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Refer to:	LIGO-T040189-B
Date:	March 4, 2010

Common Mode Servo Board Test Procedure

Required equipment:

A description of the mode cleaner common mode board can be found in T040148.

- Beckhoff system for common mode slow controls
- Signal generator
- Oscilloscope
- Network analyzer (1Hz to 10MHz)
- Spectrum analyzer (100kHz bandwidth)
- SR560 low noise preamplifier

Preparations:

Test Engineer	Date	Pass

Write down revision, serial number and whether it is a mode cleaner board or a interferometer common mode board.

Board	Revision C/D	Serial	MC/CM
D040180			

Hook up the slow controls and enable the fast path. Hook up the power and check that the current drawn from the ±17V power supply is between 0.3A and 0.6A.

Power supply	Current	Nominal
+24V		0.02
24V		0.02
+17		.45
-17		.45

Test for oscillations:

Use scope on all outputs and make sure they are not oscillating.

Output	OUT1	OUT2	SERVO	A:IN1	A:IN2	B:IN1	B:IN2
Check							
Output	DAQ1 "14"	DAQ1 "23"	DAQ2 "14"	DAQ2 "23"	D32 Input Mon	D33 Split Mon	D34 Fast Mon
Check							
Output	D39 Slow FB Mon	D40 Slow Mon	D35 Limit Indicat.				
Check							

Adjust dc bias:

Ground IN1 and adjust the dc bias (R37 and Common offset (D36)) so that the output voltage at SERVO (MC board) or OUT1 (CM board) and input mon(D32) become zero.

Check R37	
Common Offset	

Gain slider A:

Apply a 1kHz/1Vpp (CM) or 0.225Vpp (MC) sine wave to IN1, with input 1 enabled. Measure the voltage at OUT1 while pulling the specified binary inputs to GND. The measured voltages should be within 0.5dB of the nominal values.

Binary input (gain slider setting)	Measured [Vpp]	Nominal [Vpp]
—(0dB)		1
D0 (1dB)		1.12
D1 (2dB)		1.26
D2 (4dB)		1.59
D3 (8dB)		2.51
D4 (16dB)		6.31
D3 & D4 (24dB)		15.9
D5 (-32dB)		0.025

D5 & D3 (-24dB)		0.063
D5 & D4 (-16dB)		0.159
D5 & D3 & D4 (-8dB)		0.398

Gain slider B:

Apply a 1kHz/1Vpp sine wave to IN2. Measure the voltage at OUT2 while pulling the specified binary inputs to GND. The measured voltages should be within 0.5dB of the nominal values.

Binary input (slider gain)	Measured [Vpp]	Nominal [Vpp]
—		1
D6 (1dB)		1.12
D7 (2dB)		1.26
D8 (4dB)		1.59
D9 (8dB)		2.51
D10 (16dB)		6.31
D9 & D10 (24dB)		15.9
D11 (-32dB)		0.025
D11 & D9 (-24dB)		0.063
D11 & D10 (-16dB)		0.159
D11 & D9 & D10 (-8dB)		0.398

Crossbar switches:

Apply a 1kHz/1Vpp sine wave to IN1. Measure the voltage at OUT1 and OUT2 while pulling the specified binary inputs to GND. The measured voltages are either on or off.

Binary input	OUT1 state	Nominal	OUT2 state	Nominal
—		On		Off
D12 (input 1 disabled)		Off		Off
D13 (input 2 enabled)		On		Off
D14 (output switch)		On		On

Apply a 1kHz/1Vpp sine wave to IN2. Measure the voltage at OUT1 and OUT2 while pulling the specified binary inputs to GND. The measured voltages are either on or off.

Binary input	OUT1 state	Nominal	OUT2 state	Nominal
--		Off		On
D12 (input 1 disabled)		Off		On
D13 (input 2 enabled)		On		On
D14 (output switch)		Off		Off

Excitation A:

Apply a 1kHz/1Vpp sine wave to IN1. Measure the voltage at A:TEST1 and A:TEST2 while pulling the specified binary inputs to GND. The measured voltages should be within 0.5dB of the nominal values.

Binary input	A:TEST1	Nominal [Vpp]	A:TEST2	Nominal [Vpp]
—		1.00		-1.00

Apply a 1kHz/1Vpp sine wave to A:EXC. Measure the voltage at A:TEST2 and OUT1 while pulling the specified binary inputs to GND. The measured voltages should be within 0.5dB of the nominal values. Nominal values are given for CM/MC.

Binary input	A:TEST2	Nominal [Vpp]	OUT1	Nominal [Vpp]
—		Off		Off
D18 (com exc enable)		0.10		0.10/0.45
D18 & D19 (com option)		0.10		Off

Split:

Apply a 1kHz/1Vpp(CM) or 0.225Vpp(MC) sine wave to IN1. Measure the voltage at OUT1 and SERVO while pulling the specified binary inputs to GND. Use R100 and slow offset (D37) to zero offset at Slow FB mon when slow comp is enabled. The measured voltages should be within 0.5dB of the nominal values. Nominal values are given for CM/MC.

Binary input	OUT1	Nominal [Vpp]	SERVO	Nominal [Vpp]
—		1.00		-1.00/+0.11
lift D22 (disable fast)		1.00		Off
D21 (common filter)		1.00		-1.00/+0.11
D23 (fast polarity)		1.00		+1.00/-0.11
D20 (slow polarity)		-1.00		-1.00/+0.11
D24 (slow option)		0		-1.00/+0.11
Lift D28 (slow comp)		0		-1.00/+0.11
D29 (slow boost)		1.00 (offset)		-1.00/+0.11
D30 (slow filter)		1.00		-1.00/+0.11
D25 and lift D28 (slow bypass and slow comp)		1.00		-1.00/+0.11
D27 (slow offset enable)		1.00 (change offset with slow offset, D38)		-1.00/+0.11
D27 and D26 (slow 5V offset)		1.00 (5 V offset)		-1.00/+0.11

Latching:

Apply a 1kHz/1Vpp sine wave to IN1. Measure the voltage at SERVO. Ground P1/11 (latch enable). Now ground D12 (input 1 enable) and make sure the signal at the output stays on all the time.

Check	

Excitation B:

Apply a 1kHz/1Vpp sine wave to IN1. Measure the voltage at B:TEST1 and B:TEST2 while pulling the specified binary inputs to GND. The measured voltages should be within 0.5dB of the nominal values.

Binary input	B:TEST1	Nominal [Vpp]	B:TEST2	Nominal [Vpp]
—		1.00		-1.00

Apply a 1kHz/1Vpp sine wave to B:EXC. Measure the voltage at B:TEST2 and SERVO while pulling the specified binary inputs to GND. The measured voltages should be within 0.5dB of the nominal values. Nominal values are given for CM/MC.

Binary input	B:TEST2	Nominal [Vpp]	SERVO	Nominal [Vpp]
—		Off		Off
D47 (fast exc. enable)		0.10		-0.10/0.05
D47 & D48 (fast option)		0.10		Off

Limiter:

Apply a 1kHz/20Vpp sine wave to IN1. Measure the voltage at SERVO while pulling the specified binary inputs to GND. The measured voltage should be within 25% of the nominal value. Nominal values are given for CM/MC.

Binary input	Measured [Vpp]	Nominal [Vpp]
-		20.0/10.0
D31 (fast limiter)		2 * (zener + 0.6) / 1 * (zener + 0.6) [6.6/3.3]

Gain slider C:

Apply a 1kHz/1Vpp(CM) or 2Vpp(MC) sine wave to IN1. Measure the voltage at SERVO while pulling the specified binary inputs to GND. Short D31 to GND. The measured voltages should be within 0.5dB of the nominal values.

Binary input (slider gain)	Measured [Vpp]	Nominal [Vpp]
—		1
D41 (1dB)		1.12
D42 (2dB)		1.26
D43 (4dB)		1.59
D44 (8dB)		2.51
D45 (16dB)		6.31
D44 & D45 (24dB)		15.9 (scale for MC)
D46 (-32dB)		0.025
D46 & D44 (-24dB)		0.063
D46 & D45 (-16dB)		0.159
D46 & D45 & D44 (-8dB)		0.398

EPICS readbacks:

Apply first a 1Hz/1Vpp and then a 99Hz/1Vpp sine wave to IN1. Watch analog outputs for a peak to peak value. The measured voltage should be within 1 dB (6dB for D34) of the nominal value.

EPICS readback	1Hz	Nominal [Vpp]	100Hz	Nominal [Vpp]
D32 (input mon)		1.00		0.080
D33 (split mon)		1.00		0.080
D34 (fast mon) (MC/CM)		10.00/0.4		0.80/0.03
D39 (slow FB mon)		1.00		
D40 (slow mon)		1.00		

Limit indicator:

Apply a 0.1Hz/10Vpp square wave to IN1. Look at the signal at D35(limit indicator) compare with the nominal response; see Appendix A6.

Check	

Apply a 1kHz sine wave to IN1. Increase its amplitude from 0.0V in 0.1V steps until D35 goes from high to low.

Binary input	Measured [Vpp]	Nominal [Vpp]
—		30 xR175/(R170+R175+R176) (6.0)

Distortion:

Apply a 1kHz/1Vrms sine wave to IN1(with D12 on, input 1 enabled, fast enabled (D21). Use a spectrum analyzer to measure the harmonic components at SERVO; see Appendix A7. Repeat the measurement with IN2 (Input2 enabled ,D13 on).

Harmonic	IN1	SERVO [dBc]	IN2	SERVO [dBc]
1 (1kHz)		0		0
2 (2kHz)		>70		>70
3 (3kHz)		>70		>70
4 (4kHz)		>70		>70
5 (5kHz)		>70		>70

Noise spectra:

Ground IN1 and IN2. Measure the noise density at OUT1, OUT2 and SERVO. Write down the values at 100Hz, 1kHz, 10kHz and 100kHz. Nominal values are given for CM/MC. Attach hardcopies of the measured spectra; see Appendix A1 for typical examples.

Frequency	OUT1	< [nV/□Hz]	OUT2	< [nV/□Hz]	SERVO	< [nV/□Hz]
100Hz		40/300		30		50
1kHz		30/200		30		40
10kHz		30/50		30		40
100kHz		30/20		30		40

Basic transfer functions:

Use a network analyzer to measure the transfer function from IN1 to OUT1, from IN1 to SERVO and from IN2 to OUT. Sweep the frequency from 100kHz down to 1Hz with 100mV source amplitude. Write down the values at 10Hz, 100Hz, 1kHz, 10kHz and 100kHz. They should be within 1dB and 5° of nominal. Nominal values are given for CM/MC. Attach hardcopies of the measured transfer function; see Appendix A2 for typical examples.

Frequency	OUT1/IN1 [dB]	Nominal	OUT1/IN1[deg]	Nominal
10Hz		0/14		0/0
100Hz		0/14		0/3
1kHz		0/13		0/28
10kHz		0/0		5/80
100kHz		3/20		50/90

Input 1 enable (D12) and fast enable (D22):

Frequency	SERVO/IN1 [dB]	Nominal	SERVO/IN1 [deg]	Nominal
10Hz		2/6.0		115/0
100Hz		0/6.0		173/0
1kHz		0/6.0		179/0
10kHz		0/6.0		181/3
100kHz		0/3.0		189/10

Frequency	OUT2/IN2 [dB]	Nominal	OUT2/IN2 [deg]	Nominal
10Hz		0/0		180/180
100Hz		0/0		180/180
1kHz		0/0		180/180
10kHz		0/0		180/180
100kHz		0/0		183/183

High frequency transfer function:

Use a network analyzer to measure the transfer function from IN1 to SERVO. Sweep the frequency from 10MHz down to 10kHz with –20dBm source. Write down the values at 100kHz, 300kHz and 1MHz. To remove cable delays first measure the transfer function against a BNC barrel and use as a reference. They should be within 1dB and 5° of nominal. Nominal values are given for CM/MC. Attach a hardcopy of the measured transfer function; see Appendix A3 for typical examples.

Frequency	SERVO/IN1 [dB]	Nominal	SERVO/IN1 [deg]	Nominal
100kHz		0/3		170/4
300kHz		0/1		150/30
1MHz		2/2		75/130

Transfer functions of boost gain stages:

Use a SR560 low noise preamplifier, turn the filter off, set its gain to 1 or 2, select invert and connect its input to OUT1 (CM) or SERVO (MC) and its output to IN1. Make sure the feedback loop is stable and that it does not oscillate. Now use a network analyzer to measure the transfer function from A:TEST2 to A:TEST1 by injecting into A:EXC. Short D18 (common excitation enable) to GND and sweep the frequency from 100kHz down to 1Hz with 5V source amplitude. Make a reference trace when the boost gain stages are off and measure the transfer functions of the boost gain stages relative to the reference. Determine the poles and zeros of the boost gain stages and write down their values (last stage may be too difficult; check at least the dc gain). They should be within 20% of nominal. For 2 and 3 stages use the previous measurement as the reference. It is also possible to measure these boost stages by using TP3, TP8, TP9, TP10 and TP11A. Attach hardcopies of the measured transfer functions; see Appendix A4 for typical examples.

