LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

LIGO Laboratory / LIGO Scientific Collaboration

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Suspension Watchdog Requirements

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1 Introduction

The purpose of this document is to describe the requirements for a suspension protection system.

2 Overview

The intent of the suspension (SUS) protection system is to provide an independent means to protect all aLIGO quadruple and triple suspension systems from mechanical damage due to:

1) Possible errors in the software that provides control for the suspension system or to the seismic isolation (SEI) systems on to which the suspension systems are mounted.
2) Faults in the hardware that provide the drive signals to the suspension and seismic isolation systems.

In general terms, this protection is to be provided by:

1) Monitoring top OSEM position sensors for large oscillations, as detected by Root Mean Square (RMS) calculations.
2) When RMS values exceed fault trip points for a specified period of time, turn off the electronics which provide the drive power to SEI systems associated with that suspension's chamber.
3) If the fault condition continues beyond a TBD time period after (2) above, remove all suspension coil drive capabilities.

Presently, protection is provided via software "watchdogs" built into the control models for SUS and SEI systems. This software detects faults and then responds to faults by sending all 0 (zero) outputs to the associated Digital to Analog Convertor (DAC) modules that provide the actuator drive systems via various electronics hardware. It is intended that these watchdogs remain in place and provide the first line of protection.

The new independent watchdog (IWD) system is intended to be the last line of protection in the event that the computer equipment or software has failed to correct the problem, or the problem is beyond the "reach" of the computer and software i.e. fault has occurred in the drive hardware itself and the computer shutting off the DAC outputs would have no effect. Therefore, a couple of additional general requirements for this system:

1) The system must provide sufficient time lag, prior to taking shutdown action, for the computer and software to detect and attempt to correct the problem.
2) The system must have direct access to the electronics that provide the drive signals to the actuators, sufficient to at least reduce the drive signals below levels that may cause damage.

3 System Requirements

A basic block diagram of the IWD for a single suspension (IWD Unit, IWDU) is shown in the following figure. This diagram depicts the primary input/output signals, and key components of the IWD. It also shows the basic differences between quad and triple suspensions, which are primarily:

1) Triple has only three satellite amplifiers, as opposed to five needed for a quad suspension system.
2) BSC chambers contain a single quad suspension. However, a HAM chamber may contain up to four triple suspensions. This requires the IWD for HAM chambers to include the “Multi Suspension AND Gate” feature, either within an IWDS unit or as a separate chassis.

