Replaced U2.

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No……..Mon263.....
Test Engineer…..Xen…….
Date……..8/12/10..…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.82	√
-15V (TP6)	-14.98	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	300mA
-15v (TP6)	√	5mV	250mA

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Test Engineer…..Xen……
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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1		2.4	**2.4V to 2.6V**	√
Ch2		2.4	**2.4V to 2.6V**	√
Ch3		2.4	**2.4V to 2.6V**	√
Ch4		2.4	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1		2.4	**2.4V to 2.6V**	√
Ch2		2.4	**2.4V to 2.6V**	√
Ch3		2.4	**2.4V to 2.6V**	√
Ch4		2.4	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1		1.75	**1.6V to 1.9V**	√
Ch2		1.75	**1.6V to 1.9V**	√
Ch3		1.75	**1.6V to 1.9V**	√
Ch4		1.75	**1.6V to 1.9V**	√

Serial No……..Mon263.....
Test Engineer…..Xen……
Date……..8/12/10..……

Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1		1.7	**1.6V to 1.9V**	√
Ch2		1.7	**1.6V to 1.9V**	√
Ch3		1.7	**1.6V to 1.9V**	√
Ch4		1.7	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.95	**4.7V to 5.2V**	√
Ch2		4.95	**4.7V to 5.2V**	√
Ch3		4.95	**4.7V to 5.2V**	√
Ch4		4.95	**4.7V to 5.2V**	√

Serial No……..Mon263.....
Test Engineer…..Xen……
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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.45	1.45	1.45	1.50
TP6	4	4	4	4	2.2	2.2	2.2	2.2
TP7	8	8	8	8	3.2	3.2	3.2	3.2

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.45	1.45	1.45	1.45	√
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	√
TP7/TP6	2	2	2	2	1.5	1.5	1.5	1.5	√

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10	**9.7 to 10V**	√	4.95	**4 to 5.5V**	√
Ch2	**TP10**	10	**9.7 to 10V**	√	4.95	**4 to 5.5V**	√
Ch3	**TP10**	10	**9.7 to 10V**	√	4.95	**4 to 5.5V**	√
Ch4	**TP10**	10	**9.7 to 10V**	√	4.95	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		1.99	**1.9 to 2.1V**	√
Ch2		1.99	**1.9 to 2.1V**	√
Ch3		1.99	**1.9 to 2.1V**	√
Ch4		1.99	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0	0	0	0	√
(2) 3V in	**1V +/- 0.1V**	1	1	1	1	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5	1.5	1.5	1.5	√
(4) 6V in	**2V +/- 0.1V**	2	2	2	2	√

Serial No……..Mon263.....
Test Engineer…..Xen……
Date……..8/12/10..……

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.716	**0.707 (0.68 to 0.72V)**	√
Ch2	0.710	**0.707 (0.68 to 0.72V)**	√
Ch3	0.709	**0.707 (0.68 to 0.72V)**	√
Ch4	0.711	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.360	**0.35V (0.33 to 0.37V)**	√
Ch2	0.354	**0.35V (0.33 to 0.37V)**	√
Ch3	0.355	**0.35V (0.33 to 0.37V)**	√
Ch4	0.355	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.0	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.0	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.0	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.0	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.02	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.02	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.01	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No……Mon264……
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1. Block diagram

2. Test equipment

3. Description

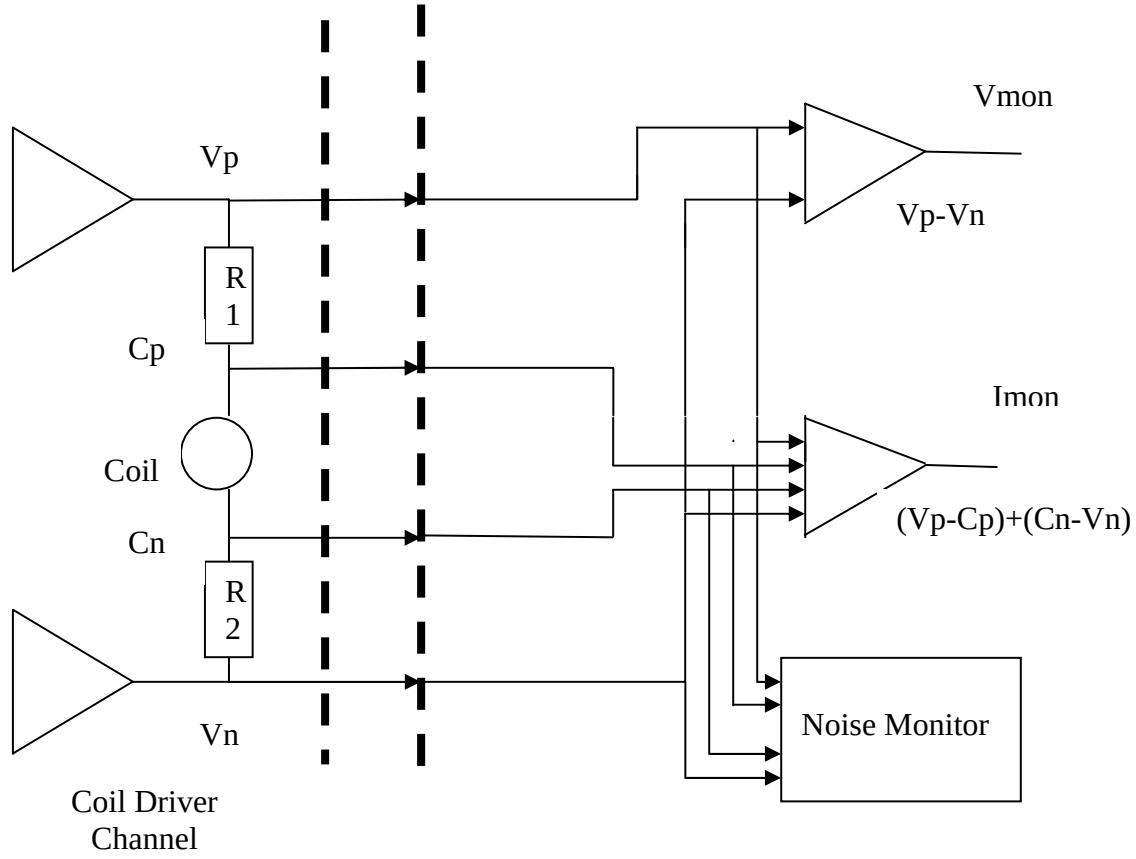
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

Serial No……Mon264……
Test Engineer...Xen……
Date……8/12/10……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Replaced U2.

