

LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY
- LIGO -
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Suspension Test Stand Operator's Manual
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1 INTRODUCTION

1.1. Scope

This document covers the operation and control of the suspension test stand control electronics installed at the Hanford and Livingston sites. Detailed descriptions of each electronics module are not covered by this document.

1.2. Purpose

The purpose of this document is to provide a general overview of the test stand control electronics. This general overview should be sufficient for operators to use in normal day to day operation of the systems. The document includes general troubleshooting guidelines and tips that the operators can use to detect and possibly correct system problems.

It should be noted that the test stand actually houses two identical suspension control systems that can be used independently. The descriptions and procedures outlined in this document apply to both systems.

1.3. Document Organization

The document is organized into the following sections:

- Operator interfaces- descriptions of each operator interface including the location of the MEDM files.
- Electronics- block diagram level descriptions of each module.
- Software- file names of the databases and state notation programs and a brief description of their function.
- Troubleshooting- Troubleshooting guidelines and tips for the system.
- Schematics- detailed schematics for the systems and each module.

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1.4. Suspension System Block Diagram

The figure below is a block diagram of a typical suspension control system.

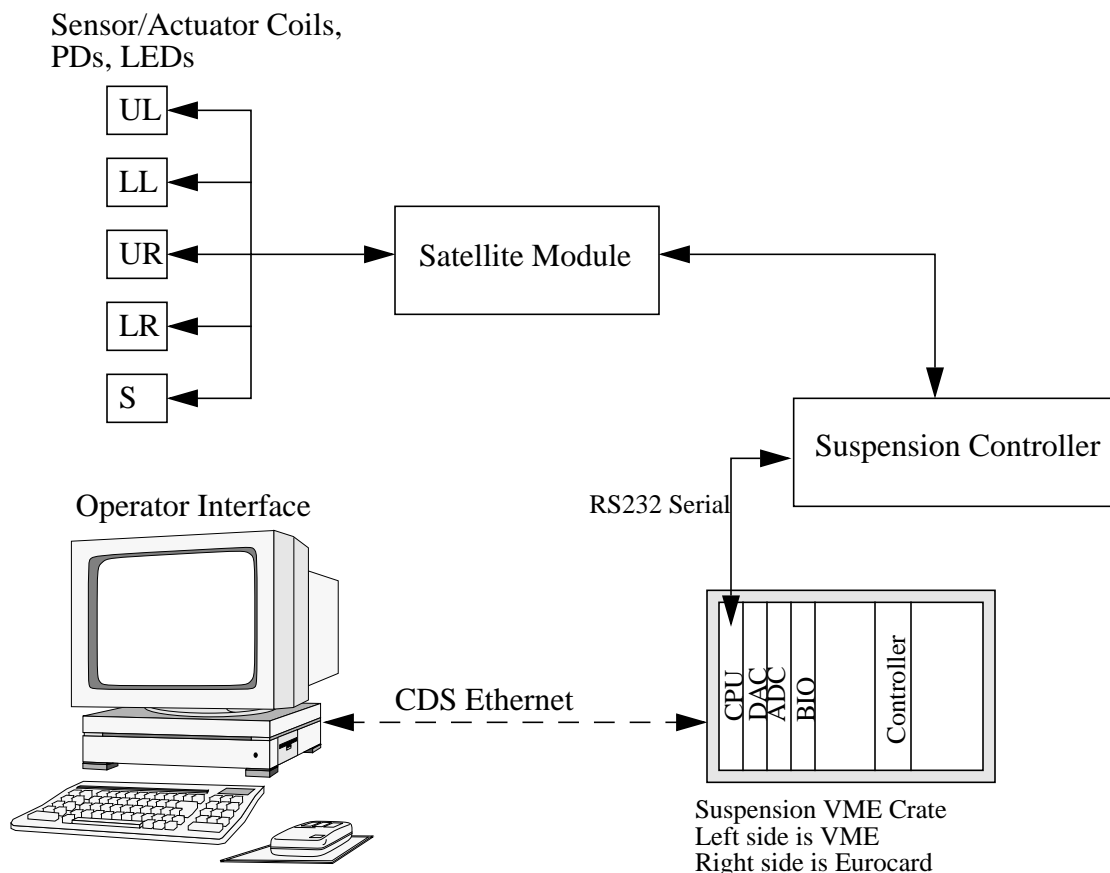


Figure 1: Suspension Control System Block Diagram

The sensor/actuator heads shown in the figure include the LEDs and photodiodes used for local orientation sensing and the coils used to control the orientation of the optic under control. The coils, LEDs and PDs are connected to the suspension satellite module using a combination of multiconductor cables and connectors that take the place of the cables and connectors internal and external to the vacuum system in an interferometer suspension system.

