LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

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UK Top Driver Pre-Production Prototype Bench Test and Evaluation

J. Heefner, T. Etzel

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This is an internal working note of the LIGO Laboratory

California Institute of Technology
LIGO Project – MS 18-33
Pasadena, CA 91125
Phone (626) 395-2129
Fax (626) 304-9834
E-mail: info@ligo.caltech.edu

Massachusetts Institute of Technology
LIGO Project – MS 20B-145
Cambridge, MA 01239
Phone (617) 253-4824
Fax (617) 253-7014
E-mail: info@ligo.mit.edu

www: http://www.ligo.caltech.edu/

1 Introduction

This tests report documents the bench test results and evaluation of the AdL Suspension Top Driver chassis supplied as a pre-production prototype by the University of Birmingham. Bench tests were conducted in accordance with LIGO document number T080014-v2, “AdL UK Top Coil Driver Pre-Production Test Plan”. 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 Top Driver chassis provided to LIGO for testing and evaluation is a pre-production prototype. The photos below are front and rear views of the Top Driver with the cover removed.

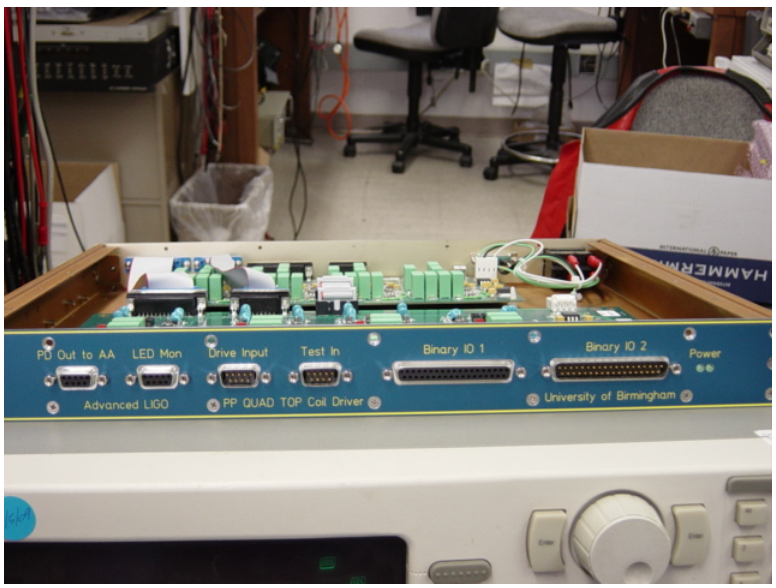

Figure 1: Top Driver Chassis Front

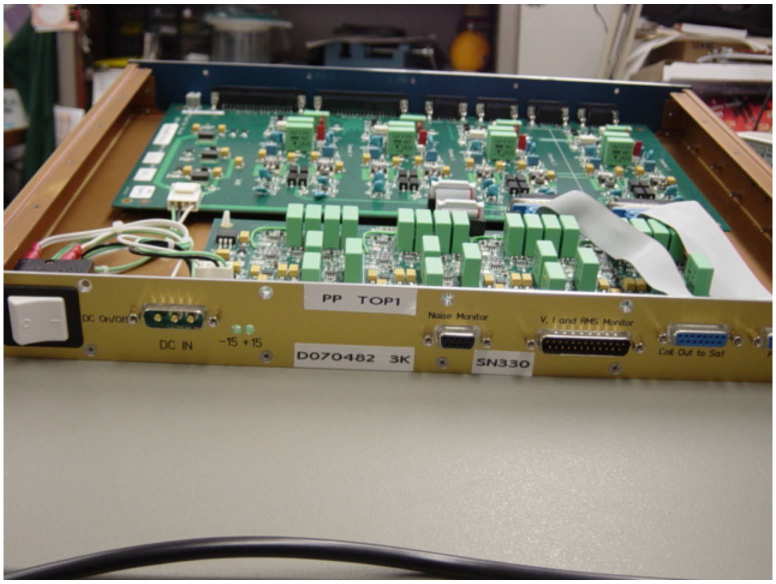

Figure 2: Top Driver Chassis Rear

As can be seen from the photos, the chassis are professionally assembled and the connectors are clearly labeled.

