CALIFORNIA INSTITUTE OF TECHNOLOGY
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Laser Interferometer Gravitational Wave Observatory (LIGO) Project

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Refer to:	LIGO-T040189-00
Date:	September 20, 2004

Common Mode Servo Board Test Procedure

Required equipment:

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

- Eurocard crate & P1/P2 interface blocks with cables
- 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	Serial	MC/CM
D040180			

Hook up the P1 and P2 interface blocks; **short D27 to GND**.

Insert the board and check that the current drawn from the ±24V power supply is between 0.3 A and 0.4 A.

Power supply	Current	Nominal
+24V		0.35
–24V		0.35

Test for oscillations:

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

Output	OUT1	OUT2	SERVO	A:TEST1	A:TEST2	B:TEST1	B:TEST2
Check							
Output	DAQ14	DAQ23	D32	D33	D34	D35	
Check							

Adjust dc bias:

Ground IN1 and adjust the dc bias (R50) so that the output voltage at SERVO (MC board) or OUT1 (CM board) becomes zero.

Check	

Gain slider A:

Apply a 1kHz/1Vpp(CM) or 0.225Vpp(MC) sine wave to IN1. 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 (slider gain)	Measured [Vpp]	Nominal [Vpp]
—		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 1 kHz/1 Vpp sine wave to IN2. Measure the voltage at OUT2 while pulling the specified binary inputs to GND. The measured voltages should be within 0.5 dB 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 1 kHz/1 Vpp 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
D18		Off		Off
D19		On		Off
D20		On		On

Apply a 1 kHz/1 Vpp 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
D18		Off		On
D19		On		On
D20		Off		Off

Excitation A:

Apply a 1 kHz/1 Vpp 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 0.5 dB of the nominal values.

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

Apply a 1 kHz/1 Vpp 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 0.5 dB of the nominal values. Nominal values are given for CM/MC.

Binary input	A:TEST2	Nominal [Vpp]	OUT	Nominal [Vpp]
—		Off		Off
D24		0.10		0.10/0.45
D24 & D25		0.10		Off

Split:

Apply a 1 kHz/1 Vpp(CM) or 0.225Vpp(MC) sine wave to IN1. Measure the voltage at OUT1 and SERVO while pulling the specified binary inputs to GND. The measured voltages should be within 0.5 dB 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 D27		1.00		Off
D26		1.00		–1.00/+0.11
D28		1.00		+1.00/–0.11

Latching:

Apply a 1 kHz/1 Vpp sine wave to IN1. Measure the voltage at SERVO. Ground P2/16A. Now lift D27 and make sure the signal at the output stays on all the time.

Check	

Excitation B:

Apply a 1 kHz/1 Vpp 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 0.5 dB of the nominal values.

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

Apply a 1 kHz/1 Vpp 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 0.5 dB of the nominal values. Nominal values are given for CM/MC.

Binary input	B:TEST2	Nominal [Vpp]	SERVO	Nominal [Vpp]
—		Off		Off
D29		0.10		0.10/0.05
D29 & D30		0.10		Off

Limiter:

Apply a 1 kHz/20 Vpp 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]
D31		20.0/10.0
—		2 * (zener + 0.6) / 1 * (zener + 0.6)

Gain slider C:

Apply a 1 kHz/1 Vpp(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 0.5 dB of the nominal values.

Binary input (slider gain)	Measured [Vpp]	Nominal [Vpp]
—		1
D12 (1dB)		1.12
D13 (2dB)		1.26
D14 (4dB)		1.59
D15 (8dB)		2.51
D16 (16dB)		6.31
D15 & D16 (24dB)		15.9 (scale for MC)
D17 (–32dB)		0.025
D17 & D15 (–24dB)		0.063
D17 & D16 (–16dB)		0.159
D17 & D15 & D16 (–8dB)		0.398

EPICS readbacks:

Apply first a 1 Hz/1 Vpp and then a 100 Hz/1 Vpp sine wave to IN1. Measure the voltage at D32, D33 and D34. The measured voltage should be within 1 dB (6 dB for D34) of the nominal value.

EPICS readback	1Hz	Nominal [Vpp]	100Hz	Nominal [Vpp]
D32		1.00		0.080
D33		1.00		0.080
D34 (MC/CM)		10.0/0.4		0.80/0.03

Limit indicator:

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

Check	

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

Binary input	Measured [Vpp]	Nominal [Vpp]
—		$30.0 \times \frac{R134}{R129 + R134 + R135}$ (6.0)

Distortion:

Apply a 1 kHz/1 Vrms sine wave to IN1. Use a spectrum analyzer to measure the harmonic components at SERVO; see Appendix A7. Repeat the measurement with IN2 (D19 to GND).

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

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

Frequency	OUT2/IN2 [dB]	Nominal	OUT2/IN2 [deg]	Nominal
10 Hz		0/0		–180/–180
100 Hz		0/0		–180/–180
1 kHz		0/0		–180/–180
10 kHz		0/0		–180/–180
100 kHz		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 10 MHz down to 10 kHz with –20 dBm source. Write down the values at 100 kHz, 300 kHz and 1 MHz. To remove cable delays first measure the transfer function against a BNC barrel and use as a reference. They should be within 1 dB 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
100 kHz		0/–3		170/4
300 kHz		0/–1		150/–30
1 MHz		–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 D24 to GND and sweep the frequency from 100 kHz down to 1 Hz with 5 V 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.

Binary input	Pole [Hz]	Nominal	Zero [Hz]	Nominal
D23 (1 stage)		40		4000
D21 (1 stage)		1000		20000
D22 (2 stages)		1000		20000
D21 & D22 (3 stages)		500		10000

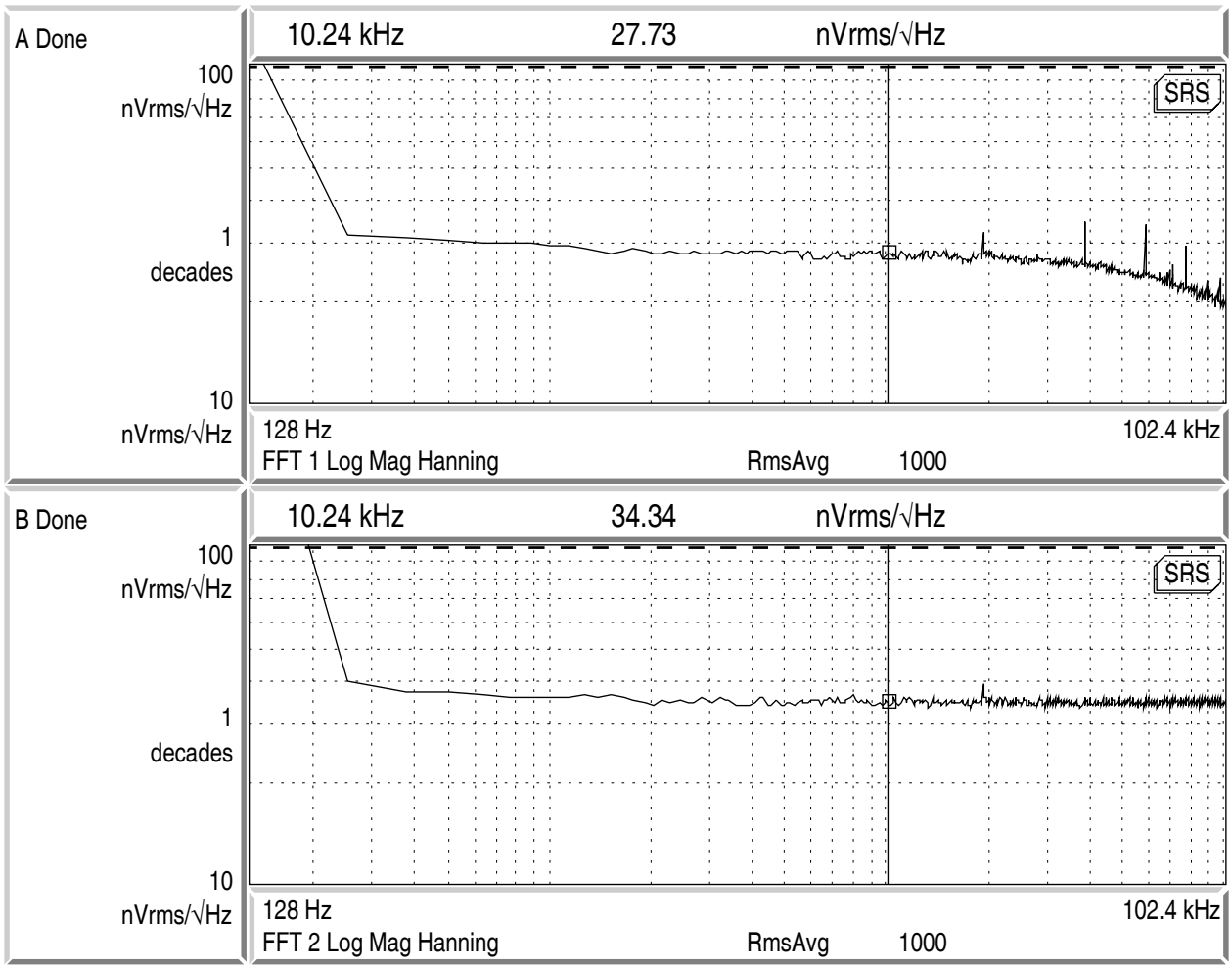
Transfer functions of DAQ channels:

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

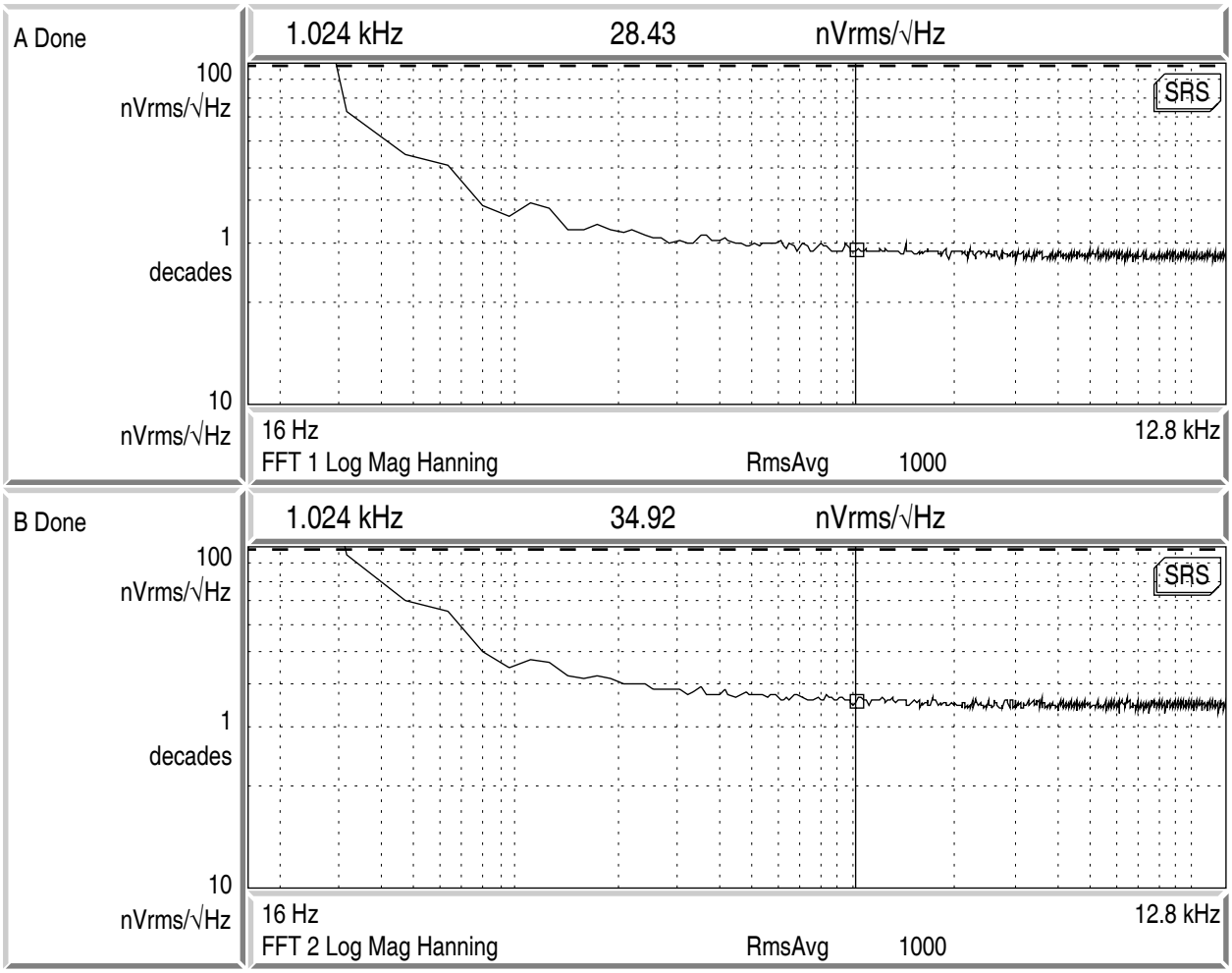
Frequency	DAQ1/IN1 [dB]	Nominal	DAQ1/IN1 [deg]	Nominal
dc		—/–20		—/0
10 kHz		20/20		0/0

Frequency	DAQ2/IN1 [dB]	Nominal	DAQ2/IN1 [deg]	Nominal
dc		20/20		–180/–180
10 kHz		20/20		–180/–180

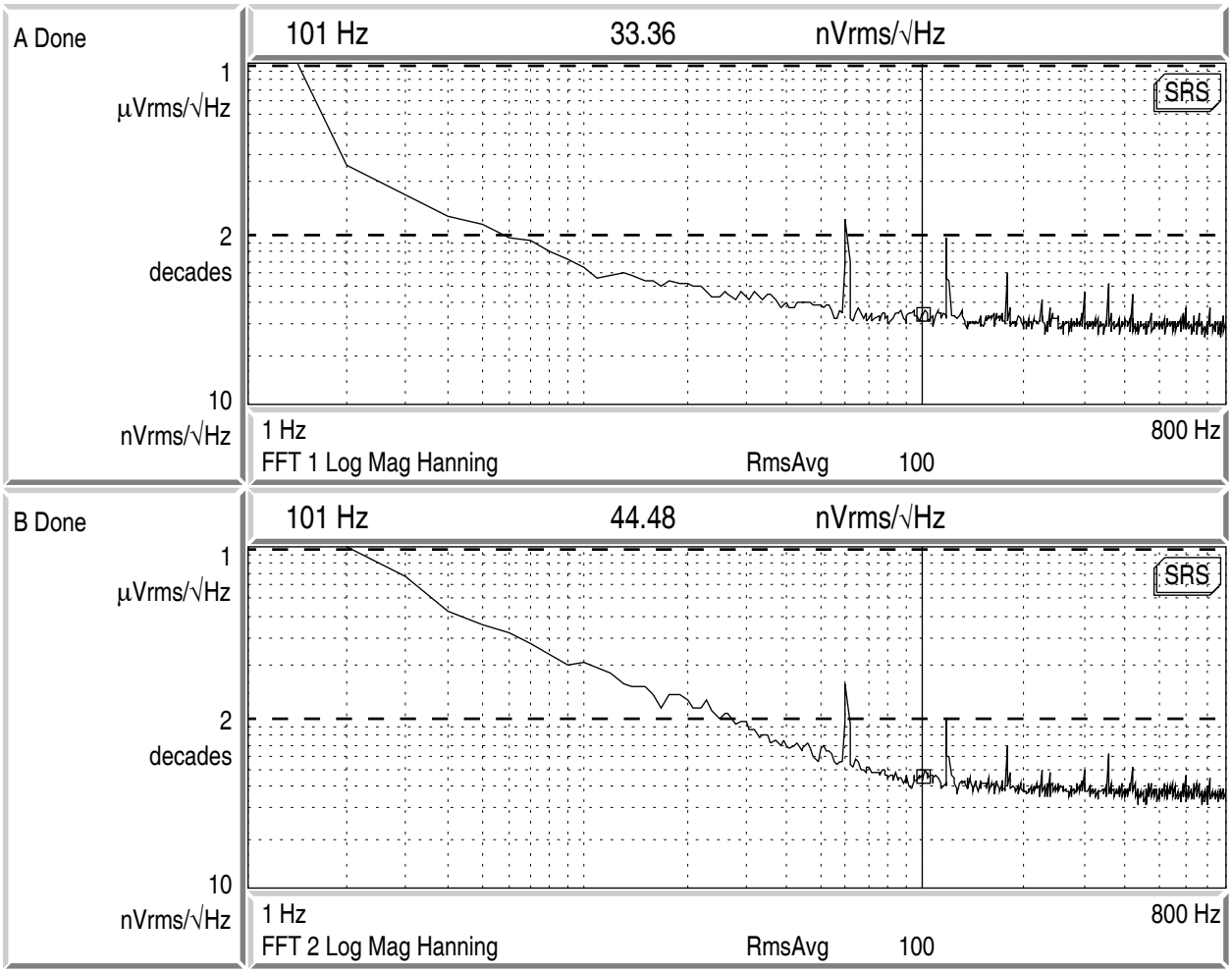
Appendix A1: Noise spectra



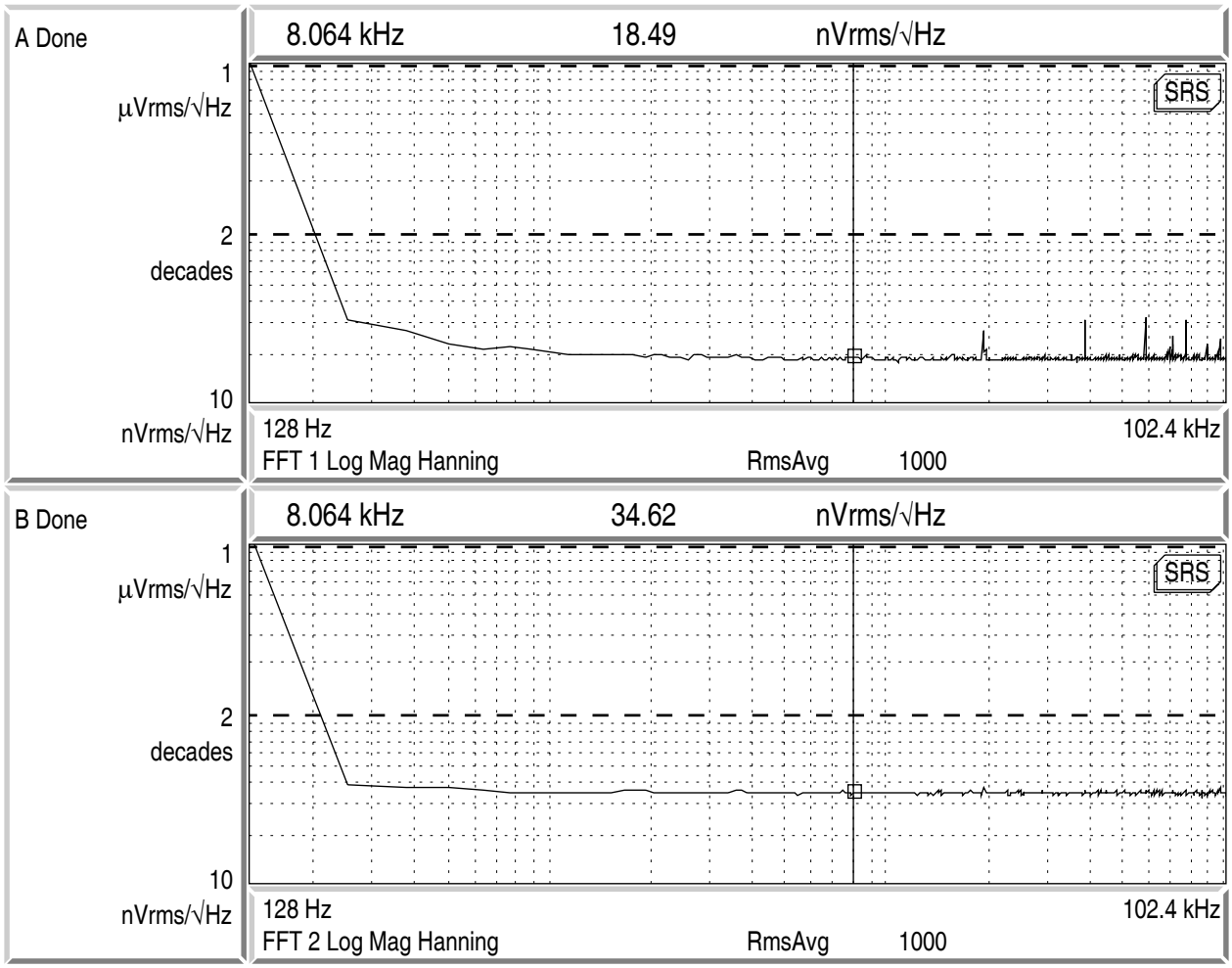
Noise spectra for IN1 (top) and SERVO (bottom).