The satellite module provides the following functions:

- local amplification (current to voltage conversion) of the signal from each photodiode
- current supply for each LED
- connection of coil drive signals from controller coil drive circuitry to orientation coils.

The suspension controller is the heart of the suspension control system and provides the functionality described in section 3.2 of this document.

The suspension VME crate contains the VME CPU, ADCs, DACs and BIO modules that are used to control the system. The CPU is a Motorola MVME162-333 processor running VxWorks OS and the EPICS control software. Detailed descriptions of EPICS and VxWorks are outside the scope of this document and can be obtained from various sources. The filenames for the EPICS databases and state notation programs used by the test stand suspension control systems are listed in section 4 of this document.

The operator interface is any CDS operator station that has been setup to run the EPICS operator interface software (MEDM). Detailed descriptions of the operation of MEDM is outside the scope of this document and can be obtained from various sources. The filenames for the test stand suspension operator screens and a brief description of each is covered in section 2 of this document.

2 OPERATOR INTERFACES

2.1. Screen Organization and File Names

The operator interfaces for the suspension controls are hierarchially organized. This hierarchy is shown in the figure below. All operator screens are located in the directory /opt/CDS/epics/apple/Hanford/sus/opi/medm.

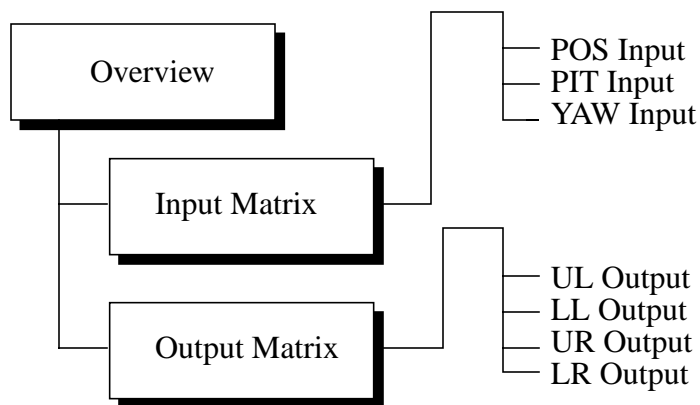


Figure 2: Suspension Controls Operator Screen Organization

Table 1: Suspension Test Stand Operator Interfaces

<i>Operator Screen</i>	<i>Description</i>	<i>Filename</i>
SOS1TS_Overview	Controller 1 overview screen	SOS1TS_Overview.adl
SOS1TS_POS_IN	Controller 1 Position input matrix	SOS1TS_POS_IN.adl
SOS1TS_PIT_IN	Controller 1 Pitch input matrix	SOS1TS_PIT_IN.adl

