LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

-LIGO-

CALIFORNIA INSTITUTE OF TECHNOLOGY

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Document Type	DCC Number T1100084-v5	Dec 2020
A Plus LIGO HAM-A Coil Driver Board Test Plan		
J. Heefner Updates by David Hoyland and Luis Sanchez.		

Distribution of this draft:
This is an internal working note of the LIGO Laboratory

California Institute of Technology
LIGO Project – MS 18-33
Pasadena, CA 91125
Phone (626) 395-2129
Fax (626) 304-9834
E-mail: info@ligo.caltech.edu

Massachusetts Institute of Technology
LIGO Project – MS 20B-145
Cambridge, MA 01239
Phone (617) 253-4824
Fax (617) 253-7014
E-mail: info@ligo.mit.edu

www: http://www.ligo.caltech.edu/

1 Introduction

The tests described below will be utilized to test the A-Plus LIGO HAM-A Coil Driver (with pcb D1100117-v4). These boards will be used to drive the HDS and Tip Tilts Suspension Coil Drivers mirrors of the A-Plus IFOs. The design requirements for the driver can be found in LIGO document number T0900495-v4, “HAM Auxiliary Suspensions Electronics Requirements”, also for related documents please see E2000182, E1201027, E1201036, D1100687 and T1200264.

2 Test Equipment

- Stanford Research SR785 analyzer
- Voltmeter
- Oscilloscope
- Board Schematics- TBD

3 Tests

3.1 Quiescent Current draw and Continuity Test

Measure each internal power supply current and record the results in the next table.

Power Rail Supply (v)	Quiescent Current (mA)	LED’s ON				Measured Value (mA)	Pass	Fail
		+14v Front Panel	-14v Front Panel	+18v Front Panel	-18v Front Panel			
±18V Supply	+230±50, -190±50			Y	Y	+234/-192	Pass	
±14V Supply	+ 86±10, -86±10	Y	Y			+85/-85	Pass	

Verify Photodiode connection path from D1100117-v4 by performing a continuity test from connector J1(dB9F) to connector J2(dB25F).

Coil Channel	Test Point		Predicted Continuity (Ω)	Measured Continuity (Ω)	Pass	Fail
	J1	J2				
PD1P	**1**	**1**	**0.5±0.2**	0.40	Pass	
PD1N	**6**	**14**	**0.5±0.2**	0.50	Pass	
PD2P	**2**	**2**	**0.5±0.2**	0.46	Pass	
PD2N	**7**	**15**	**0.5±0.2**	0.55	Pass	
PD3P	**3**	**3**	**0.5±0.2**	0.51	Pass	
PD3N	**8**	**16**	**0.5±0.2**	0.55	Pass	
PD4P	**4**	**4**	**0.5±0.2**	0.45	Pass	
PD4N	**9**	**17**	**0.5±0.2**	0.51	Pass	

3.2 Input Enable Relay Operation

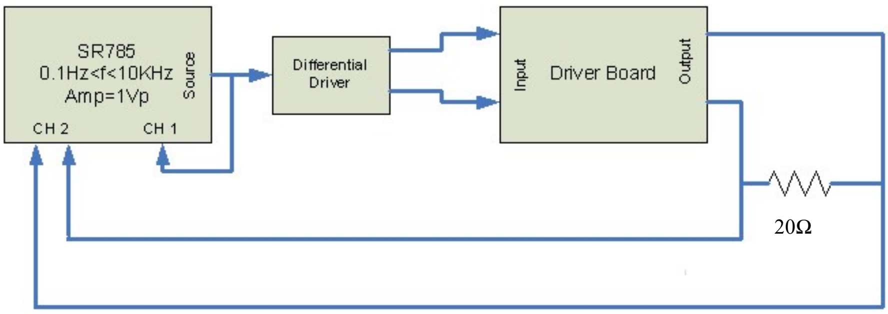
In this section the operation of the input relay (K1) will be tested. If this relay is not energized, the inputs to each coil driver channel are tied to circuit ground. The operation is tested using the jumpers on the board (P4). Each channel can be controlled separately and has an LED indicator. There is also an external monitor signal that can be used by the control system to verify the position of this relay. Operation of this monitor signal will also be verified. The test is performed by connecting a 1KHz 1Vp-p sine wave to each input and verifying that the signal only propagates to the output when the relay is energized using the appropriate jumper. In the table below record the results of the tests for each channel.

