LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

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Frequency Devices VME DAC Prototype Test Results		
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1 Introduction

This technical note describes the tests and test results for the Frequency Devices model 8217 VME DAC module prototype. All tests were performed at Caltech using the prototype module supplied by Frequency Devices and software written at Caltech.

2 Output Referred Noise Using a Single Tone

In this test software was written to produce a continuous tone at a single frequency. The amplitude and frequency of the tone were adjustable, but were not changed once a given test was started. The output-referred noise of the DAC was then measured at frequencies away from the tone frequency using a SR785 analyzer. A block diagram of the test setup is shown in the figure below.

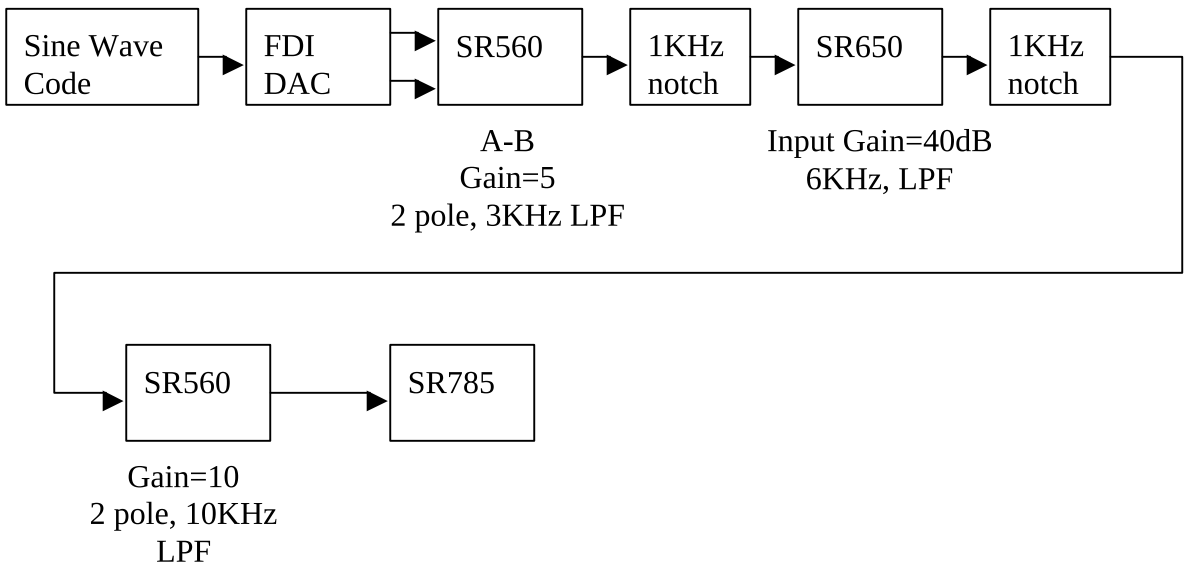

Figure 1: Single Tone Test Setup

A plot of the transfer function of the measurement chain from the first SR560 through the SR785 is shown in the figure below.