Table 1: Suspension Test Stand Operator Interfaces

<i>Operator Screen</i>	<i>Description</i>	<i>Filename</i>
SOS1TS_YAW_IN	Controller 1 Yaw input matrix	SOS1TS_YAW_IN.adl
SOS1TS_UL_OUT	Controller 1 UL output matrix	SOS1TS_UL_OUT.adl
SOS1TS_LL_OUT	Controller 1 LL output matrix	SOS1TS_LL_OUT.adl
SOS1TS_UR_OUT	Controller 1 UR output matrix	SOS1TS_UR_OUT.adl
SOS1TS_LR_OUT	Controller 1 LR output matrix	SOS1TS_LR_OUT.adl
SOS2TS_Overview	Controller 2 overview screen	SOS2TS_Overview.adl
SOS2TS_POS_IN	Controller 2 Position input matrix	SOS2TS_POS_IN.adl
SOS2TS_PIT_IN	Controller 2 Pitch input matrix	SOS2TS_PIT_IN.adl
SOS2TS_YAW_IN	Controller 2 Yaw input matrix	SOS2TS_YAW_IN.adl
SOS2TS_UL_OUT	Controller 2 UL output matrix	SOS2TS_UL_OUT.adl
SOS2TS_LL_OUT	Controller 2 LL output matrix	SOS2TS_LL_OUT.adl
SOS2TS_UR_OUT	Controller 2 UR output matrix	SOS2TS_UR_OUT.adl
SOS2TS_LR_OUT	Controller 2 LR output matrix	SOS2TS_LR_OUT.adl

2.2. Overview Screen

A copy of an overview screen is shown in Appendix 2. The overview operator screen allows the operator to adjust/control the following:

1. Gain for each controller signal path
 - position,
 - pitch,
 - yaw
 - side

Note that all gain adjustments are in percentage gain 0 to 100%.

2. Pitch and Yaw mode of operation
 - ASC Pitch input enable
 - ASC Yaw input enable
 - ASC Pitch and Yaw filter bypass
3. Channel polarity
4. Coil Driver Run/Acquire Mode
5. Test input enable for:
 - position
 - pitch

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- yaw
- side
- LSC

6. Coil test enable for each coil

It should be noted that the overview operator screen has been designed and laid out to be a block diagram representation of the controller similar to the block diagram shown in Appendix 3.

2.3. Input Matrix Screen

There are three operator screens associated with the input matrix for each of the suspension systems. These screens allow the operator to adjust the input balance for position, pitch and yaw. The adjustment is in percentage gain from 0 to 100% in 256 discrete steps. The gain setting can be adjusted by dragging the sliders on the operator screen, using the arrow keys while the pointer is inside the slider area or by right mouse clicking on the slider and entering the desired gain setting. The software will then set the slider to the closest gain step. The screens can be displayed using one of two methods:

1. Open the screen using the MEDM screen manager. Shown in the figure below.



Figure 3: MEDM Screen Manager Window

2. Pushing the appropriate popup menu button on the controller overview screen.

2.4. Output Matrix Screen

There are four operator screens associated with the output matrix for each of the suspension systems. These screens allow the operator to adjust the output balance for each of the four coil drivers (UL, LL, UR, LR). The adjustment is in percentage gain from 0 to 100% in 4096 discrete steps. The gain setting can be adjusted by dragging the sliders on the operator screen or by right mouse clicking on the slider and entering the desired gain setting. The software will then set the slider to the closest gain step. The screens can be displayed using one of two methods:

1. Open the screen using the MEDM screen manager.

2. Pushing the appropriate popup menu button on the controller overview screen.

3 ELECTRONICS

3.1. Satellite Module

The satellite module electronics are located in a field box close to the suspension tower under test. The satellite module provides the following functions:

1. Bias of each of the 5 LEDs used for local orientation sensing. The bias current to each LED is 10 mA.
2. Reverse bias (10 volts) each of the 5 photodiodes used for local orientation sensing.
3. Amplify the current signal from each photodiode. The gain of each channel is 20 V/mA (20 Kohm transimpedance amplifier).
4. Pass the coil drive signals from the suspension controller to each of the 5 coils used to control orientation.

The schematic for the satellite module is shown in Appendix 1.

3.2. Suspension Controller

A block diagram of the suspension controller is shown in Appendix 3.

3.2.1. Functional Description

3.2.1.1 Servo Filtering Function

The transfer function of the “main” servo filter for each channel of the suspension controller is a 10 pole, 12 Hz, 1 dB ripple chebychev low pass filter with a zero at DC. Input Matrix

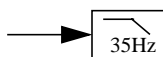
The function of the input matrix is two fold:

1. transform the signals from photodiodes into position, pitch, yaw and side orientation signals, and
2. allow the operator to trim these signals to account for gain differences, etc. in the system.