Channel	Channel Enable Monitor Signal Pins (Pin 5 is return)	Relay NOT Energized- Signal not at Output and LED OFF and J9 monitor HIGH?	Relay Energized- Signal at Output and LED ON And J9 Monitor LOW?	Pass	Fail
1	J9- 6, 5	Yes	Yes	Pass	
2	J9- 7, 5	Yes	Yes	Pass	
3	J9- 8, 5	Yes	Yes	Pass	
4	J9- 9, 5	Yes	Yes	Pass	

The jumpers used to energize each of the input relays in this section should be left in for the remainder of the testing.

3.3 Transfer Function Tests

The transfer function for each mode of operation is measured by injecting a signal into the input of a channel and measuring the current through a 20-ohm resistor connected across the corresponding channel output. Measurements are made for frequencies from 0.1Hz to 10KHz. A block diagram of the test setup is shown in the figure below.



3.3.1 Straight Through Mode

In the straight through mode, relay K2 is NOT energized. The nominal response of the coil driver in this mode essentially flat and is shown in the plot below. Note that the transfer function is in units of volts in to amps output into a 20-ohm load, so if the transfer function is measured by measuring the voltage across the load resistor 26dB must be subtracted from the measurement to convert to dBA/V. Gain is adjusted with factor 2 (for differential driver between the DSA and Driver Inputs, subtract 6dB).

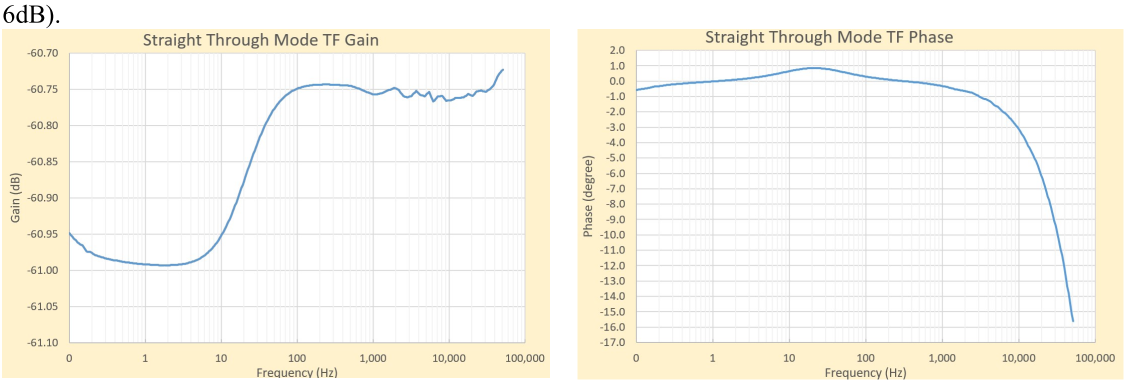


Figure 1: Straight Through Mode Transfer Function

Serial Number: ___S2001170____ Date: _19/12/20____

Tech: __Steve Hateley_______________ T1100084-v5, Page 4

In the tables below, record the measured magnitude and phase of the response for each channel. In addition, save the transfer function for one representative channel to disk and record the file name in space provided below. Gains should be +/-1dB and phases should be +/- 4 degrees for all measurements. Also record that the LED showing that the channel is in Straight-through mode is NOT illuminated and that the remote indicator provided on connector J9 LOW. Note that J9 pin 5 is the return for all indicators on J9.