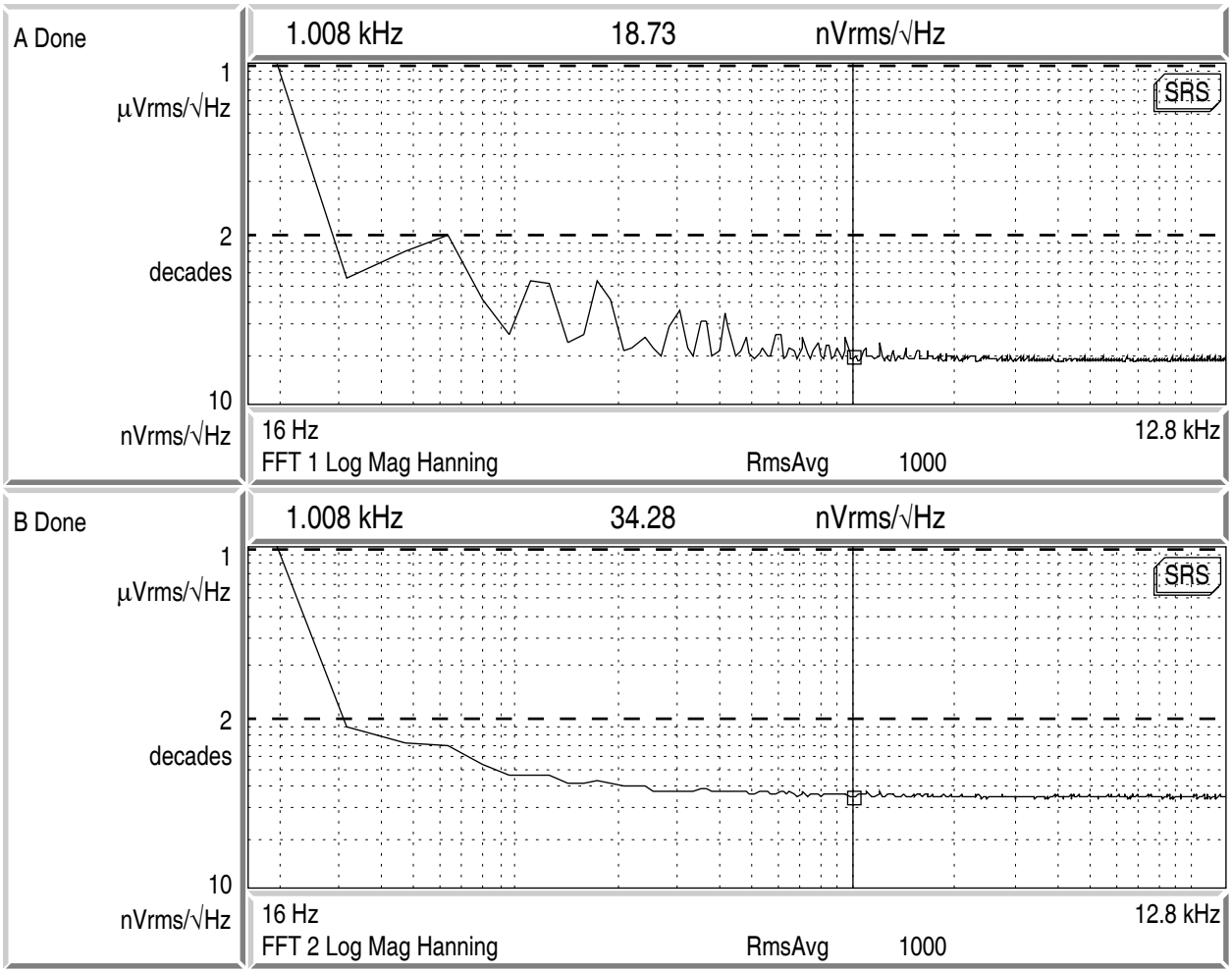
Noise spectra for IN1 (top) and SERVO (bottom).



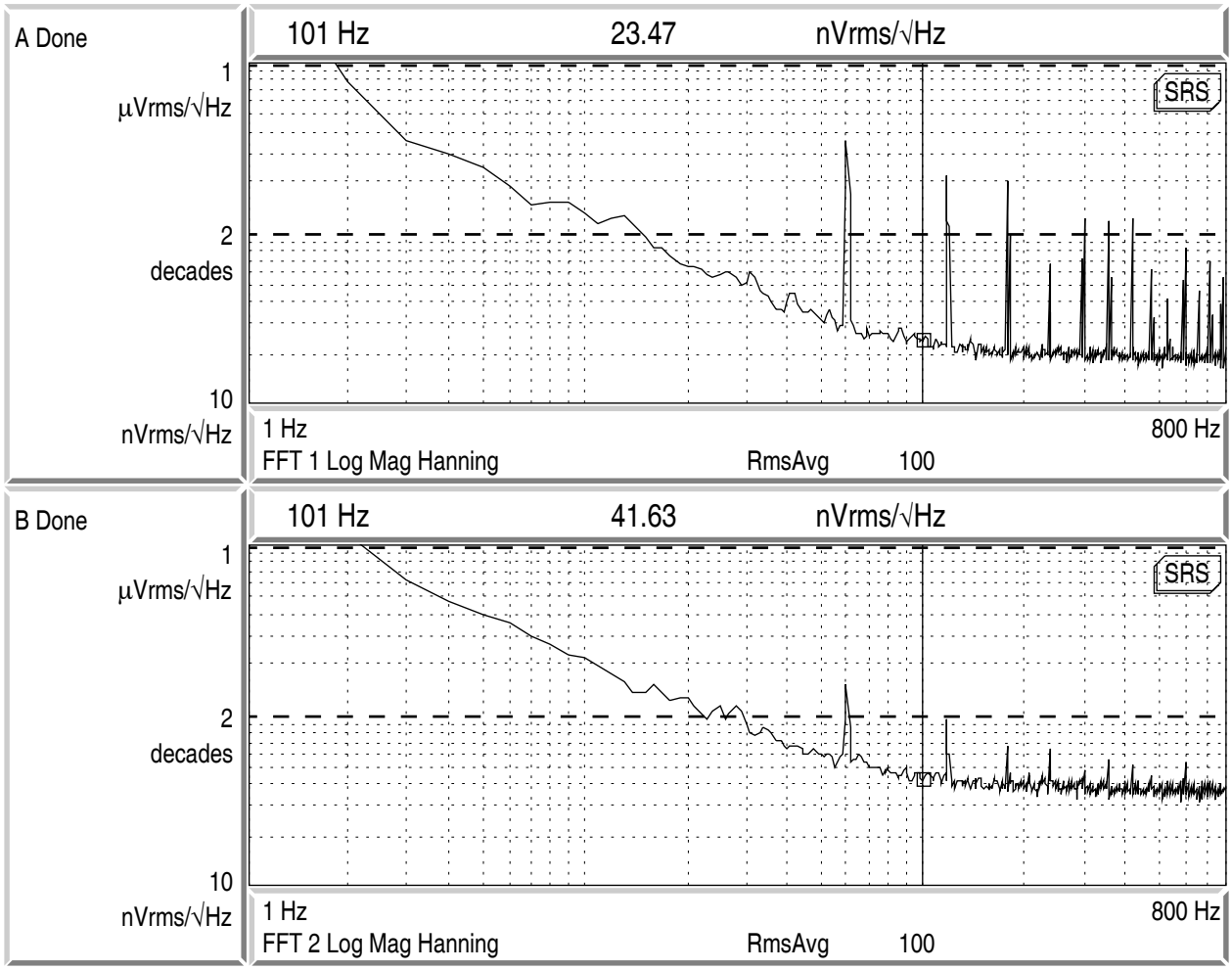
Noise spectra for IN1 (top) and SERVO (bottom).



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

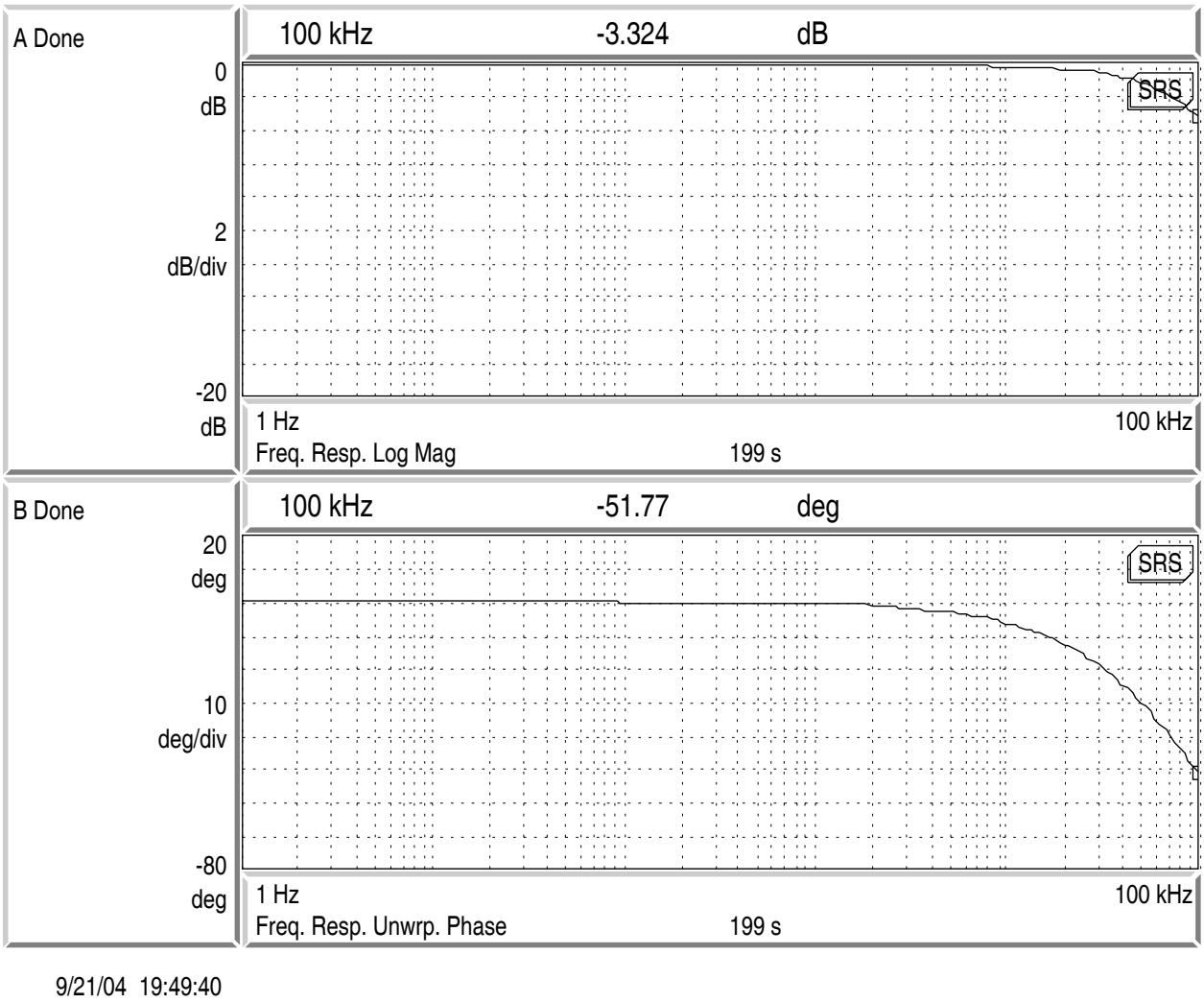


Noise spectra for IN2 (top) and SERVO (bottom).