The input matrix is represented by the 12 adjustable gain stages on the left hand side of the block diagram. These gain stages are also referred to as pots 0 through 11.

3.2.1.2 ASC Inputs

The suspension controller has ASC inputs for pitch and yaw. The ASC input for pitch and yaw each have incorporated into the a 4th order, 4 dB pass band ripple, 60 dB stop band attenuation, 35Hz, elliptic low pass filter. These inputs can be enabled and disabled and the filters can be bypassed by the operator. The ASC Inputs are represented by



in the block diagram.

3.2.1.3 Initial AC Filtering

The initial AC filtering function is represented by



in the block diagram. The transfer function of this block has a zero at DC and the two most real poles of the overall 10 pole, 12 Hz chebychev low pass servo filtering function.

3.2.1.4 Output Matrix

The function of the output matrix is two fold:

1. transform the signals from position, pitch, yaw and side orientation signals, and
2. allow the operator to trim these signals to account for gain differences, etc. in the system.

The output matrix is represented by the 12 adjustable gain stages on the right hand side of the block diagram. These gain stages are also referred to as pots 12 through 23.

3.2.1.5 Final Filtering

The final filtering is represented by



in the block diagram. The transfer function of this block is the remaining 8 poles of the nominal 10 pole chebychev response. Note that these poles can be bypassed by the operator.

3.2.1.6 Coil Drivers

The coil driver is formed by placing the coil in the feedback loop of the output op amp/buffer stage for each output channel. In the acquire mode of operation a single resistor is placed in series with the coil. In the run mode of operation this is replaced by a series/parallel combination of resistors and a capacitor. Note that run mode feature is not implemented for the suspension test stand.

3.2.1.7 LSC Input

The LSC input is shown in the block diagram. The input can be enabled and disabled by the operator.

3.2.1.8 Test Inputs

Test inputs are provided for position, pitch, yaw, side, LSC and each of the coils. The input impedance of the position, pitch, yaw, side and LSC test inputs is 1 Kohm. The input impedance of each coil test input is 400 ohms when the coil test is enabled and an open circuit when the coil test is disabled. Note that when the coil test is enabled, the drive signal from the servo amplifier is disconnected and the coil test signal is connected to the coil driver circuitry.

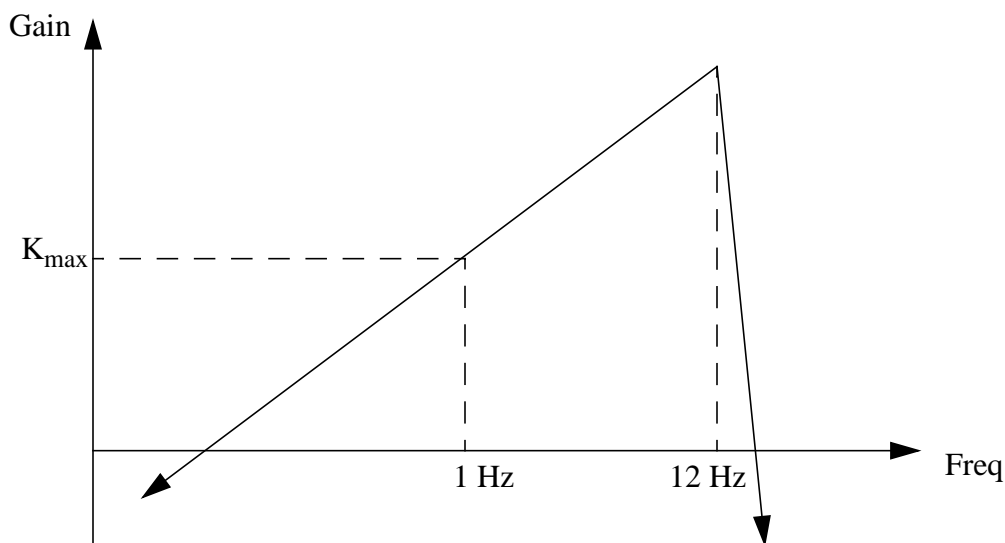
3.2.2. Modes of Operation

3.2.2.1 Local Damping Mode

The local AC gain mode of operation is provided for pitch and yaw. This mode of operation is enabled by performing the following steps.