Boost #	Pole [Hz]	Nominal	Zero [Hz]	Nominal
Common Compensation (D17)		40		4000
1 (D15)		1000		20000
2 (D16)		1000		20000
3 (D15+D16)		500		10000

Slow boost gain stages:

Connect SR560's output to OUT1, and check transfer function with the following settings, and common exc enabled (D18).

	Pole [Hz]	Nominal	Zero [Hz]	Nominal
--		100kHz		-
D28 (slow comp)		4		-
D29 (slow boost)		4		400

Transfer functions of DAQ channels:

Use a network analyzer to measure the transfer function from IN1 to the DAQ chanels. Sweep the frequency from 10kHz down to 1Hz with 1mV source amplitude. Write down the values at dc and 10kHz. They should be within 1dB and 5° of nominal. Nominal values are given for CM/MC. Attach hardcopies of the measured transfer function; see Appendix A5 for typical examples.

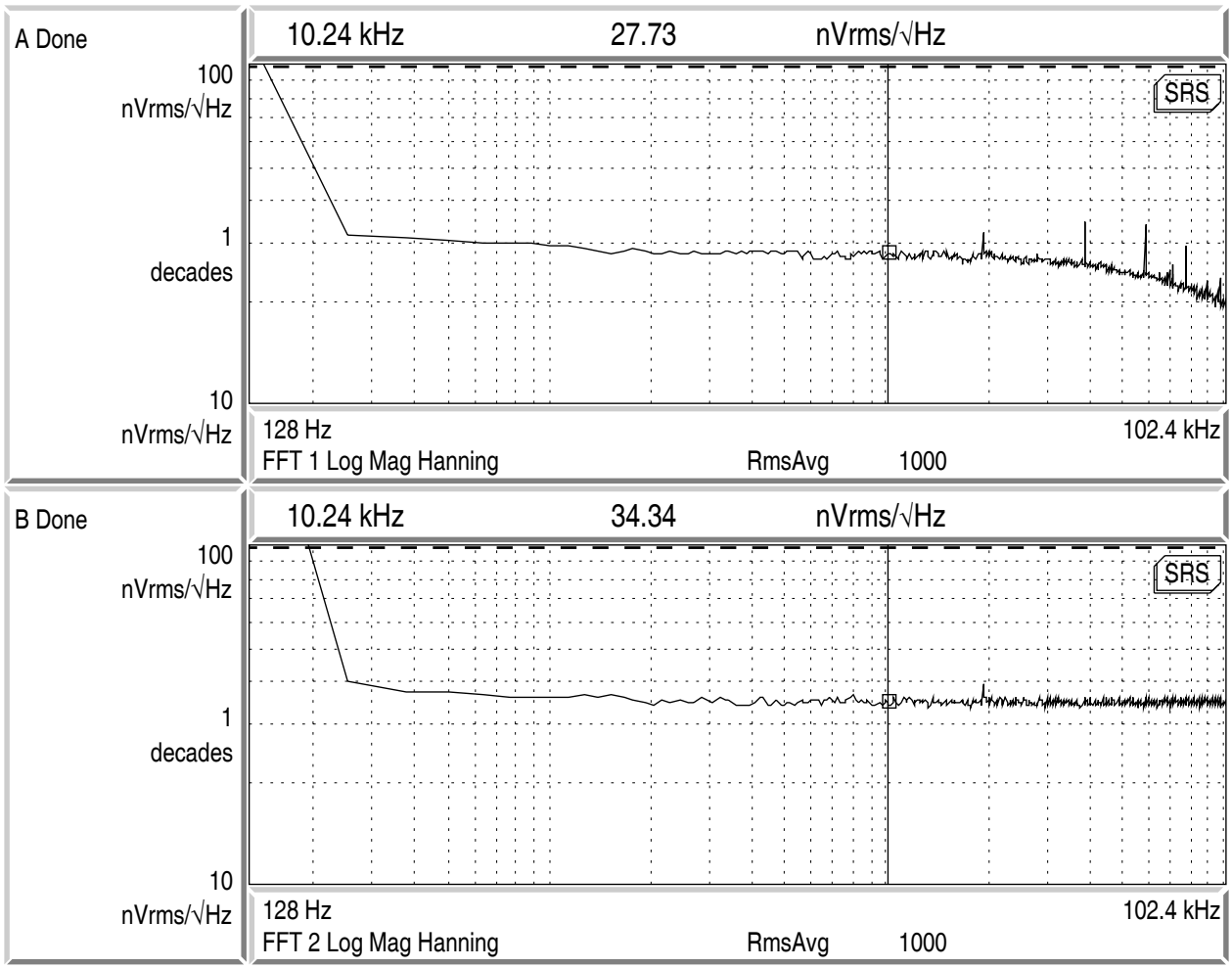
Frequency	DAQ1B (3)/IN1 [dB]	Nominal	DAQ1B(3)/IN1 [deg]	Nominal
dc		-20		0
10kHz		20		-12

Frequency	DAQ1A(4)/IN1 [dB]	Nominal	DAQ1A(4)/IN1 [deg]	Nominal
dc		20		0
10kHz		20		0

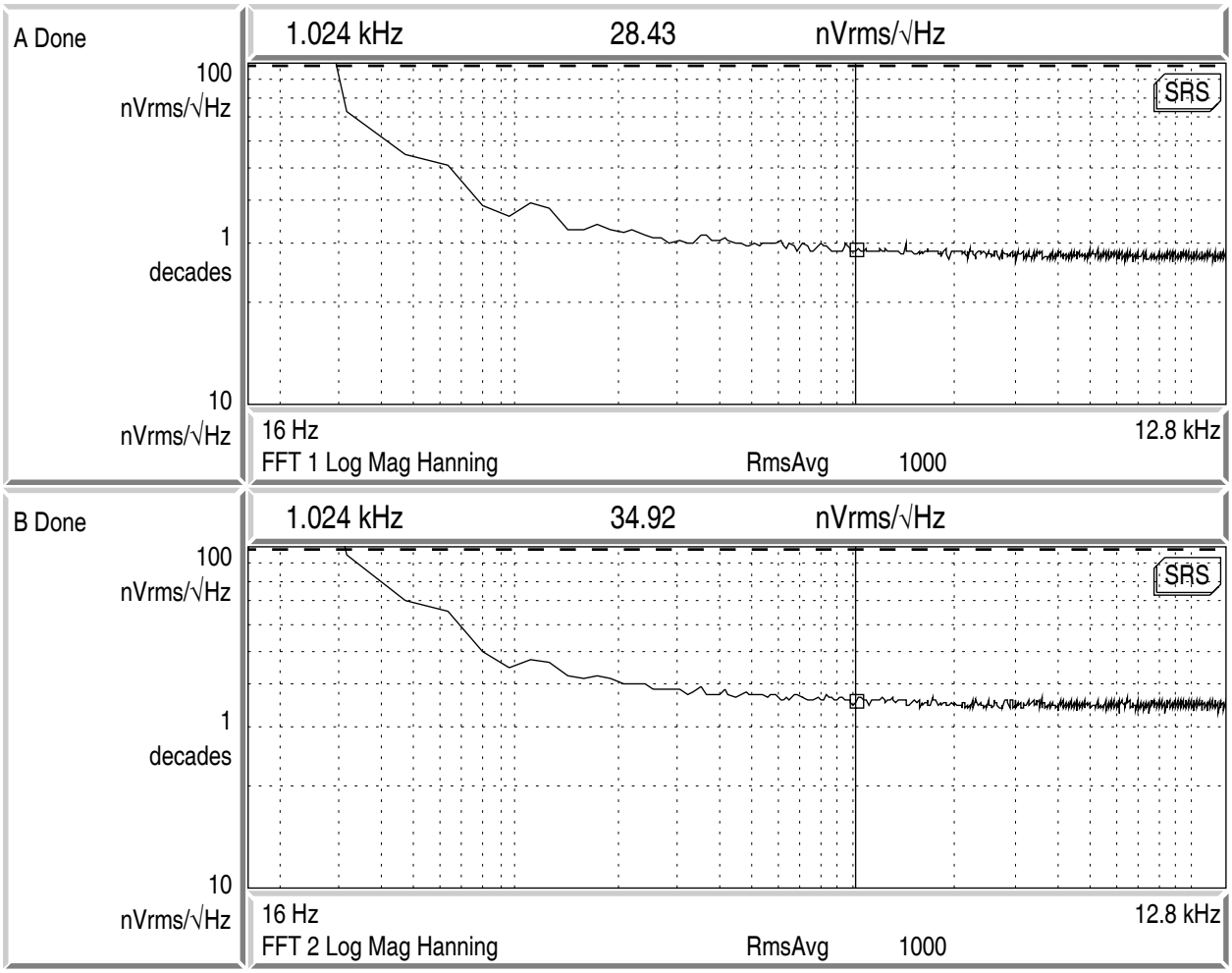
Frequency	DAQ2B (3)/IN1 [dB]	Nominal	DAQ2B(3)/IN1 [deg]	Nominal
dc		20		0
10kHz		20		0

Frequency	DAQ2A (4)/IN1 [dB]	Nominal	DAQ2A (4)/IN1 [deg]	Nominal
dc		--		--
10kHz		40		-180