Table 1: Channel 1 Transfer Function Measurements

Freq (Hz)	Nominal Gain (dBamps/Volt)	Nominal Phase (Degrees)	Actual Gain (dBamps/Volt)	Actual Phase (Degrees)	LED OFF?	J9- 1, 5 LOW?	Pass	Fail
1	-60.8 ±1	0.0 ±4	-61.0	0	OFF	LOW	Pass	
10	-60.8 ±1	0.0 ±4	-61.0	0.7	OFF	LOW	Pass	
100	-60.8 ±1	0.0 ±4	-60.7	0.3	OFF	LOW	Pass	
1K	-60.8 ±1	0.0 ±4	-60.7	0	OFF	LOW	Pass	
10K	-60.8 ±1	0.0 ±4	-60.7	-0.7	OFF	LOW	Pass	

Table 2: Channel 2 Transfer Function Measurements

Freq (Hz)	Nominal Gain (dBamps/Volt)	Nominal Phase (Degrees)	Actual Gain (dBamps/Volt)	Actual Phase (Degrees)	LED OFF?	J9- 2, 5 LOW?	Pass	Fail
1	-60.8 ±1	0.0 ±4	-60.9	0	OFF	LOW	Pass	
10	-60.8 ±1	0.0 ±4	-60.9	0.7	OFF	LOW	Pass	
100	-60.8 ±1	0.0 ±4	-60.8	0.3	OFF	LOW	Pass	
1K	-60.8 ±1	0.0 ±4	-60.8	0	OFF	LOW	Pass	
10K	-60.8 ±1	0.0 ±4	-60.8	-0.7	OFF	LOW	Pass	

Files: S2001170Ch2GS.78D, S2001170Ch2PS.78D, S2001170Ch2S.pcx

Table 3: Channel 3 Transfer Function Measurements

Freq (Hz)	Nominal Gain (dBamps/Volt)	Nominal Phase (Degrees)	Actual Gain (dBamps/Volt)	Actual Phase (Degrees)	LED OFF?	J9- 3, 5 LOW?	Pass	Fail
1	-60.8 ±1	0.0 ±4	-61.0	0	OFF	LOW	Pass	
10	-60.8 ±1	0.0 ±4	-61.0	0.7	OFF	LOW	Pass	
100	-60.8 ±1	0.0 ±4	-60.8	0.3	OFF	LOW	Pass	
1K	-60.8 ±1	0.0 ±4	-60.7	0	OFF	LOW	Pass	
10K	-60.8 ±1	0.0 ±4	-60.7	-0.7	OFF	LOW	Pass	

Table 4: Channel 4 Transfer Function Measurements

Freq (Hz)	Nominal Gain (dBamps/Volt)	Nominal Phase (Degrees)	Actual Gain (dBamps/Volt)	Actual Phase (Degrees)	LED OFF?	J9- 4, 5 LOW?	Pass	Fail
1	-60.8 ±1	0.0 ±4	-61.0	0	OFF	LOW	Pass	
10	-60.8 ±1	0.0 ±4	-61.0	0.7	OFF	LOW	Pass	
100	-60.8 ±1	0.0 ±4	-60.8	0.3	OFF	LOW	Pass	
1K	-60.8 ±1	0.0 ±4	-60.8	0	OFF	LOW	Pass	
10K	-60.8 ±1	0.0 ±4	-60.8	-0.7	OFF	LOW	Pass	

3.3.2 Filtered Mode

In the Filtered mode, relay K2 is energized using on board jumpers on P3. The nominal response of the coil driver in Filtered mode is poles at 1Hz and 200Hz, and zeros at 10Hz and 20Hz and is shown in the plot below. Note that the transfer function is in units of volts in to amps output into a 20-ohm load, so if the transfer function is measured by measuring the voltage across the load resistor 26dB must be subtracted from the measurement to convert to dBA/V. Gain is adjusted with factor 2 (for differential driver between the DSA and Driver Inputs, subtract 6dB).