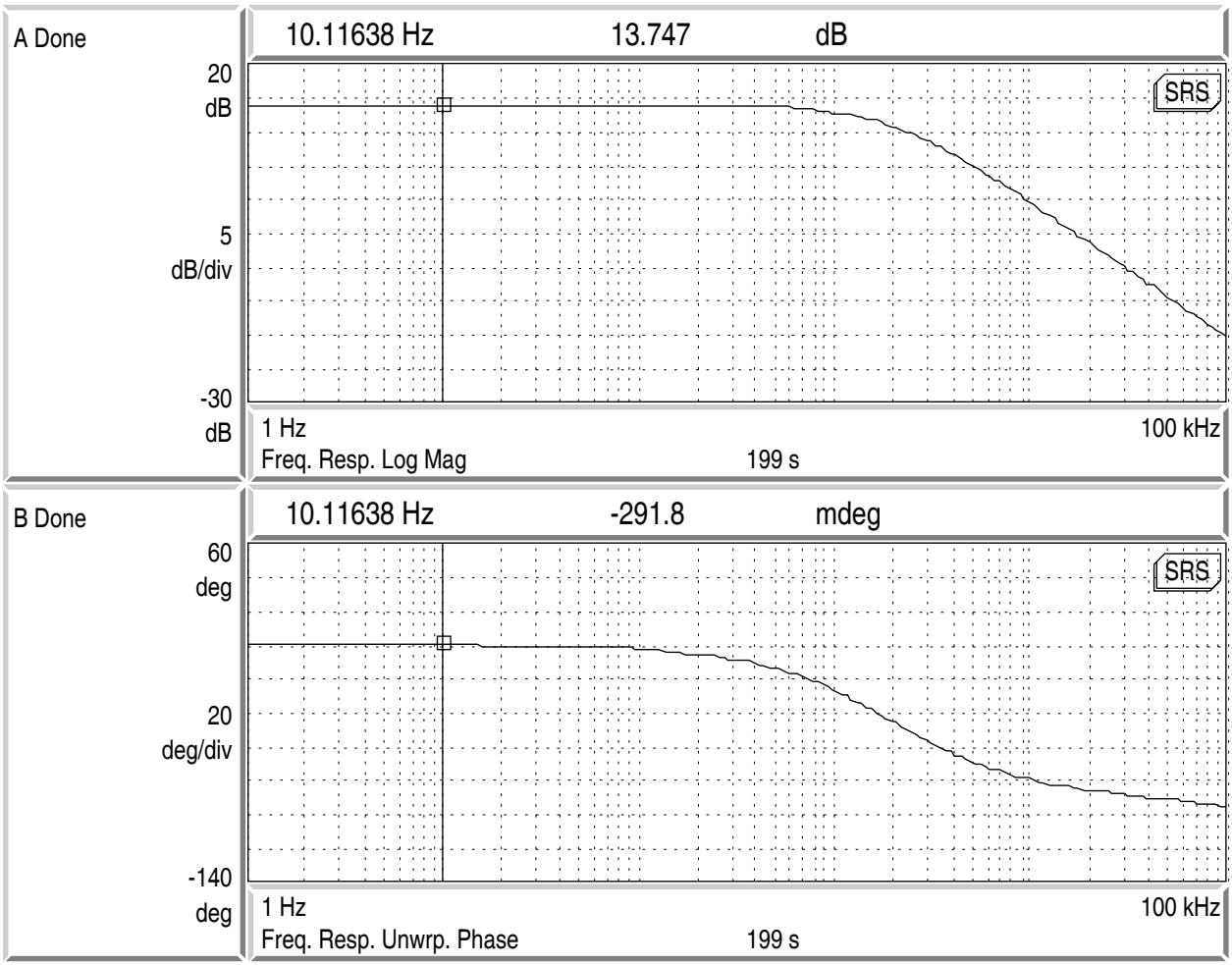


Noise spectra for IN2 (top) and SERVO (bottom).

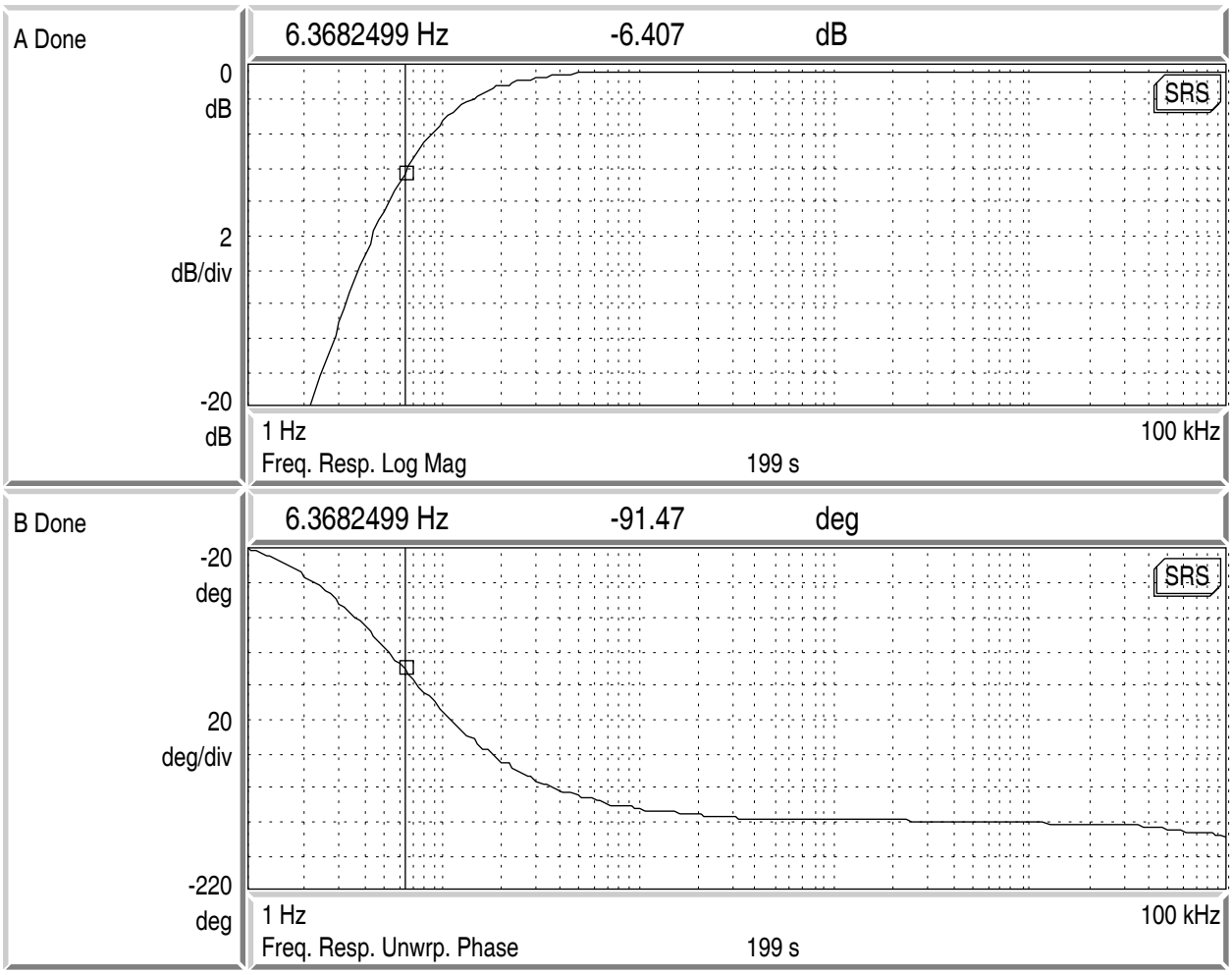
Appendix A2: Basic transfer functions



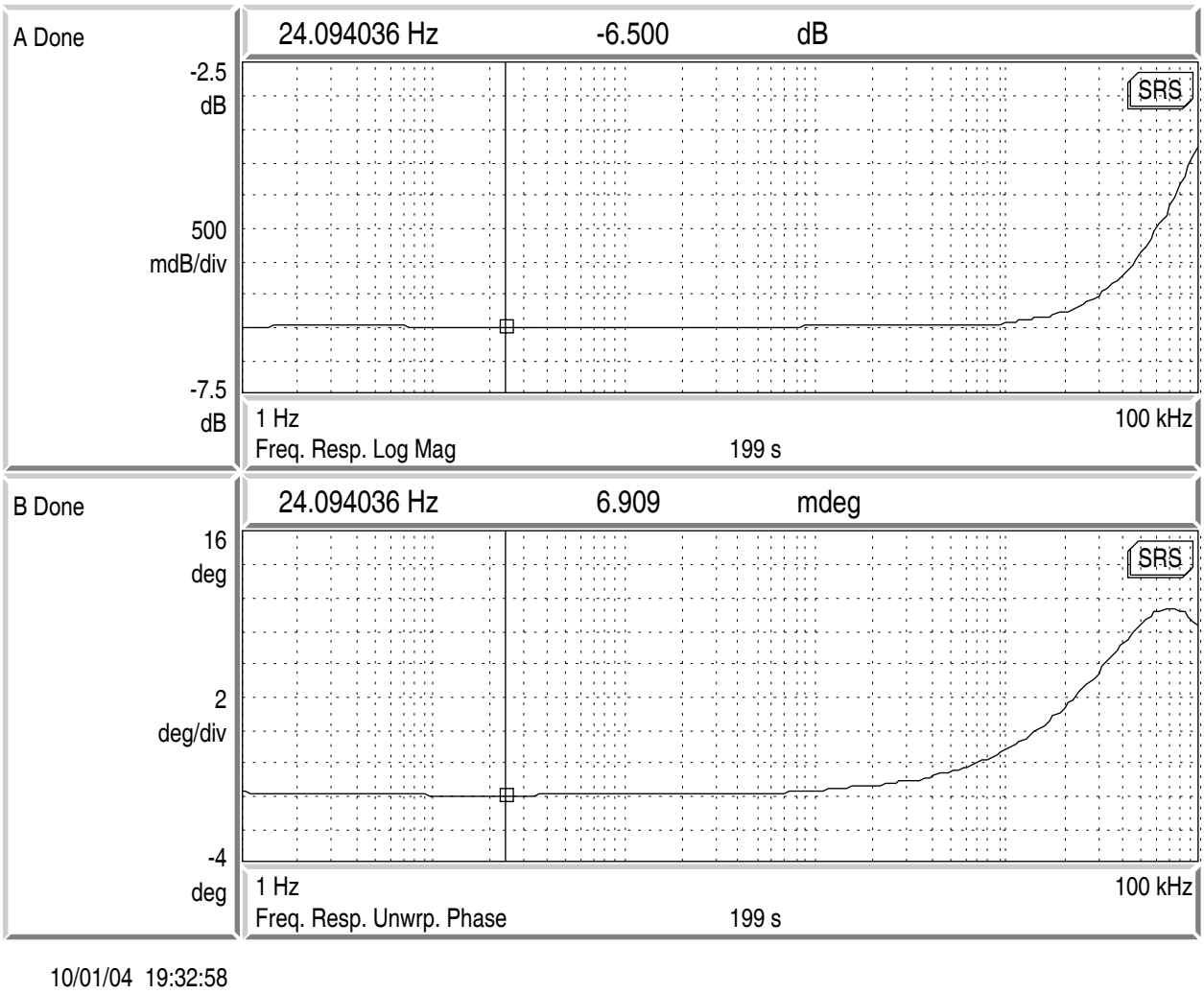
Transfer function from IN1 to OUT1 (LSC common mode).