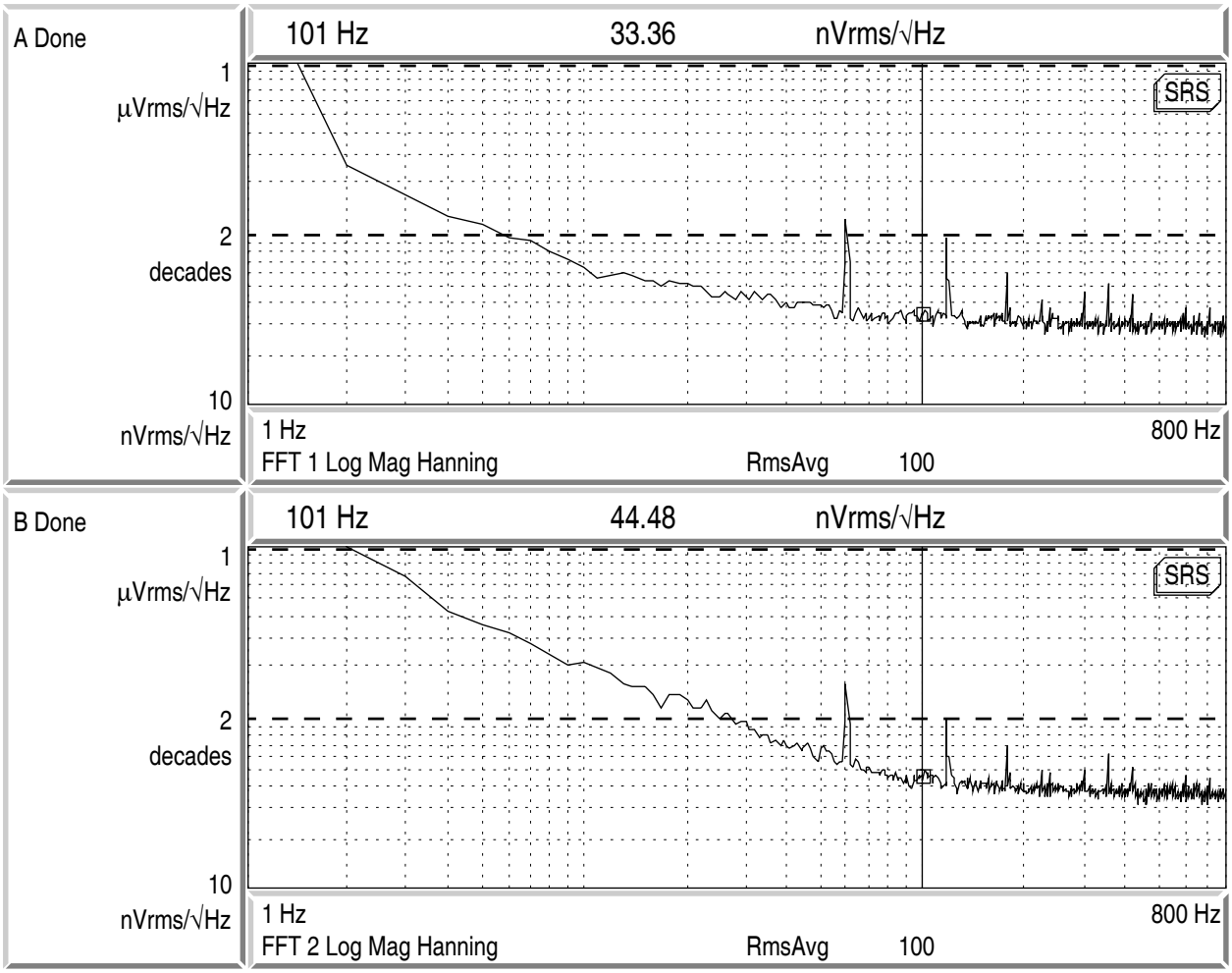
Appendix A1: Noise spectra



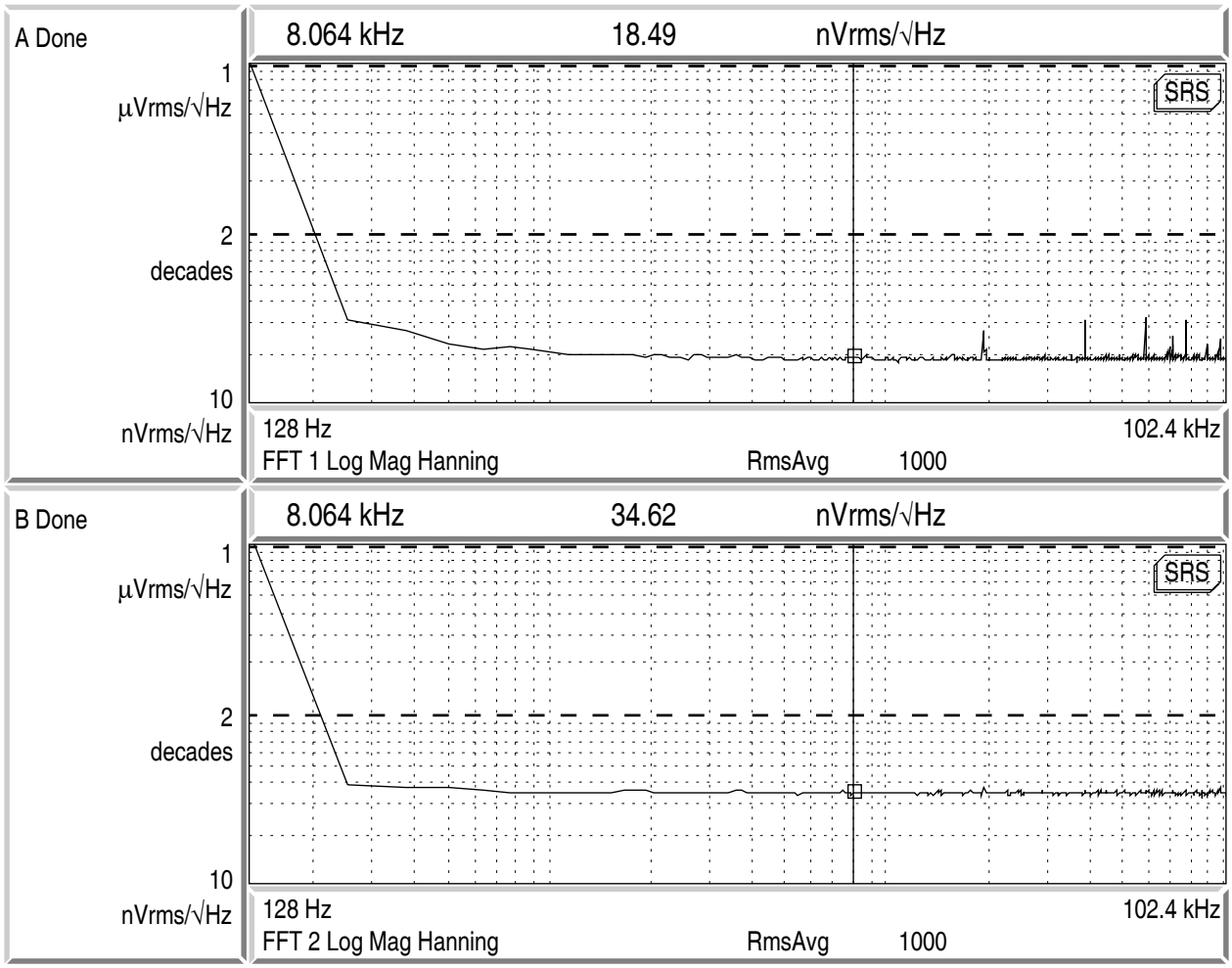
Noise spectra for IN1 (top) and SERVO (bottom).



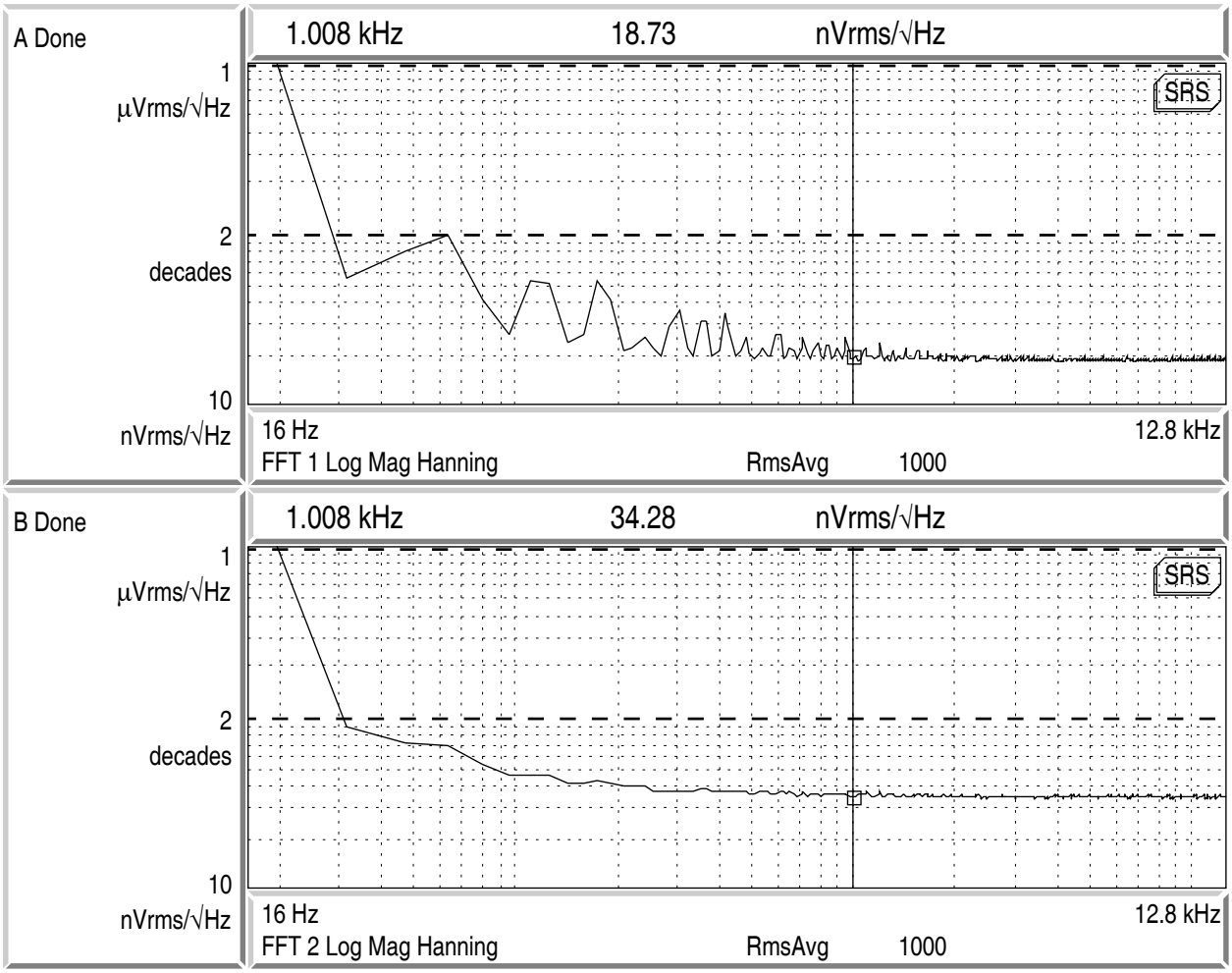
Noise spectra for IN1 (top) and SERVO (bottom).



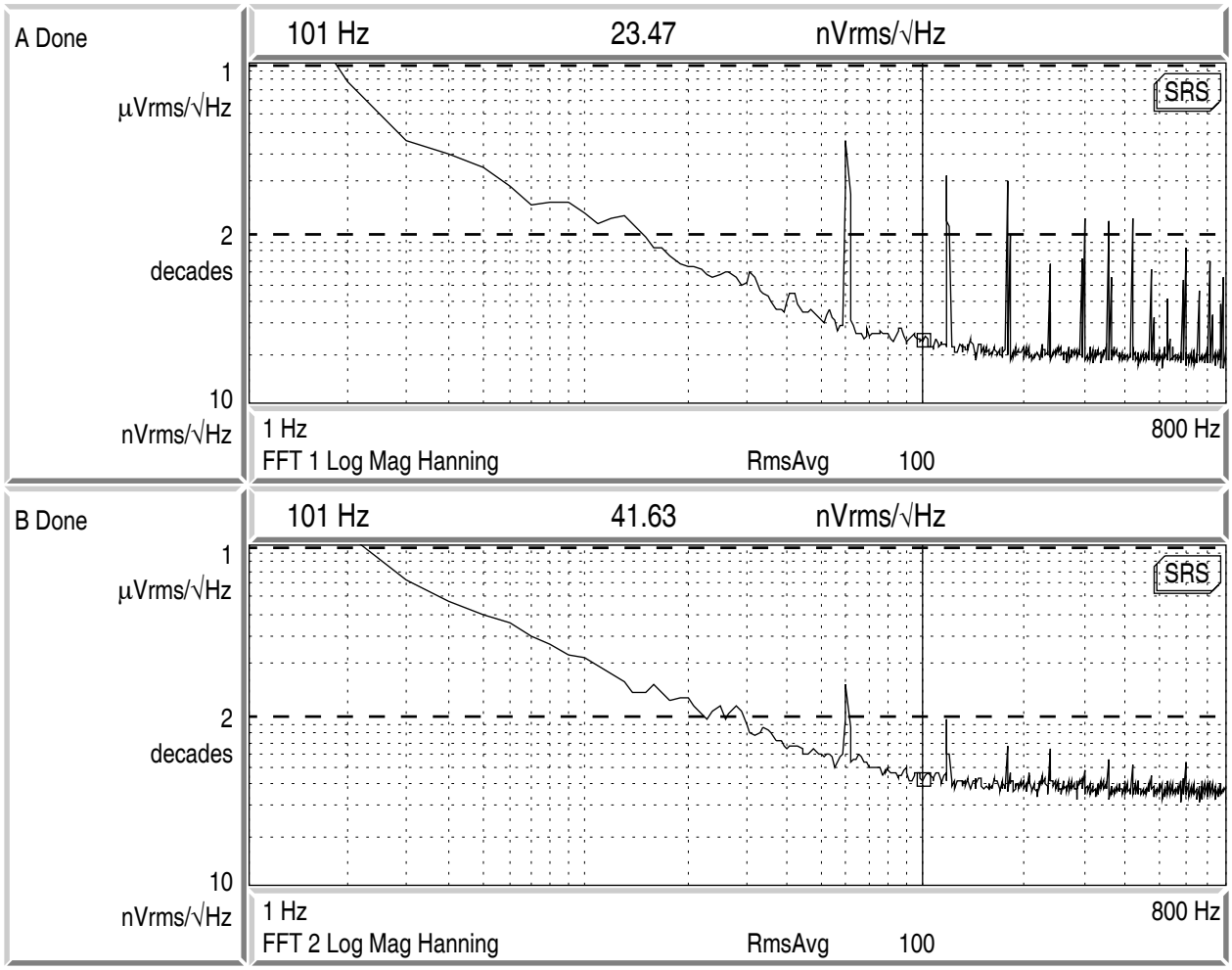
Noise spectra for IN1 (top) and SERVO (bottom).



Noise spectra for IN2 (top) and SERVO (bottom).