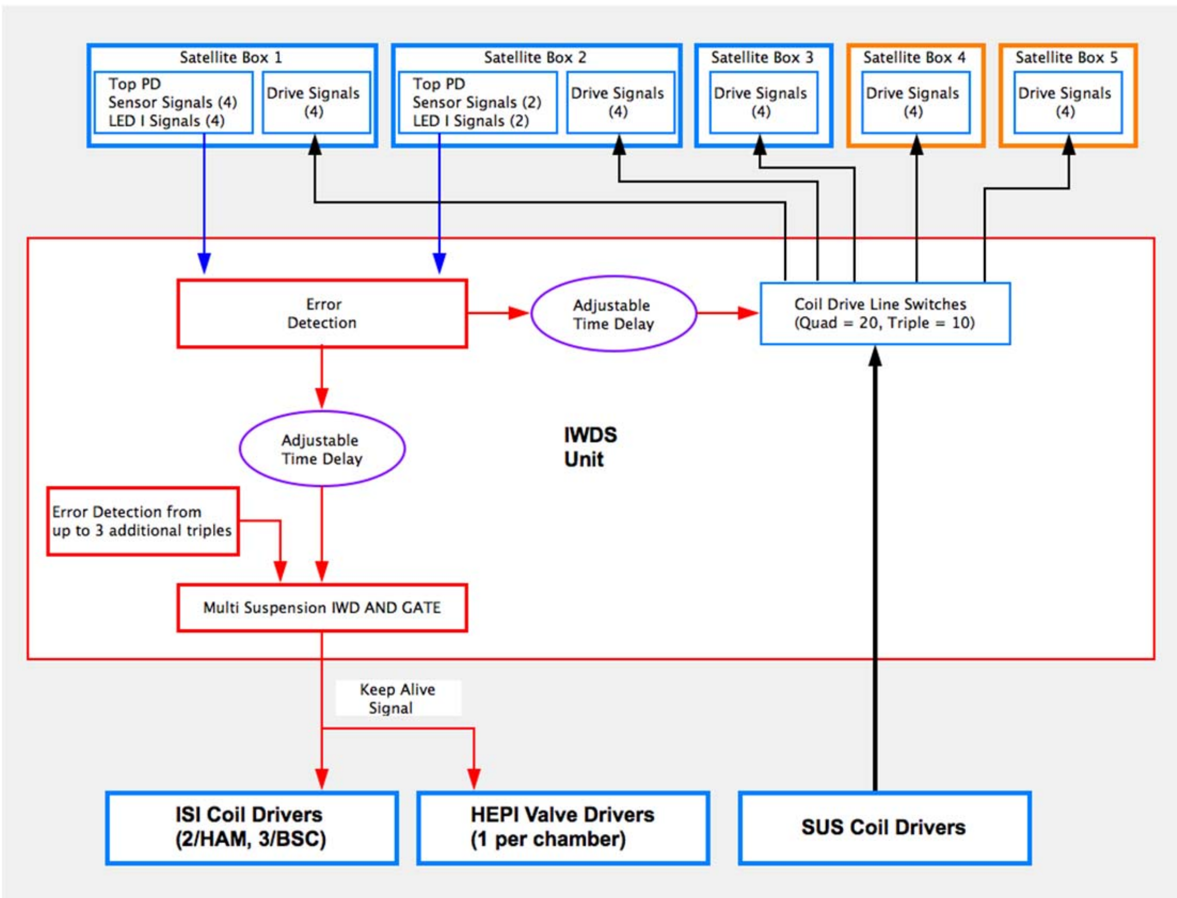

Figure 1: Basic Quad Suspension Diagram

The following diagram is provided to show a more global view, showing the various chambers and optics in each, and how the IWDS combine in a site view.