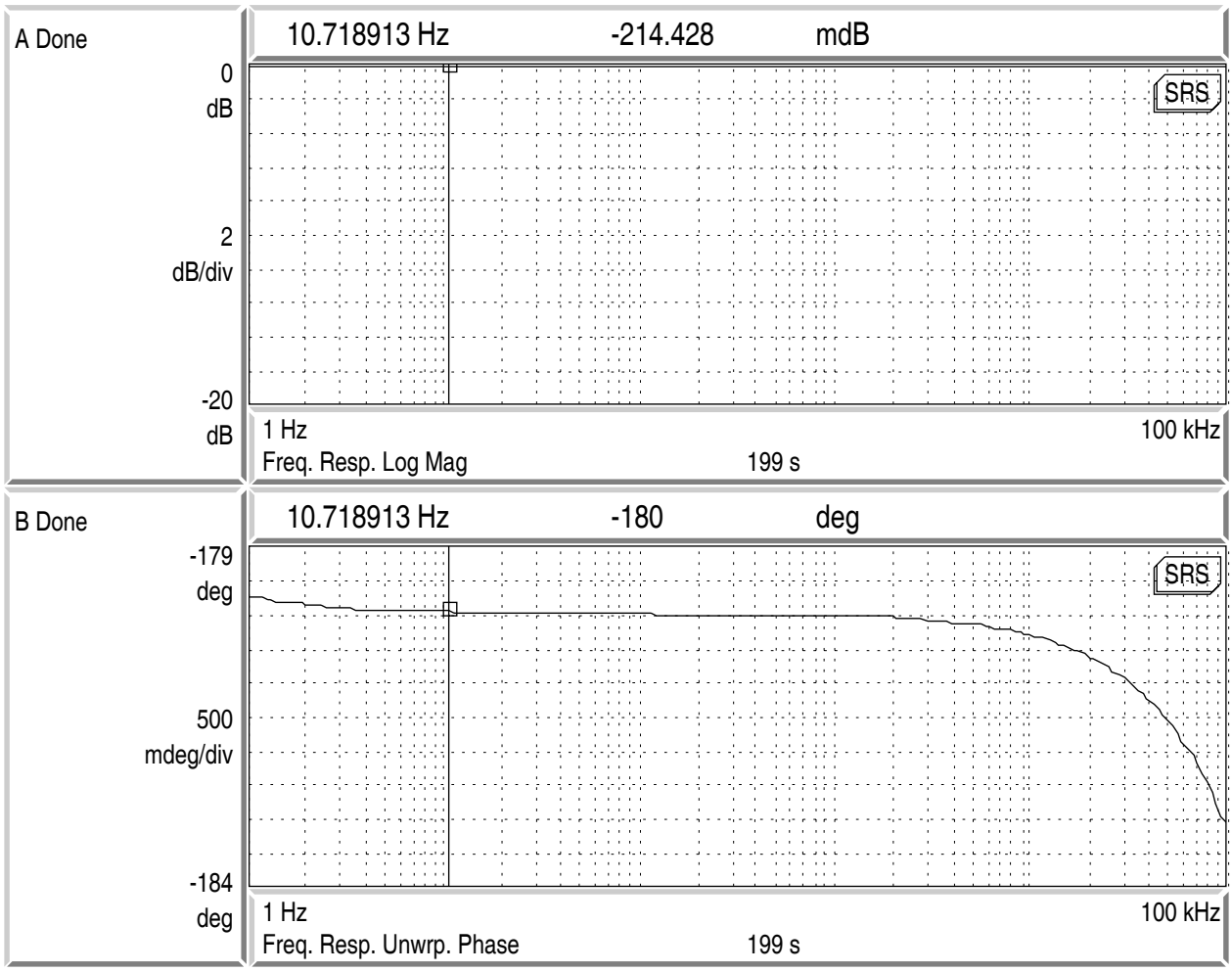
Transfer function from IN1 to OUT1 (mode cleaner).



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

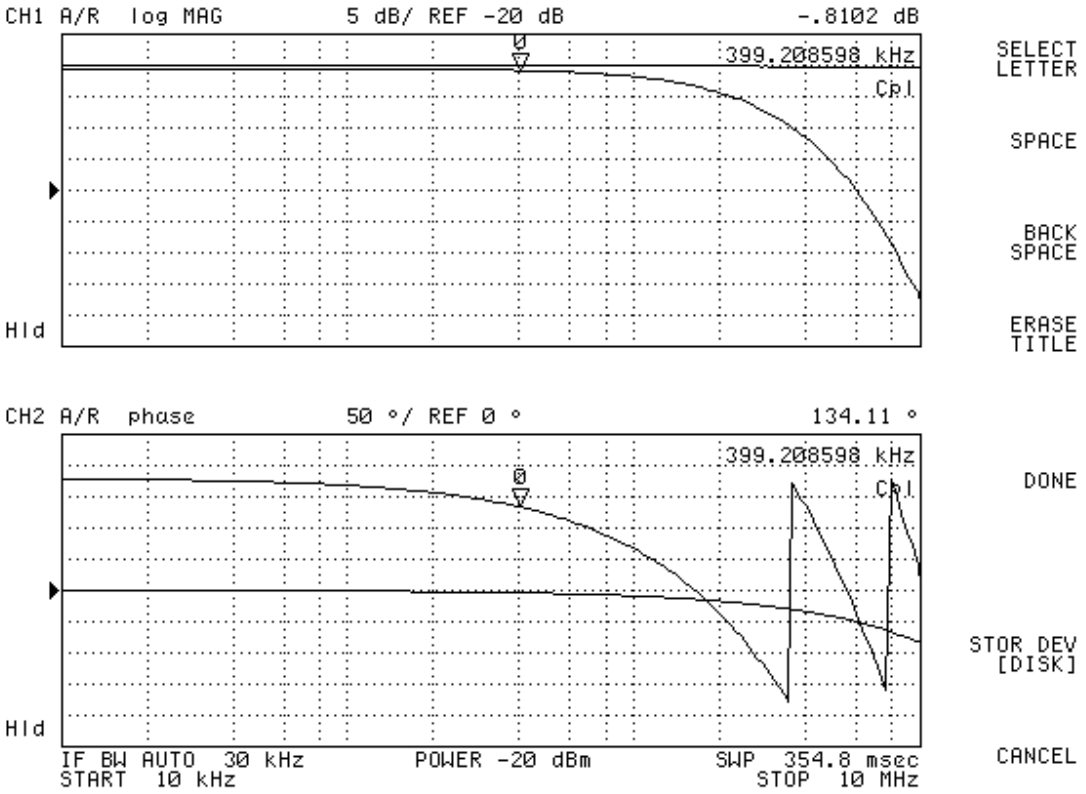


Transfer function from IN1 to SERVO (mode cleaner).

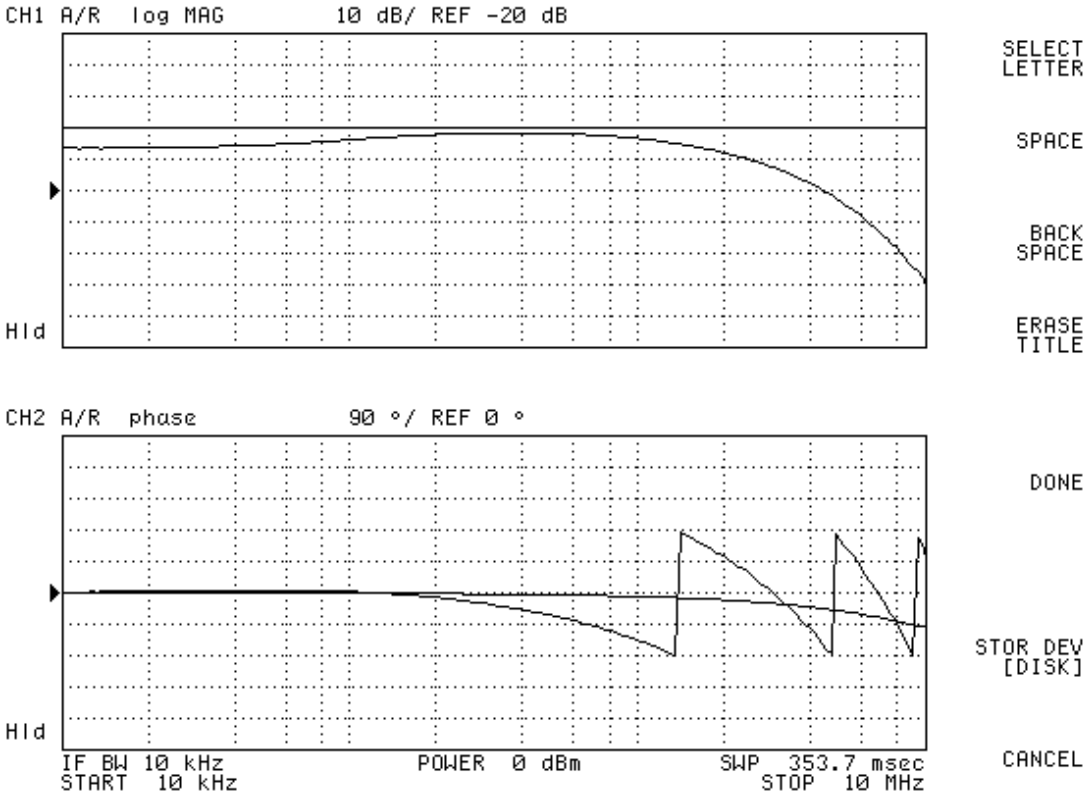


Transfer function from IN2 to OUT2 (LSC common mode and mode cleaner).