2.1.1 Chassis Labeling and Identification

Referring to the figures above, it can be seen that the chassis is identified with a serial number and the drawing number associated with the driver schematic.

Power indicators are included on the front and rear panels. These labels and power indicators as well as the power switch are acceptable for production units.

2.1.2 Circuit Boards

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

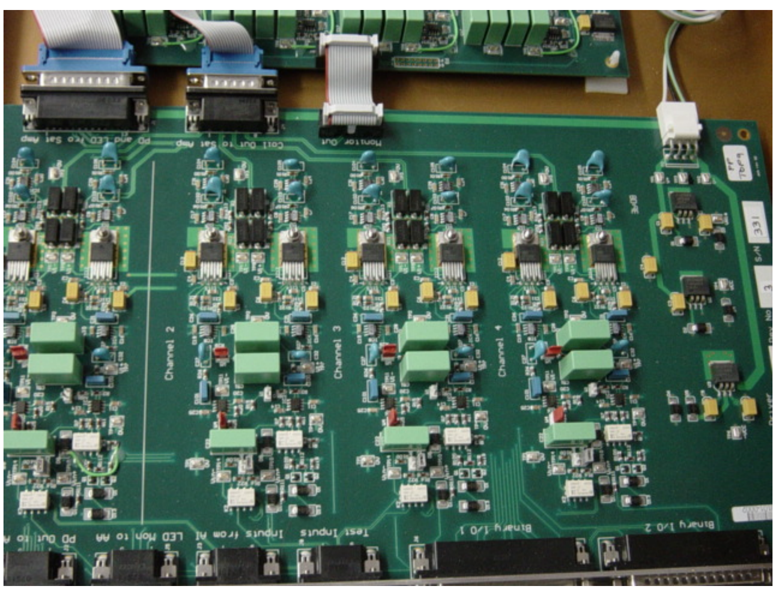

Figure 3: Top Driver Circuit Board

It cannot be clearly seen in the photograph, but the footprint used for the diodes is not correct and should probably be corrected prior to production as the spacing between the pads is much too large for the component used.

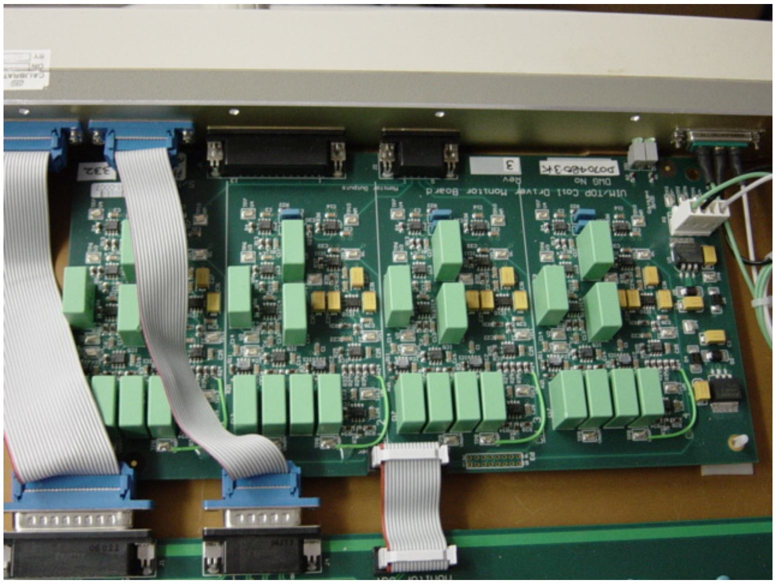

Figure 4: Monitor Board

The Monitor board (figure above) was manufactured in a similar fashion and the only circuit board issues observed were jumpers used to correct a design mistake (see figure below). The circuit board artwork should be corrected to eliminate the need for these jumpers prior to production. Both boards (driver and monitor) are identified in the space provided with the drawing number, revision number and serial number for the board. The circuit board (pcb artwork) revision number is included on the silkscreen for each board.

