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LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

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UK PUM Driver Pre-Production Prototype Test Plan		
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1 Introduction

The tests described below will be utilized to test the pre-pre-production prototype of the Adl Quad Suspension PUM Coil Driver. These drivers are being designed and build by the UK group located at the University of Birmingham. The design requirements for the driver can be found in LIGO document number T060067-00-C, "AdL Quad Suspension UK Coil Driver Design Requirements".

These tests are not comprehensive and will only be utilized to verify that the driver meets the design requirements. It is assumed that the drivers have been thoroughly tested by the University of Birmingham prior to shipment.

2 Test Equipment

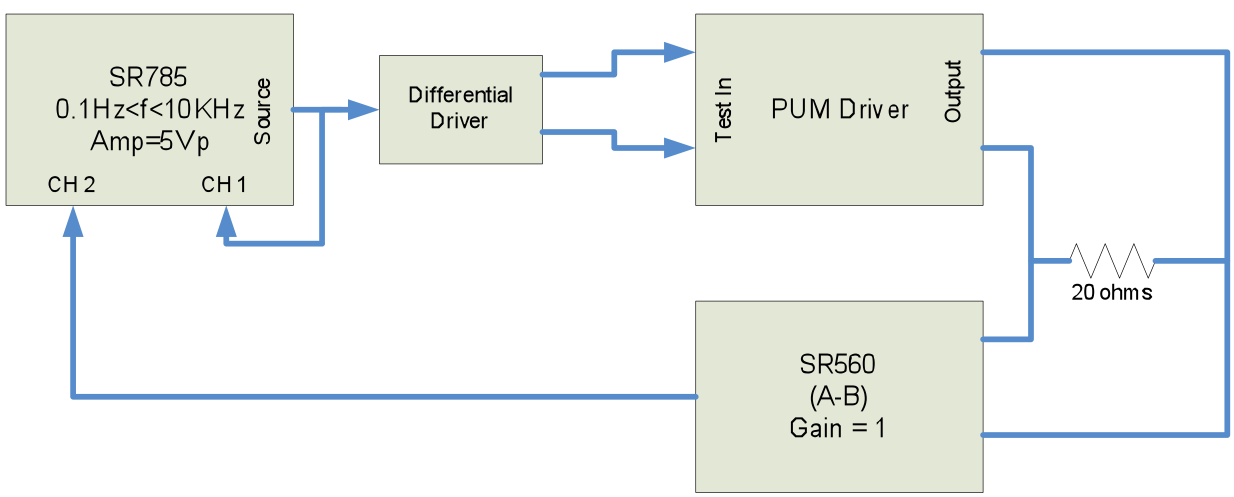
- Stanford Research SR785 analyzer
- Voltmeter
- Oscilloscope
- Board Schematics- TBD

3 Tests

The tests are broken into the same categories used in the design requirements document, noise, dynamic range and monitors/controls. The tests for each of these categories are described in the sections below.

3.1 Dynamic Range and Transfer Function Tests

Each channel of the PUM coil driver is equipped with three relays that are used to change the response from a very high dynamic range high noise to a low dynamic range, low noise response. Relay K3 is used to enable/disable the low noise mode of operation. Relays K4 and K5 are used to enable/disable the high dynamic range mode. The tests for each of these two modes are described in the sections that follow. The transfer function for each mode of operation is measured by injecting a signal into the test 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.



3.1.1 High Dynamic Range Mode

In the high dynamic range mode, relay K3 is NOT energized and relays K4 and K5 are energized. The nominal response of the coil driver this mode is a zero at ~1Hz and pole at ~100Hz and is shown