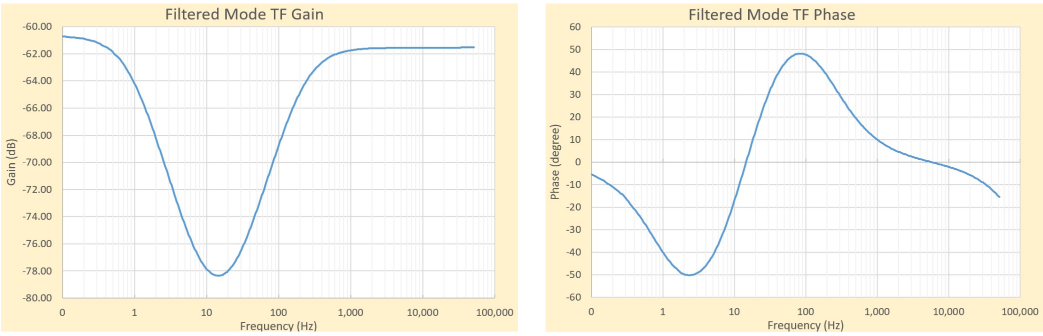


Figure 2: Filtered Mode Transfer Function

In the tables below, record the measured magnitude and phase of the response for each channel. In addition, save the transfer function for one representative channel to disk and record the file name in space provided below. Also record that the LED showing that the channel is in Filtered mode is illuminated and that the remote indicator provided on connector J9 HIGH. Note that J9 pin 5 is the return for all indicators on J9.

Table 5: Channel 1 Transfer Function Measurements

Freq (Hz)	Nominal Gain (dBamps/Volt)	Nominal Phase (Degrees)	Actual Gain (dBamps/Volt)	Actual Phase (Degrees)	LED ON?	J9- 1, 5 HIGH?	Pass	Fail
0.1	-60.8 ±1	- 5.3 ±4	-60.8	-5.5	ON	HIGH	Pass	
1	-64.1 ±1	-39.5 ±4	-64.2	-40.0	ON	HIGH	Pass	
10	-77.7 ±1	-17.3 ±4	-77.8	-17.0	ON	HIGH	Pass	
100	-68.7 ±1	47.6 ±4	-68.8	47.8	ON	HIGH	Pass	
1K	-61.7 ±1	10.2 ±4	-61.7	10.2	ON	HIGH	Pass	
10K	-61.5 ±1	0.5 ±4	-61.5	0.3	ON	HIGH	Pass	

Table 6: Channel 2 Transfer Function Measurements

Freq (Hz)	Nominal Gain (dBamps/Volt)	Nominal Phase (Degrees)	Actual Gain (dBamps/Volt)	Actual Phase (Degrees)	LED ON?	J9- 2, 5 HIGH?	Pass	Fail
0.1	-60.8 ±1	- 5.3 ±4	-60.8	-5.5	ON	HIGH	Pass	
1	-64.1 ±1	-39.5 ±4	-64.2	-39.8	ON	HIGH	Pass	
10	-77.7 ±1	-17.3 ±4	-77.8	-17.1	ON	HIGH	Pass	
100	-68.7 ±1	47.6 ±4	-68.8	47.7	ON	HIGH	Pass	
1K	-61.7 ±1	10.2 ±4	-61.8	10.25	ON	HIGH	Pass	
10K	-61.5 ±1	0.5 ±4	-61.6	0.3	ON	HIGH	Pass	

File S2001170CH2F.PCX, File S2001170CH2GF.78D, File S2001170CH2PF.78D

Table 7: Channel 3 Transfer Function Measurements

Freq (Hz)	Nominal Gain (dBamps/Volt)	Nominal Phase (Degrees)	Actual Gain (dBamps/Volt)	Actual Phase (Degrees)	LED ON?	J9- 2, 5 HIGH?	Pass	Fail
0.1	-60.8 ±1	- 5.3 ±4	-60.8	-5.5	ON	HIGH	Pass	
1	-64.1 ±1	-39.5 ±4	-64.2	-40.0	ON	HIGH	Pass	
10	-77.7 ±1	-17.3 ±4	-77.8	-16.8	ON	HIGH	Pass	
100	-68.7 ±1	47.6 ±4	-68.7	47.7	ON	HIGH	Pass	
1K	-61.7 ±1	10.2 ±4	-61.7	10.1	ON	HIGH	Pass	
10K	-61.5 ±1	0.5 ±4	-61.5	0.3	ON	HIGH	Pass	