Appendix A3: High frequency transfer function

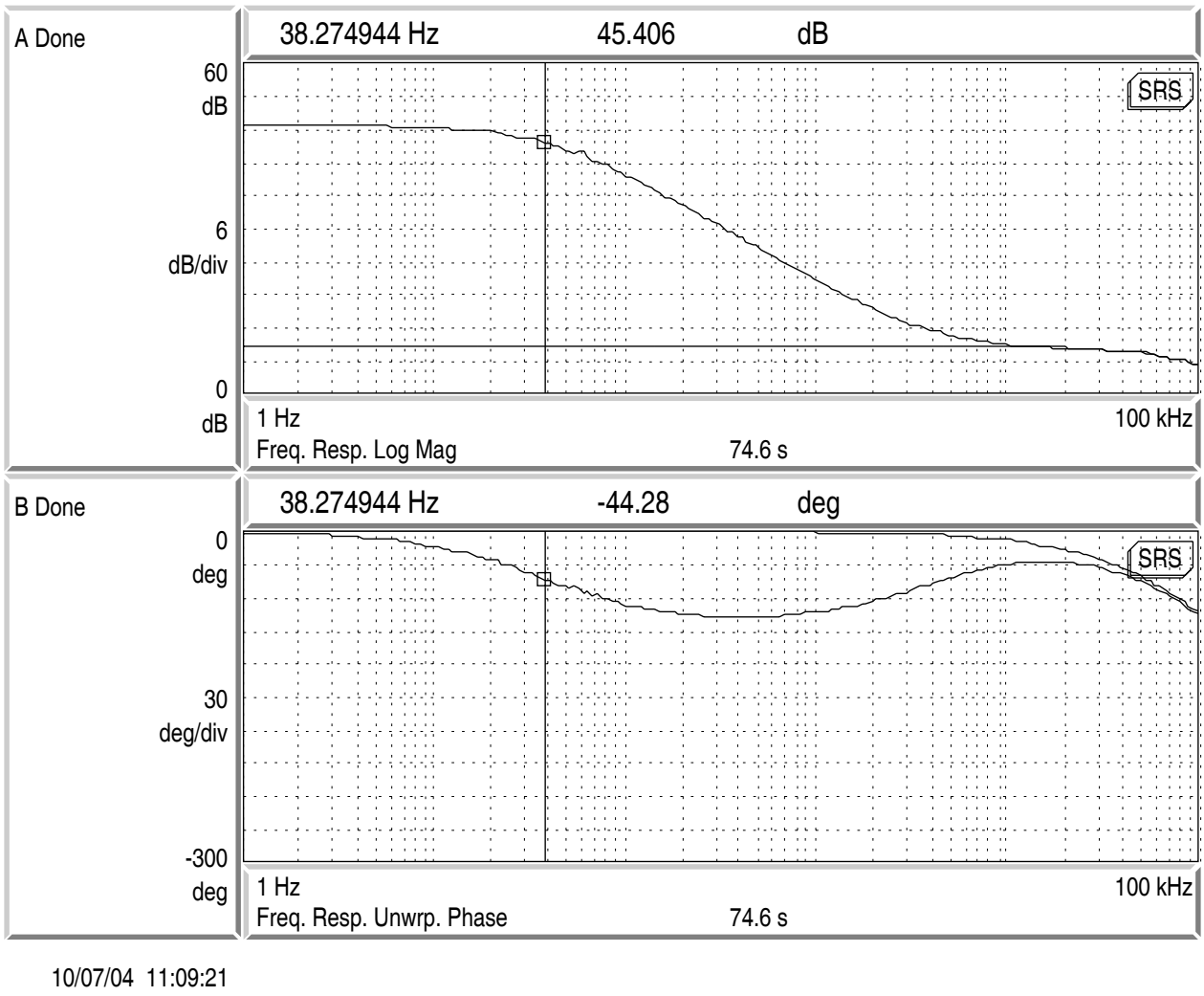


Transfer function from IN1 to SERVO (LSC common mode). Flat(er) trace is reference against a BNC barrel.

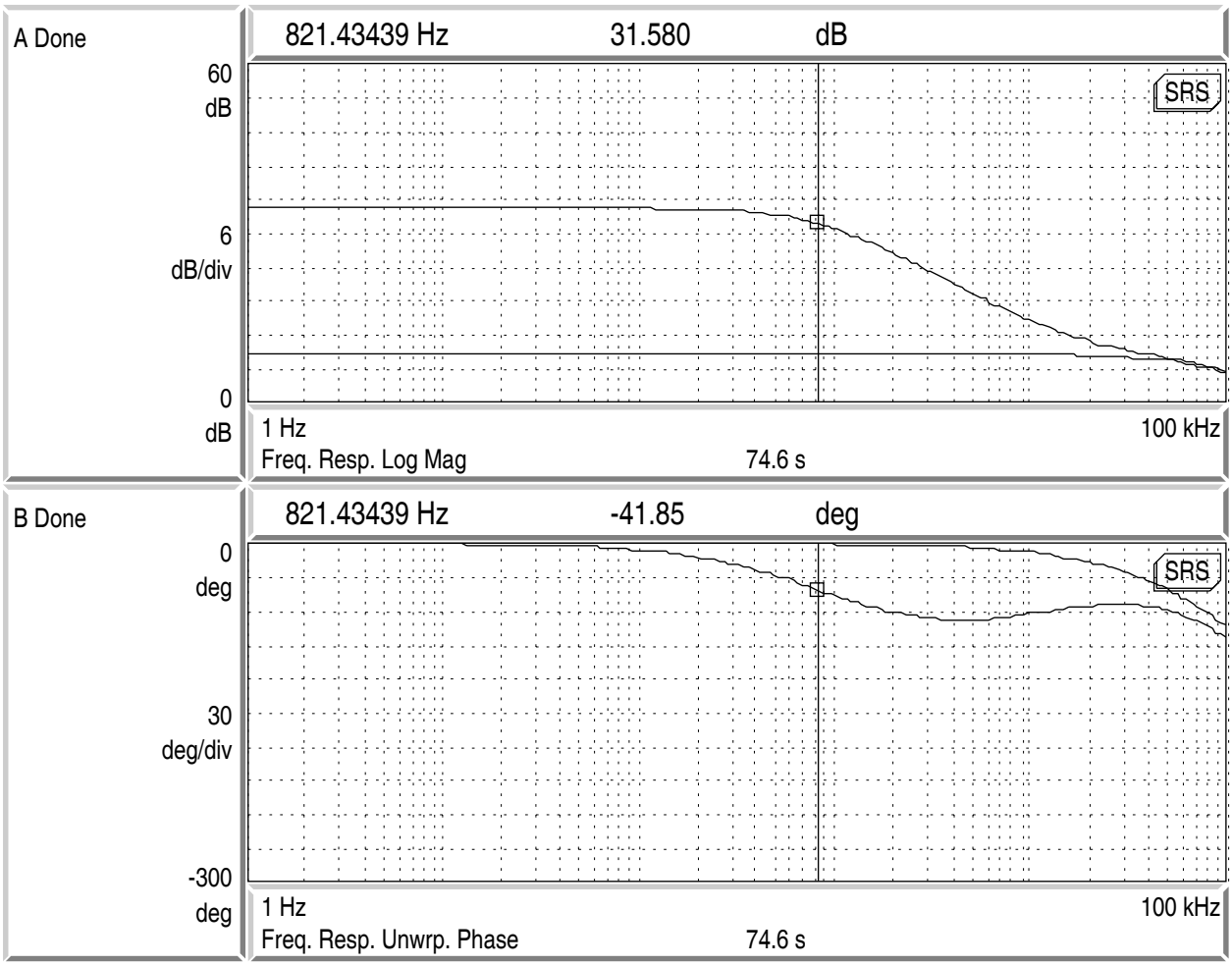


Transfer function from IN1 to SERVO (mode cleaner).

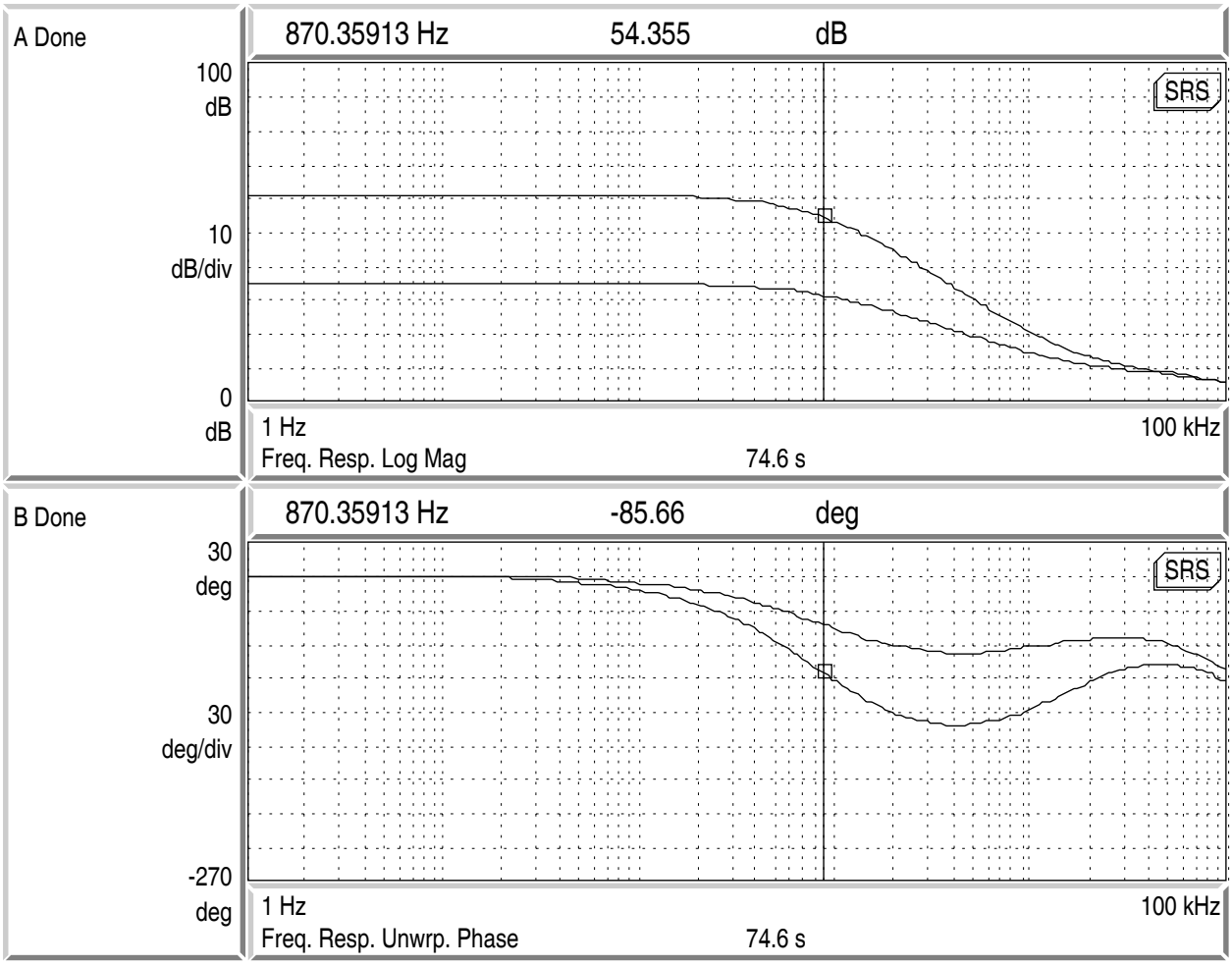
Appendix A4: Transfer functions of boost gain stages