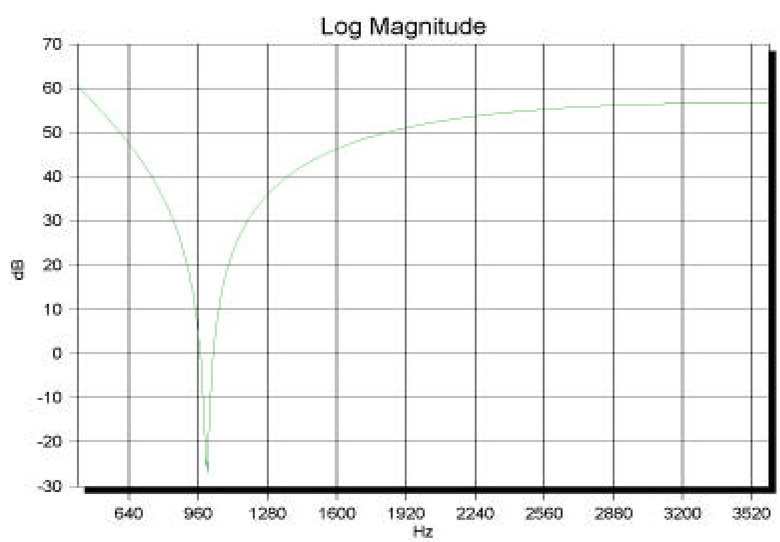

Figure 2: Single Tone Test Setup Response

All of the measurements shown were performed on channel 1 of the module, but they are consistent with the noise measured on all channels of the module. The output clock frequency for the tests was 16384 Hz and was derived from an input 2^{22} Hz clock. All noise measurements for this these tests were made at 3.6KHz, but an effort was made to find any inconsistencies in the noise measurements at frequencies from 100 Hz to 3.6KHz. No inconsistencies were observed other than possible glitches that will be discussed later. As can be seen from the response plot above, the gain at 3.6KHz is 56.9 dB. This number was used to calculate the actual output referred noise voltages recorded in the table below.

Table 1: Single Tone Noise Measurement Results

Tone Freq (Hz)	Amplitude (counts)	Amplitude (Vp-p)	Measured Noise at 3.6KHz (dBV/ÖHz)	Equivalent Output Noise (nV/ÖHz)
GND[1]	N/A	N/A	-86	79
1000	250000000	2	-73	355
1000	25000000	0.2	-80	158
1000	2500000	0.02	-83	112
1024	2500000	0.02	-83	112
1024	25000000	0.2	-83	112
1024[2]	250000000	2	-89	141

The high output noise measured for a 2Vp-p, 1KHz sine wave output appears to be related to phase truncation in the sine wave generation process. For this reason the generated frequency was shifted to a sub-harmonic of the sample frequency. As can be seen from the results in the table above, the output-referred noise for smaller amplitude sine wave is on the order of 112 nV/√Hz and is approximately 141 nV/√Hz for a large amplitude sine wave at 1024 Hz. This is consistent with the measurements performed by Frequency Devices at their facility.

3 Output Referred Noise Using a Random Noise Source

In this set of tests a random white noise source was used as the input to the system. The digitized noise was then passed through a series of software bandpass filters and sent to the FDI DAC. The output noise spectrum was then measured using the SR785 analyzer. A block diagram of the test setup is shown in the figure below.

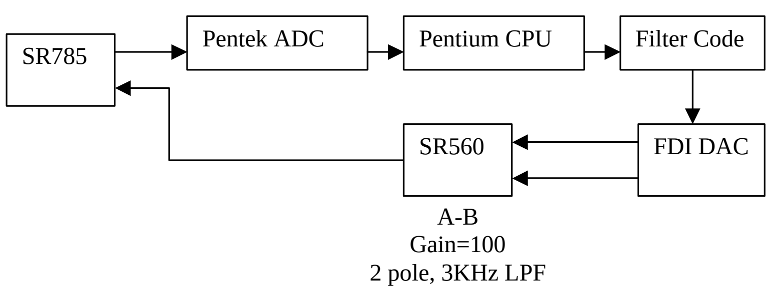

Figure 3: Output Noise Measurement Setup Using Filtered Random Noise

[1] Test setup noise floor measurement. The input to the test setup was grounded and the output noise measured. The equivalent noise at the DAC input to the test setup was then calculated.

[2] The input gain of the first stage was lowered from gain=5 to gain=2 to avoid saturation since the notches were tuned to 1KHz. Therefore there was 8dB less gain in the setup. The new measured noise floor of the test setup was 90nV/√Hz.

The transfer function of the first filter used is shown in the figure below. The filter was an 8^{th} order, 100 dB attenuation, 1 dB ripple, 500 to 1500 Hz elliptic bandstop filter.