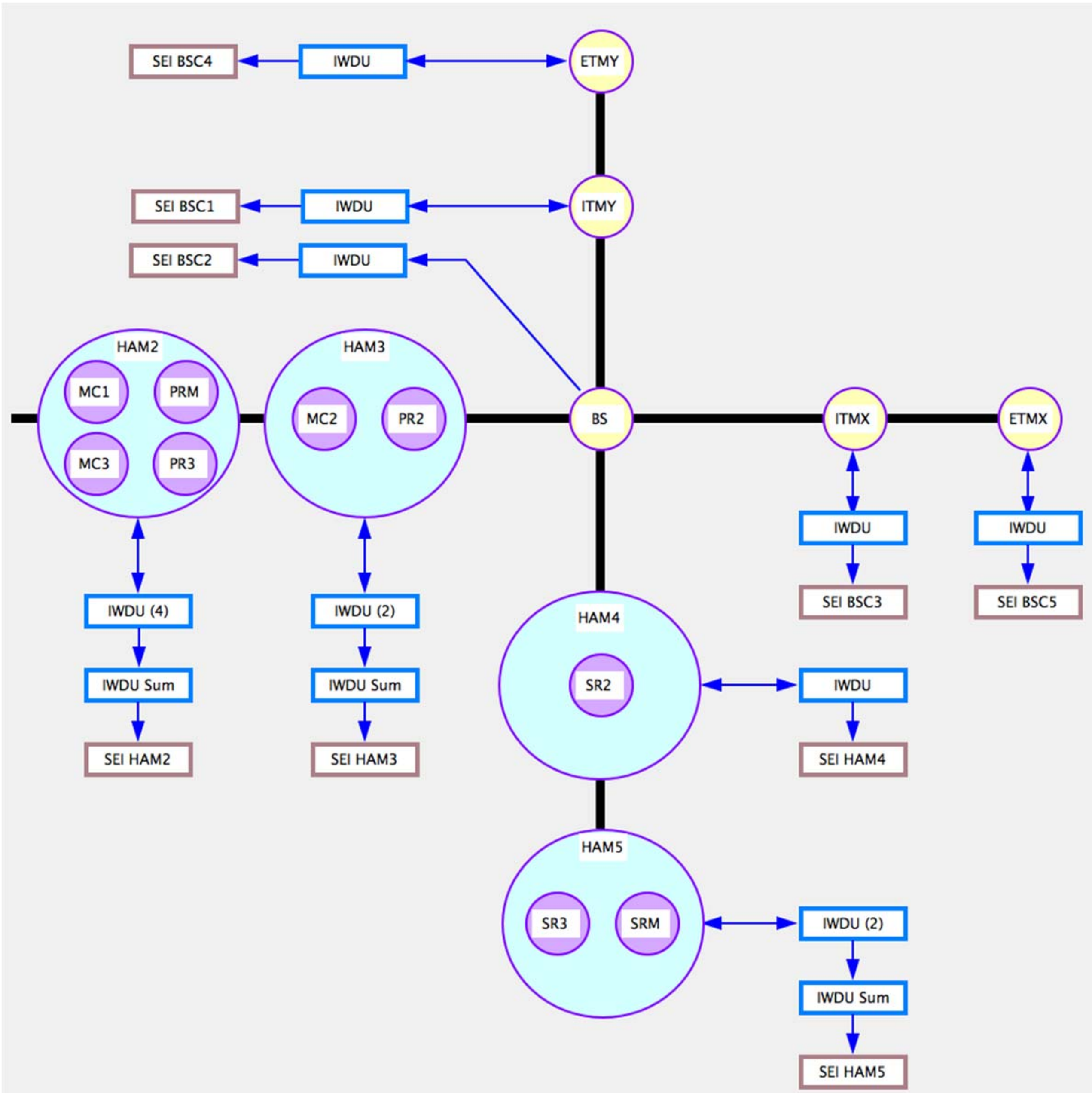

Figure 2: IFO View

3.1 Signal Inputs

3.1.1 Sensor Signals

For each quad/triple suspension, the IWDU shall monitor the following signals:

1) Photodiode (PD) sensor signals from the top stage (6 each).
2) LED current signals from the top stage (6 each).

These signals are available at several locations, as shown in the following figure.

1) PD signals may be extracted at locations marker 1, 2 and 3.
2) LED signals may only be accessed at J4 of the satellite amplifier unit (Local Diagnostics Connector). The connector is not presently attached to the control system.

If location 2 or 3 is used by the IWD to obtain the PD signals:

a. The IWD must pass the signals through to the coil drivers (2) or AA chassis (3).
b. The IWD must in no manner degrade the signal fidelity in the pass through process.

Location 1 is the preferred signal pickup point:

1) Not presently used and therefore an independent signal path.
2) Only location to obtain both PD and LED current signals.