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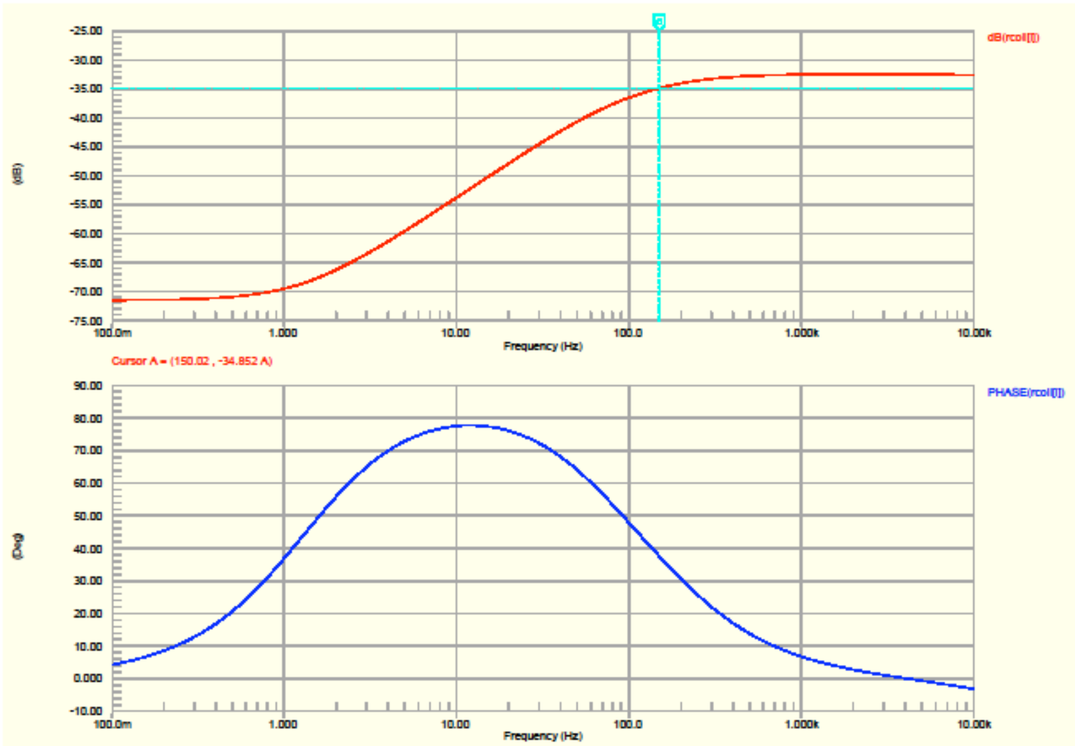
in the plot below. Note that the transfer function is in units of volts in to amps output into a 20 ohm load; therefore if the transfer function measurement is made by measuring the voltage across the load resistor, 26 dB will need to be subtracted from each reading on the SR785.



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.

Table 1: Channel 1 Transfer Function Measurements

Freq (Hz)	Nominal Gain (dBamps/Volt)	Nominal Phase (Degrees)	Actual Gain (dBamps/Volt)	Actual Phase (Degrees)
0.1	-71.5	4.2		
1	-69.5	36.9		
10	-53.7	77.6		
100	-36.5	47.8		
1K	-32.5	6.8		
10K	-32.6	-3.2		

Table 2: Channel 2 Transfer Function Measurements

Freq (Hz)	Nominal Gain (dBamps/Volt)	Nominal Phase (Degrees)	Actual Gain (dBamps/Volt)	Actual Phase (Degrees)
0.1	-71.5	4.2		
1	-69.5	36.9		
10	-53.7	77.6		
100	-36.5	47.8		
1K	-32.5	6.8		

10K	-32.6	-3.2		

Table 3: Channel 3 Transfer Function Measurements

Freq (Hz)	Nominal Gain (dBamps/Volt)	Nominal Phase (Degrees)	Actual Gain (dBamps/Volt)	Actual Phase (Degrees)
0.1	-71.5	4.2		
1	-69.5	36.9		
10	-53.7	77.6		
100	-36.5	47.8		
1K	-32.5	6.8		
10K	-32.6	-3.2		

Table 4: Channel 4 Transfer Function Measurements

Freq (Hz)	Nominal Gain (dBamps/Volt)	Nominal Phase (Degrees)	Actual Gain (dBamps/Volt)	Actual Phase (Degrees)
0.1	-71.5	4.2		
1	-69.5	36.9		
10	-53.7	77.6		
100	-36.5	47.8		
1K	-32.5	6.8		
10K	-32.6	-3.2		

File Name for transfer function measurement (High Dynamic Range Mode):__________________

3.1.2 Low Noise Mode

In the acquire mode, relay K3 is energized and relays K4 and K5 are NOT energized. The nominal response of the coil driver in low noise mode is poles at 0.5Hz and 250Hz and zeros at 5Hz and 20Hz. The nominal response 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; therefore if the transfer function measurement is made by measuring the voltage across the load resistor, 26 dB will need to be subtracted from each reading on the SR785.

