LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

-LIGO-

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HEPI Electronics Design

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1 Document Scope

The Hydraulic External Pre-isolator (HEPI) system and associated hydraulic pump control system are used in the seismic noise remediation effort at the LIGO observatories. During the prototype phase, much of the physical design has been tested and evaluated. The purpose of this document is to describe the electronics associated with the HEPI system, as it will appear in the first site installation at the LIGO Livingston Observatory (LLO).

Rather than delving into the details of electronics implementation, this document focuses on the completeness of the features and sensibility of the way the electronics are arranged.

The requirements for the HEPI electronics are described in LIGO-T030214-00-C, HEPI Electronics Requirements.

2 HEPI System Overview Diagram

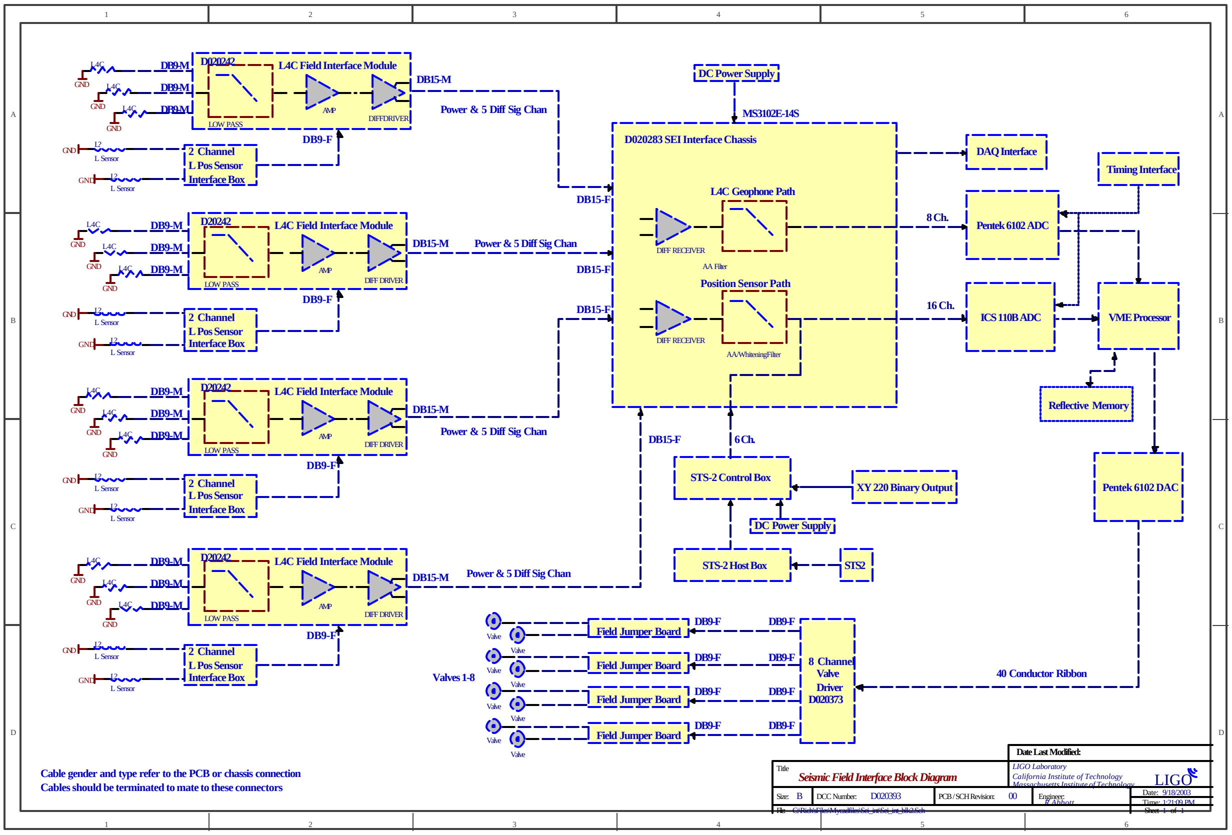

Figure 1: HEPI Overview

3 Detailed block descriptions

In the following sections, the characteristics are presented for the system blocks. In all cases, the electronics should be judged against our revised RFI mitigation procedures. All switching power supplies will be replaced with linear equivalents to the extent possible. The addition of features relative to the prototype will, most likely, result in significant re-design and re-packaging.