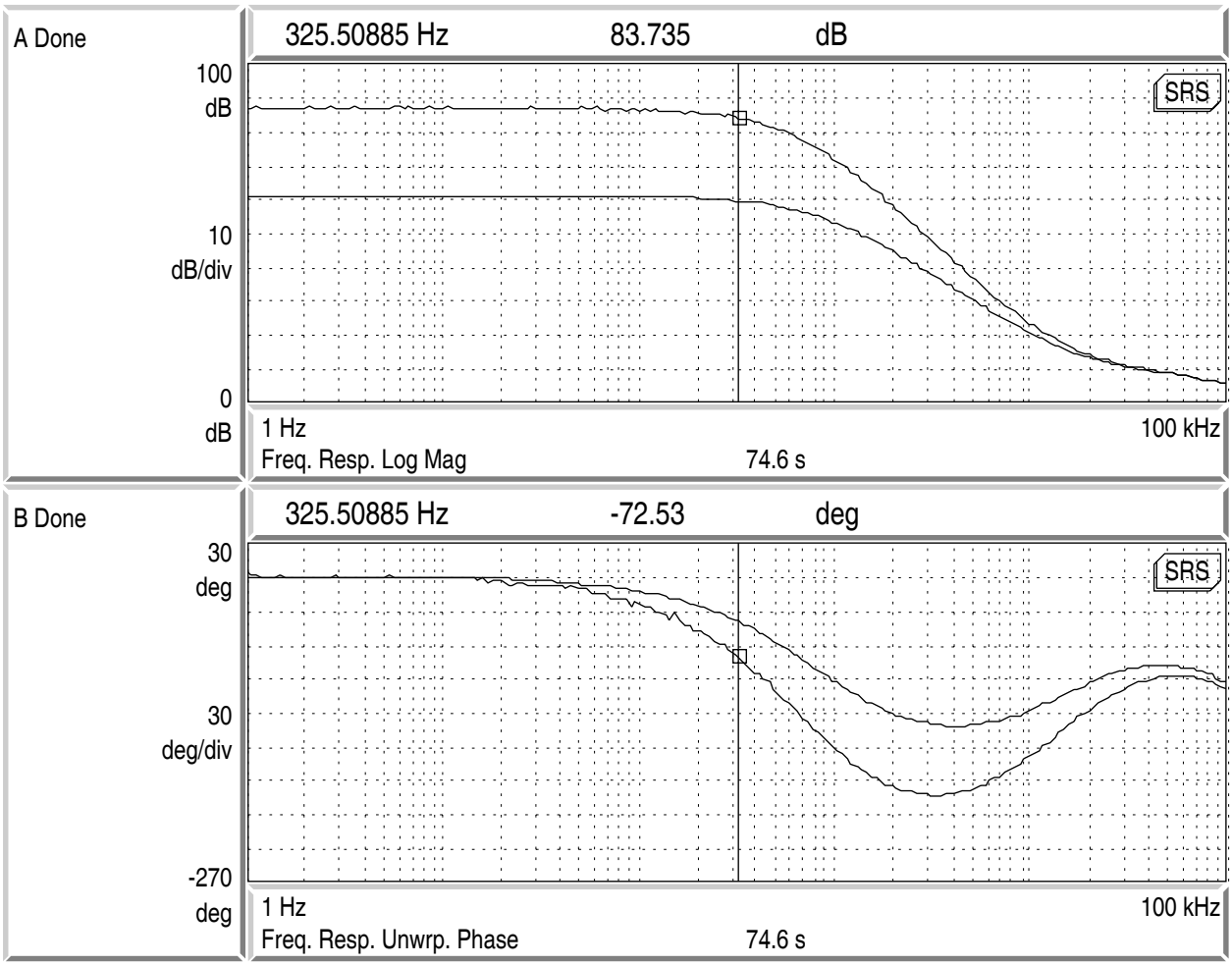
First boost gain stage (D23).



Second boost gain stage (D21).

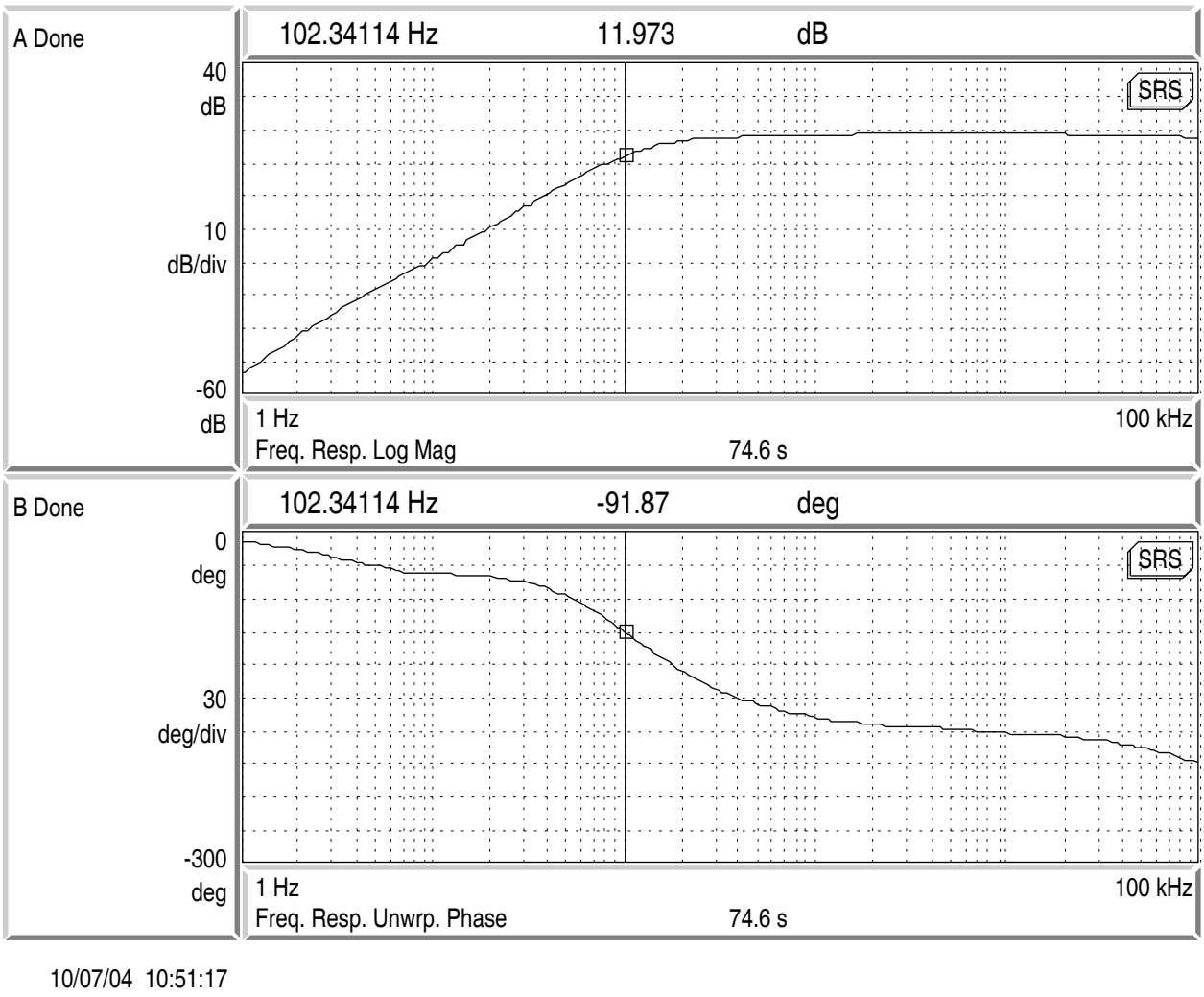


Second and third boost gain stage (D22).

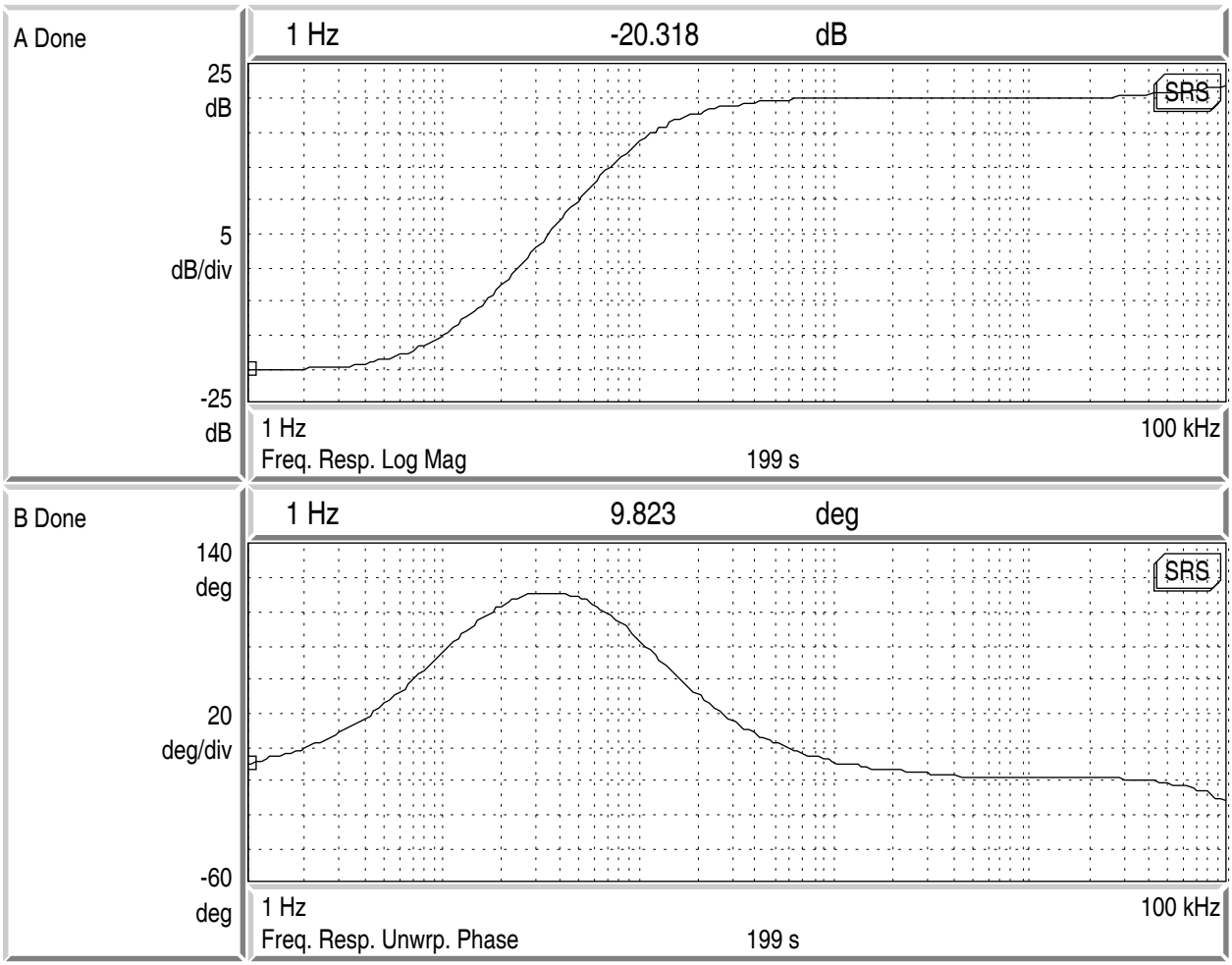


Second, third and fourth boost gain stage (D21 & D22).