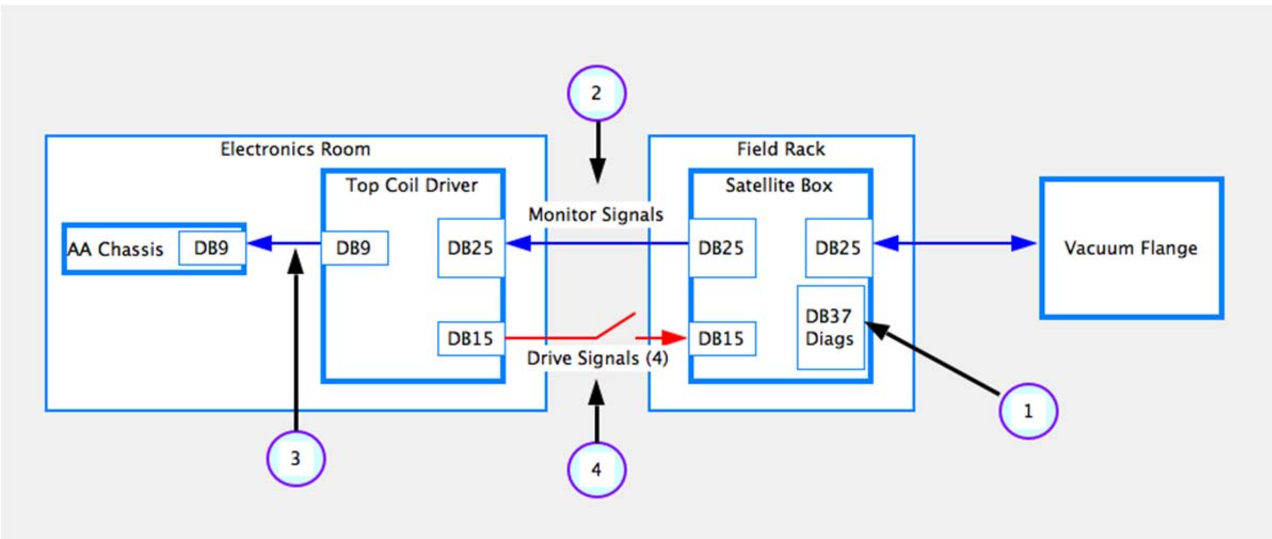

Figure 3: Basic Suspension Signal Chain

Referring back to Figure 1, two connections are required to pick up the six top PD/LED signals, 4 from one unit and two from another.

3.1.2 Suspension Coil Drive Signals

If a fault condition is detected by the IWDU, as described in Section 3.2 Error Detection, it is required that the coil drive signals be removed from all stages of the associated quad/triple suspension system. This requires that the drive signals from the suspension coil drivers be passed through and switched by the IWDU, shown as (4) in figure 2 above. Note that simply shutting off power to the suspension coil drivers is not an option, as the coil drivers provide power to the satellite amplifiers. If power is lost to these units, then monitoring signals are no longer available.

3.2 Error Detection

A block diagram of the error detection circuitry requirements is shown in Figure 4: Error Detection Block Diagram.

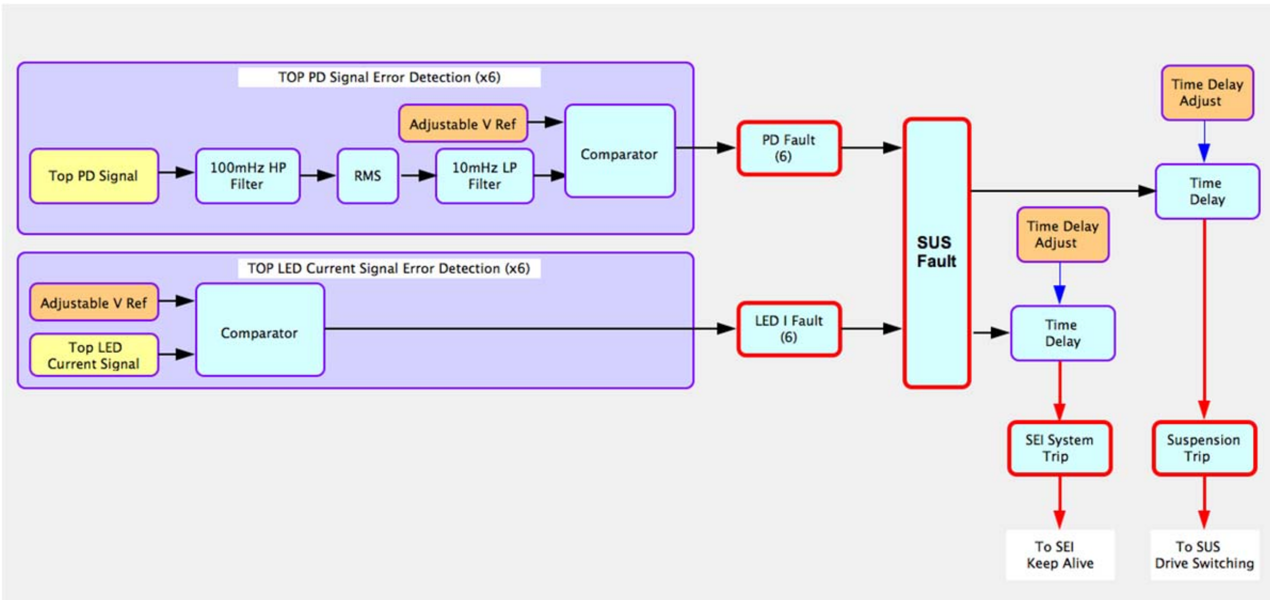

Figure 4: Error Detection Block Diagram

3.2.1 PD Signals

The PD signal processing chain is shown in the upper left of the figure above. A PD fault indication shall occur whenever the RMS value exceeds the adjustable reference set point. The reference point adjustment shall be variable across the full signal range of the RMS output signal.