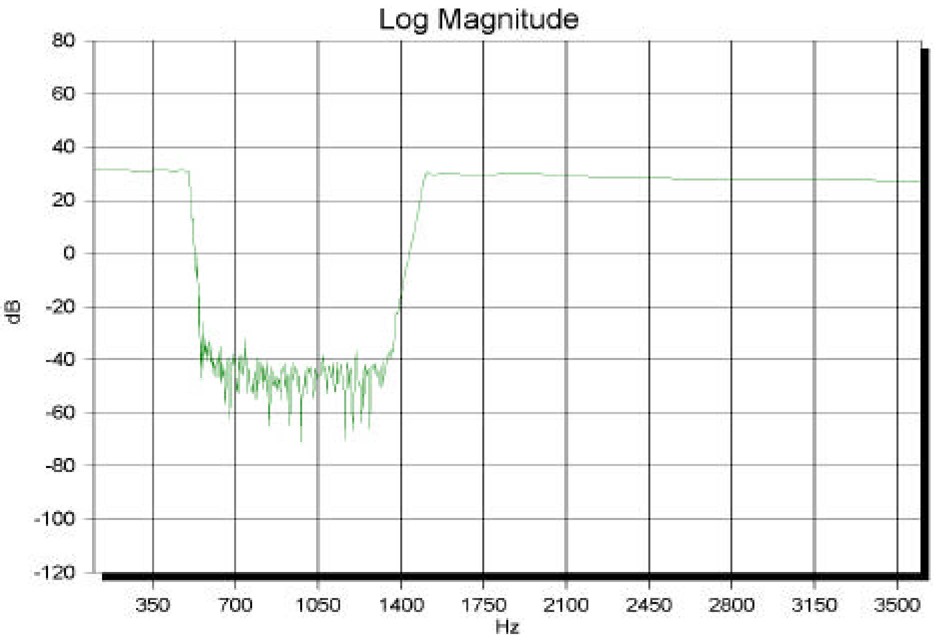

Figure 4: Software Filter 1 Transfer Function

The figure below is a plot of the output noise spectrum for random noise levels of 1mV, 10mV and 100mV. Traces SR001.78D, SR002.78D and SR003.78D correspond to 10mV, 100mV and 1mV, respectively. Note that the 40dB gain stage prior to the SR785 must be taken into account when calculating the output referred noise of the DAC.

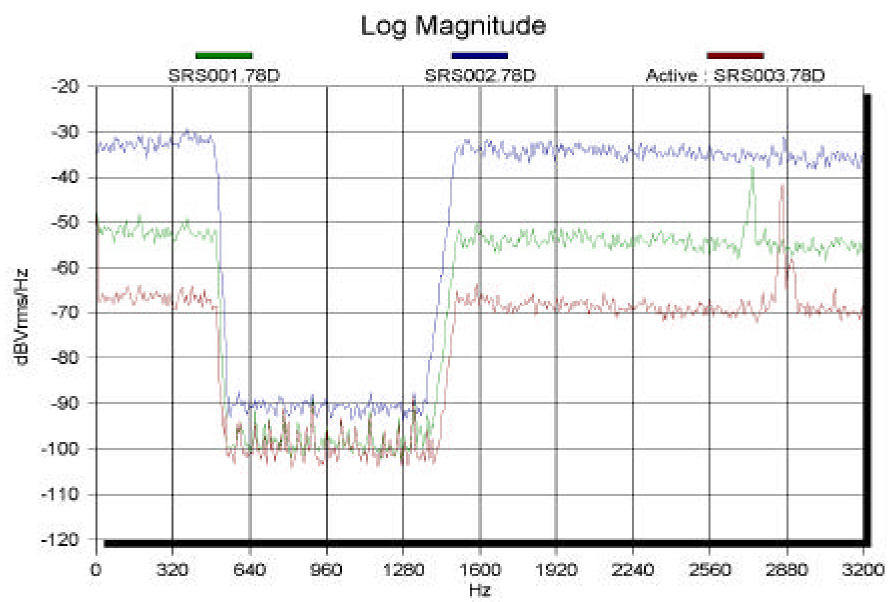

Figure 5: Software Filter 1 Noise Measurement

The output referred noise of the DAC from 500Hz to 1500 Hz for 1mV and 10mV is approximately 115nV/√Hz. The output refered noise for the 100mV case is approximately 250nV/√Hz. The hash and peaks seen in the stop band and around 2800Hz appeared to be related to the measurement set up and not the DAC itself.

