LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

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UK Satellite Amplifier Pre-Production Prototype Bench Test and Evaluation		
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1 Introduction

This tests report documents the bench test results and evaluation of the AdL Suspension Satellite Amplifier supplied as a pre-production prototype by the University of Birmingham. Bench tests were conducted in accordance with LIGO document number T080062-00-C, "AdL UK Satellite Amplifier Pre-Production Test Plan". A link to the completed test plan with results is included in Appendix A of this document. The design requirements for the Top Driver can be found in LIGO document number T060067-00-C, "AdL Quad Suspension UK Coil Driver Design Requirements".

The format of this report roughly follows the format of LIGO document T070288-00-C, "Adl Noise Prototype Electronics Test Plan". The tests outlined in T0700288-00-C are a series of tests and evaluations that will be used to evaluate the full set of electronics provided by the University of Birmingham for the AdL Quad Suspension system. The major categories of the plan are:

- Manufacturing
- Operational
- Performance

This test report covers relevant portions corresponding to each of these categories.

2 Manufacturing

2.1 Quality of Manufacture

The Satellite Amplifier provided to LIGO for testing and evaluation is a pre-production prototype and should be treated as such. Many of the comments and suggestions in this section relate to the prototype nature of the driver and should not be taken as criticism, but as general recommendations. The photos below show the Satellite Amplifier Box top cover and circuit board, respectively.

Figure 1: Satellite Amplifier Box Top Cover

Figure 2: Satellite Amplifier with Top Cover and attached Circuit Board Removed

2.1.1 Chassis Labeling and Identification

As can be seen from the first photo (Figure 1), all connectors and indicators are labeled. The serial number of the unit is also written on the cover. For the full production units, the drawing number associated with the chassis assembly drawing should also be added to front or rear panel labels.

Power indicators are included on the top cover and should be maintained in the production design.

2.1.2 Circuit Boards

The photo below is a closer view of the circuit board. As can be seen from the picture, the circuit board is multi-layer, professionally manufactured circuit board.

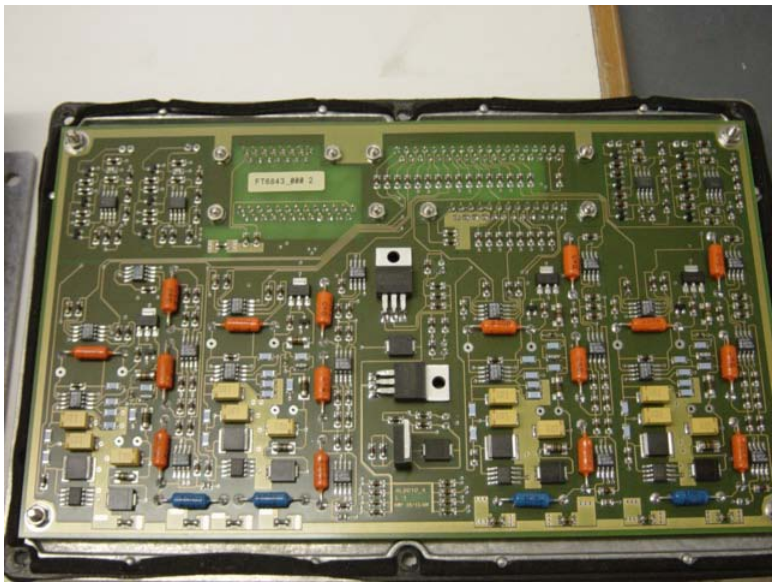

Figure 3: Closer view of Satellite Amplifier Circuit Board

The circuit board provided as the pre-production version did not include a silkscreen layer, but the silkscreen layer was provided on a paper printout with the boards. Lack of a silkscreen layer or some means of identifying components on the board other than the paper copy made evaluation, checkout and debug of the unit extremely difficult. The silkscreen layer must be included in the full production units.

Trace widths on the board appear to be 10-12 mils. Although this may be adequate, it is recommended that these widths be increased to a minimum of 15mils (0.381 mm). This will increase the reliability of the units as modifications and repairs are made over the life of the amplifiers.

The regulators used in the design are not tied to the circuit board and there is no thermal pad on the circuit board for the regulator tab. Adequate thermal pads, heatsinking and mounting hardware need to be included in the production units.

2.1.3 Cabling, Connectors and Harnesses

.As can be seen from the photos there are no internal wiring harnesses, cables and/or connectors in the unit. All connections to the circuit board are made via connectors that mount through holes in the amplifier box. This feature should me maintained in the production units.

2.2 Serviceability

The box used for the amplifier is a commercially available box and is adequate for the production units.

No test points are included on the circuit board. The lack of test points and a silkscreen layer make test, debug and repair of the amplifiers extremely difficult. Clearly identified test points need to be included in the production units. These test points should also be identified on the schematics.

2.3 Adequacy of Documentation

An incomplete set of schematics was provided with the pre-production units. No bill of materials, test plans, test results, quick start guide or other documentation was provided. Prior to production all materials listed in Electronics Requirements document (T060067) and LIGO document T000053-04-D, “Universal Suspension Subsystem Design Requirements Document” need to be evaluated.