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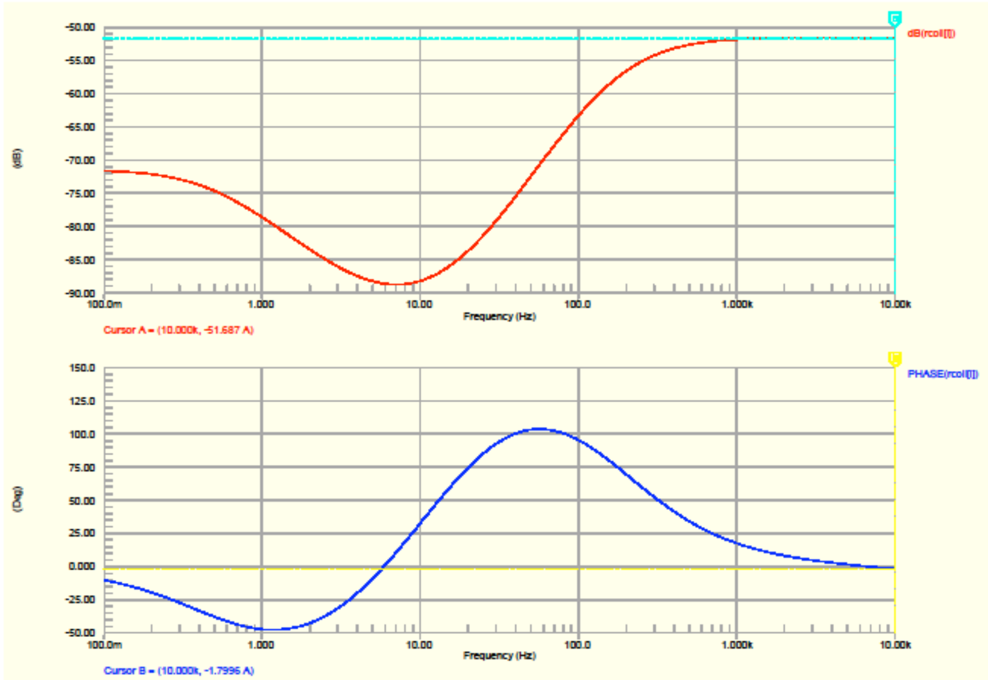

In the tables below, record the measured magnitude and phase of the response for each channel. In addition, save the transfer function for one representative channel to disk and record the file name in space provided below.

Table 5: Channel 1 Transfer Function Measurements

Freq (Hz)	Nominal Gain (dBamps/Volt)	Nominal Phase (Degrees)	Actual Gain (dBamps/Volt)	Actual Phase (Degrees)
0.1	-71.6	-10.2		
1	-78.7	-47.3		
10	-88.2	33.0		
100	-63.3	95.4		
1K	-51.8	17.6		
10K	-51.7	-1.8		

Table 6: Channel 2 Transfer Function Measurements

Freq (Hz)	Nominal Gain (dBamps/Volt)	Nominal Phase (Degrees)	Actual Gain (dBamps/Volt)	Actual Phase (Degrees)
0.1	-71.6	-10.2		
1	-78.7	-47.3		
10	-88.2	33.0		
100	-63.3	95.4		
1K	-51.8	17.6		
10K	-51.7	-1.8		

Table 7: Channel 3 Transfer Function Measurements

Freq (Hz)	Nominal Gain	Nominal	Actual Gain	Actual Phase

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	(dBamps/Volt)	Phase (Degrees)	(dBamps/Volt)	(Degrees)
0.1	-71.6	-10.2		
1	-78.7	-47.3		
10	-88.2	33.0		
100	-63.3	95.4		
1K	-51.8	17.6		
10K	-51.7	-1.8		

Table 8: Channel 4 Transfer Function Measurements

Freq (Hz)	Nominal Gain (dBamps/Volt)	Nominal Phase (Degrees)	Actual Gain (dBamps/Volt)	Actual Phase (Degrees)
0.1	-71.6	-10.2		
1	-78.7	-47.3		
10	-88.2	33.0		
100	-63.3	95.4		
1K	-51.8	17.6		
10K	-51.7	-1.8		

File Name for transfer function measurement (Low Noise Mode):____________________
Channel Number for saved file: ________

3.1.3 Dynamic Range Tests

3.1.3.1 Run (Low Noise) Mode

The maximum output current requirement for the driver is $16mA_{rms}$ for frequencies from 200Hz to 5KHz. The tests below will verify that the design meets this requirement. In addition the chassis and 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 (1KHz), 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. Note that the measurement is made using a 1KHz sine wave as the input source. Relay K3 is energized and relays K4 and K5 are not energized.