The transfer function of the second filter used is shown in the figure below. The filters were two an 8^{th} order, 100 dB attenuation, 1 dB ripple, elliptic bandstop filters. The first stop band was from 100Hz to 500Hz and the second was from 1KHz to 2KHz.

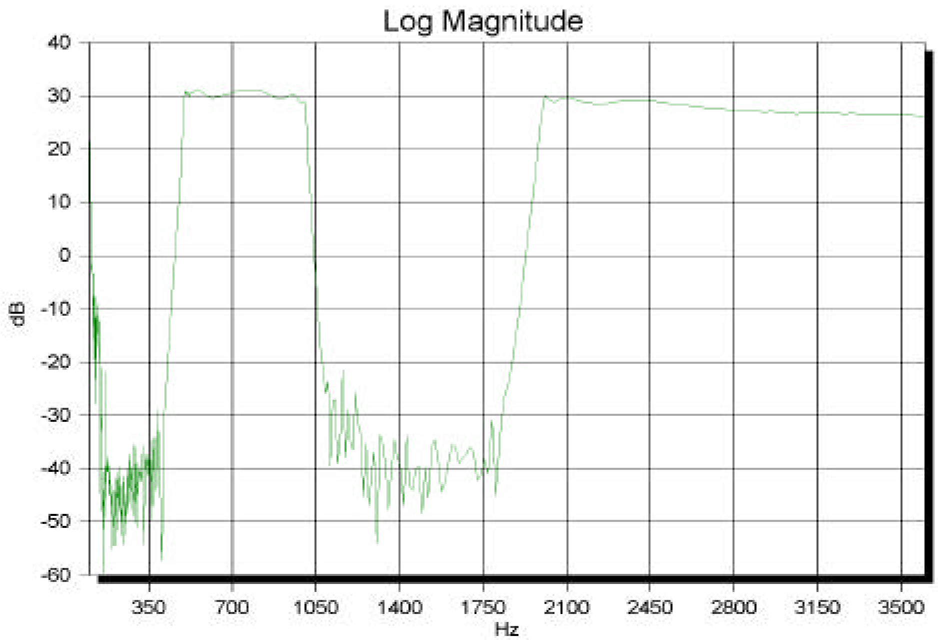

Figure 6: Transfer Function for Software Filter 2

The figure below is a plot of the output noise spectrum for random noise levels of 1mV, 10mV and 100mV. Traces SR006.78D, SR007.78D and SR008.78D correspond to 100mV, 10mV and 1mV, respectively.