3.2.2 LED Current Signals

Typically, PD signals in the zero volt range fall within the allowable (OK) signal range. However, this reading is also possible if there is no LED light provided to the PD sensors, or a cable is disconnected, etc. Therefore, the LED current signals are to be monitored to verify cable integrity and that light is being produced for the shadow sensors.

1) All top LED current signals shall be monitored and compared to local reference voltages, adjustable over the complete signal range.
2) If the LED current signal falls below the compared voltage reference, a LED fault indication shall occur.

3.2.3 Fault Signal Summation

The outputs from the 6 PD and 6 LED error detection chains shall be logically combined to produce a single SUS Fault indication if any single chain indicates a fault condition.

3.2.4 Trip (Shutdown) Signals

The SUS Fault signal shall be used to set two trip (shutdown) signals.

1) SEI System Trip
2) SUS Trip

Independent, adjustable time delays, shall be provided for each trip signal. If the SUS Fault persists continuously >= to the time delay setting, then a trip condition shall be set.

1) Time delay shall be adjustable in range of 5 minutes to 20 minutes.
2) It is intended that the SEI System trip always occur before the Suspension trip.
3) If the SUS Fault clears before the specified time delay, then the timer shall reset to zero and start over on the next occurrence of a SUS Fault signal.

3.2.5 Fault Latching and Reset

Once a trip signal is generated after the time delay, this trip signal shall be latched i.e. even if monitored signals move back within the OK range, the final fault output shall not be automatically cleared.

To clear the fault condition, a manual reset shall be provided:

1) Shall be a physical, mechanical momentary switching device.
2) Shall not be capable of being remotely controlled.
3) Shall only reset if there is not a fault indicated by the SUS Fault block.

3.2.6 Multiple Optics per Chamber

In the case of multiple triple suspensions within a single chamber, the IWD must provide another summation point of up to four SEI System trip signals, one per suspension.

3.3 Suspension Coil Drive Switching

3.4 Signal Outputs

3.4.1 SEI System Keep Alive

The IWD shall provide a BNC connection output to transmit a status signal to the SEI coil driver electronics chassis. This output shall provide the following signal levels:

1) Open: Trip condition
2) 5VDC: OK condition; at a 5VDC level, the IWD must provide a minimum drive current capability of TBD.

3.4.2 SUS Coil Drive Signals

The IWD shall provide a shut off capability to the SUS drive at either the:

1) SUS coil drivers, via the TEST relay inputs, or
2) SUS satellite amplifiers, by opening the drive signals between the top coil driver chassis and the satellite amplifier drive signal inputs.

3.4.3 IWD Monitoring Signals

The IWD shall provide monitoring capabilities for the following signals:

1) The six RMS output values for each top PD.
2) Status of the two trip signals -This output shall provide the following signal levels: SEI trip and SUS trip.

3.4.4 Notes from Conceptual Design Review at CDS Meeting 22 August, 2012

1) Carl Adams points out that there will not be DC power in the SUS field racks.
2) Brian Lantz points out that we should pay attention to the way the system rides out a site power loss. How does the system react once power is restored, especially as relates to the manual reset switches
3) Dennis made the decision that only the QUAD suspensions will be outfitted with hardware interlocks for the initial design
4) A consensus decision was made to have a remote reset capability
5) Green LEDs will designate an “OK” condition, and red LEDs will designate a fault condition
6) All local LED indicators must be available in a remote diagnostic connector compatible with a binary input monitor so that the state of the interlocks may be viewed remotely.
7) A system level checkout must be done on the hardware interlock prior to implementation in the field. It may be that a computer emulator can act as a test bed for the interlock checkout.