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No……Mon264……
Test Engineer...Xen……
Date……8/12/10……

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.93	√
-15V (TP6)	-15.06	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	4mV	300mA
-15v (TP6)	√	5mV	250mA

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1		2.4	**2.4V to 2.6V**	√
Ch2		2.4	**2.4V to 2.6V**	√
Ch3		2.4	**2.4V to 2.6V**	√
Ch4		2.4	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1		2.4	**2.4V to 2.6V**	√
Ch2		2.4	**2.4V to 2.6V**	√
Ch3		2.4	**2.4V to 2.6V**	√
Ch4		2.4	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1		1.75	**1.6V to 1.9V**	√
Ch2		1.75	**1.6V to 1.9V**	√
Ch3		1.75	**1.6V to 1.9V**	√
Ch4		1.75	**1.6V to 1.9V**	√

Serial No……Mon264……
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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1		1.7	**1.6V to 1.9V**	√
Ch2		1.7	**1.6V to 1.9V**	√
Ch3		1.7	**1.6V to 1.9V**	√
Ch4		1.7	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.95	**4.7V to 5.2V**	√
Ch2		4.95	**4.7V to 5.2V**	√
Ch3		4.95	**4.7V to 5.2V**	√
Ch4		4.95	**4.7V to 5.2V**	√

Serial No……Mon264……
Test Engineer...Xen……
Date……8/12/10……

Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.45	1.45	1.45	1.45
TP6	4	4	4	4	2.2	2.1	2.1	2.1
TP7	8	8	8	8	3.2	3.2	3.2	3.2

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.45	1.45	1.45	1.45	√
TP6/TP4	2	2	2	2	1.5	1.4	1.4	1.4	√
TP7/TP6	2	2	2	2	1.5	1.5	1.5	1.5	√

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	10	**9.7 to 10V**	√	4.9	**4 to 5.5V**	√
Ch2	**TP10**	10	**9.7 to 10V**	√	4.9	**4 to 5.5V**	√
Ch3	**TP10**	10	**9.7 to 10V**	√	4.9	**4 to 5.5V**	√
Ch4	**TP10**	10	**9.7 to 10V**	√	4.9	**4 to 5.5V**	√

Serial No……Mon264……
Test Engineer...Xen……
Date……8/12/10……

6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		1.99	**1.9 to 2.1V**	√
Ch2		1.99	**1.9 to 2.1V**	√
Ch3		1.99	**1.9 to 2.1V**	√
Ch4		1.99	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0	0	0	0	√
(2) 3V in	**1V +/- 0.1V**	1	1	1	1	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5	1.5	1.5	1.5	√
(4) 6V in	**2V +/- 0.1V**	2	2	2	2	√

Serial No……Mon264……
Test Engineer...Xen……
Date……8/12/10……

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.709	**0.707 (0.68 to 0.72V)**	√
Ch2	0.711	**0.707 (0.68 to 0.72V)**	√
Ch3	0.713	**0.707 (0.68 to 0.72V)**	√
Ch4	0.717	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.355	**0.35V (0.33 to 0.37V)**	√
Ch2	0.356	**0.35V (0.33 to 0.37V)**	√
Ch3	0.357	**0.35V (0.33 to 0.37V)**	√
Ch4	0.360	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.0	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.0	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.0	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.0	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.02	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.02	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.02	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.02	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No……Mon265……
Test Engineer……Xen……..……
Date……13/12/10……

Contents

1. Block diagram

2. Test equipment

3. Description

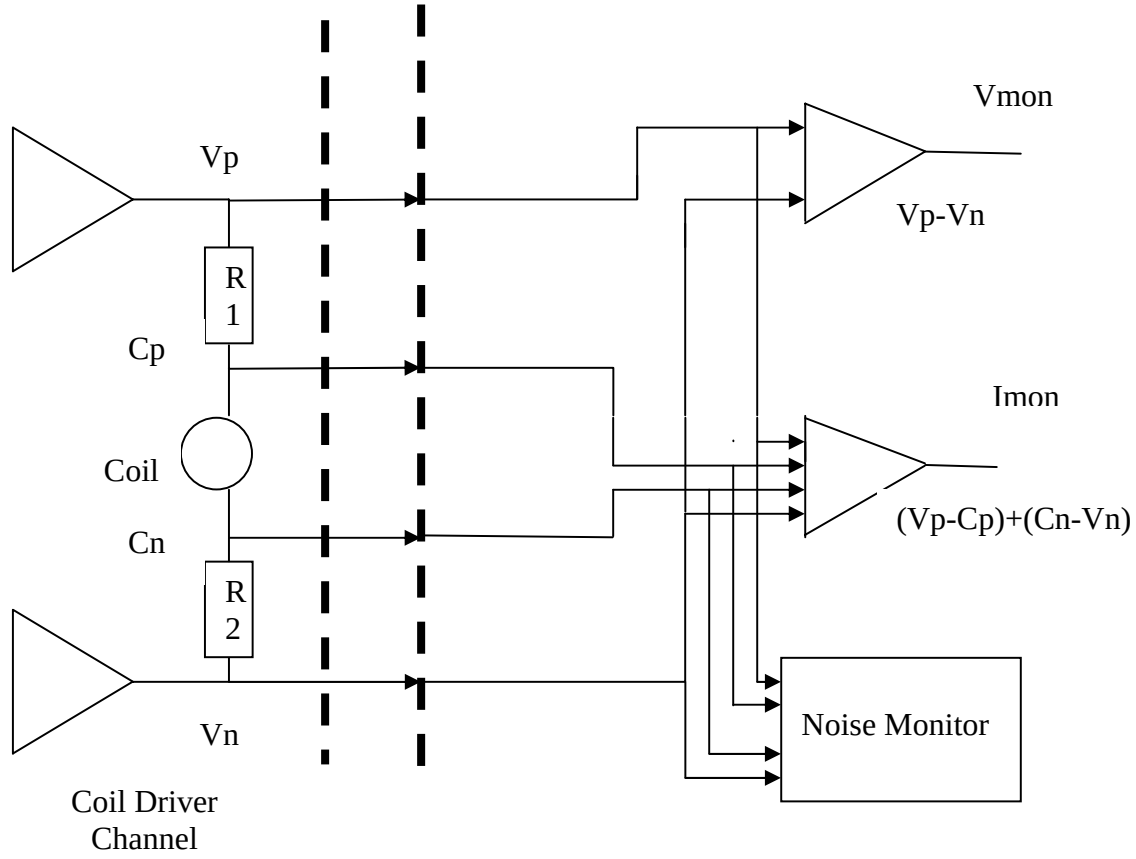
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

Serial No……Mon265……
Test Engineer……Xen……..……
Date……13/12/10……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Replaced U3.