1. Enable the position, pitch and yaw signal paths
2. Set the gain for each path to the desired value using sliders for each path. Verify that the read back value matches the slider requested value.
3. Set the polarity for each path to the appropriate setting using the push buttons on the screen.
4. Set the input and output matrix gains to the desired values using the sliders on the appropriate operator screens. Check that the readbacks for each button match the desired state.
5. Disable the coil test for each coil driver output. Check that the readbacks for each button show “disabled”.

The transfer function for the local damping mode of operation is shown in the figure below. Note that the maximum gain at 1 Hz shown in the figure is obtained by setting all sliders (including the input and output matrix) in the signal path to 100%.



$K_{\max} = 67.5$ dB POS
 $K_{\max} = 53.5$ dB PIT
 $K_{\max} = 53.5$ dB YAW
 $K_{\max} = 91$ dB Side

Figure 4: Local Damping Transfer Function

3.2.2.2 Run/Acquire Mode

This mode of operation is not incorporated into the controllers used on the test stand

3.2.2.3 Coil Test Mode

Coil test mode is provided for each coil driver and is enabled by pushing the appropriate button or buttons on the overview operator screen. Note that if a coil test is enabled the output drive from the suspension controller for that particular coil driver is disconnected.

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3.2.2.4 LSC Input Enable/Disable

The LSC input can be enabled or disabled by pushing the enable/disable button on the LSC input operator screen.

4 SOFTWARE

The following table is a list of the EPICS databases and state notation programs that are used for control and monitoring of the BS and RCM suspension systems.

Table 2: Suspension Test Stand Software

<i>Database/Program</i>	<i>Description</i>	<i>Location</i>
SUS_SOS1_TS.db	Controller 1 database	/opt/CDS/epics/apple/Hanford/sus/susvme/dev/database
SOS1TSpots.st	Controller 1 SNL program	/opt/CDS/epics/apple/Hanford/sus/susvme/dev/src
SUS_SOS2_TS.db	Controller 2 database	/opt/CDS/epics/apple/Hanford/sus/susvme/dev/database
SOS2TSpots.st	Controller 2 SNL program	/opt/CDS/epics/apple/Hanford/sus/susvme/dev/src

5 TROUBLESHOOTING

The following table can be used as a troubleshooting guide. It not intended to be an exhaustive troubleshooting list, but is geared to help the system operator eliminate easily correctable prob-

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lems at the system level.

Table 3: Suspension System Troubleshooting Guide

<i>Symptom</i>	<i>Possible Cause</i>
Slider request does not match readback	<ul style="list-style-type: none"> • Serial cable disconnected • Power to controller off • SNL program has stopped or has locked up
Button readback does not match request	<ul style="list-style-type: none"> • VME power off • VME CPU stopped • VME or operator console ethernet disconnected or malfunctioning
Operator screen is not updating	<ul style="list-style-type: none"> • VME power off • VME or operator console ethernet disconnected or malfunctioning
Suspended optic does not damp	<ul style="list-style-type: none"> • Cable to satellite module disconnected • Cable from satellite module to Sensor/actuator heads disconnected • Coil test is enabled for one or more channels • Power is off to controller and/or satellite module • Channels gains are too low or channels are disabled • Input and/or output gain matrix not adjusted properly • Pitch or Yaw bias adjustment has saturated the channel • Polarity for one or more channels is incorrect

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Table 3: Suspension System Troubleshooting Guide

<i>Symptom</i>	<i>Possible Cause</i>
Suspended optic does not damp properly or oscillates improperly when channels polarity is inverted	<ul style="list-style-type: none"> • Coil test is enabled for one or more channels • Coil wires for one or more OSEM heads not connected • Input and/or output gain matrix not adjusted properly • Pitch or Yaw bias adjustment has saturated the channel • Output filtering bypassed for one or more channels
MEDM will not start on operator console	<ul style="list-style-type: none"> • EPICS has not been setup properly
Screen updates and/or system response to operator requests is slow	<ul style="list-style-type: none"> • CDS ethernet is busy • Operator console is overloaded • Too many channel access connections to the VME CPU