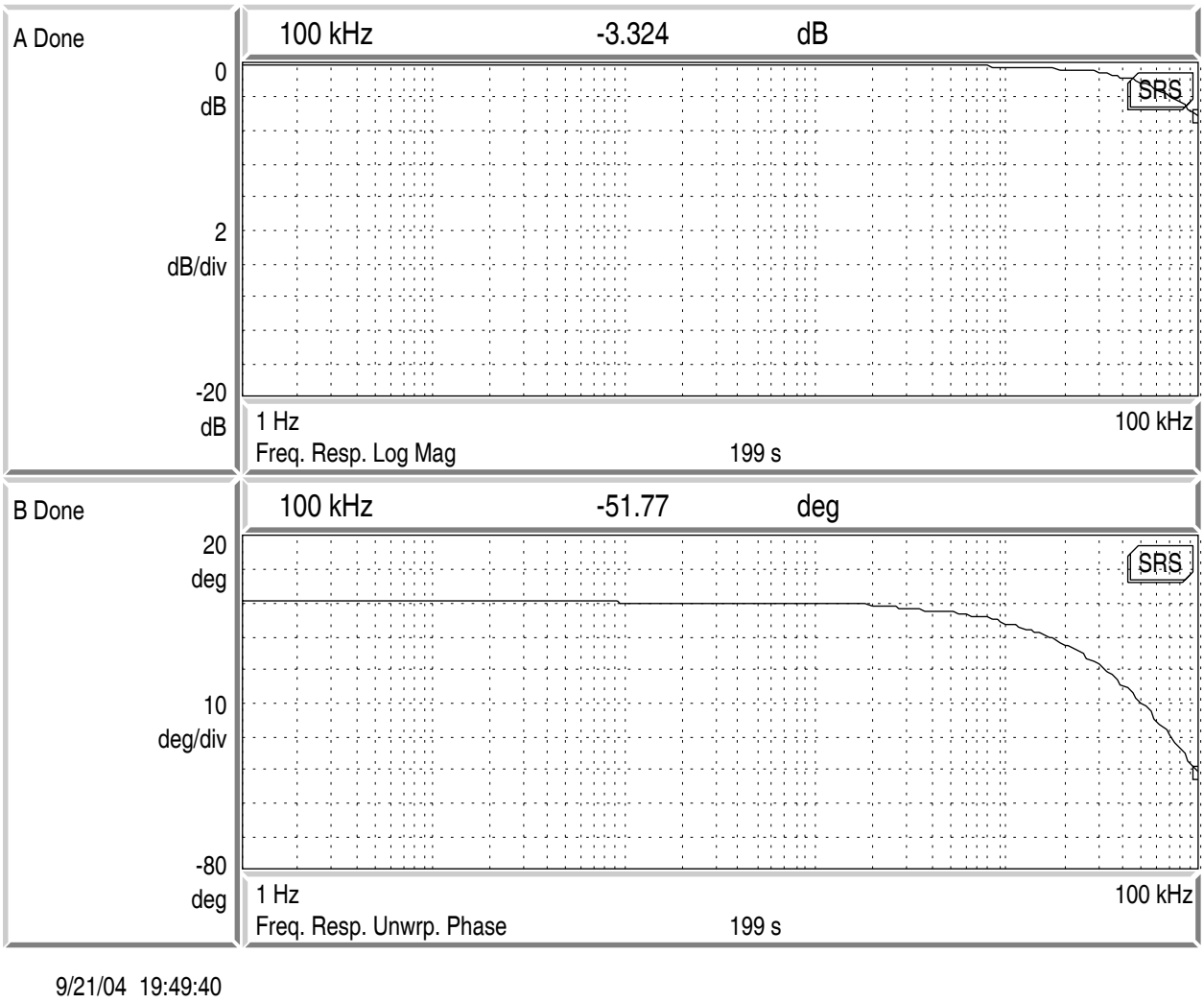


Noise spectra for IN2 (top) and SERVO (bottom).

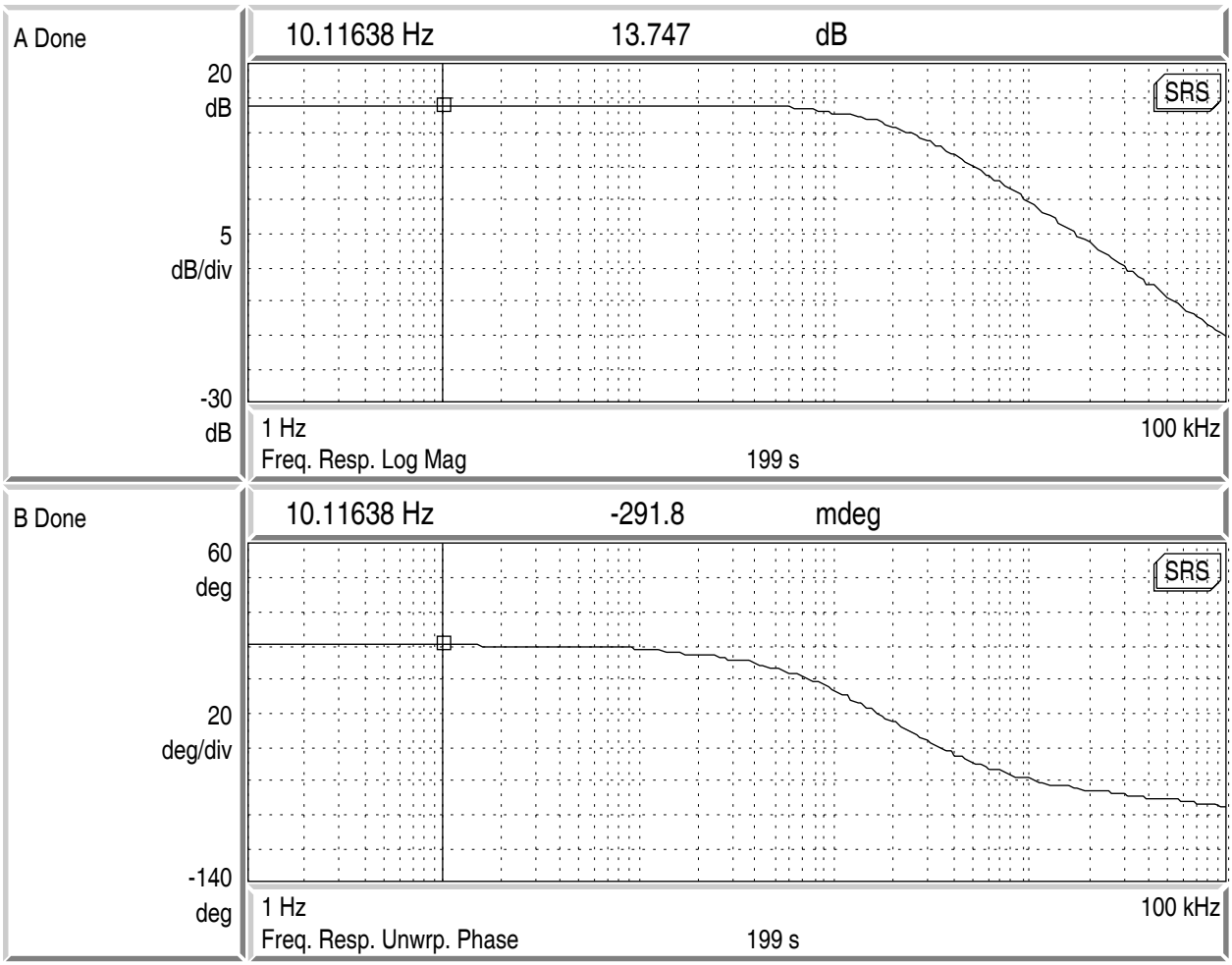


Noise spectra for IN2 (top) and SERVO (bottom).

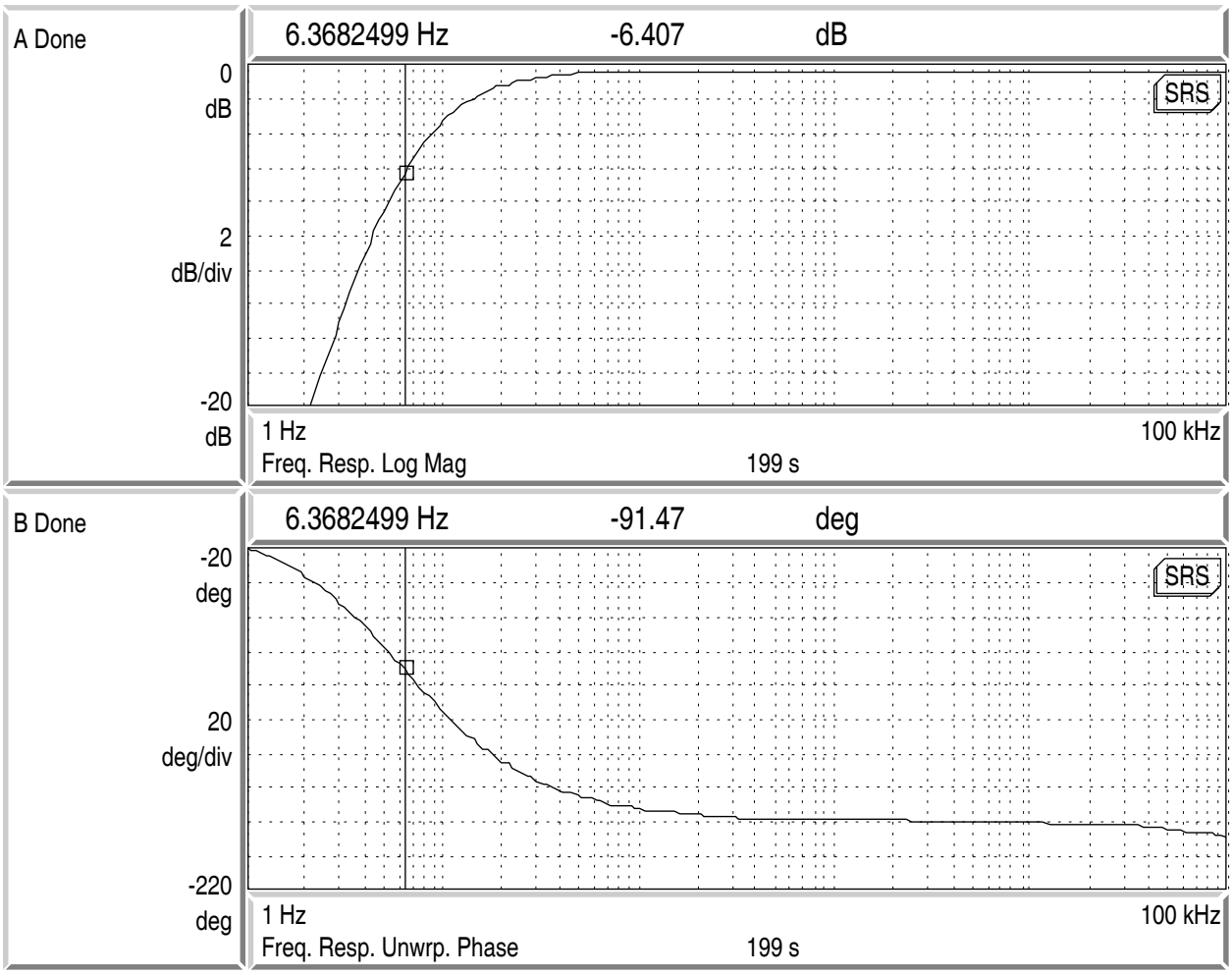
Appendix A2: Basic transfer functions



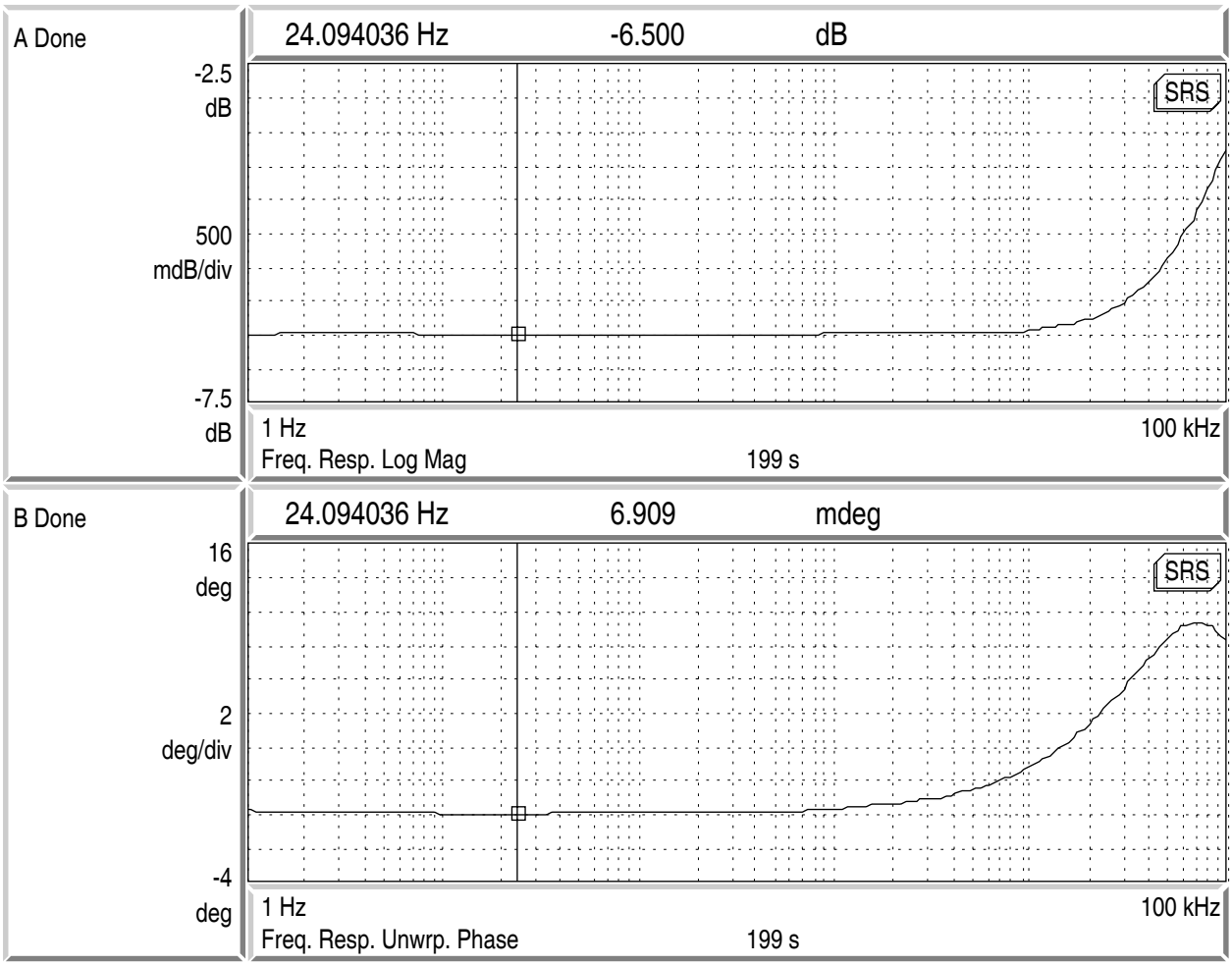
Transfer function from IN1 to OUT1 (LSC common mode).