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No……Mon265……
Test Engineer……Xen……..……
Date……13/12/10……

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.97	√
-15V (TP6)	-15.07	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	1mV	300mA
-15v (TP6)	√	5mV	250mA

Serial No……Mon265……
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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1		2.4	**2.4V to 2.6V**	√
Ch2		2.4	**2.4V to 2.6V**	√
Ch3		2.4	**2.4V to 2.6V**	√
Ch4		2.4	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1		2.4	**2.4V to 2.6V**	√
Ch2		2.4	**2.4V to 2.6V**	√
Ch3		2.4	**2.4V to 2.6V**	√
Ch4		2.4	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1		1.8	**1.6V to 1.9V**	√
Ch2		1.8	**1.6V to 1.9V**	√
Ch3		1.8	**1.6V to 1.9V**	√
Ch4		1.8	**1.6V to 1.9V**	√

Serial No……Mon265……
Test Engineer……Xen……..……
Date……13/12/10……

Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1		1.8	**1.6V to 1.9V**	√
Ch2		1.8	**1.6V to 1.9V**	√
Ch3		1.8	**1.6V to 1.9V**	√
Ch4		1.8	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.95	**4.7V to 5.2V**	√
Ch2		4.95	**4.7V to 5.2V**	√
Ch3		4.95	**4.7V to 5.2V**	√
Ch4		4.95	**4.7V to 5.2V**	√

Serial No……Mon265……
Test Engineer……Xen……..……
Date……13/12/10……

Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.45	1.45	1.45	1.45
TP6	4	4	4	4	2.2	2.2	2.2	2.2
TP7	8	8	8	8	3.4	3.4	3.4	3.4

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.45	1.45	1.45	1.45	√
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	√
TP7/TP6	2	2	2	2	1.5	1.5	1.5	1.5	√

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	9.9	**9.7 to 10V**	√	4.9	**4 to 5.5V**	√
Ch2	**TP10**	9.9	**9.7 to 10V**	√	49	**4 to 5.5V**	√
Ch3	**TP10**	9.9	**9.7 to 10V**	√	4.9	**4 to 5.5V**	√
Ch4	**TP10**	9.9	**9.7 to 10V**	√	4.9	**4 to 5.5V**	√

Serial No……Mon265……
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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		1.99	**1.9 to 2.1V**	√
Ch2		1.99	**1.9 to 2.1V**	√
Ch3		1.99	**1.9 to 2.1V**	√
Ch4		1.99	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0	0	0	0	√
(2) 3V in	**1V +/- 0.1V**	1	1	1	1	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5	1.5	1.5	1.5	√
(4) 6V in	**2V +/- 0.1V**	2	2	2	2	√

Serial No……Mon265……
Test Engineer……Xen……..……
Date……13/12/10……

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.715	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713	**0.707 (0.68 to 0.72V)**	√
Ch3	0.711	**0.707 (0.68 to 0.72V)**	√
Ch4	0.711	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357	**0.35V (0.33 to 0.37V)**	√
Ch2	0.357	**0.35V (0.33 to 0.37V)**	√
Ch3	0.356	**0.35V (0.33 to 0.37V)**	√
Ch4	0.356	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.0	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.0	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.0	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.0	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.02	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.02	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.02	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.02	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No……Mon266…..…….
Test Engineer…..Xen……..…….
Date……..13/12/10…….

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1. Block diagram

2. Test equipment

3. Description

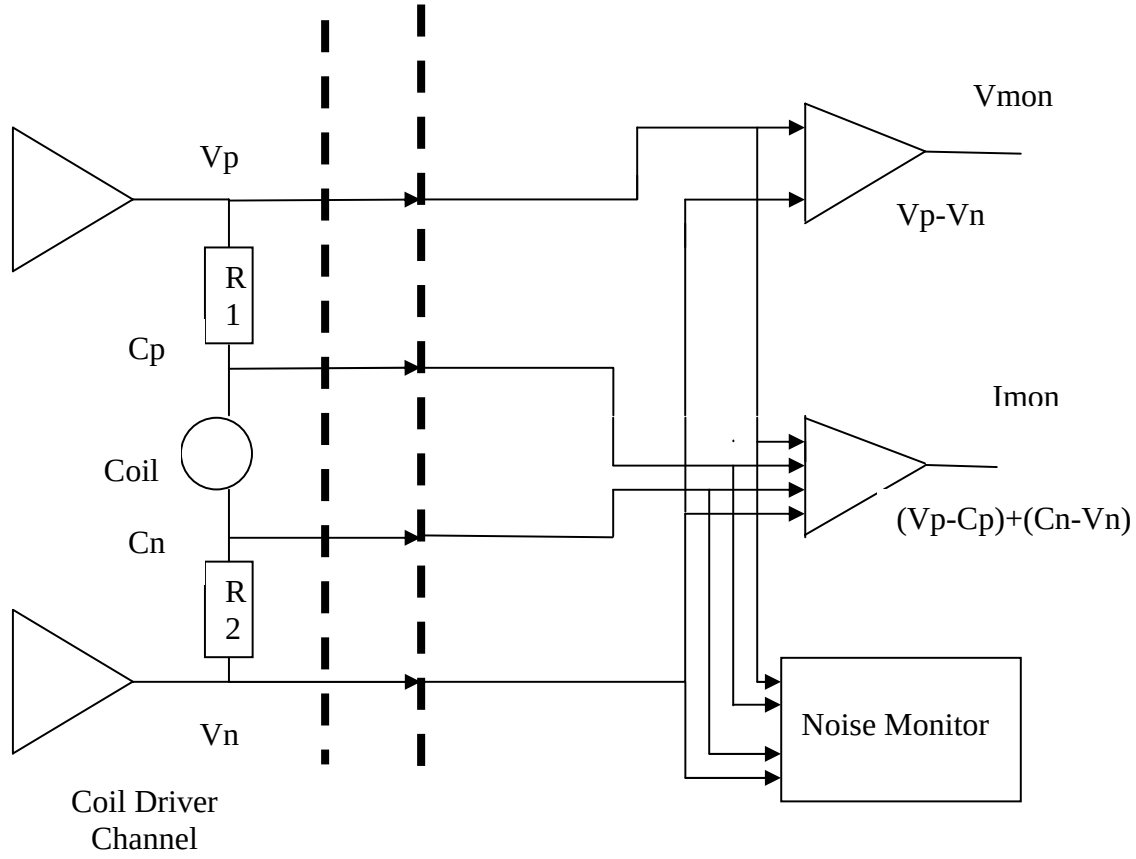
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

Serial No……Mon266…..…….
Test Engineer…..Xen……..…….
Date……..13/12/10…….