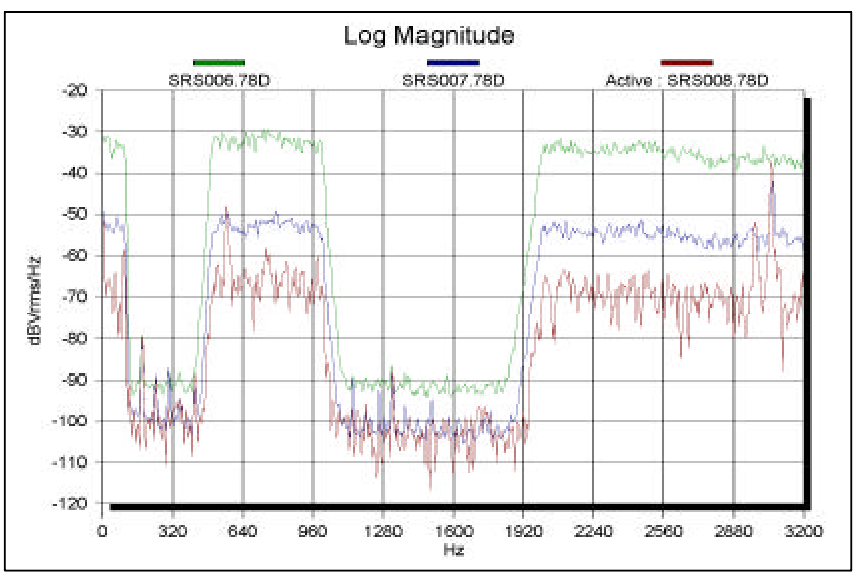

Figure 7: Output Noise Measurements for Software Filter 2

The output referred noise of the DAC from 100Hz to 500 Hz for 1mV and 10mV is approximately 115nV/√Hz. The output refered noise for the 100mV case is approximately 250nV/√Hz. The output referred noise of the DAC from 1KHz to 2KHz for 1mV and 10mV is approximately 71nV/√Hz. The output refered noise for the 100mV case is approximately 250nV/√Hz. . The hash and peaks seen in the stop band and around 3KHz appeared to be related to the measurement set up and not the DAC itself.

As an additional test the idle channel noise of the DAC was measured. In this test the software gain of the system was set to zero. This caused the software to put out a constant value corresponding to zero on every clock cycle. The figure below is a plot of the measured noise.

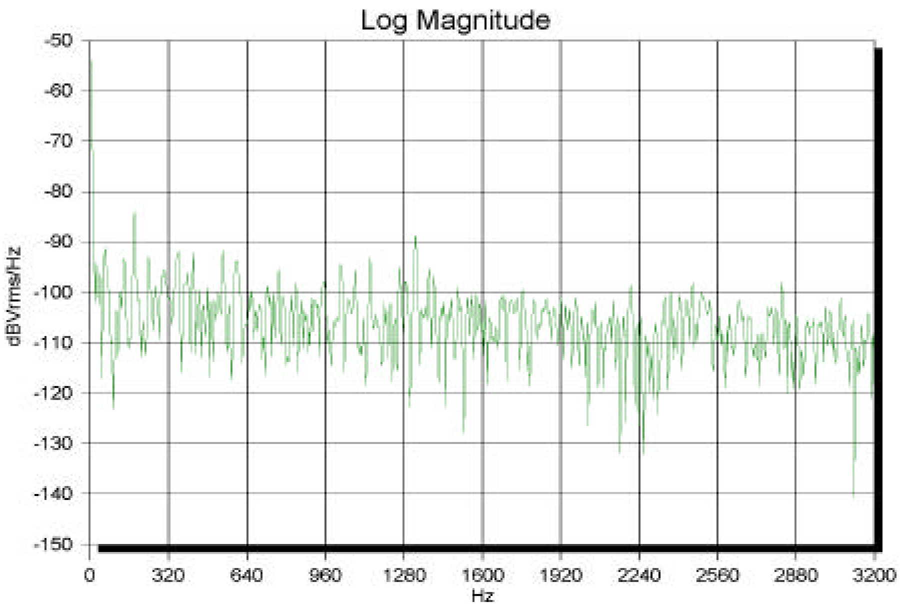

Figure 8: Idle Channel Noise Measurement

As can be seen from the plot, the average idle channel noise across the measurement band is less than 100nV/√Hz.

4 Conclusions and Recommendations

- During the testing there were several instances where output glitches we observed. The glitch incidence rate seemed to be the highest when the module was asked to output a sine wave in the 200mVp-p range. A few of these glitches were captured using an o-scope and it appeared as if both the positive and negative DAC outputs for the channel in question were outputting a value close to zero volts when they should have been outputting the next value in the sine function. The glitch rate appeared to be random and it is unlikely that the software was writing the wrong value to the module. Frequency Devices has been told about the glitch and they feel that they can fix it by tuning the phase of the clocks used on the board.
- The measured output noise for the module appears to be close to the 100nV/√Hz requirement when the single tone method is used. In the filtered random noise tests the output-referred noise is also close to the requirement for smaller output voltages, but was measured to be as high as 250nV/√Hz in the 1volt case.

- There appears to be a slight negative slope to the measured output noise in figures 7 and 8. This slope may be caused by the DC-DC converter noise that FDI had previously discovered. It may be advantageous for us to repeat the measurements with an external linear supply installed.