Table 9: Channel 1 Output Current vs. Input Voltage

Input Voltage (rms) at 1KHz	Nominal Output Current (mA rms)	Actual Output Current (mA rms)	Notes
1V	2.6		
5V	12.9		
10V	25.7		

Table 10: Channel 2 Output Current vs. Input Voltage

Input Voltage (rms) at 1KHz	Nominal Output Current (mA rms)	Actual Output Current (mA rms)	Notes
1V	2.6		

5V	12.9		
10V	25.7		

Table 11: Channel 3 Output Current vs. Input Voltage

Input Voltage (rms) at 1KHz	Nominal Output Current (mA rms)	Actual Output Current (mA rms)	Notes
1V	2.6		
5V	12.9		
10V	25.7		

Table 12: Channel 4 Output Current vs. Input Voltage

Input Voltage (rms) at 1KHz	Nominal Output Current (mA rms)	Actual Output Current (mA rms)	Notes
1V	2.6		
5V	12.9		
10V	25.7		

3.1.3.2 Acquire Mode

In Acquire Mode the PUM Driver should be capable of supplying 400mA peak for frequencies from 200Hz to 5KHz. The tests below will verify that the design meets this requirement. In addition the chassis and 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 (1KHz), 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. Note that the measurement is made using a 1KHz sine wave as the input source. Relay K3 is not energized and relays K4 and K5 are energized. It should be noted that the driver chassis has been equipped with protection circuitry that will disable the output of the driver if the output current exceeds $150mA_{rms}$ for more than a few seconds. The reading at 10V will need to be made quickly and in the notes section verify that the output protection circuitry functioned correctly.

Table 13: Channel 1 Output Current vs. Input Voltage

Input Voltage (rms) at 1KHz	Nominal Output Current (mA rms)	Actual Output Current (mA rms)	Notes
1V	23.7		
5V	118.3		
6V	142.0		
10V	236.7		

Table 14: Channel 2 Output Current vs. Input Voltage

Input Voltage (rms) at	Nominal Output Current (mA rms)	Actual Output Current (mA rms)	Notes

1KHz			
1V	23.7		
5V	118.3		
6V	142.0		
10V	236.7		

Table 15: Channel 3 Output Current vs. Input Voltage

Input Voltage (rms) at 1KHz	**Nominal Output Current (mA rms)**	**Actual Output Current (mA rms)**	**Notes**
1V	23.7		
5V	118.3		
6V	142.0		
10V	236.7		

Table 16: Channel 4 Output Current vs. Input Voltage

Input Voltage (rms) at 1KHz	**Nominal Output Current (mA rms)**	**Actual Output Current (mA rms)**	**Notes**
1V	23.7		
5V	118.3		
6V	142.0		
10V	236.7		

3.2 Noise Tests

The most stringent noise requirement for the PUM Driver comes at 10Hz where the output noise current from the driver needs to be less than 4 pA/√Hz. Measuring the actual noise current into the 20 ohm load resistor is a very difficult measurement, so the noise current must be implied by measuring the output noise voltage of the driver using test points on the board (TP10 and TP12). The total series impedance in the output of the driver including the 20 ohm load is 3.4 Kohms at 10Hz. The means that the output voltage noise measured needs to be less than 13.6nV/√Hz at 10Hz. A plot of the simulated noise versus frequency is shown in the figure below.