For the first site installation, a total of 9 chambers will be instrumented for HEPI - 7 in the corner station and 1 at each end station. The corner station implementation plays heavily in the architecture in order to make the best use of shared system components.

The corner station implementation will not require all the STS-2 inputs to be utilized. This opens the possibility of using these spare ADC channels in unforeseen applications

3.1 L4C Field Interface Box

The function of the L4C field interface board is to interface both the L4Cs and the inductive position sensors back to the rack-mounted receiver. Gain and filtering is locally applied to the L4C channels to ensure the output signals can reasonably be transmitted back to the control rack. The inductive position sensors inputs are a simple 'pass through' to facilitate efficient cabling back to the rack.

3.1.1 Inputs

- DC power from rack

3.1.2 Outputs

- 3 differential channels of L4C coil readout
- 2 differential channels of inductive position sensors
- DC power to the inductive position sensor

3.2 Required changes from prototype

- Change the plastic box to a metal box for better shielding
- Review the physical mounting to the pier to ensure good performance in the field

3.3 SEI Interface Chassis

The SEI interface chassis functions as the central interface point for the HEPI system. The key features and functions of this block are:

- Provide differential receivers for the L4Cs, inductive position sensors and a single STS-2 tri-axial seismometer
- Provide anti-aliasing for all analog channels being fed into the ADCs. The prototype used ~750 Hz 2nd order Butterworth filters which were fine at the higher sample rates, but which are probably insufficient at 2048 Hz sample frequency. A 4th order Chebyshev, 0.1 dB ripple filter with a cutoff frequency of 750 Hz will be used as a standard filter. The resulting insertion phase at 30 Hz is ~5.6 degrees.

- Provide signal whitening for each channel of inductive position sensor
- Provide physical interface to the ICS-110B and Pentek 6102 ADCs
- Provide DC power to the L4C field interface boxes to ensure control of ground loops that could occur with locally derived power sources

This central box approach is a best compromise of packaging and cabling. Only one cable is needed to each pier for sensing and power distribution thus minimizing loop coupling area and installation time.

The Pentek and ICS-110B ADCs provide a total of 24 channels of ADC data per chamber. These thresholds are set by efficient use of VME cards and cabling ease. Exceeding these numbers will result in purchasing additional VME cards for each chamber

3.3.1 SEI interface chassis inputs

- 12 channels of L4Cgeophones – 4 horizontal, 4 vertical and 4 witness channels
- 8 channels of inductive position sensors
- 3 channels from a STS-2 seismometer consisting of X, Y, and Z signals
- 3 channels from an STS-2 seismometer consisting of the 3 mass position sensor signals
- DC power from a rack mounted linear supply

3.3.2 SEI interface chassis Outputs

- One connector routing all 8 differential L4C channels to a single Pentek 6102 card. This fully uses all of the available inputs to the 6102. These signals must be voltage limited so as not to overdrive the ADC inputs.
- One connector routing 4 witness L4Cs, 8 channels of inductive position, and 3 channels of STS-2 (X, Y, and Z) for a total of 15 out of the available 16 channels. These signals must also be voltage limited so as not to overdrive the ADC inputs
- DAQ interface to route all 26 channels to the DAQ system. This will require a separate module to efficiently connect to the current DAQ interface. It isn't desirable to route many individual cables as would otherwise be needed.

3.3.3 SEI interface chassis physical construction

This portion of the system needs the most work. Instead of a single massive circuit board, several smaller boards of dedicated function will best implement this chassis. A reasonable distribution would be:

- Differential receiver board
- Anti-aliasing and whitening filter board
- Pentek ADC interface board
- ICS ADC interface board
- DAQ interface board

Breaking down boards by function increases the interconnection complexity, but results in a more manageable overall design. The issues of packaging are also more easily addressed in this configuration.