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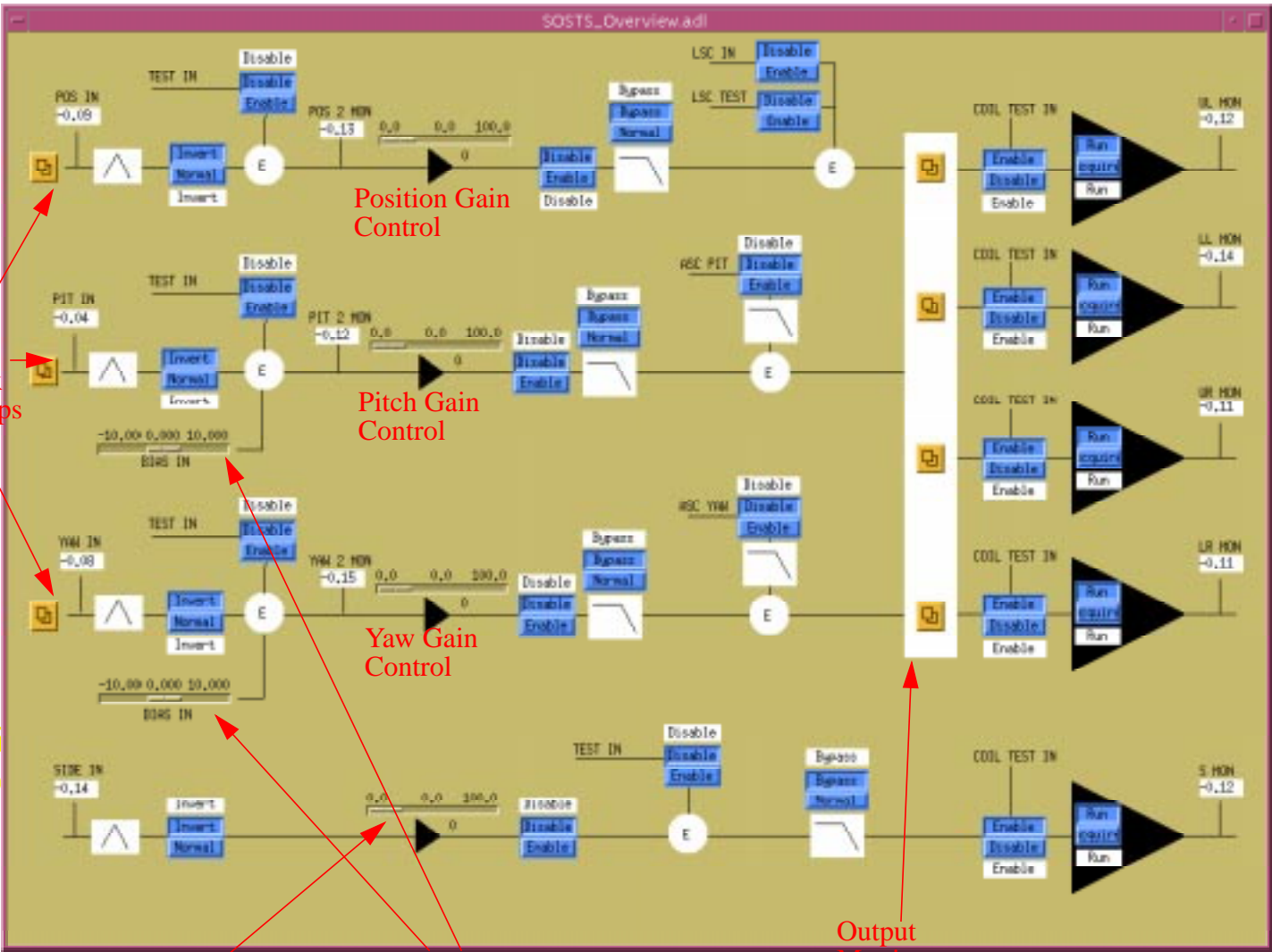
APPENDIX 1 SCHEMATICS