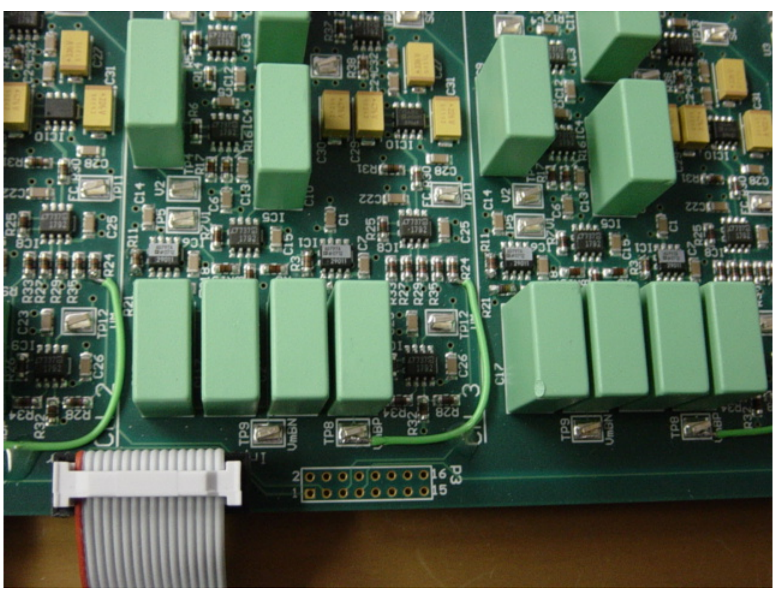

Figure 5: Monitor Board Jumpers

It cannot be clearly seen in any of the included pictures, but each of the circuit boards (Driver and Monitor) have many test points that are clearly labeled. These test points are the same SMT style that has been used in many LIGO and AdL designs.

2.1.3 Cabling, Connectors and Harnesses

All internal power wiring and cabling follows the standard LIGO color codes and is neatly routed and dressed. All chassis interface connectors are standard Dsub connectors and are acceptable for production.

2.2 Serviceability

The chassis used for the pre-production prototype is a Hamilton MetalCraft chassis which is the same type of chassis used for US AdL and Enhanced LIGO electronics. This chassis is acceptable for production as it allows for easy access to internal boards and is familiar to LIGO personnel.

Although a complete bill of materials was not provided, a check of the availability of the capacitors used in the critical portions of the circuit showed that they may not be readily available in the US. If this is the case, then an adequate number of spares need to be provided with the production units. The same can be said of any other components used in the designs. This possibility will need to be evaluated when a complete set of documentation is supplied.

The layout of the boards in the chassis, and positioning of the connectors allows for easy removal or access to the components on the boards.

2.3 Adequacy of Documentation

A complete set of schematics was provided with the pre-production units. Test plans and test results were also supplied with the unit. No bill of materials, 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" will need to be evaluated.

The only difficulty found with the test plans provided with the units was that in the transfer function measurements only the magnitude response of the unit is measured and recorded. Typically in AdL and LIGO systems both the magnitude and phase response of the devices is measured and recorded. In systems with multiple poles and zeros in the response the phase information has proved to be invaluable. It is strongly recommended that the test plans be revise to included tests of both magnitude and phase response.

Additionally, the complete Alitum project and all files required for production of the units will need to be provided.

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 Top Driver includes test inputs for each channel. These test inputs are connected to the input and can be enabled or disabled via an external control signal or a local board connection. When the test input is connected, the input from the control system is disconnected and visa versa. The use of the normally closed contact for the test input allows this relay to be used as a fail-safe enable/disable for the control input. All relays used in the design provide a separate read back of the actual relay position in accordance with the requirements. One observation worthy of mentioning is that when link W2 is left open and the test input switch in the normally closed position, there is no bias return path for op amps IC2 and IC6. This leads to amplifier offsets and drifts that may not be acceptable in AdL. It is recommended that W2 be installed.