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Replaced U3.

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No……Mon266…..…….
Test Engineer…..Xen……..…….
Date……..13/12/10…….

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.94	√
-15V (TP6)	-14.94	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	2mV	300mA
-15v (TP6)	√	5mV	250mA

Serial No……Mon266…..……
Test Engineer…..Xen……..……
Date……..13/12/10……

6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1		2.4	**2.4V to 2.6V**	√
Ch2		2.4	**2.4V to 2.6V**	√
Ch3		2.4	**2.4V to 2.6V**	√
Ch4		2.4	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1		2.4	**2.4V to 2.6V**	√
Ch2		2.4	**2.4V to 2.6V**	√
Ch3		2.4	**2.4V to 2.6V**	√
Ch4		2.4	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1		1.8	**1.6V to 1.9V**	√
Ch2		1.8	**1.6V to 1.9V**	√
Ch3		1.8	**1.6V to 1.9V**	√
Ch4		1.8	**1.6V to 1.9V**	√

Serial No……Mon266…..……
Test Engineer…..Xen……..……
Date……..13/12/10……

Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1		1.7	**1.6V to 1.9V**	√
Ch2		1.7	**1.6V to 1.9V**	√
Ch3		1.7	**1.6V to 1.9V**	√
Ch4		1.7	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.95	**4.7V to 5.2V**	√
Ch2		4.95	**4.7V to 5.2V**	√
Ch3		4.95	**4.7V to 5.2V**	√
Ch4		4.95	**4.7V to 5.2V**	√

Serial No……Mon266…..……
Test Engineer…..Xen……..……
Date……..13/12/10……

Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV	Ch1 mV	Ch2 mV	Ch3 mV	Ch4 mV
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.45	1.40	1.45	1.40
TP6	4	4	4	4	2.20	2.10	2.20	2.10
TP7	8	8	8	8	3.20	3.10	3.20	3.10

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	Ch2	Ch3	Ch4	Ch1	Ch2	Ch3	Ch4	
TP4/TP5	2	2	2	2	1.45	1.40	1.45	1.40	√
TP6/TP4	2	2	2	2	1.50	1.50	1.50	1.50	√
TP7/TP6	2	2	2	2	1.50	1.50	1.50	1.50	√

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	Spec @ 500Hz	OK?	5kHz (V peak)	Spec @ 5kHz	OK?
Ch1	**TP10**	9.99	**9.7 to 10V**	√	4.90	**4 to 5.5V**	√
Ch2	**TP10**	9.99	**9.7 to 10V**	√	4.99	**4 to 5.5V**	√
Ch3	**TP10**	9.99	**9.7 to 10V**	√	4.99	**4 to 5.5V**	√
Ch4	**TP10**	9.99	**9.7 to 10V**	√	4.99	**4 to 5.5V**	√

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Test Engineer…..Xen……..…….
Date……..13/12/10…….

6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		1.99	**1.9 to 2.1V**	√
Ch2		1.99	**1.9 to 2.1V**	√
Ch3		1.99	**1.9 to 2.1V**	√
Ch4		1.99	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0	0	0	0	√
(2) 3V in	**1V +/- 0.1V**	1	1	1	1	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5	1.5	1.5	1.5	√
(4) 6V in	**2V +/- 0.1V**	2	2	2	2	√

Serial No……Mon266…..…….
Test Engineer…..Xen……..…….
Date……..13/12/10…….

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.713	**0.707 (0.68 to 0.72V)**	√
Ch2	0.715	**0.707 (0.68 to 0.72V)**	√
Ch3	0.712	**0.707 (0.68 to 0.72V)**	√
Ch4	0.713	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358	**0.35V (0.33 to 0.37V)**	√
Ch3	0.356	**0.35V (0.33 to 0.37V)**	√
Ch4	0.357	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.0	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.0	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.0	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.0	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.02	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.02	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.02	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.02	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No……Mon267……
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Contents

1. Block diagram

2. Test equipment

3. Description

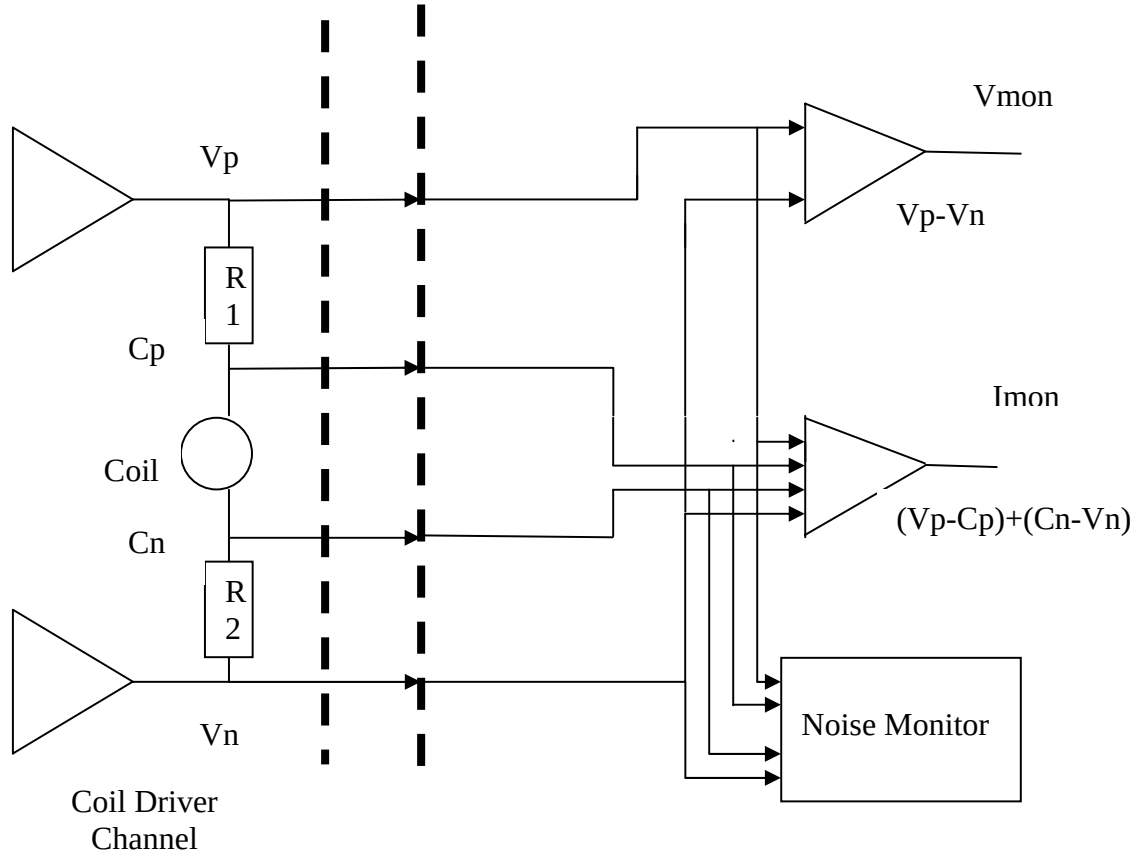
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Replaced U3.