Table 4: Suspension Test Stand Schematics

<i>Schematic</i>	<i>Number</i>
LOS Controller	D980013
SOS Controller	D980181
Satellite Amplifier	D961289
Suspension Controller DAQ Daughter Board	D980234
Suspension Test Stand Rack Drawing	D980212
Suspension Test Stand Wiring	D980214

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APPENDIX 2 SUSPENSION TEST STAND OVER-VIEW SCREEN



Input Matrix Pop Ups

Position Gain Control

Pitch Gain Control

Yaw Gain Control

Side Gain Control

Pitch & Yaw Bias Adjust

Output Matrix Pop Ups

APPENDIX 3 SUSPENSION CONTROLLER BLOCK DIAGRAM

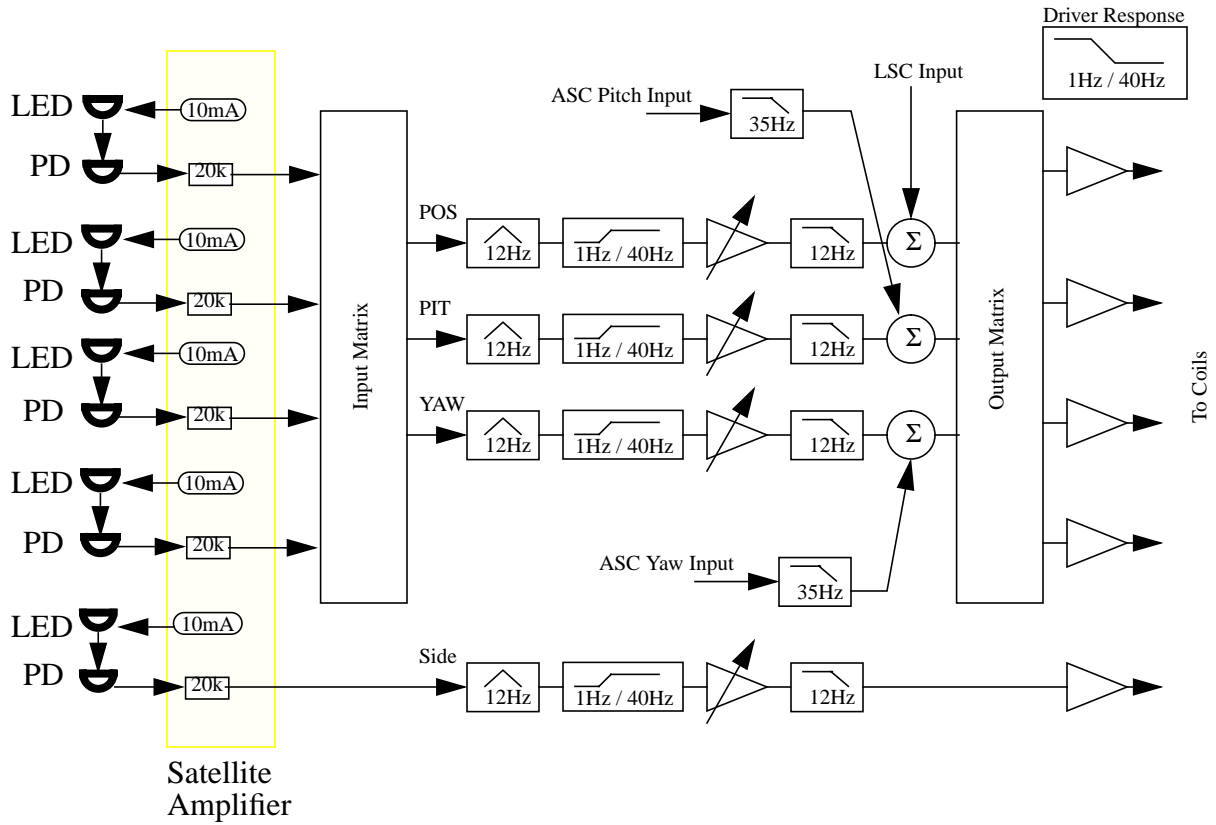


Figure 5: Suspension Control System Block Diagram

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