Other monitors included in the design and in accordance with the requirements are:

- Low noise monitor of the driver output
- Fast output current monitor
- RMS current monitor

These appear to be adequate for use in AdL.

In the initial tests, there was a discrepancy between the predicted and measured values for the voltage, fast current and RMS current monitors for the +/-1V input of channel 1 of the chassis (Section 3.5.3 of the test plan). These channels were retested and the discrepancy was resolved.

3.3 Long Term Reliability and Stability

The tests conducted on the Top Driver took place over a two week time frame where the unit was intermittently powered and turned off for testing. Upon initial testing of channel 3 of the driver board, IC9 appeared to be damaged and was replaced. Once IC9 was replaced, the channel was retested and passed. It is not know when or how this IC was damaged. No other failures or stability issues were observed. Additionally, no overheating or heat management issues were observed.

4 Performance

Performance of the chassis was measured using the set of tests outlined in LIGO document T080014-v2. The sections below summarize the tests results.

4.1 Noise and Dynamic Range

4.1.1 Driver Noise

The noise requirements for the low noise mode of operation are outlined in T060067. For convenience the summary table from T060067 is repeated below.

Frequency	**Current Noise Requirement**
1 Hz	1 nA/√Hz
10 Hz	73 pA/√Hz
100 Hz	1000 nA/√Hz
1000 Hz	1000 nA/√Hz

Note that the requirements are given in units of current spectral density. Measuring current noise directly is very difficult so the tests performed measured the output voltage noise of the driver and the current noise inferred by dividing by the load impedance at the frequency of interest. The most stringent noise requirement is at at 10Hz. As can be seen in section 3.2 of the test plan, the driver appears to meet or be very close to meeting this requirement.

4.1.2 Monitor Noise

One of the requirements for monitors on the Top driver is a noise monitor capable of “seeing” output referred noise voltage of the driver at 10Hz (hardest requirement) in the low noise mode of operation. In an effort to do this, the University of Birmingham has designed a noise monitor that is a high gain AC coupled differential amplifier tied to the voltage output legs of the driver. The output referred noise of the driver at 10Hz should be less than 8nV/√Hz. This was tested, confirmed and described in the section above. Given the design of the noise monitor, the output noise of the monitor at 10Hz should be less than 1uV/√Hz. Simulations conducted at Caltech on the circuit design suggest that the output noise should be approximately 2uV/ √Hz which is above the requirement by a factor of 2. The measured noise at 10Hz was 2.2, 2.5, 4 and 5.6uV/√Hz for channels 1 through 4, respectively. In the test report received with the unit the output noise at the noise monitor output was -117.48, -118, -118 and -107 dBV/rtHz, for channels 1 through 4, respectively. This translates to 1.3, 1.25, 1.25 and 4.5uV/√Hz. The measurement for channel 4 is in line with the measurement made at Caltech, but the other channels measurements made by the University of Birmingham are lower. This discrepancy and the possibility that the circuit cannot meet the requirement should be resolved prior to production.

4.1.3 Dynamic Range

The dynamic range requirement for the Top Driver is +/-200 mA at DC. The dynamic range of the driver was tested in section 3.1.3 of the test plan. The driver appears to meet this requirement.

4.1.4 Transfer Function Measurements

4.1.4.1 Driver Transfer Function

The transfer function of the Top driver from input to current output was measured and compared to the Altium simulation. The driver transfer function appears to match the simulation very well. Note that the results shown in the test plan are from the input of the driver to the voltage measured across the 40 ohm load resistor so the actual gain Voltage in to Current out is 42dB less than the measurement.

4.1.4.2 Noise Monitor Transfer Function

The transfer function from the input of the driver to the output of the noise monitor circuit was measured in section 3.3.1 of the test plan. The measured transfer functions for all four channels were found to be in close agreement with the Altium simulation.

4.2 Local Damping

This section of the test plan is not applicable and can only be conducted on a full quad suspension system.

4.3 Environmental

No environmental tests were conducted during the bench testing of the pre-production prototype. Testing at LASTI or on the BSC Test Stands at LHO and LLO 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.