LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

-LIGO-

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UK Coil Driver Reviewer Comments Summary		
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1 Introduction

The purpose of this document is to summarize the comments from the review panel regarding the AdL SUS UK design effort. In preparation for review, the UK design team distributed document LIGO-T070008-00-K. The review team was comprised of LIGO Lab personnel not involved in the AdL SUS design effort. Review team members were: Rich Abbott, Josh Myers, Paul Schwinberg, Vern Sandberg and Daniel Sigg. Reviewers' comments have been grouped into three categories:

- General Observations and Comments
- Critical Design Issues- i.e. potential show-stoppers
- Non-critical Design Issues

2 General Comments and Observations

The review team regarded the submitted design status document as a work in progress and as representing a snapshot of the design that is likely to change and evolve as the final design progresses. It is the consensus of the reviewers that a more final set of schematics, design details and test results should be reviewed prior to production of the electronics for the SUS Quad noise prototype. Details that should be included in the next review should include:

- A full set of schematics for each board and or module
- Power supply details and requirements
- Detailed bill of materials
- More detailed designs of the monitor points used in the circuitry. The design presented does not detail any of the required monitors and these are critical to operational success in AdL.
- Status readbacks for all mode switches in the design. The design presented does not detail any of the required status monitors.

3 Critical Design Issues

3.1 Fully Differential Coil Driver Topology

A general concern for the floating inputs and the question of where do the coil-driver front ends get their bias currents? With no bias return to ground, it's not a given that the coil voltage is zero if the inputs are unplugged. Worse, the undefined path allows common-mode noise to sneak in.

The balanced differential without ground (earth) reference driver may seem like the ideal design but instead of setting the common mode voltage of the coil it simply passes all common mode signals through without attenuation and leaves the system subject to cross coupling and translation into the differential mode by stray couplings to ground. For this reason, we recommend that the differential input signal be converted into a single ended signal, referenced to the local ground, which then drives the differential output driver. The filtering is either imbedded as before and/or placed between the input and output stages. It should be noted that in the current design the two input poles are not as stated and interact so the pole frequencies move depending on the configuration switched in.

The US team may want to suggest a suitable single-ended design example or have a discussion directly with the UK designers. There is concern with the cost-benefit result that drives these fully differential filter designs. The UK should think seriously about abandoning the fully differential approach. Any decision we can make right now that has the potential of root 2 improvement in noise and a large reduction in component count is interesting. Tossing out the differential approach seems to offer hope of that.

3.2 Clarification of the Requirements for Range regarding Differential Designs

There appears to be a potential for a factor of two disconnect between the range requirements and differential inputs and outputs. We need to be clear on the meaning of phrases such as "20Vp-p" and similar specifications related to balanced signals and single-ended signals. This could easily lead to factor of two problems in the design. To elaborate, we need clarification about the single-ended vs. differential. It says the ranges are ±10V (20Vpp). We assume this is single-ended and that the differential spec would be ±20V (40Vpp). In the same spirit a 100nV/rtHz noise level at a single-ended input would translate to a 200nV/rtHz noise level differentially. We also assume that all DAC/ADC interfacing is fully differentially both ways.

3.3 Top Coil Driver Output Transistors

The transistors shown in the top coil driver schematic appear to be inadequate for the design. The requirement for the driver is to be capable of supplying 200mA to the coil. The maximum continuous collector current for both the 2N3904 and 2N3906 is 200mA. This is not sufficient margin. The reviewers suggest using a buffer amplifier in place of the transistors. The BUF634 is one possible candidate that has been used successfully in LIGO.

3.4 Switching Transients and Mode Switches

The design presented for the UIM Coil Driver uses very large capacitor values. Measurements of the transients associated with switching these large capacitances in and out of the circuit need to be made and documented. The reviewers recommend reducing the size of these capacitors to as small as possible by changing circuit topologies if necessary.

In addition, the circuit presented for the UIM coil driver may not lend itself to mode switching as we presently use it in LIGO. In LIGO we typically compensate for analog filters switching in and out of circuit using a compensating digital filter per analog filter stage. As stated above, the poles and zeros at the input of the UIM Coil Driver design presented will change depending on which filter stages are enabled or disabled. Compensation of these two filters will not be possible using the single digital filter compensation presently used in LIGO and AdL prototypes. The reviewers recommend that the circuit topology be changed such that the single compensating digital filter for each analog filter section can be used.

The design presented appears to be using reed relays. The actual parts used in the design will need to be evaluated for switching times so that switching of analog and digital filters can be coordinated. If possible, faster switches and possibly analog switches should be considered.

3.5 OSEM Force Coefficient

There is a potential problem with the force coefficient being used for the osems. We need to make sure that the UK design team was using the correct value. One type was 1.2N/A and the other is 2.05N/A. This could cause a factor of two error in the design.

3.6 Acoustic and Electrical Noise

Any hardware received from the UK eventually will need to be located in the LVEA and will need to be evaluated for acoustic and electrical noise. This should be part of any final design presentation.

4 Non-Critical Design Issues

4.1 Whitening and Dewhitening Filters and Requirements

There was general agreement among the reviewers that the requirements for whitening and dewhitening of signals be more fully integrated between the US and UK efforts. The requirements originally given to the UK design team call for minimum noise levels for signals at the US-UK interfaces to 100nV/√Hz or more. This may not be optimal from the standpoint of signal to noise or system design and performance. The most optimal design would place as much whitening and dewhitening in the UK electronics as possible. To this end, the US and UK should try to work towards a design where the minimum noise is at a level more consistent with the planned ADCs and DACs. The modules presently envisioned for the LASTI noise prototype tests have input and output referred noise levels closer to 10uV/√Hz. In addition, any filters placed in the UK electronics should be switchable.

4.2 LED Current Source and Window Comparator

The LED current source design may be overkill and can possibly be simplified. A quick calculation of the required current stability of the LED current source puts the level at approximately 400pA/√Hz. If this is indeed the case the design could be replaced by a filter voltage reference and series resistor to each LED. The calculated stability should be checked and if possible, the design simplified.

The window comparator on the LED source may not be necessary, but some reviewers feel that local indication of the operational status of the circuit has potential advantages.

4.3 Sallen-Key and Twin T Filters

In general, Sallen-Key designs have weaknesses for out of band signals. The Sallen-Key low pass filter has some limitation as well, see this article:
http://www.edn.com/article/CA6356063.html?nid=2433&rid=203906415 .

There was a general dislike of Twin-Tee notch filter design suggested. The reviewers suggest that a more detailed analysis of this design is needed and should take into account such things as:

- Sensitivity to component variations and tolerances
- Implementation of switching the filter in and out of the circuit.

4.4 Photocurrent Monitor

The photocurrent monitor shown in figure 12 of the design document does not reflect the “true” differential voltage being sent out of the module. The design of this monitor should be changed so that it is a measure of the differential sensor voltage output.

4.5 Component Choices

The US has had bad experiences with the AD797. The front end tends to blow up, ruining the noise figure but leaving the amp in an operational state. This failure can be very hard to track down and troubleshoot. The reviewers recommend using the Linear Technology substitutes such as the LT1028 family.

D. Sigg has just released LIGO-T070016, a document specifying nrecommendations on resistors and caps we will use internally in AdLIGO. It should be available in the DCC soon.

J. Heefner conducted some preliminary measurements on excess noise is resistors. The results of these test are summarized in document LIGO-T070019-01-C.