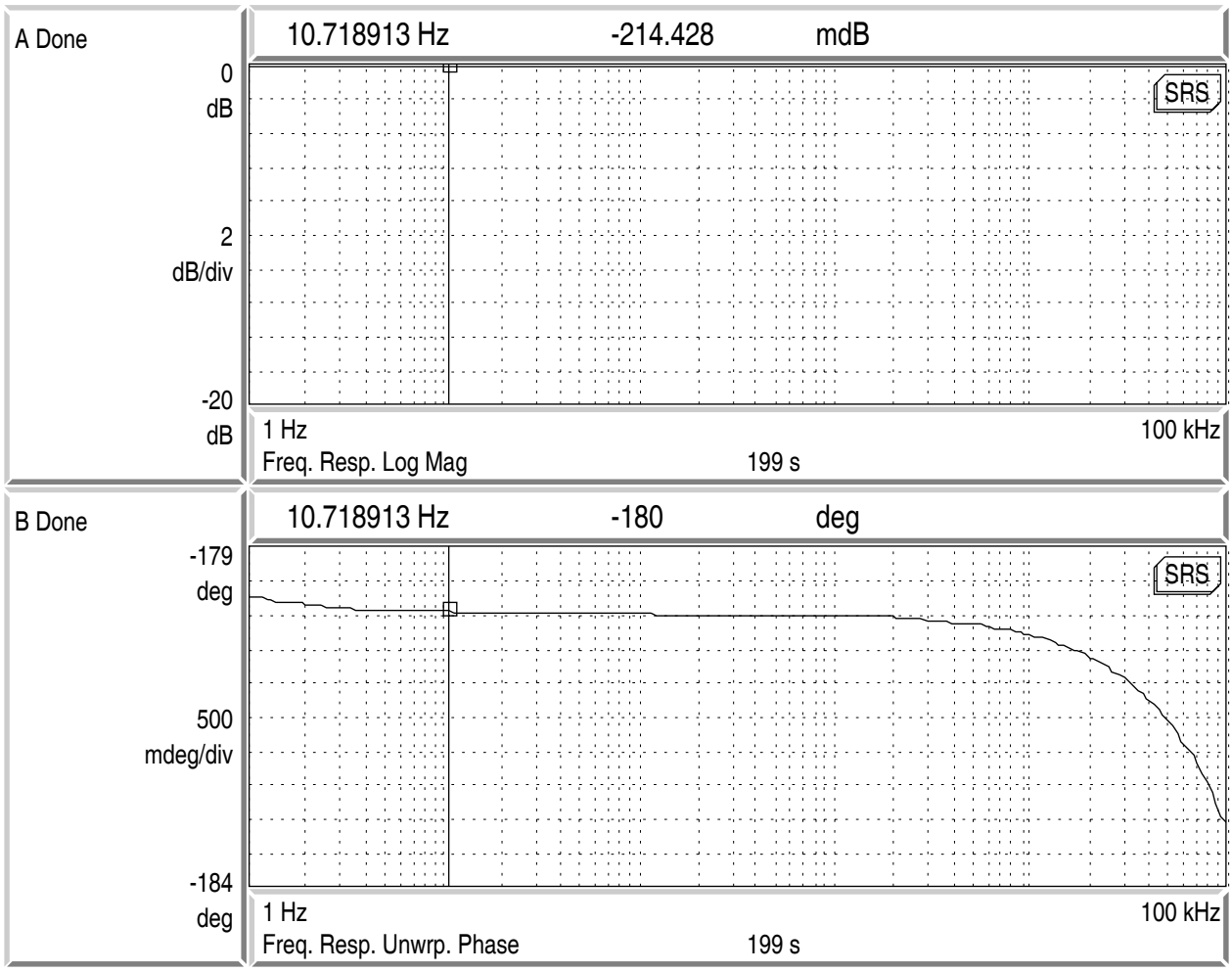
Transfer function from IN1 to OUT1 (mode cleaner).



Transfer function from IN1 to SERVO (LSC common mode).

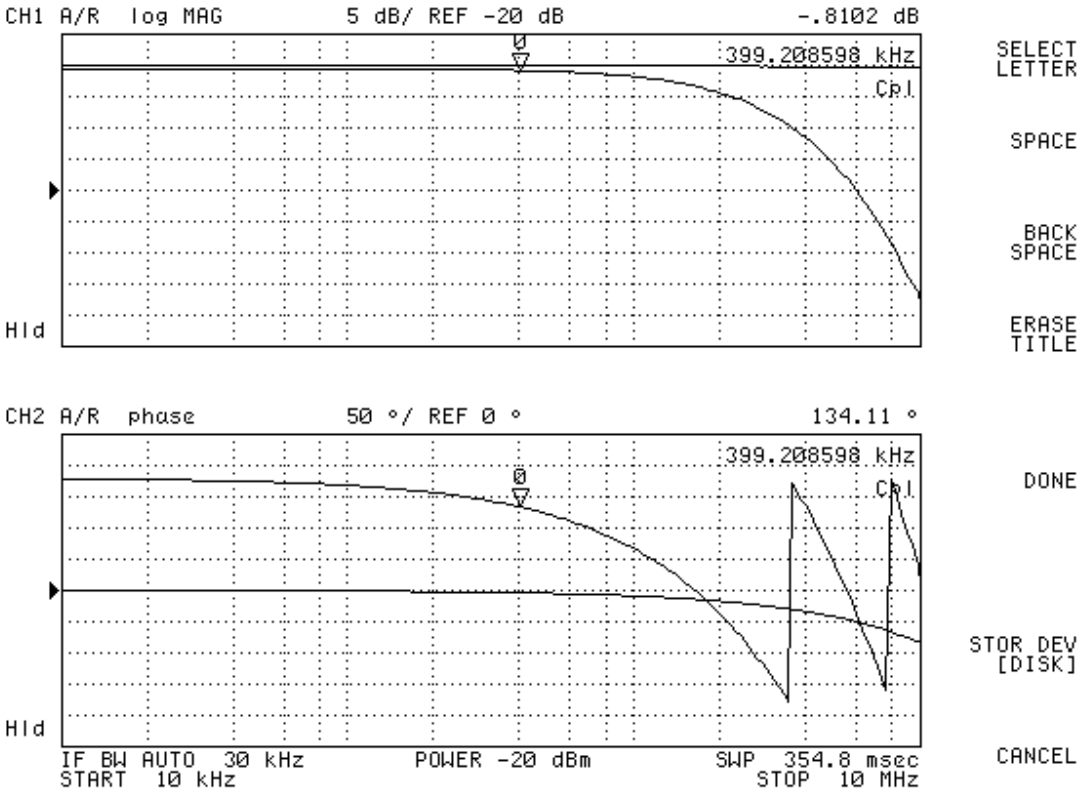


Transfer function from IN1 to SERVO (mode cleaner).

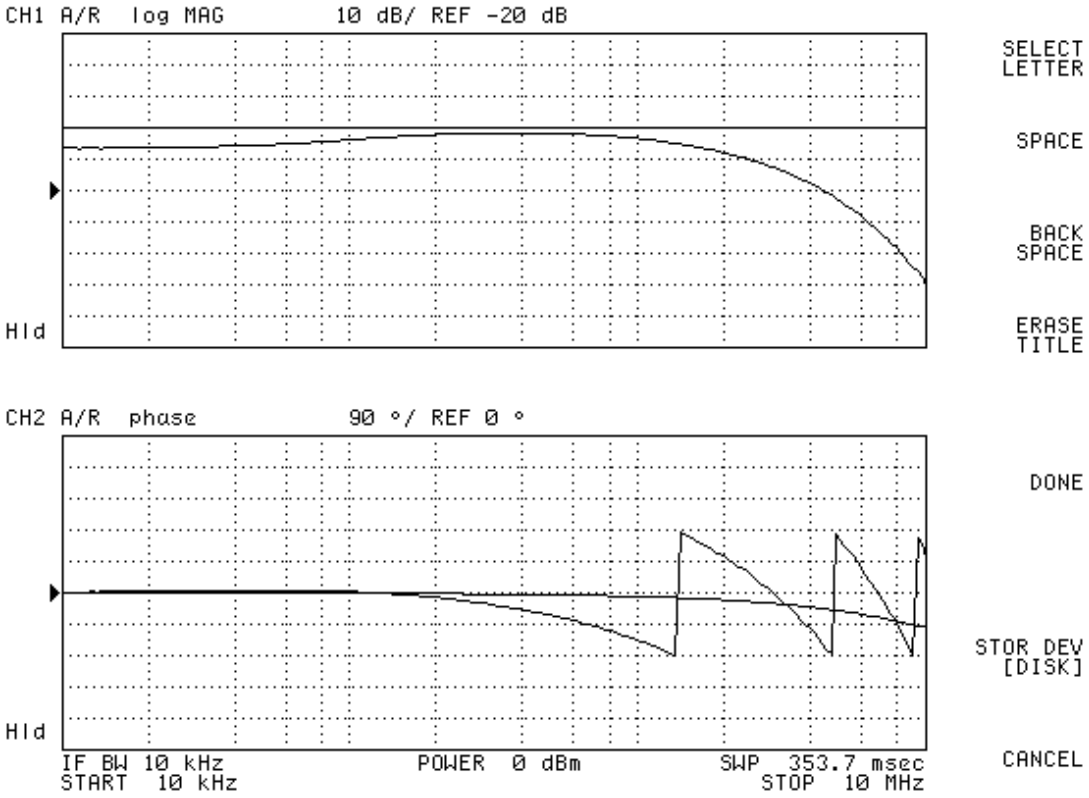


Transfer function from IN2 to OUT2 (LSC common mode and mode cleaner).

Appendix A3: High frequency transfer function

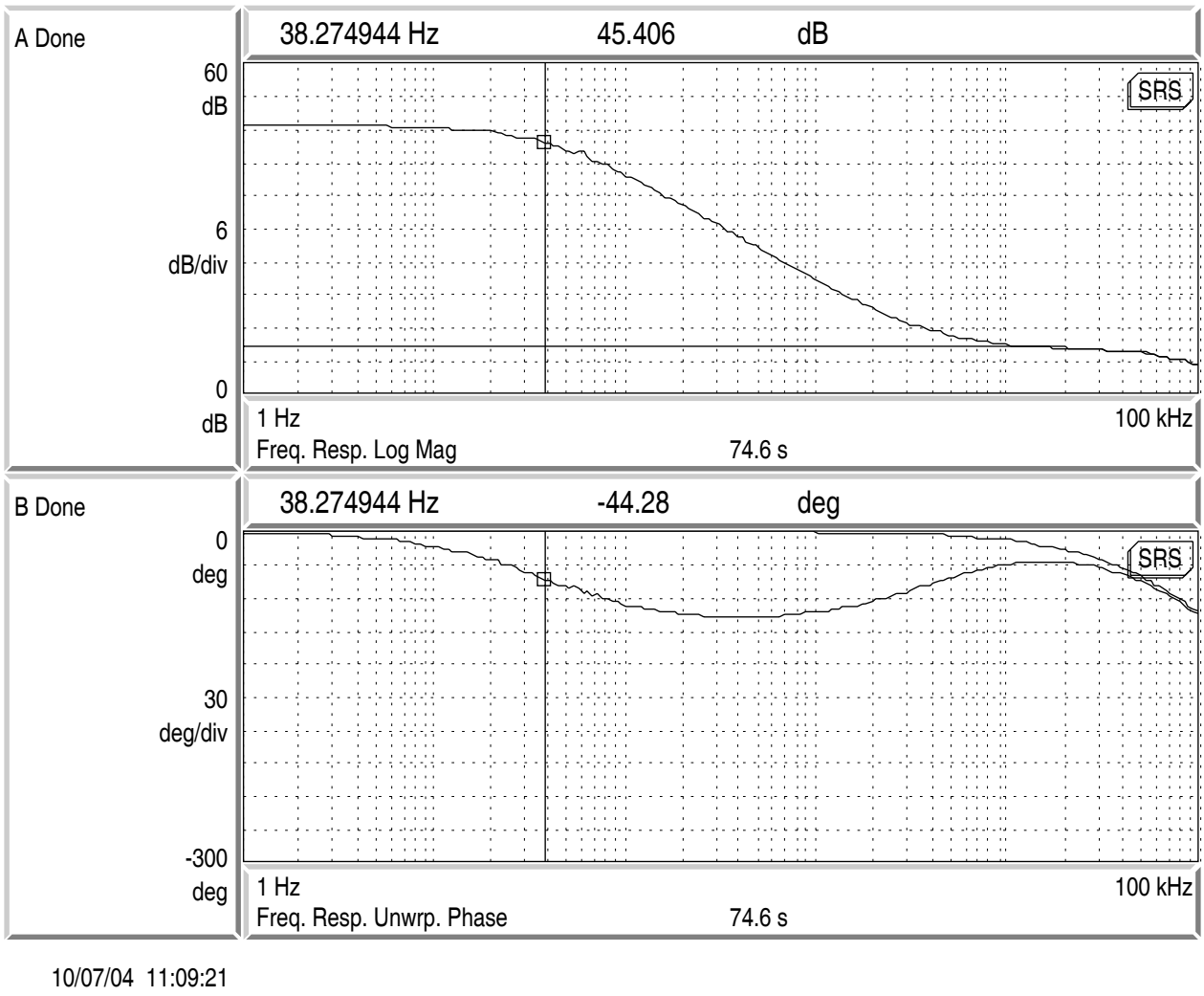


Transfer function from IN1 to SERVO (LSC common mode). Flat(er) trace is reference against a BNC barrel.