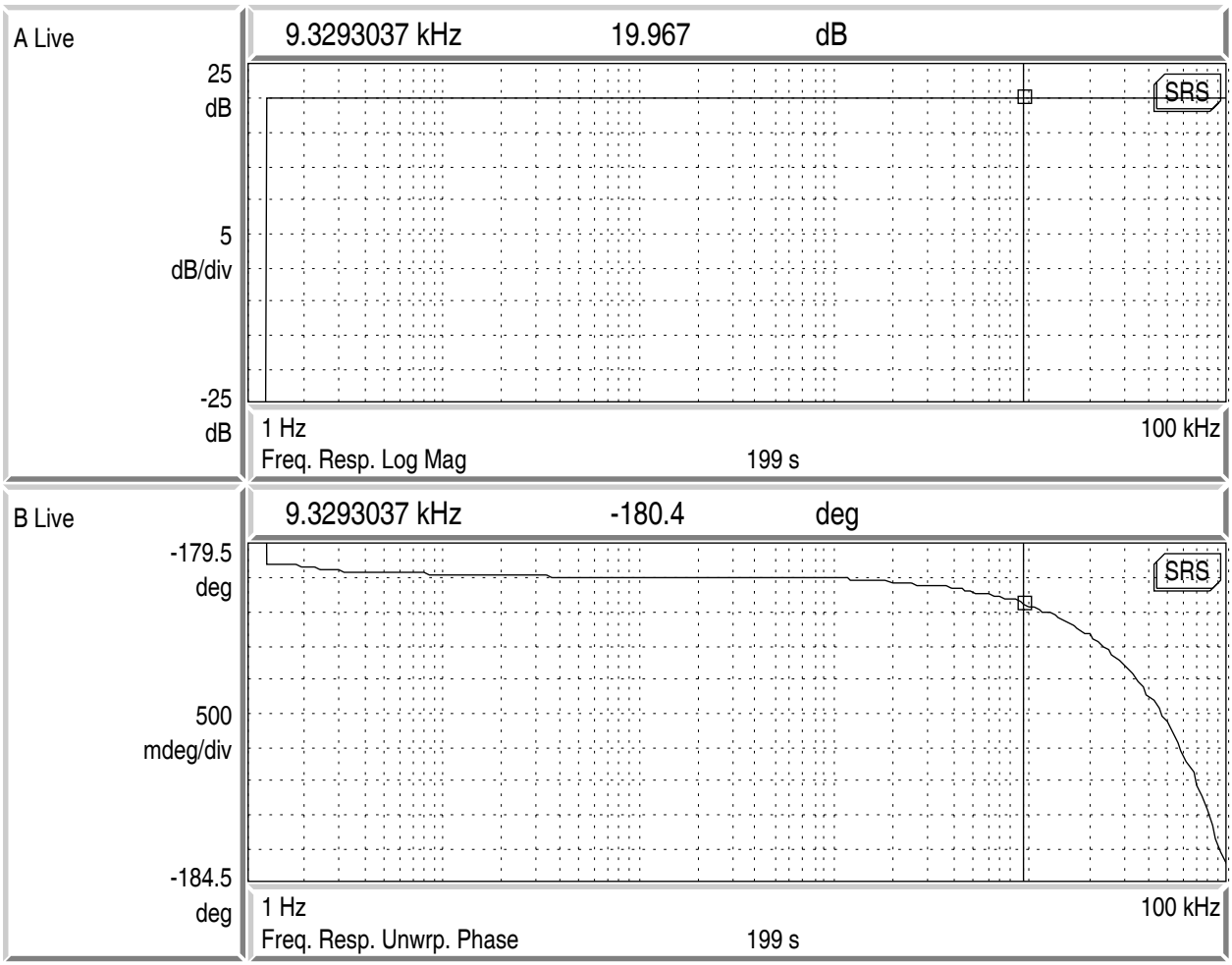
Appendix A5: Transfer functions of DAQ channels



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

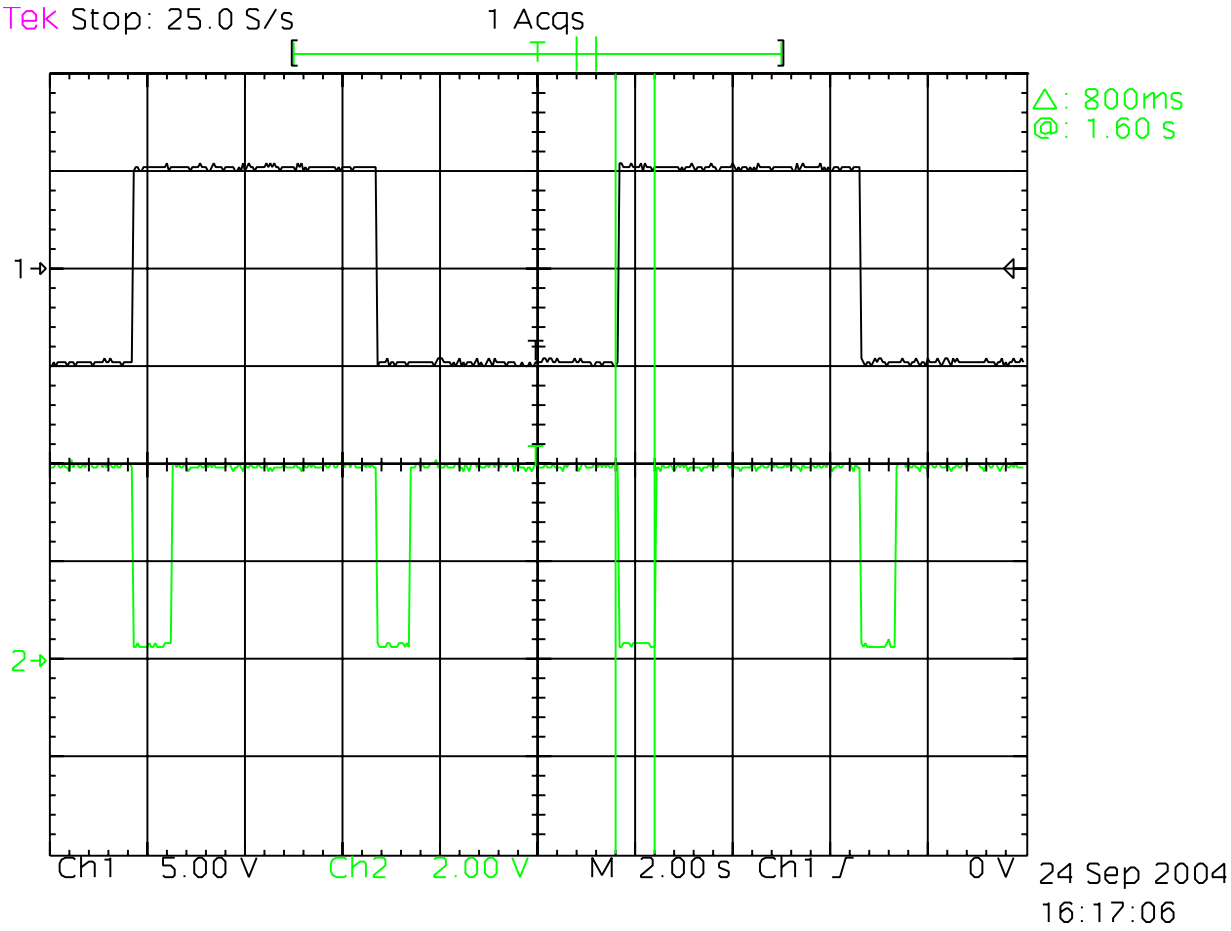


Transfer function to first DAQ channel (mode cleaner).



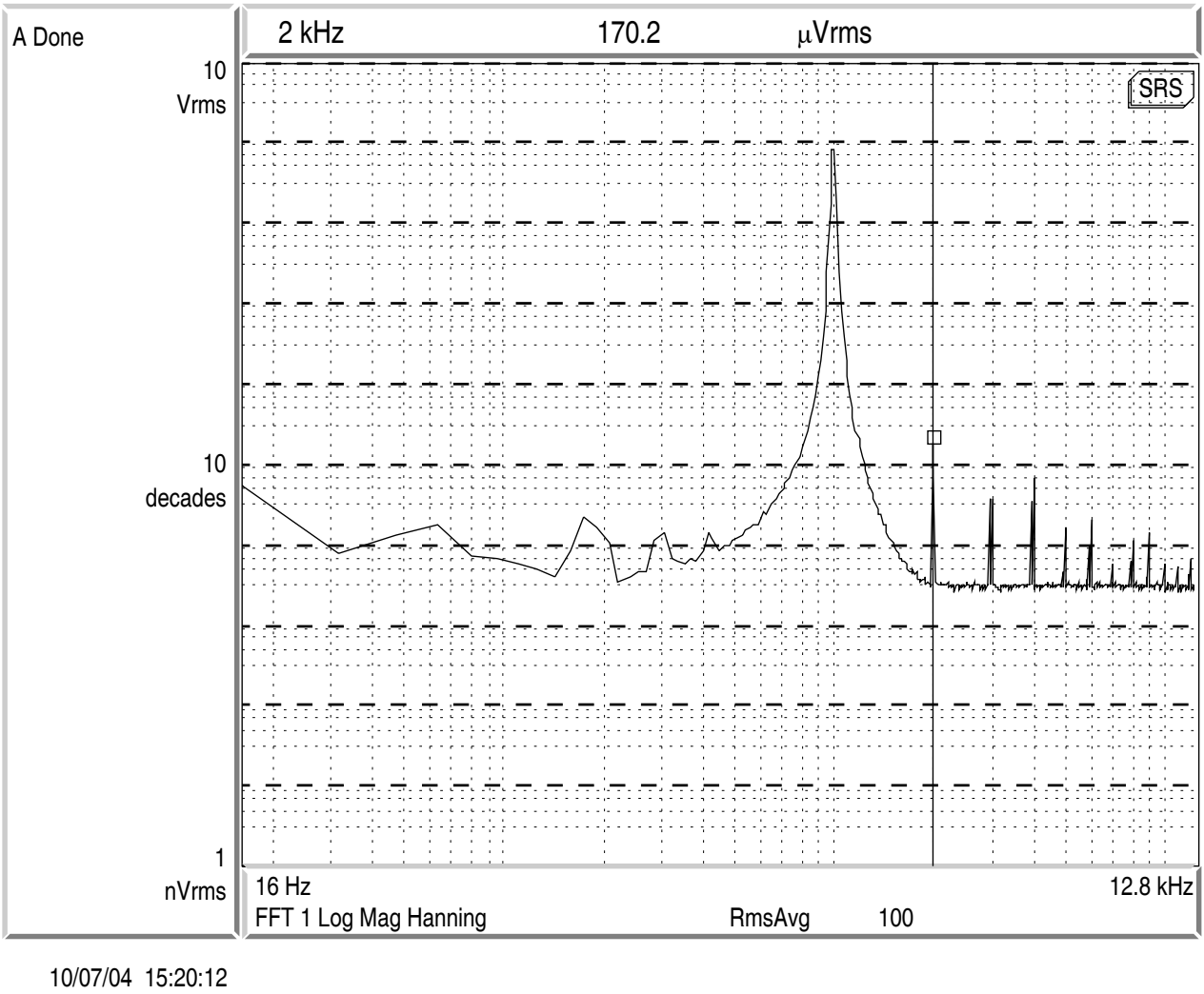
Transfer function to second DAQ channel.

Appendix A6: Limit indicator



Limiter output.

Appendix A7: Distortion measurement



Typical distortion spectrum.