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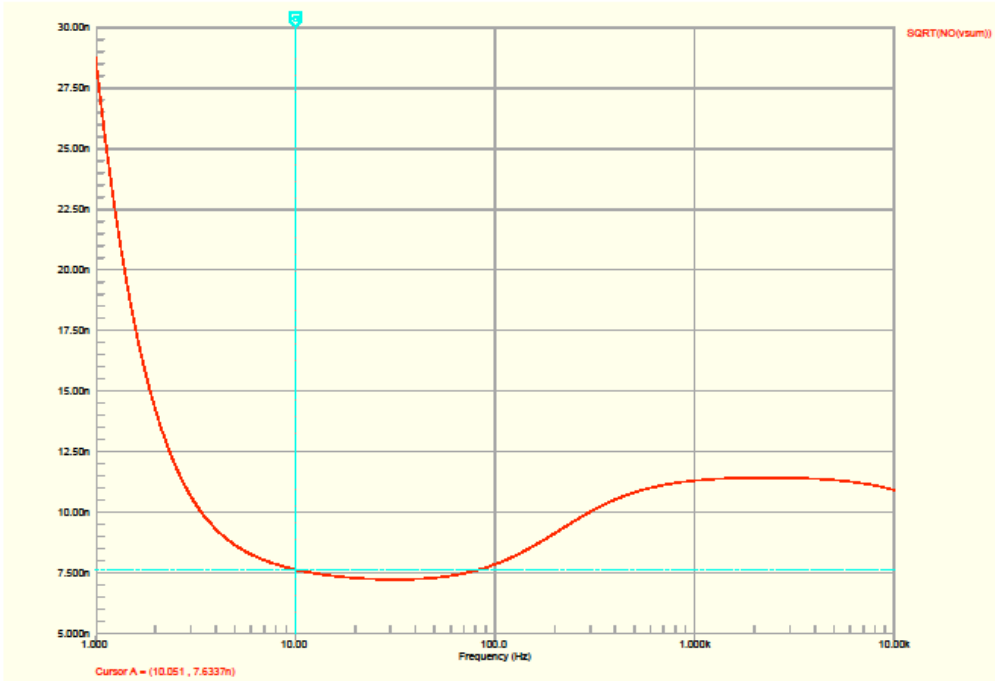

The simulation predicts that the noise at 10Hz should be approximately 7.6nV/√Hz which is slightly below the requirement. In the table below, record the output noise at 10Hz measured using sum and difference voltages for each channel. The inputs to the channel under test should be tied to circuit ground, relay K3 energized, relays K4 and K5 not energized (Low Noise Mode). In addition, save the noise data for one representative channel to disk and record the file name in space provided below. The frequency range for the saved file should be from 0.1Hz to 100Hz.

Channel Number	Measured Noise at 10Hz
1	
2	
3	
4	

File Name for noise measurement (Low Noise Mode):__________________
Channel Number for saved file: ________

3.3 Monitors, Controls and Circuit Protection

3.3.1 Noise Monitor Transfer Function Tests

The noise monitor board in the driver chassis provides a low-noise, AC coupled monitor of the voltage output of each channel. The nominal transfer function of the monitor is 4 zeros at DC, 4 poles at 5Hz and 2 poles at 5KHz which are added to the response of the driver channel. These tests measure the transfer function from the input of a particular driver channel to the corresponding noise monitor output. The coil driver output should be load with 20 ohms during the tests. Relay K3 should be energized relays K4 and K5 should not be energized during the tests. The figure below shows the response nominal response.

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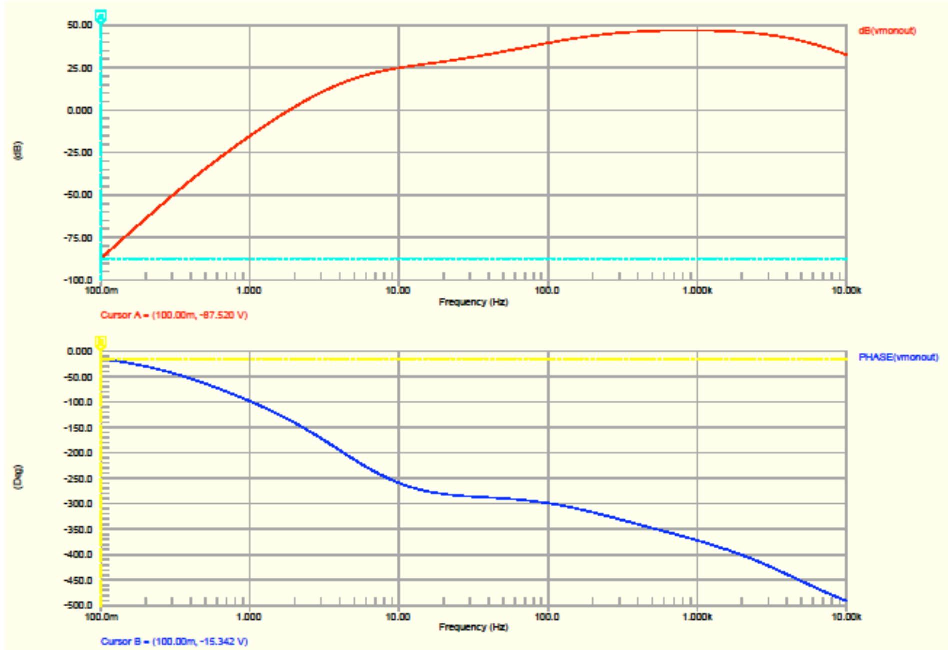