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Date ……

NOTES

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.92	√
-15V (TP6)	-15.01	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	2mV	300mV
-15v (TP6)	√	5mV	250mV

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1		2.4	**2.4V to 2.6V**	√
Ch2		2.4	**2.4V to 2.6V**	√
Ch3		2.4	**2.4V to 2.6V**	√
Ch4		2.4	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1		2.4	**2.4V to 2.6V**	√
Ch2		2.4	**2.4V to 2.6V**	√
Ch3		2.4	**2.4V to 2.6V**	√
Ch4		2.4	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1		1.8	**1.6V to 1.9V**	√
Ch2		1.8	**1.6V to 1.9V**	√
Ch3		1.8	**1.6V to 1.9V**	√
Ch4		1.8	**1.6V to 1.9V**	√

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Test Engineer……Xen……..……
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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1		1.8	**1.6V to 1.9V**	√
Ch2		1.8	**1.6V to 1.9V**	√
Ch3		1.8	**1.6V to 1.9V**	√
Ch4		1.8	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.95	**4.7V to 5.2V**	√
Ch2		4.95	**4.7V to 5.2V**	√
Ch3		4.95	**4.7V to 5.2V**	√
Ch4		4.95	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.5	1.5	1.5	1.5
TP6	4	4	4	4	2.2	2.2	2.2	2.2
TP7	8	8	8	8	3.4	3.4	3.4	3.4

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.5	1.5	1.5	1.5	√
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	√
TP7/TP6	2	2	2	2	1.5	1.5	1.5	1.5	√

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	9.99	**9.7 to 10V**	√	4.99	**4 to 5.5V**	√
Ch2	**TP10**	9.99	**9.7 to 10V**	√	4.99	**4 to 5.5V**	√
Ch3	**TP10**	9.99	**9.7 to 10V**	√	4.99	**4 to 5.5V**	√
Ch4	**TP10**	9.99	**9.7 to 10V**	√	4.99	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		1.99	**1.9 to 2.1V**	√
Ch2		1.99	**1.9 to 2.1V**	√
Ch3		1.99	**1.9 to 2.1V**	√
Ch4		1.99	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0	0	0	0	√
(2) 3V in	**1V +/- 0.1V**	1	1	1	1	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5	1.5	1.5	1.5	√
(4) 6V in	**2V +/- 0.1V**	2	2	2	2	√

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Test Engineer……Xen……..……
Date……13/12/10……

6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.712	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713	**0.707 (0.68 to 0.72V)**	√
Ch3	0.710	**0.707 (0.68 to 0.72V)**	√
Ch4	0.711	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.357	**0.35V (0.33 to 0.37V)**	√
Ch2	0.359	**0.35V (0.33 to 0.37V)**	√
Ch3	0.356	**0.35V (0.33 to 0.37V)**	√
Ch4	0.356	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.0	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.0	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.0	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.0	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.01	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.02	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.02	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No……Mon268……
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1. Block diagram