3 Operational

3.1 Interfaces

The interfaces (connector types, pinouts, signal levels) between the University of Birmingham electronics and the AdL Electronics appear to be in compliance with Universal Design Requirements document (T000053).

3.2 Test Inputs and Monitoring

The design of the satellite amplifier and its use within the suspension system are such that separate test inputs are not required.

The design does have the following monitors available on a DB37 pin connector on the top cover:

- LED Current Monitors
- LED Voltage Monitors
- PD Amplifier Output Monitors
- Coil Voltage Monitors
- Power Supply Voltage Monitors

This set of monitors appears to be adequate for the production units with a few minor caveats.

1. The PD output monitors only look at one leg of the differential output. The design should be changed such that the monitor is a true measure of the full differential output voltage.
2. The pin out of the connections on the DB37 connectors does not lend itself to use with the standard twisted pair cable pin outs used throughout LIGO. If possible, the pin outs should be changed so that standard twisted pair cables can be used.

3.3 Long Term Reliability and Stability

The tests conducted on the Satellite Amplifier took place over a two week time frame where the unit was intermittently powered and turned off for testing. While no failures or stability issues were observed, this time period is inadequate to determine if there are any long term reliability or stability issues. Additionally, no overheating or heat management issues were observed. Noise Prototype testing at LASTI should last for many months and may provide addition information in this category.

4 Performance

Performance of the chassis was measured using the set of tests outlined in LIGO document T080062-00-C. The completed report is included in Appendix A. The sections below summarize the tests results.

4.1 Photodiode Amplifier Test

4.1.1 Amplifier Noise

The noise floor for the B-OSEM used in the AdL Quad noise prototype is approximately $5x10^{-11}$ m/√Hz at 10 Hz. This corresponds to a current noise of 1.3pA/√Hz at the output of the B-OSEM photodiode. The gain of the photodiode amplifier circuit designed for the Satellite Amplifier is 309Kohms. This leads to an output referred noise voltage of:

$$1.3\text{pA}/\sqrt{\text{Hz}} \times 309\text{K} = 402\ \text{nV}/\sqrt{\text{Hz}},$$

where the output is defined as the output of the satellite amplifier. The output noise of each PD amplifier was measured and the results of the measurements are shown in the table below.

Channel Number (Measurement Point)	Noise at 10Hz	Noise at 100Hz
1 (J2-14, J2-1)	145 nV/√Hz	140 nV/√Hz
2 (J2-15, J2-2)	175 nV/√Hz	125 nV/√Hz
3 (J2-16, J2-3)	160 nV/√Hz	155 nV/√Hz
4 (J2-17, J2-4)	124 nV/√Hz	145 nV/√Hz

Note that the actual measured noise of each channel is better than required to “see” the noise floor of the B-OSEM by approximately a factor of three. This factor of three safety factor can be increased by another factor of two with a small change to the design of the PD amplifier circuit. The design on the pre-production unit uses, as a first stage, an I/V circuit with a gain of 32.9Kohms. This I/V stage is then followed by a differential gain stage with a total gain of 9.4 V/V. If the first stage gain is increased to 150Kohms and the second stage gain decreased to 2 V/V, better noise performance of the circuit can be achieved.

After the initial requirements for the electronics were supplied to the UK group, the input-referred noise of the ADCs to be used for AdL prototypes and possibly for AdL Systems was measured to be approximately 3uV/√Hz. In order to match the output referred noise of the Satellite Amplifier PD signal to the input noise of the ADC a small amount of whitening is required. It would advantageous if this whitening were included in the design of the satellite amplifier PD circuit. The required

whitening would consist of a single zero at 0.4Hz and a single pole at 10Hz. This whitening stage would not need to be switched.

4.1.2 Amplifier Response

The response of ach PD amplifier was measured and found to be as expected. It should be noted that the design of the Satellite Amplifier is tailored for use with the B-OSEM which can be run without a reverse bias voltage applied across the PD. If this satellite amplifier is to be used with LIGO OSEMs, the ability to apply approximately 10V of reverse bias to each PD needs to be included. This may be done using on board jumpers and does not need to be remotely controlled or monitored. The PD used in the LIGO OSEMs is a Honeywell model SMD-2420. The datasheet for the PD can be viewed at: http://content.honeywell.com/sensing/prodinfo/infrared/006445_2.pdf

4.2 LED Current Driver

The LED current driver circuit was tested and found to provide the necessary 35mA current for each OSEM LED.

4.3 Monitors and Indicators

The monitors and indicators in the design were tested and found to operate as expected.

4.4 Environmental

No environmental tests were conducted during the bench testing of the pre-production prototype. Testing at LASTI should include measurements of the sensitivity of the design to external acoustic and magnetic noise. An assessment of the grounding and shielding of the system should also be made.

Appendix A

Test Plan and Results

A copy of the completed test plan for the Pre-production Satellite Amplifier can be found at:
http://www.ligo.caltech.edu/~jay/downloads/CompletedSatAmpTestPlan.pdf