In the tables below, record the measured magnitude and phase of the response for each channel. In addition, save the transfer function for one representative channel to disk and record the file name in space provided below.

Table 13: Channel 1 Noise Monitor Transfer Function Measurements

Freq (Hz)	Nominal Gain (dBV/Volt)	Nominal Phase (Degrees)	Actual Gain (dBV/Volt)	Actual Phase (Degrees)
0.1	-87.5	-15.3		
1	-15.2	-98.3		
10	24.9	-259.3		
100	39.5	-299.0		
1K	46.9	-372.1		
10K	32.7	-490.7		

Table 14: Channel 2 Noise Monitor Transfer Function Measurements

Freq (Hz)	Nominal Gain (dBV/Volt)	Nominal Phase (Degrees)	Actual Gain (dBV/Volt)	Actual Phase (Degrees)
0.1	-87.5	-15.3		
1	-15.2	-98.3		
10	24.9	-259.3		
100	39.5	-299.0		
1K	46.9	-372.1		
10K	32.7	-490.7		

Table 15: Channel 3 Noise Monitor Transfer Function Measurements

Freq (Hz)	Nominal Gain (dBV/Volt)	Nominal Phase (Degrees)	Actual Gain (dBV/Volt)	Actual Phase (Degrees)

0.1	-87.5	-15.3		
1	-15.2	-98.3		
10	24.9	-259.3		
100	39.5	-299.0		
1K	46.9	-372.1		
10K	32.7	-490.7		

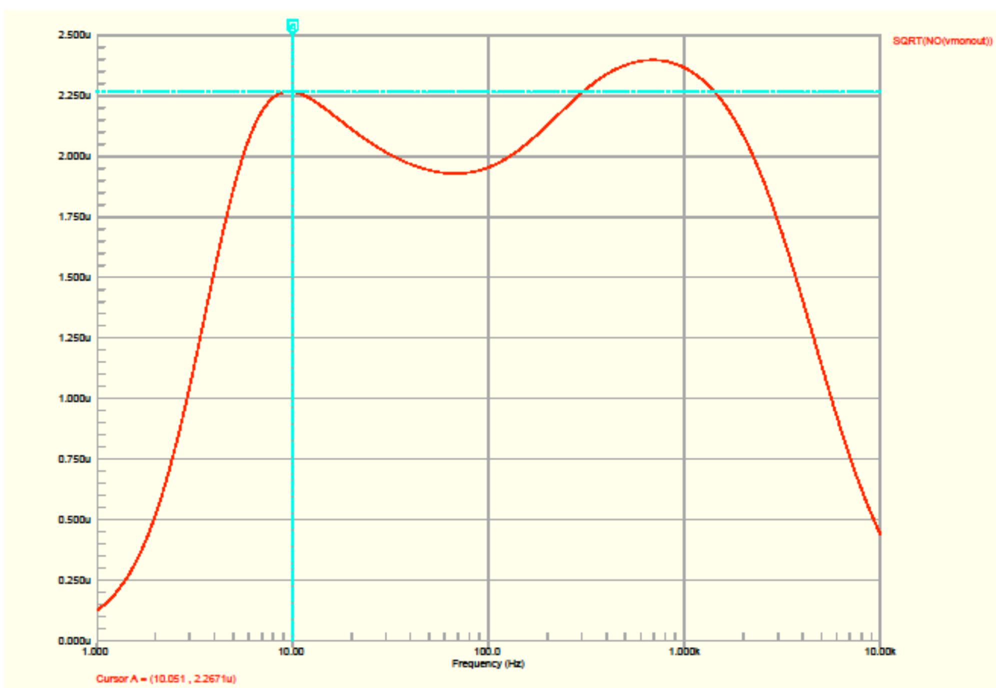
Table 16: Channel 4 Noise Monitor Transfer Function Measurements