2. Test equipment

3. Description

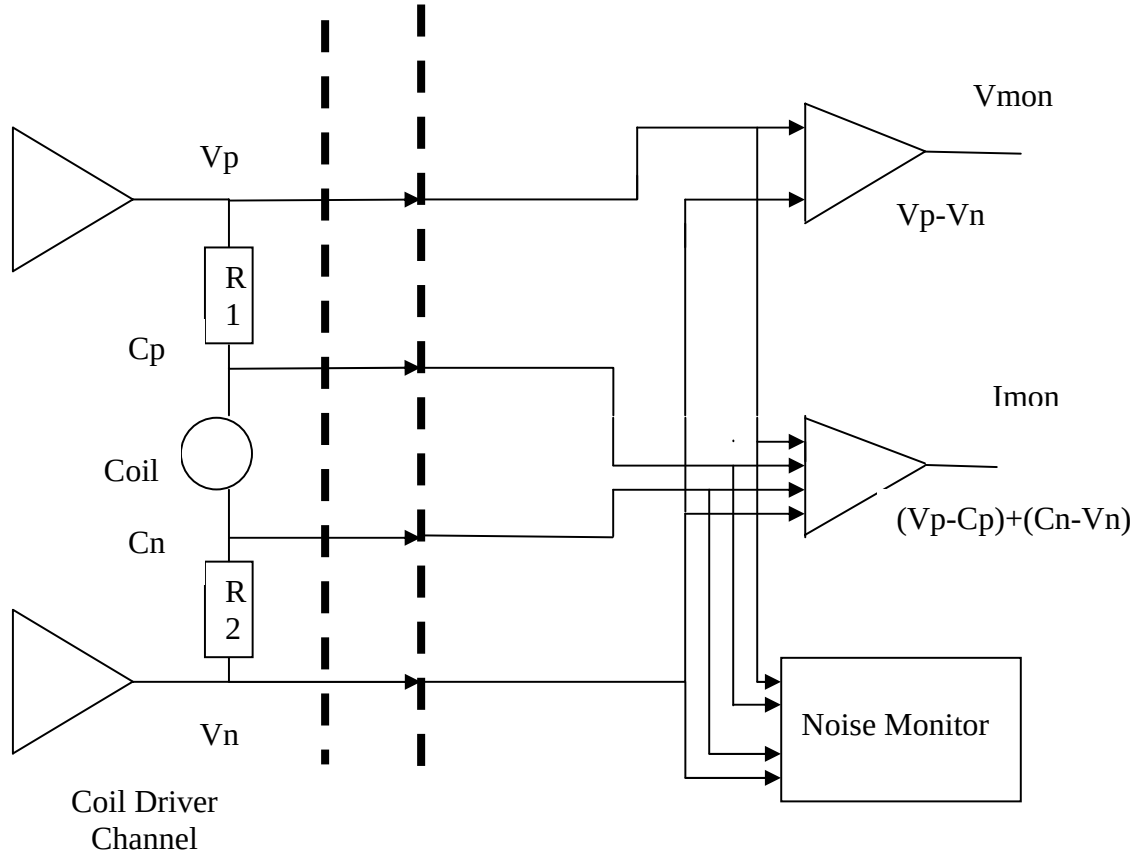
4. Inspection

5. Power

6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

Serial No ……...
Test Engineer ……
Date ……

4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Replaced U2.

Serial No ……...
Test Engineer ……
Date ……

NOTES

Serial No……Mon268……
Test Engineer……Xen……..……
Date……15/12/10……

5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	15.00	√
-15V (TP6)	-14.95	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	2mV	300mA
-15v (TP6)	√	5mV	250mA

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1		2.4	**2.4V to 2.6V**	√
Ch2		2.4	**2.4V to 2.6V**	√
Ch3		2.4	**2.4V to 2.6V**	√
Ch4		2.4	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1		2.4	**2.4V to 2.6V**	√
Ch2		2.4	**2.4V to 2.6V**	√
Ch3		2.4	**2.4V to 2.6V**	√
Ch4		2.4	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1		1.75	**1.6V to 1.9V**	√
Ch2		1.75	**1.6V to 1.9V**	√
Ch3		1.75	**1.6V to 1.9V**	√
Ch4		1.75	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1		1.70	**1.6V to 1.9V**	√
Ch2		1.70	**1.6V to 1.9V**	√
Ch3		1.70	**1.6V to 1.9V**	√
Ch4		1.75	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.95	**4.7V to 5.2V**	√
Ch2		4.95	**4.7V to 5.2V**	√
Ch3		4.95	**4.7V to 5.2V**	√
Ch4		4.95	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.5	1.5	1.5	1.5
TP6	4	4	4	4	2.2	2.2	2.2	2.2
TP7	8	8	8	8	3.2	3.2	3.2	3.3

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.5	1.5	1.5	1.5	√
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	√
TP7/TP6	2	2	2	2	1.5	1.5	1.5	1.5	√

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	9.99	**9.7 to 10V**	√	4.9	**4 to 5.5V**	√
Ch2	**TP10**	9.99	**9.7 to 10V**	√	4.9	**4 to 5.5V**	√
Ch3	**TP10**	9.99	**9.7 to 10V**	√	4.9	**4 to 5.5V**	√
Ch4	**TP10**	9.99	**9.7 to 10V**	√	4.9	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		1.99	**1.9 to 2.1V**	√
Ch2		1.99	**1.9 to 2.1V**	√
Ch3		1.99	**1.9 to 2.1V**	√
Ch4		1.99	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0	0	0	0	√
(2) 3V in	**1V +/- 0.1V**	1	1	1	1	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5	1.5	1.5	1.5	√
(4) 6V in	**2V +/- 0.1V**	2	2	2	2	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.712	**0.707 (0.68 to 0.72V)**	√
Ch2	0.712	**0.707 (0.68 to 0.72V)**	√
Ch3	0.710	**0.707 (0.68 to 0.72V)**	√
Ch4	0.716	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.358	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358	**0.35V (0.33 to 0.37V)**	√
Ch3	0.355	**0.35V (0.33 to 0.37V)**	√
Ch4	0.361	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.0	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.0	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.0	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.0	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.02	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.02	**1V (0.9 to 1.1V)**	√

MONITOR BOARD TEST PLAN

Serial No……Mon270……
Test Engineer……Xen……..……
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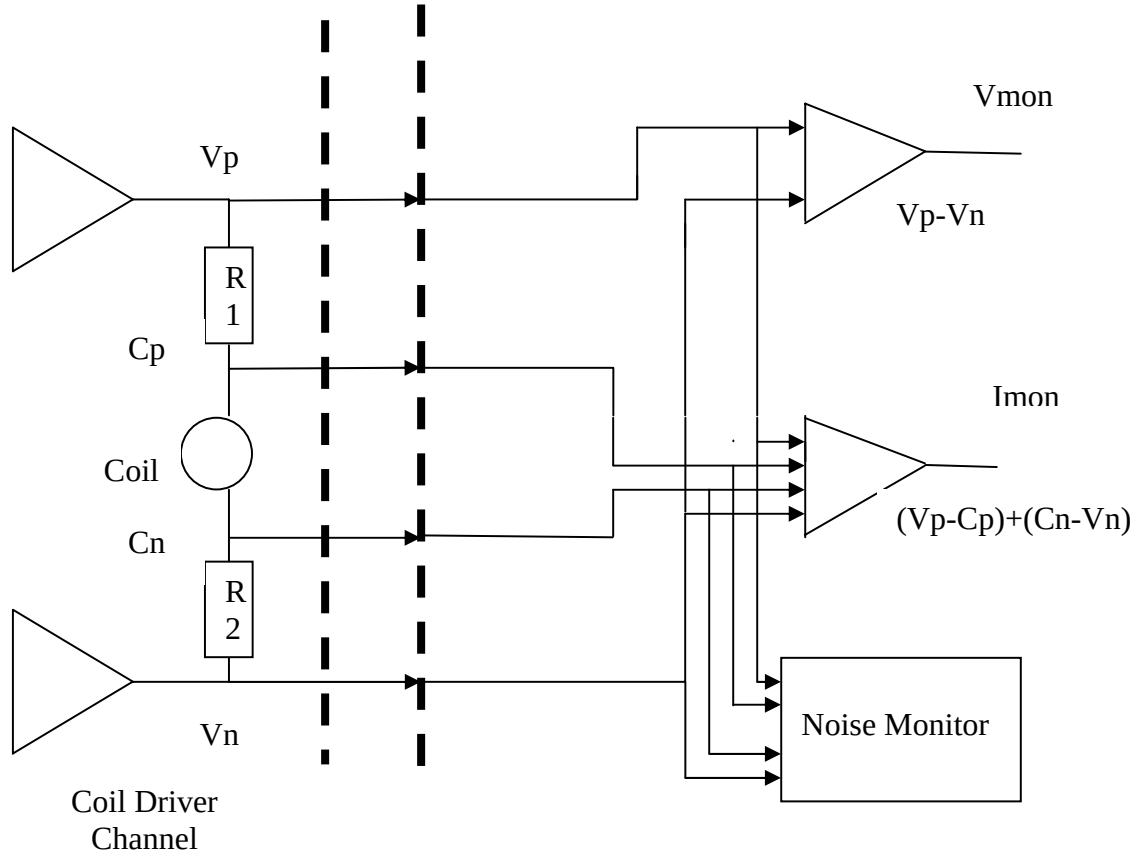
6. Circuit operation