Table 8: Channel 4 Transfer Function Measurements

Freq (Hz)	Nominal Gain (dBamps/Volt)	Nominal Phase (Degrees)	Actual Gain (dBamps/Volt)	Actual Phase (Degrees)	LED ON?	J9- 2, 5 HIGH?	Pass	Fail
0.1	-60.8 ±1	- 5.3 ±4	-60.8	-5.56	ON	HIGH	Pass	
1	-64.1 ±1	-39.5 ±4	-64.2	-40.0	ON	HIGH	Pass	
10	-77.7 ±1	-17.3 ±4	-77.8	-16.8	ON	HIGH	Pass	
100	-68.7 ±1	47.6 ±4	-68.5	47.7	ON	HIGH	Pass	
1K	-61.7 ±1	10.2 ±4	-61.7	10.1	ON	HIGH	Pass	
10K	-61.5 ±1	0.5 ±4	-61.5	0.3	ON	HIGH	Pass	

3.3.3 Dynamic Range Tests

The dynamic range requirement for the A-Plus HAM-A Driver is 3.5mA peak for frequency<1KHz. The tests below will verify that the design meets this requirement. In addition, the board components will be checked for overheating. The tests for all channels should be conducted simultaneously and each test step/reading should be held for a minimum of 5 minutes to allow the temperature of the chassis and components to stabilize. In the tables below, record the output current versus input voltage (both peak), note any component heating and if possible the temperature of the component. Output current should be measured across the 20-ohm load resistor connected to the channel under test. The input signal used for this should be a 1KHz sine wave. The driver board should be in the Straight Through mode configuration used in section 3.3.1 of this test plan.

Tambient = 22 Celcius

Table 9: Channel 1 Output Current vs. Input Voltage

Input Voltage Peak (1KHz)	Nominal Output Current (mApeak)	Actual Output Current (mApeak)	Notes	Pass	Fail
1V	0.91	0.91	Temp 33.6 C	Pass	
5V	4.6	4.5		Pass	

Table 10: Channel 2 Output Current vs. Input Voltage

Input Voltage Peak (1KHz)	Nominal Output Current (mApeak)	Actual Output Current (mApeak)	Notes	Pass	Fail
1V	0.91	0.90	Temp 37 C	Pass	
5V	4.6	4.5		Pass	

Table 11: Channel 3 Output Current vs. Input Voltage

Input Voltage Peak (1KHz)	Nominal Output Current (mApeak)	Actual Output Current (mApeak)	Notes	Pass	Fail
1V	0.91	0.90	Temp 36 C	Pass	
5V	4.6	4.5		Pass	

Table 12: Channel 4 Output Current vs. Input Voltage

Input Voltage Peak (1KHz)	Nominal Output Current (mApeak)	Actual Output Current (mApeak)	Notes	Pass	Fail
1V	0.91	0.90	Temp 36 C	Pass	
5V	4.6	4.5		Pass	

3.4 Noise Tests

The simulation of current noise from A-Plus LIGO HAM-A Driver, document E1900347, shows that at 10Hz we will see 194pA/√Hz (with 1K2 output resistors 20R load) at the coil (Incl DAC noise). The noise of the driver alone is significantly lower. It is very difficult to measure noise currents of this magnitude, so the output voltage noise of the driver will be measured using TP3 and TP7 (ie before the output resistors). The output noise of the driver across these points should be 33±10nV/√Hz at 10Hz (in Filtered Mode).

Table 13: Noise Test Results

Channel Number	Measure Pin	Predicted Noise at 10Hz (nV/√Hz)	Measured Noise at 10Hz (nV/√Hz)	Pass	Fail
1	TP3, TP7	33 ±10	32	Pass	
2	TP3, TP7	33 ±10	33	Pass	
3	TP3, TP7	33 ±10	31	Pass	
4	TP3, TP7	33 ±10	30	Pass	

For reference record the noise in straight thro mode.

Table 14: Noise Test Results

Channel Number	Measure Pin	Predicted Noise (typ) at 10Hz (nV/√Hz)	Measured Noise at 10Hz (nV/√Hz)
1	TP3, TP7	100	124
2	TP3, TP7	100	127
3	TP3, TP7	100	114
4	TP3, TP7	100	100

Release Notes

V3 to 4 Clarified limits for Supply currents. Widened tolerance on Filter mode Tx function phase (to 4Deg). Clarified Tx function test setup block diagram in sec 3.3.

V4 to 5 Clarified test limits and mode of operation for noise tests (filter mode). Added new table to record noise in straight thro mode for reference.