Freq (Hz)	Nominal Gain (dBV/Volt)	Nominal Phase (Degrees)	Actual Gain (dBV/Volt)	Actual Phase (Degrees)
0.1	-87.5	-15.3		
1	-15.2	-98.3		
10	24.9	-259.3		
100	39.5	-299.0		
1K	46.9	-372.1		
10K	32.7	-490.7		

File Name for Noise Monitor Measurement:__________________
Channel number for saved file: __________

3.3.2 Noise Monitor Output Noise Tests

A plot of the simulated noise versus frequency is shown in the figure below.



As can be seen from the plot, the noise at 10Hz at the monitor output should be approximately 2.3uV/√Hz. In the table below, record the output noise at 10Hz. The inputs to the channel under test should be tied to circuit ground and relay K3 energized relays K4 and K5 not energized (Low Noise

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Mode). In addition, save the noise data for one representative channel to disk and record the file name in space provided below. The frequency range for the saved file should be from 0.1Hz to 100Hz.

Channel Number	Measured Noise at 10Hz
1	
2	
3	
4	

File Name for noise measurement:__________________
Channel Number for saved file: ________

3.3.3 Output Voltage and Current Monitor Tests

The monitor board connected to the PUM Driver board inside the chassis provides continuous monitors of the output voltage and current (FC) and rms current (SC) for each channel. These monitors are tested in this section. The driver should be in the low noise mode of operation, K3 energized, K4 and K5 not energized. In the tables below, record the current and voltage monitor output for each input voltage.

Table 17: Channel 1 Monitor Output Tests

Input Voltage (DC)	Nominal Voltage Monitor	Nominal Current Monitor (FC)	Nominal rms Current Mon (SC)	Actual Voltage Monitor (Volts)	Actual Current Monitor (Volts)	Actual Current rms Monitor (Volts)
+1V	0.401	0.199	0.199			
-1V	-0.401	-0.199	0.199			
+5V	2.0	0.995	0.995			
-5V	-2.0	-0.995	0.995			
+10V	4.01	1.99	1.99			
-10V	-4.01	-1.99	1.99			
+20V	8.02	3.98	3.98			
-20V	-8.02	-3.98	3.98			

Table 18: Channel 2 Monitor Output Tests

Input Voltage (DC)	Nominal Voltage Monitor	Nominal Current Monitor (FC)	Nominal rms Current Mon (SC)	Actual Voltage Monitor (Volts)	Actual Current Monitor (Volts)	Actual Current rms Monitor (Volts)
+1V	0.443	0.199	0.199			
-1V	-0.443	-0.199	0.199			
+5V	2.22	0.995	0.995			
-5V	-2.22	-0.995	0.995			
+10V	4.43	1.99	1.99			
-10V	-4.43	-1.99	1.99			
+20V	8.87	3.98	3.98			
-20V	-8.87	-3.98	3.98			

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Table 19: Channel 3 Monitor Output Tests

Input Voltage	Nominal Voltage Monitor	Nominal Current Monitor (FC)	Nominal rms Current Mon (SC)	Actual Voltage Monitor (Volts)	Actual Current Monitor (Volts)	Actual Current rms Monitor (Volts)
+1V	0.443	0.199	0.199			
-1V	-0.443	-0.199	0.199			
+5V	2.22	0.995	0.995			
-5V	-2.22	-0.995	0.995			
+10V	4.43	1.99	1.99			
-10V	-4.43	-1.99	1.99			
+20V	8.87	3.98	3.98			
-20V	-8.87	-3.98	3.98			

Table 20: Channel 4 Monitor Output Tests

Input Voltage (DC)	Nominal Voltage Monitor	Nominal Current Monitor (FC)	Nominal rms Current Mon (SC)	Actual Voltage Monitor (Volts)	Actual Current Monitor (Volts)	Actual Current rms Monitor (Volts)
+1V	0.443	0.199	0.199			
-1V	-0.443	-0.199	0.199			
+5V	2.22	0.995	0.995			
-5V	-2.22	-0.995	0.995			
+10V	4.43	1.99	1.99			
-10V	-4.43	-1.99	1.99			
+20V	8.87	3.98	3.98			
-20V	-8.87	-3.98	3.98			