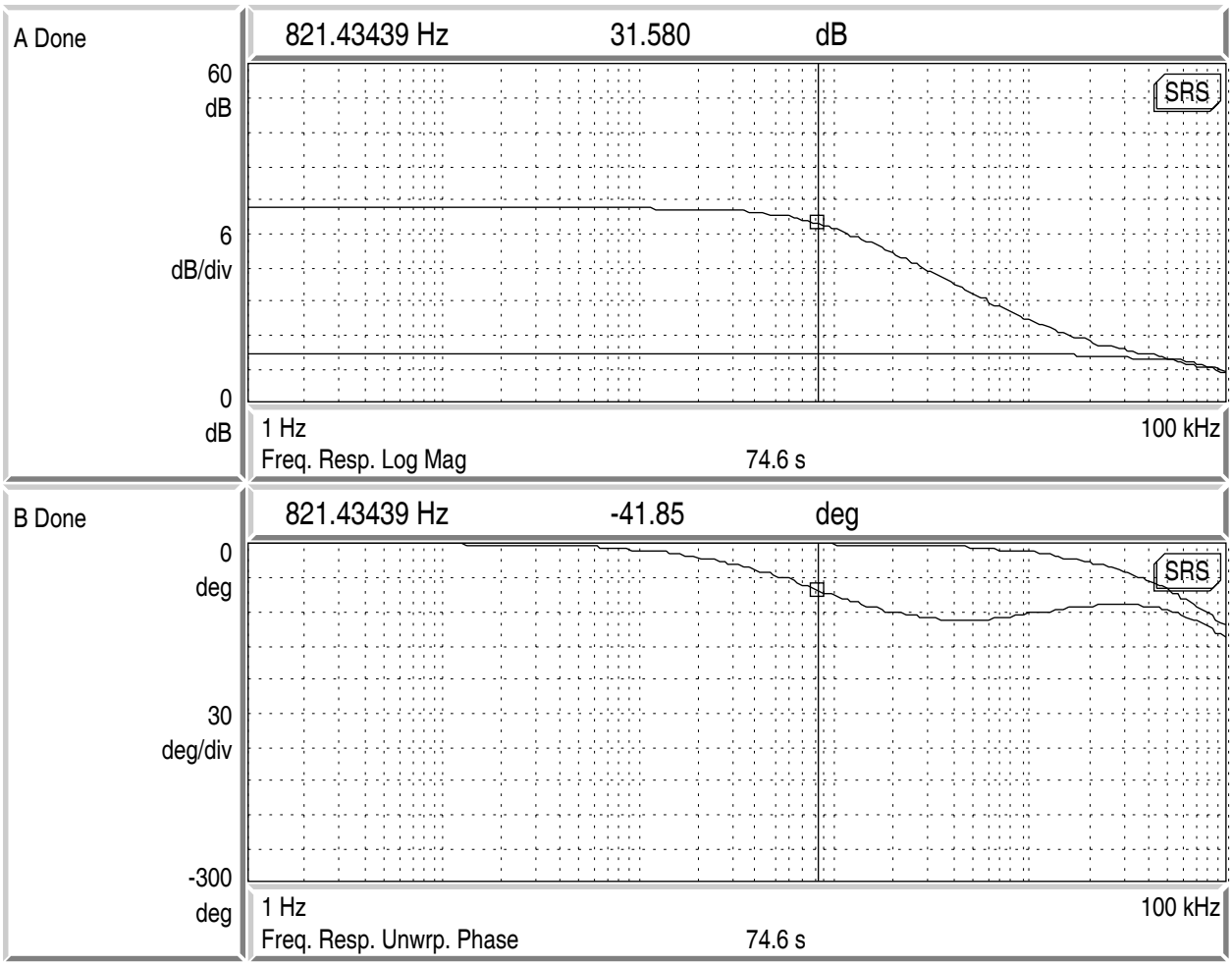


Transfer function from IN1 to SERVO (mode cleaner).

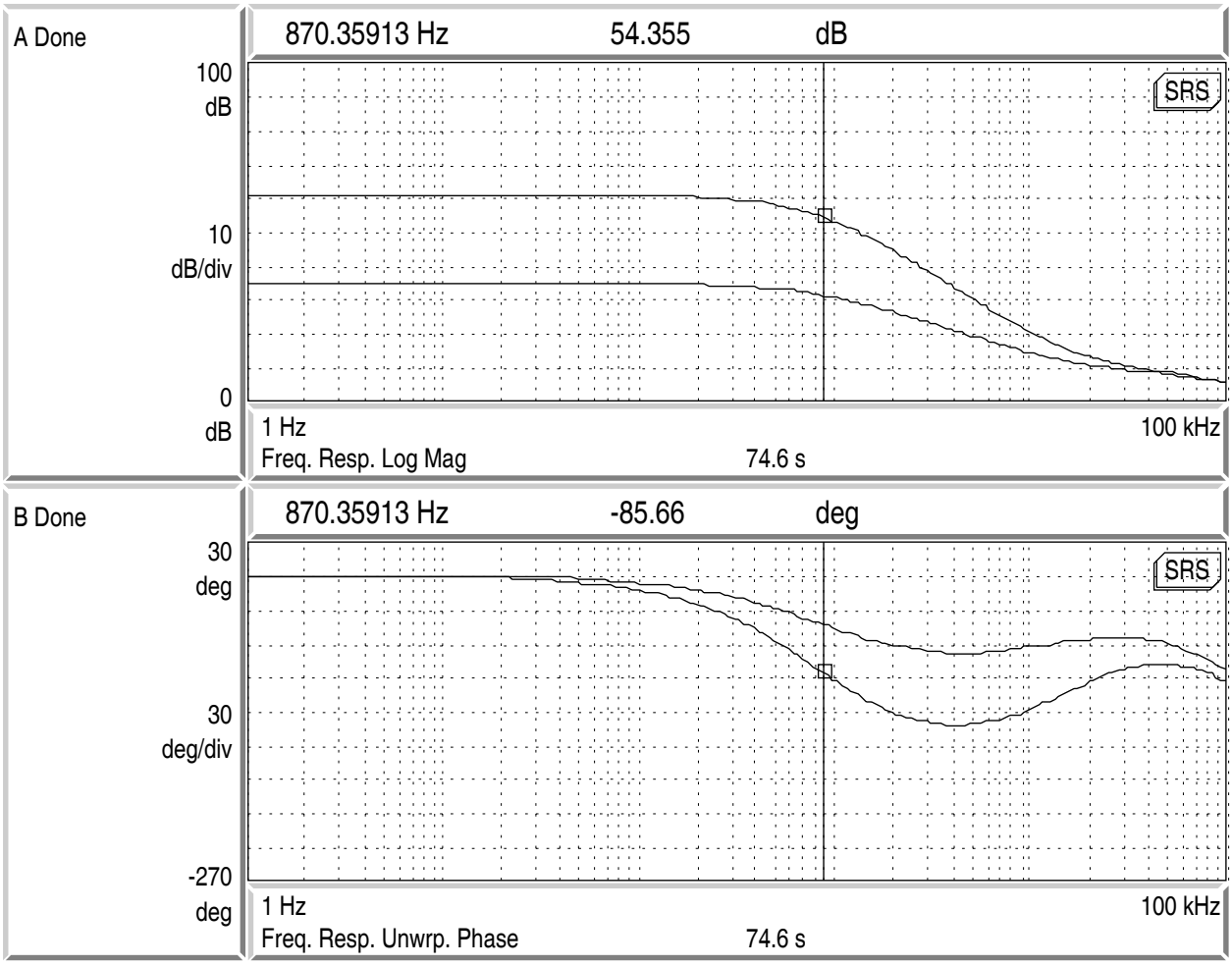
Appendix A4: Transfer functions of boost gain stages



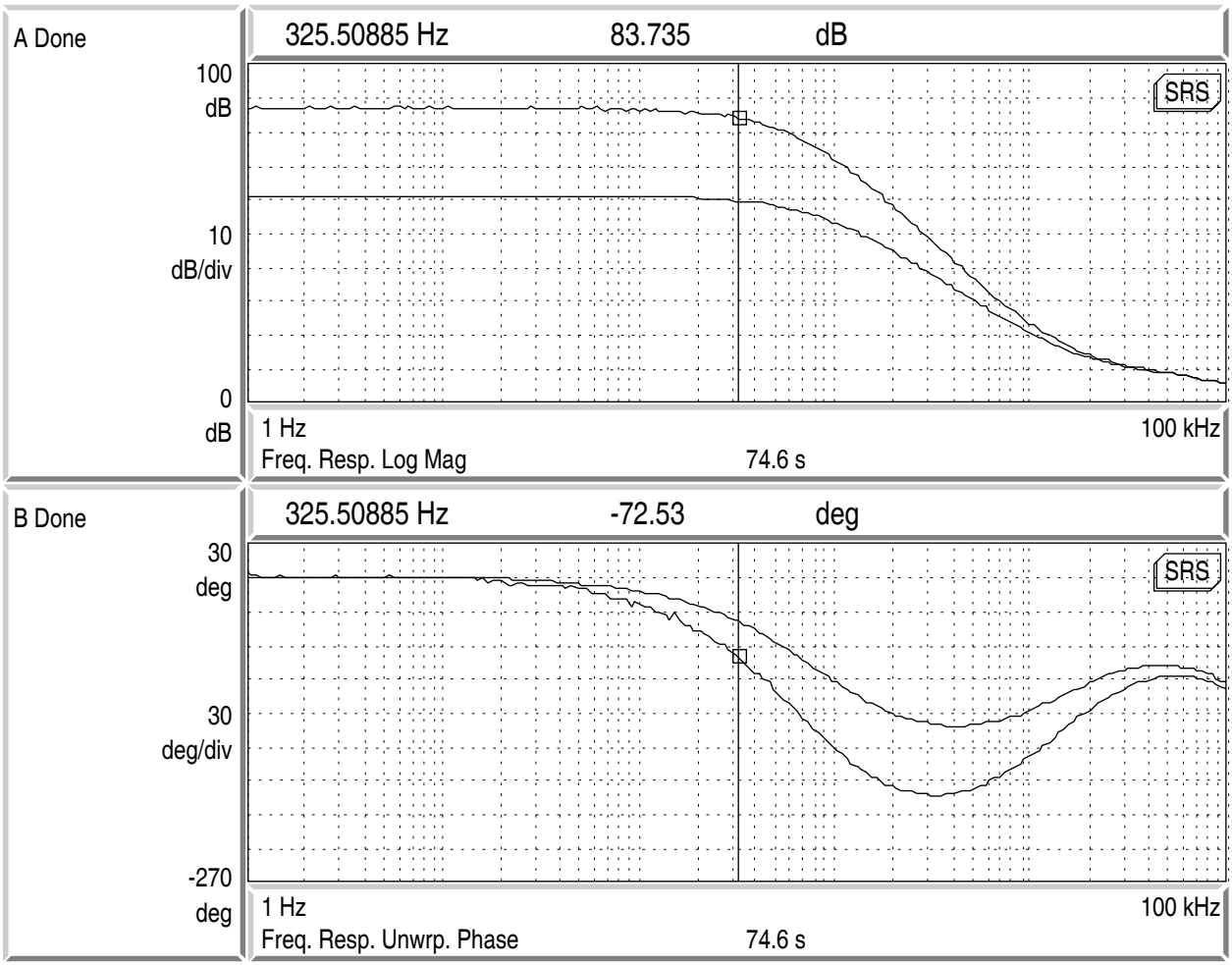
First boost gain stage (D23).