3.4 Required changes from prototype

- Split the board function per section 3.2.3 of this document
- Change the anti-aliasing filter per new requirements

- Move the whitening filters to the correct channel
- Fix some CAD errors on the differential drivers
- Implement a convenient physical interface to the ADCs
- Remove switching supply and replace with linear equivalent
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3.5 STS-2 Control Box

The STS-2 control box provides all the care and feeding previously provided by the "LSU Purple Box". Interface to the STS-2 is via the 'host box' that is commercially supplied with the STS-2. This host box serves as a passive interface that also provides some convenient local breakout functions. It is desirable to provide some front panel inputs and outputs on this chassis for infrequent setup functions.

The original prototype tested at LASTI needed repackaging (it had a separate Euro-card receiver module) and also required the addition of local (front panel) mass position outputs.

3.5.1 STS-2 Control Box Inputs

- Control bit for mass centering input (from VME based XY220)
- Control bit for selection of low frequency corner period (from VME based XY220)
- Control bit for connection/disconnection of the calibration lines (from VME based XY220)
- Control bit for selection of position or raw sensor outputs (from VME based XY220)
- Front panel BNC inputs for the 3 calibration coils
- DC power to be routed to the STS-2 through the host box
- 3 channels of position data from the STS-2 (X, Y and Z)
- 3 channels of mass position information

3.5.2 STS-2 Control Box Outputs

- 3 differential channels of X, Y and Z outputs
- 3 differential channels of mass position information
- DC power output to the host box

3.6 Required changes from prototype

The prototype module consisted of two circuit boards. From an electrical standpoint, the prototype was sufficient. The needed change summary is:

- Re-package for better physical interface
- Add front panel mass position outputs
- Replace switching power supply with linear

3.7 Pentek 6102 ADC/DAC

This VME based ADC has 16 bits input and output and has less latency than the ICS-110B. A single card has 8 channels of ADC and 8 channels of DAC. The HEPI system currently uses all inputs and outputs to this card. The critical L4C channels used in the highest frequency portion of the blended sensor array are routed to this ADC. The lower frequency sensors, or sensors not used in the closed loop response, are routed through the slower ICS-110B.

The DAC outputs to the valve driver boards can be gated on and off as needed as part of a software shutdown function.

3.8 ICS-110B ADC

This VME based 16-bit ADC has a total of 32 channels accessible through 2 input connectors on the front panel. A single chamber is serviced by one of the two input connectors allowing efficient use of these expensive modules in the corner station.

3.9 8 Channel Valve Driver

This block will be housed in a rack-mounted chassis and will provide interface between the 8 DAC outputs and the 8 hydraulic control valves. The interface is by a shielded twisted ribbon cable that can be mass terminated for ease of manufacture. Each valve driver channel provides a current source output to the respective valve. The valve driver specifications are

- Current drive of +/- 80 mA with a limit set by a resistor on the circuit board
- Voltage input range of +/- 10 V with user configurable current to voltage transfer function
- +/- 15 VDC power input for power supply derived from rack power.

3.10 Required changes from prototype

The valve driver has recently been revised due to parts obsolescence. The only change needed for the HEPI installation would be a repackaging into a rack-mounted configuration.

3.11 Field Jumper Board

This passive module provides a breakout point allowing two hydraulic valves to be driven from one cable. This board also allows the user to reconfigure the windings of one valve with respect to the other. It is not clear that later function is still needed in the current system.