6.1.1 Noise Amplifier
6.1.2 Voltage Monitor
6.1.3 Current Monitor
6.1.4 RMS Circuit

1. BLOCK DIAGRAM



**1. Block diagram of one channel of the monitor board.
Each board houses four such channels.**

2. TEST EQUIPMENT

Variable +/- 15V power supply
Precise DVM
Oscilloscope
Signal generator

The Coil Drive Simulator test equipment output is similar to the Coil Driver Channel shown above, except that the Coil is replaced by two 3.9k resistors in series.
Other resistors may be connected in parallel with this as required during the tests which follow.

3. DESCRIPTION

The function of the Monitor Board is to monitor the outputs from a drive board. It has four identical channels, one per drive board channel. Similar Monitor Boards are used to monitor the UIM Driver, the Top Driver and the PUM drivers.

Inputs

The inputs of the monitor Board are connected to the two amplifier outputs and the coil feeds. The Driver Board and the monitor Board are both mounted in a Drive unit.
The signals which are monitored on each channel are: the positive and negative output voltages from the drive amplifiers, and the positive and negative output voltages developed across the coil.

These four signals are used to measure the amplifier output voltage, the current through the coil and the output noise on each of the drive amplifier channels.

Output Voltage

The Amplifier Output Voltage is measured in IC9, by subtracting the Positive Amplifier output from the Negative Amplifier Output. The output is scaled by a factor of 3, so, for example, inputs of +15V and -15V, the sum of which is 30V, would give an output of 30V/3 = 10V.

Coil Current

The coil current is calculated by IC8, by measuring the sum of the voltages across the two output resistors (R1 and R2 on the block diagram.) The amplifier performs the following calculation:

{(Pos Voltage Output) – (Negative Voltage Output)} -
{(Pos Coil Voltage) - (Negative Coil Voltage)}

The voltage across the coil is subtracted from the voltage across the Amplifier output. This gives the voltage across the output resistors, which is proportional the coil current.
The test equipment has 3.9k resistors for R1 and R2. The coil is simulated by two 3.9k resistors in series. Each resistor will therefore drop a quarter of the sum of the two outputs. The summing amplifier has a gain of 1/3, so for +/- 15V in the output will be 5V.
IC10 is an r.m.s. converter chip, which calculates the true r.m.s. output current. It is followed by an amplifier. The overall scaling factor of the r.m.s. converter and amplifier circuits is 1/3.

Noise Measurement

As the noise level amounts to a few pico amps, it is extremely difficult to measure directly. Instead, the noise voltage across the amplifier outputs is monitored. This enables the coil noise current to be estimated. Four amplifier stages each coupled with a high pass filter are used, followed by a two stage low pass filter.

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4. Inspection

Workmanship

General **OK?** √
Comments

Visual overall check **OK?** √
Solder joint **OK?** √
Placement **OK?** √

Modifications

Replaced U2.

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5. Power

Measure output voltages from the regulators as follows:
Increase input voltages from zero up to +/-3V.
Determine that polarities are correct.
If they are correct, increase the voltages until rated input voltages are reached (+/-16.5V)

Record regulator the regulator output voltages:

Regulator	Output voltage	Pass/Fail (Nominal +/-0.5V)
+15V (TP4)	14.97	√
-15V (TP6)	-15.17	√

If output voltages are satisfactory, proceed to next section.

Record the regulator noise levels, check for stability, and record the power supply current.

Regulator	Stable?	Output Noise level pk/pk	Current (Amps)
+15v (TP4)	√	2mV	300mA
-15v (TP6)	√	5mV	250mA

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6. Circuit operation

Test the operation of each channel. The Coil Driver Simulator board will normally be used for these tests.

6.1.1 NOISE AMPLIFIER

6.1.1.1 INPUT BUFFER GAINS

Test that the gain of each of the input buffers, IC1 and IC6 is 25.

Pass band Gain

Set frequency to 20Hz
Set Amplitude 100mV peak (Signal generator indicates 100mV pk/pk)
Ground reference = Power 0V

Positive input:

	Input (TP8) (mV peak)	Output -IC1/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1		2.4	**2.4V to 2.6V**	√
Ch2		2.4	**2.4V to 2.6V**	√
Ch3		2.4	**2.4V to 2.6V**	√
Ch4		2.4	**2.4V to 2.6V**	√

Negative Input:

	Input (TP9) (mV peak)	Output - IC6/6 (V peak)	Expected value (V peak)	Pass/ Fail
Ch1		2.4	**2.4V to 2.6V**	√
Ch2		2.4	**2.4V to 2.6V**	√
Ch3		2.4	**2.4V to 2.6V**	√
Ch4		2.4	**2.4V to 2.6V**	√

6.1.1.2 GAIN AT THE CORNER FREQUENCY

Set frequency to 5Hz:
Amplitude = 100mV pk/pk
Ground reference = Power 0V

Positive input:

	Input - TP8 mV peak	Output - IC1/6 V peak	Expected value (V peak)	Pass/ Fail
Ch1		1.8	**1.6V to 1.9V**	√
Ch2		1.8	**1.6V to 1.9V**	√
Ch3		1.8	**1.6V to 1.9V**	√
Ch4		1.8	**1.6V to 1.9V**	√

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Negative Input:

	Input - TP9 mV peak	Output - IC6/6 V peak	Expected value V peak	Pass/ Fail
Ch1		1.8	**1.6V to 1.9V**	√
Ch2		1.8	**1.6V to 1.9V**	√
Ch3		1.8	**1.6V to 1.9V**	√
Ch4		1.8	**1.6V to 1.9V**	√

6.1.1.3 Summing Amplifier

Pass band Gain
Set frequency to 20Hz
Set Amplitude 100mV pk/pk (sig gen o/p = 100mV peak)
Apply input between TP8 and TP9

	Input - TP8 toTP9 (mV peak)	Output TP5 V peak	Expected value (V Peak)	Pass/ Fail
Ch1		4.95	**4.7V to 5.2V**	√
Ch2		4.95	**4.7V to 5.2V**	√
Ch3		4.95	**4.7V to 5.2V**	√
Ch4		4.95	**4.7V to 5.2V**	√

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Gains of Successive Stages:
Make measurements at 100Hz, then at 5Hz starting by setting the TP5 voltage to 1V peak for each frequency.

	100Hz				5Hz			
	Ch1 mV	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**	**Ch1 mV**	**Ch2 mV**	**Ch3 mV**	**Ch4 mV**
TP5	1	1	1	1	1	1	1	1
TP4	2	2	2	2	1.5	1.5	1.5	1.5
TP6	4	4	4	4	2.2	2.3	2.3	2.3
TP7	8	8	8	8	3.3	3.3	3.3	3.4

Calculate the ratios of successive outputs from the table above. Check that successive outputs have a ratio of x2 ± 0.1 at 100Hz, and 1.4 ± 0.1 at the 5Hz the corner frequency.

	100Hz				5Hz				P/F
	Ch1	**Ch2**	**Ch3**	**Ch4**	**Ch1**	**Ch2**	**Ch3**	**Ch4**	
TP4/TP5	2	2	2	2	1.5	1.5	1.5	1.5	√
TP6/TP4	2	2	2	2	1.5	1.5	1.5	1.5	√
TP7/TP6	2	2	2	2	1.5	1.5	1.5	1.5	√

Low Pass Output Stage
Set signal generator to give 10V peak on **TP7**. Measure and record the output at 500Hz and 5kHz **TP10**, and compare with the specifications at those frequencies.

		500Hz (V peak)	**Spec @ 500Hz**	**OK?**	**5kHz (V peak)**	**Spec @ 5kHz**	**OK?**
Ch1	**TP10**	9.99	**9.7 to 10V**	√	4.9	**4 to 5.5V**	√
Ch2	**TP10**	9.99	**9.7 to 10V**	√	4.9	**4 to 5.5V**	√
Ch3	**TP10**	9.99	**9.7 to 10V**	√	4.9	**4 to 5.5V**	√
Ch4	**TP10**	9.99	**9.7 to 10V**	√	4.9	**4 to 5.5V**	√

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6.1.2 VOLTAGE MONITOR

Set the signal generator to give 3V peak at 30Hz between TP8 and TP9.
Measure the output on TP12.

	Input -TP8, TP9 (Volts peak)	Output -TP12 (Volts peak)	Expected value (Volts peak)	Pass/ Fail
Ch1		1.99	**1.9 to 2.1V**	√
Ch2		1.99	**1.9 to 2.1V**	√
Ch3		1.99	**1.9 to 2.1V**	√
Ch4		1.99	**1.9 to 2.1V**	√

6.1.3 CURRENT MONITOR

Current monitoring is done by measuring the voltage dropped across two resistors carrying the output current. The current monitor circuit has a gain of 1/3.

The circuit is tested by applying selected voltages across the current monitor inputs, and observing the current monitor output.

Connect the Monitor Test Unit to the 16 way header on the monitor board, and power it up.
Connect the signal generator to its input.

Set frequency to 100Hz
The input voltage between TP8 and TP9 to 3V Peak
Ground reference = Power 0V

Select the following four settings in turn:
(1) Open circuit – representing zero current - zero output expected
(2) Half – giving 3 volts of current monitor signal and 1 volt out.
(3) Quarter – giving 4.5 volts of current monitor signal and 1.5 volts out
(4) Short circuit - giving 6 volts of monitor signal and 2 volts out

Test	TP11 Expected V	TP11 Ch1 (V)	TP11 Ch2 (V)	TP11 Ch3 (V)	TP11 Ch4 (V)	Pass/ Fail (V)
(1) 0V in	**0V +/- 0.1V**	0	0	0	0	√
(2) 3V in	**1V +/- 0.1V**	1	1	1	1	√
(3) 4.5V in	**1.5V +/- 0.1V**	1.5	1.5	1.5	1.5	√
(4) 6V in	**2V +/- 0.1V**	2	2	2	2	√

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6.1.4 RMS CIRCUIT

The r.m.s circuit monitors the r.m.s current flowing in the coil. A square wave of the same peak amplitude as a sine wave should give an output √2 times as high.

Sine Wave Test

Set frequency to 30Hz
Without the resistance box,

I/p sine wave amplitude (between TP8 and TP9)	r.m.s DC output (TP13)	Expected value (volts DC)	Pass/ Fail
3V Peak			
Ch1	0.710	**0.707 (0.68 to 0.72V)**	√
Ch2	0.713	**0.707 (0.68 to 0.72V)**	√
Ch3	0.711	**0.707 (0.68 to 0.72V)**	√
Ch4	0.713	**0.707 (0.68 to 0.72V)**	√
1.5V peak			
Ch1	0.356	**0.35V (0.33 to 0.37V)**	√
Ch2	0.358	**0.35V (0.33 to 0.37V)**	√
Ch3	0.356	**0.35V (0.33 to 0.37V)**	√
Ch4	0.358	**0.35V (0.33 to 0.37V)**	√

Square Wave Test

Compare the output for a sine wave input just measured with the output for a square wave input. Set input level to a 3V peak and the frequency to 30Hz.

3V peak Square Wave		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.0	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.0	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.0	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.0	**1V (0.9 to 1.1V)**	√

DC input

Apply a 3V DC input between TP8 and TP9.

3V DC		Expected value (volts DC)	Pass/ Fail
Ch1, TP13	1.02	**1V (0.9 to 1.1V)**	√
Ch2, TP13	1.01	**1V (0.9 to 1.1V)**	√
Ch3, TP13	1.01	**1V (0.9 to 1.1V)**	√
Ch4, TP13	1.02	**1V (0.9 to 1.1V)**	√