Advanced LIGO End Test Mass Transmission Monitor
LIGO-T0900423-v1

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1. Overview
A photodetector prototype has been built to serve as the Advanced LIGO End Test Mass (ETM) optical transmission monitor. This detector will be located within the vacuum envelope. Summary specifications and measured vs. simulated data are presented.

2. Circuit Description
This photodetector nominally uses an OSI Inc. Q3000, 3mm quadrant InGaAs photodiode at the detecting element. The 4 identical channels of the readout circuitry use a true current-to-voltage (I to V) converter topology with negligible input impedance at audio frequencies. A single stage of whitening is included consisting of: DC gain of 1, two zeros and two poles for a quasi-bandpass topology. This level of whitening is sufficient to ensure all signals down to the noise limit of the detector are transmitted in the vacuum system wiring at a level of 100nV/rtHz or larger at frequencies of ~0.5 Hz and above. A fully differential output driver stage is used to transmit the signal from the photodetector.

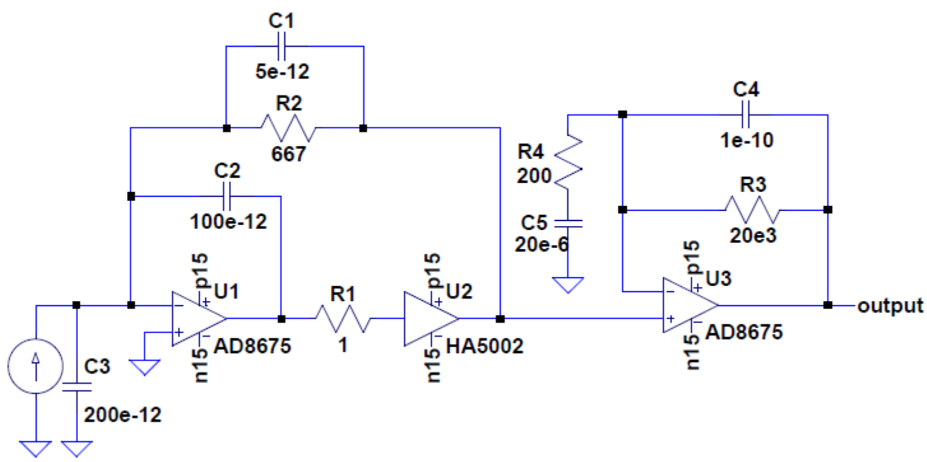
Internal regulators were used on the prototype for the DC operation amplifier supplies and the photodiode bias.

3. Overall Specifications
- 3.1. Quiescent DC Current - + 102mA, -82mA as measured on the prototype circuit with 3.81VDC photodiode bias.
- 3.2. DC Supplies - +18VDC, -18VDC
- 3.3. Transimpedance – 667 ohms (not including the differential driver gain)
- 3.4. Full Scale Photocurrent (per segment) – 15mA (produces 10VDC)
- 3.5. Maximum Steady-state Optical (total) – 100mW
- 3.6. Interface Connector – One 25 pin D-Sub.
- 3.7. Photodiode Replaceable with no tuning via socket-mount

4. Design Details

As seen in Figure 1, U1 and U2 form a transimpedance stage. The HA5002 is a no-frills, but reliable buffer that's easily capable of doing the job, and above all, is available. The choice of U1 results from a survey of available operational amplifiers, and produces the lowest combination of voltage and current noise for the operating transimpedance (667 ohms). The current source and C3 represent a simplified model of one segment of the Q3000 photodiode. C3 has a 100 ohm series resistance internally included in its model. U3 forms a whitening stage yielding: a DC gain of one, zero at 0.4Hz, pole at 40Hz, and a Pole at 80 kHz. An additional zero results from C4 and R4, although this zero is swamped by the bandwidth of U3.

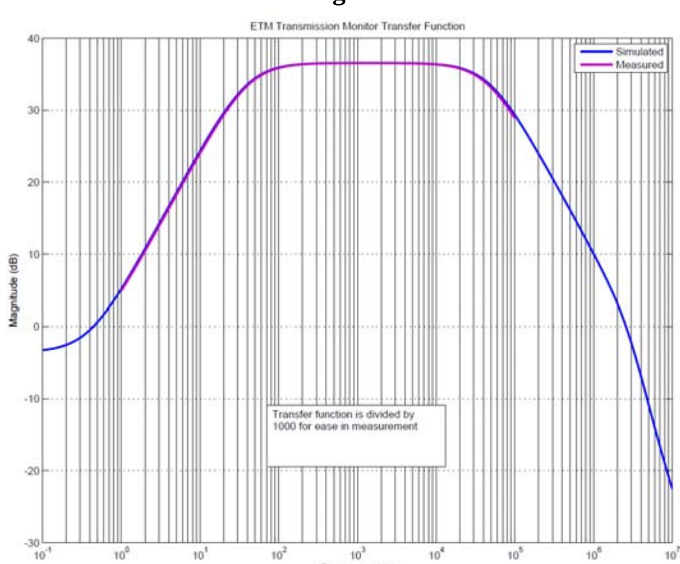
Figure 1



5. Transfer Function Plot

Figure 2 shows an overlay of the simulated and measured transfer function. In order to make the measurement simple, a 1k resistor was tacked onto the input to U1. The result of this is to divide the total gain by 1000 as reflected in the annotation. The true gain is 60dB higher than plotted (neglecting the differential driver gain).

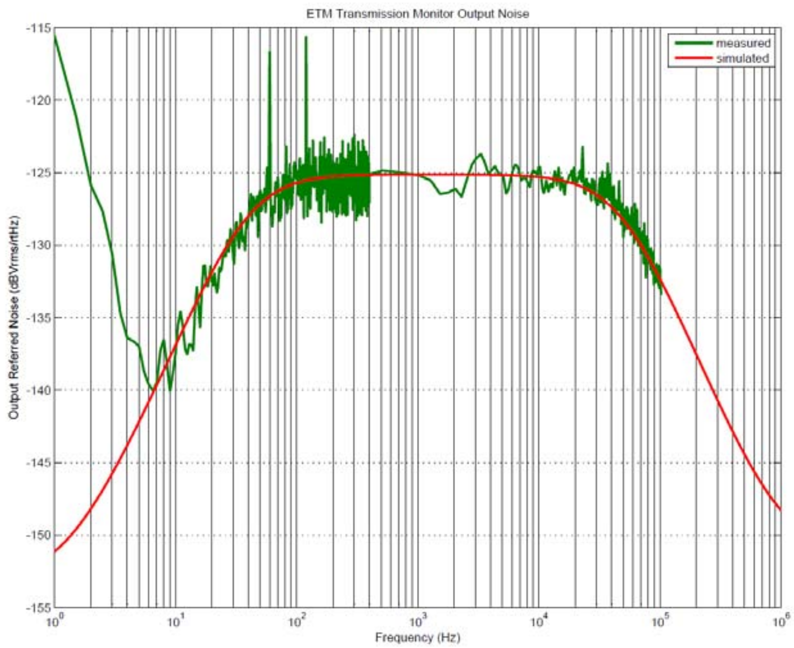
Figure 2



6. Output Noise Plot

Figure 3 shows an overlay of the simulated vs. measured output referred noise. The photodetector was biased at 3.81VDC, and shielded from stray light.

Figure 3



7. Input Referred Optical Noise

Trusting the results of the output noise plot in figure 3, a plot is shown in figure 4 depicting the equivalent input referred optical noise of 1064nm light incident on a photodiode of 95% quantum efficiency.

Figure 4