3.12 Timing System interface

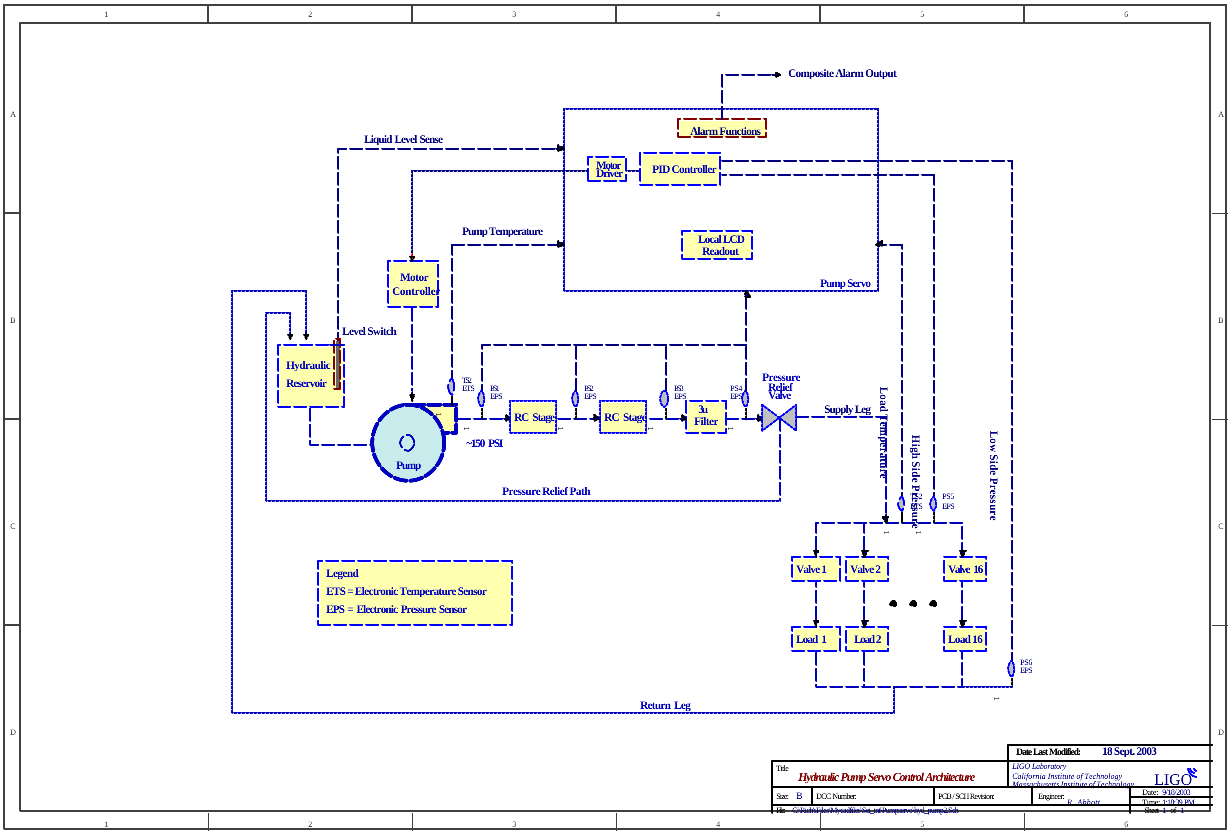
The Pentek and ICS-110B ADCs require clock inputs. The clock distribution components used at LIGO are suitable for this. In the corner station, some sharing of timing system components may be possible, but at worst case the breakdown of timing system boards needed for a single chamber is:

- 1 Slaved GPS Clock Driver Board
- 1 Pentek Clock Driver Board
- 1 ICS Clock Driver Board
- 1 ICS Clock Fan-out board

4 Hydraulic Pump Station Overview

The pump station is regarded as an autonomous system having only the simplest of external interfaces. A detailed description can be obtained in **LIGO-T020193-00-C,** The pump servo users guide. An overview of the system can be seen in figure 2.

Figure 2 Overview of the hydraulic pump station controls



4.1 Pump Servo Controller Feature Summary

The pump servo is implemented with a dedicated microprocessor based design. Many features were designed in to the unit to allow future expansion. The unit can communicate any measured parameter by RS-232, and could control an external RS-232 device for data acquisition.

The pump servo has a composite alarm bit that serves as the sole external indication of status. This is a configurable alarm that presently generates an alarm condition when:

- Any temperature or fluid level sensor is disconnected
- A high temperature condition (>54 degrees C.) is measured at either the remote valves or the pump body
- A low fluid level is detected by the micro-switch input mounted on the hydraulic fluid reservoir

- It is possible to configure this bit to represent any combination of pressure, temperature or level that is read by the pump servo controller

4.2 Required or just plain convenient changes from the prototype

The prototype pump servo is missing the following critical features:

- External kill input
- Isolation amplifier for proper interface to the noisy ground of the commercial motor controller
- On-the-board conveniences to make the new range of sensors easy to implement. The prototype was reconfigured from 8 pressure sensors to 5 pressure sensors, 1 level sensor and 2 temperature sensors.
- Better provisions for analog outputs to interface with DAQ