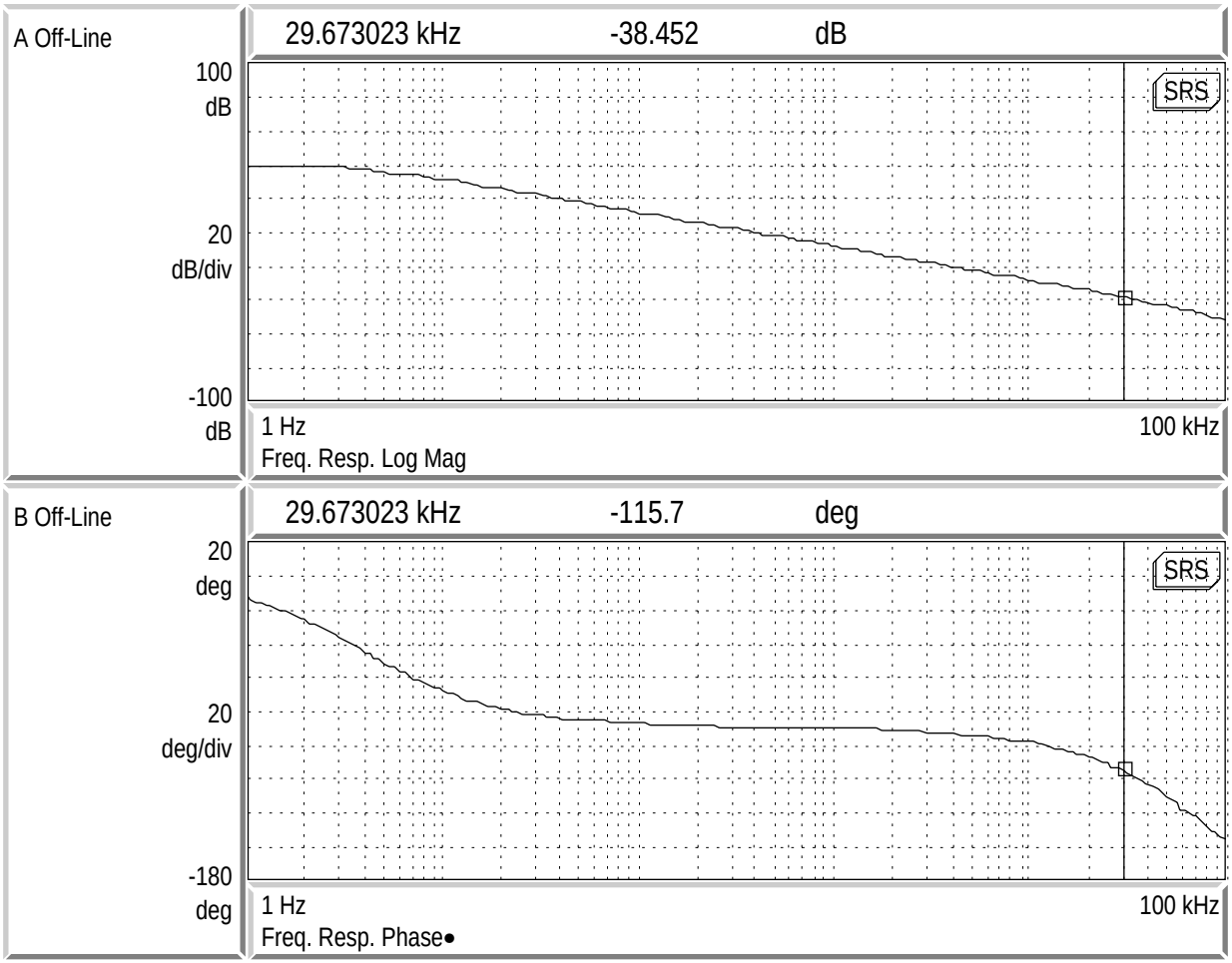
Second boost gain stage (D21).



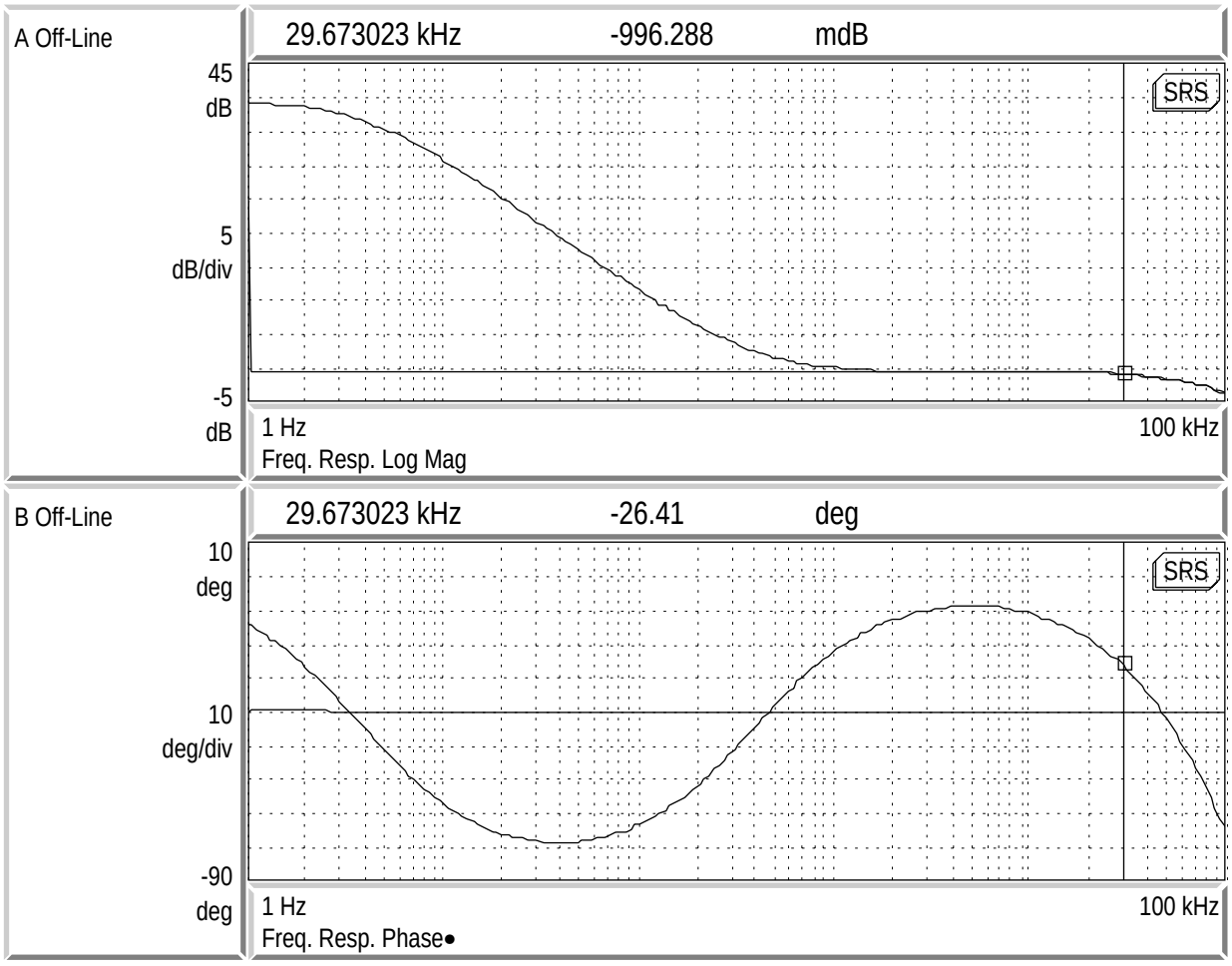
Second and third boost gain stage (D22).



Second, third and fourth boost gain stage (D21 & D22).



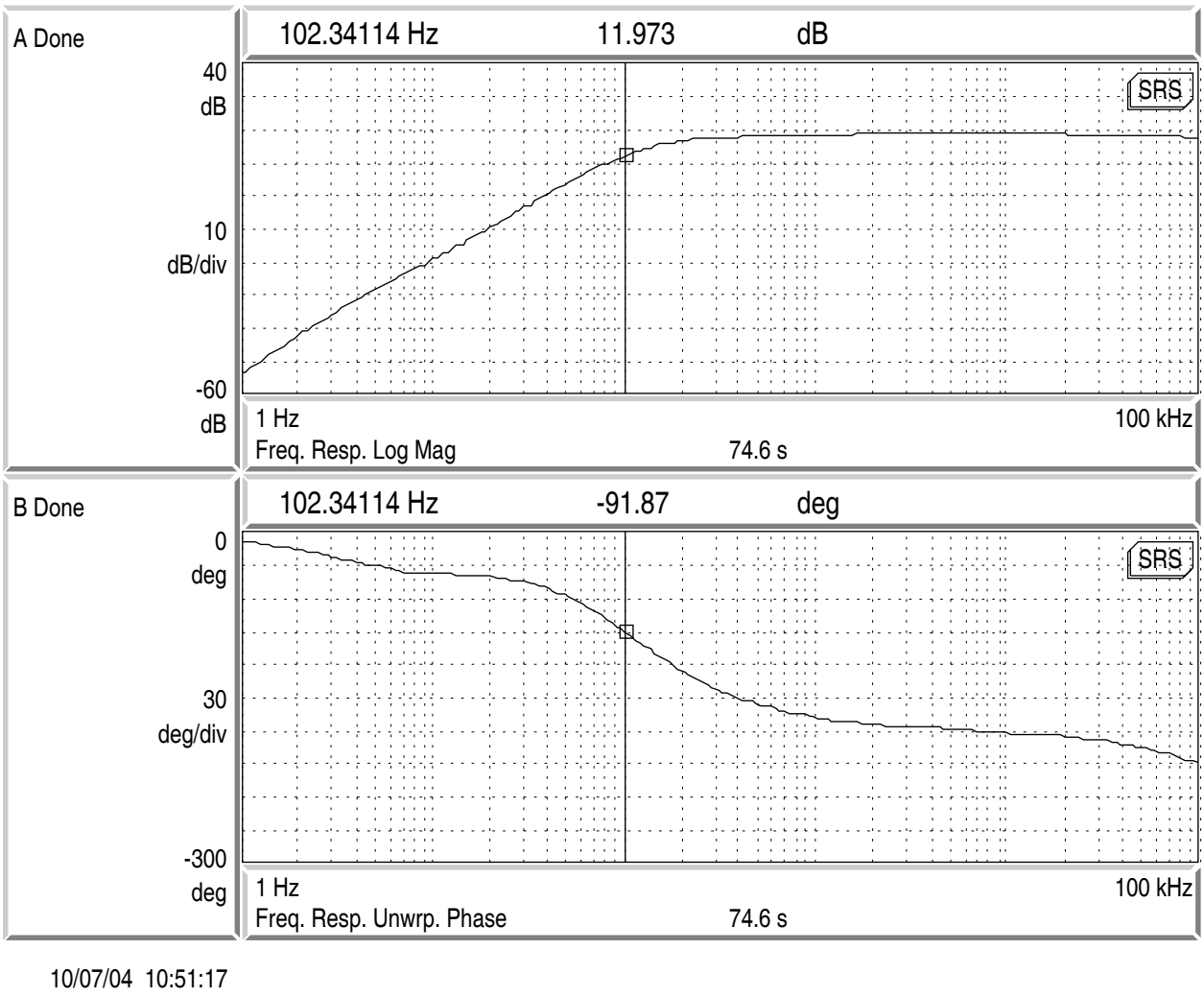
Slow compensation gain stage (D28).



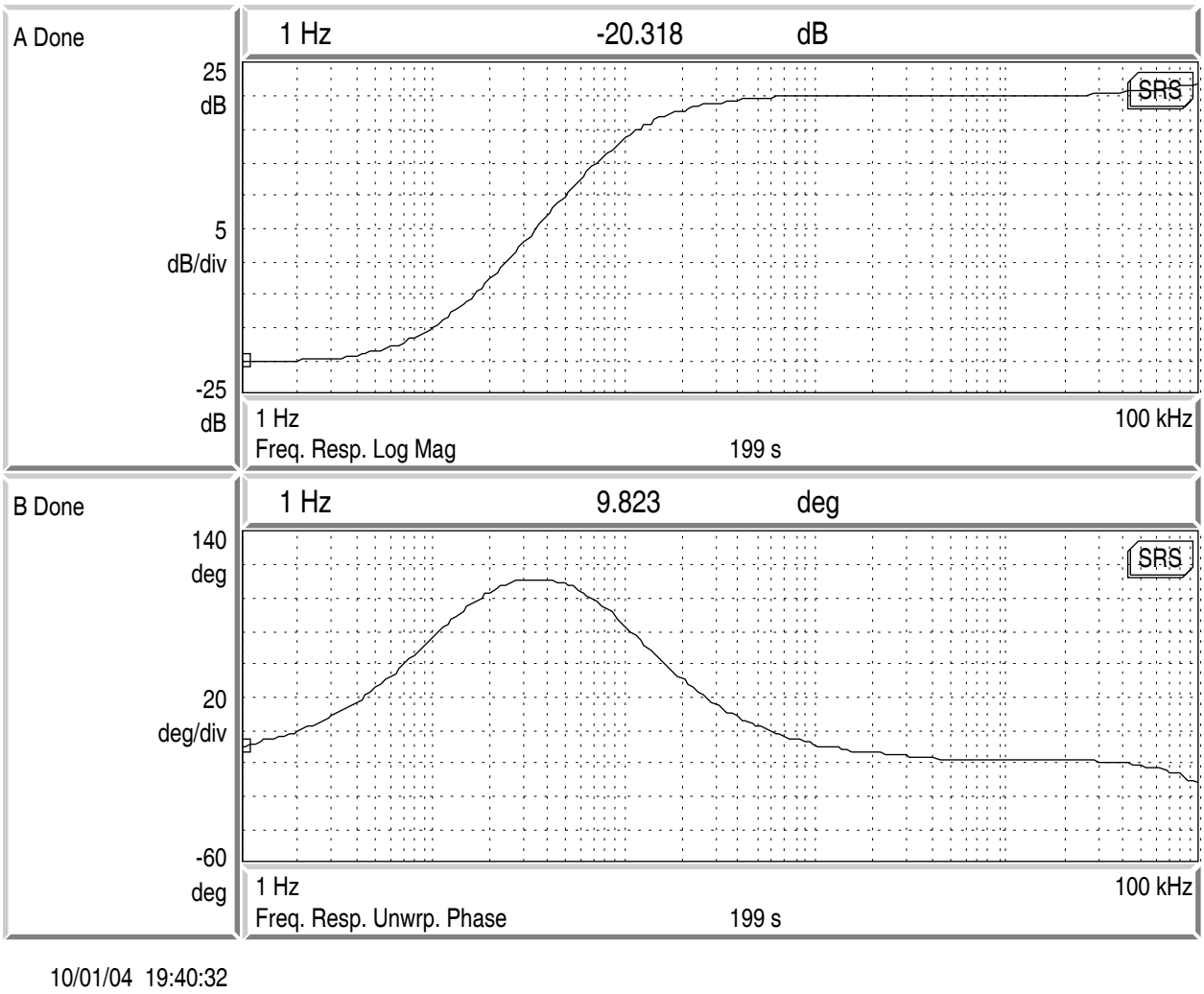
3/01/10 15:12:43

Slow boost gain stage (D29).

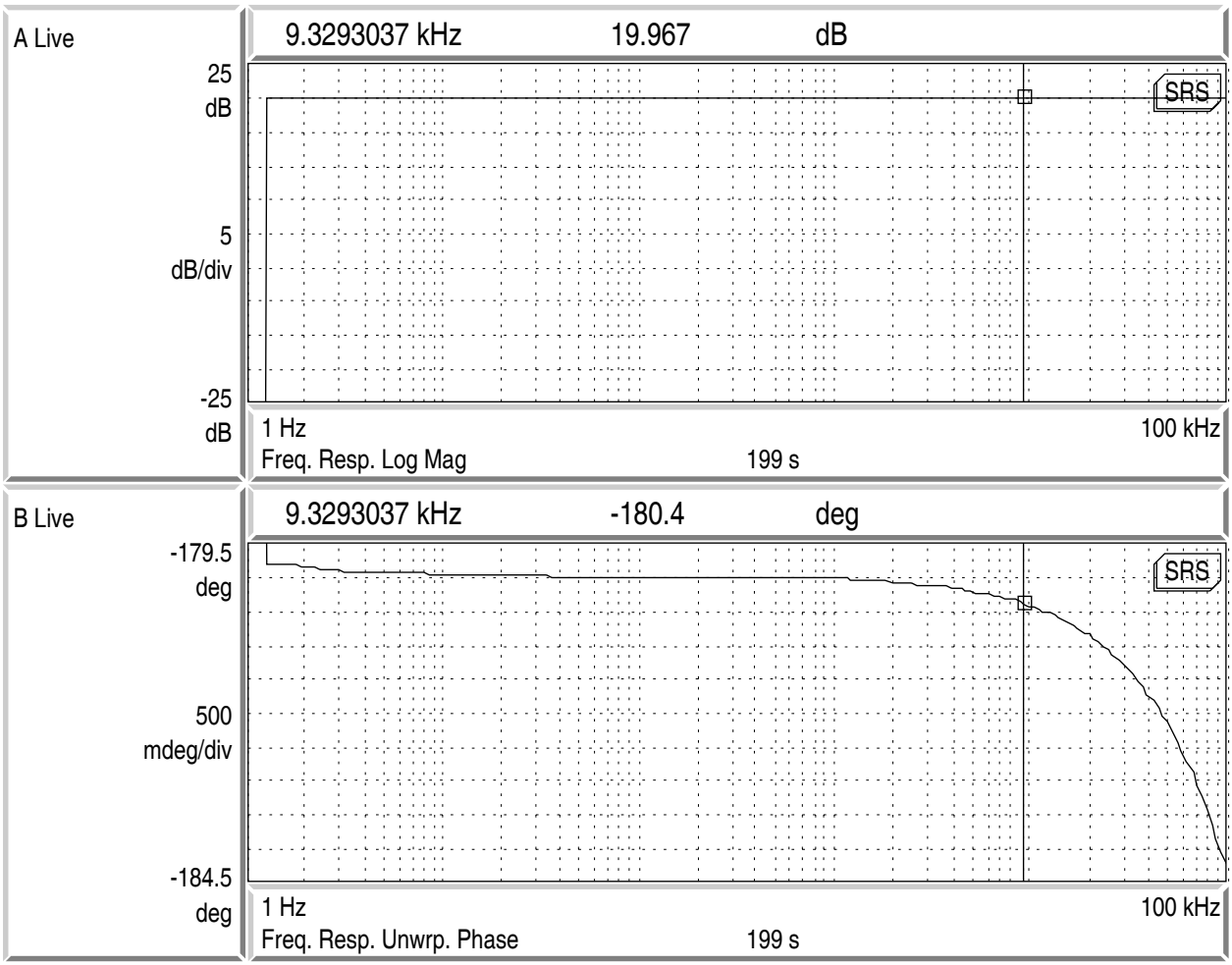
Appendix A5: Transfer functions of DAQ channels



Transfer function to first DAQ channel (LSC common mode).

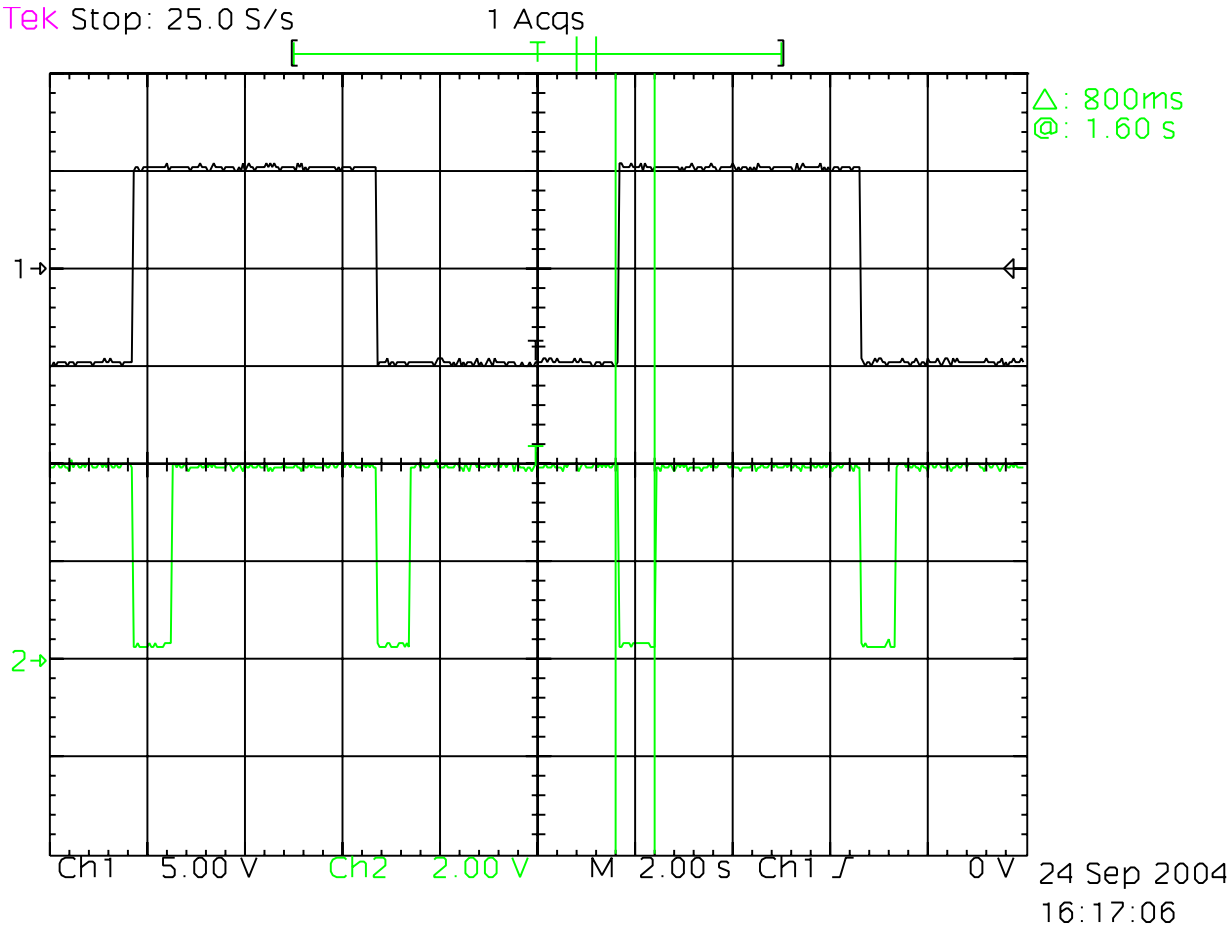


Transfer function to first DAQ channel (mode cleaner).



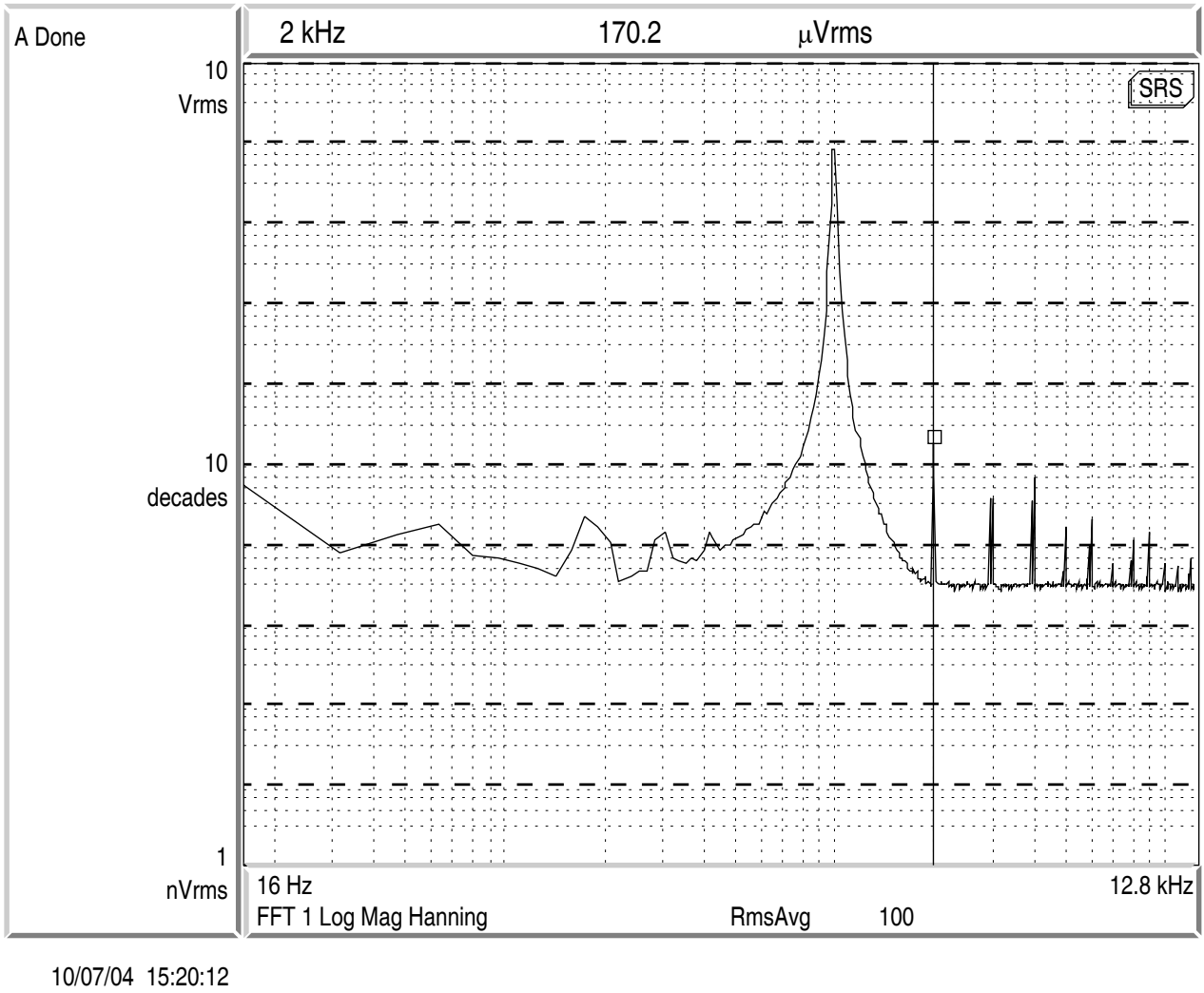
Transfer function to second DAQ channel.

Appendix A6: Limit indicator



Limiter output.

Appendix A7: Distortion measurement



Typical distortion spectrum.