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Prestabilized Laser Controls

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Contents

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LIGO-T950001-1-C

Prestabilized Laser (PSL) Subsystem Controls

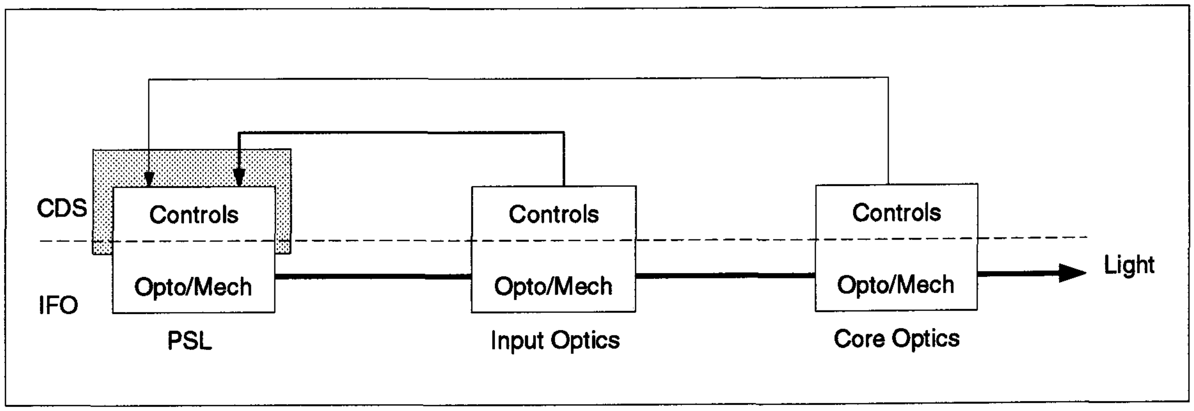
DRAFT August 10, 1995

1.0 Introduction

1.1 Scope

This document covers the development specifications and requirements for the Prestabilized Laser Controls necessary for operation on the LIGO interferometer. The Prestabilized Laser Subsystem provides frequency and power prestabilized laser light in a single mode from a modified commercial argon ion laser. A block diagram of the prestabilized laser, input optics and core optics for LIGO is shown in the figure below. As can be seen from the figure, each of these systems are composed of components that can be classified as optical/mechanical devices, provided by the interferometer group or controls devices, provided by the Control and Data System (CDS) group. Controls devices consist of the hardware (electronics, cabling, etc.) and software elements required to complete the system. The scope of this requirements document is back highlighted in the figure. Note that the scope of the requirements covers not only the control components, but the interfaces to optical/mechanical devices and other systems including other components of the CDS (not shown).

Figure 1 PSL Controls Scope Diagram



1.2 Purpose

The purpose of this document is to provide the requirements for development of a control and monitor system for the Prestabilized Laser (PSL) installed on the LIGO interferometer. The starting point for the design and the basis of many of the requirements are the existing analog control modules and optical hardware. It is intended to be a living document that will evolve through the life cycle of the project and eventually become the final requirements document for the LIGO PSL. The document will be the subject of review and sign off procedures according to standard LIGO document control.

1.3 Document Organization

The document is organized into the following sections:

1. Introduction
2. Applicable Documents
3. Requirements

    3.1 Item Definition- The item definition contains the system diagrams and descriptions, block diagrams and interface definitions. Each of the major components, in this case the subsystem LCUs (Local Control Units) are described. In addition, the minimum performance and signals required for control and monitoring of each LCU are described including alarm limits and permits.

    3.2 Characteristics- The characteristics section describes the general physical, reliability, maintainability, environmental and performance requirements that pertain to the subsystem and all components utilized for the control and monitoring of the subsystem.

    3.3 Design and Construction- The design and construction section outlines the minimum requirements and standards for materials, safety, electromagnetic radiation, workmanship and expansion capabilities.

    3.4 Documentation- The documentation section outlines the minimum requirements for subsystem and component documentation, testing, manuals and procedures.

    3.5 through 3.7 Logistics, Personnel and Training, and Precedence- These sections outline the minimum requirements for such things as spare parts, personnel requirements, and personnel training. The precedence section outlines the guidelines for determining the order of consideration that should be used in the event of conflict between this document and others.

4. Quality Assurance
5. Packaging, Handling and Transportability
6. Appendix A: Argon Ion Laser Remote Connector Pin Assignments- A copy of Table 4–2 of the laser manual is included. This table details the connector pin assignments used to interface the laser control unit to CDS.
7. Appendix B: Table of TBDs- A table of the requirements that are TBD is included. A description and comment on resolution are given for each.
8. Appendix C: Existing PSL Schematics- These schematics will be used a basis for the design of the LIGO PSL Controls.

1.4 Definitions

1.4.1 Computer Integrated Manufacturing (CIM) Model

In developing controls specifications and designs, a standard model of control levels (commonly referred to as a CIM model) has been designed for use by the LIGO CDS group. These levels are defined below.

In accordance with these definitions, the “site” is LIGO site, the “system” is Detector, and Prestabilized Laser is a “subsystem”.

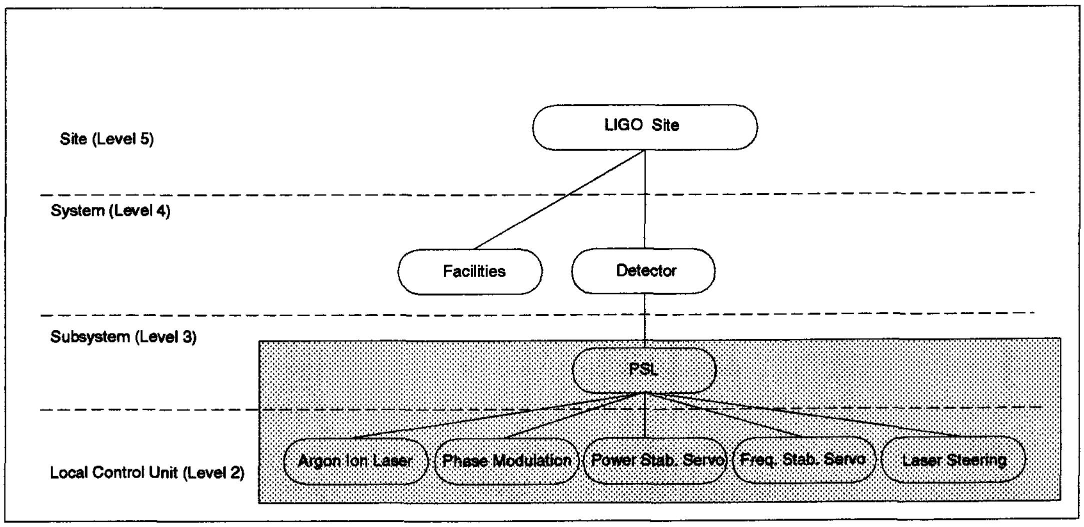
- LEVEL 6: General Computing Facilities- This is outside the scope of controls. This level is typically the interface to the control system from outside users.
- LEVEL 5: Site- A site is defined as a geographic location with a LIGO interferometer facility. These are Washington, Louisiana, Caltech Mark II and MIT 5 meter. Site controls are all hardware and software which are common to all LIGO control systems at a site and, in general, provides for Supervisory Control And Data Acquisition (SCADA) functions for a LIGO site.
- LEVEL 4: System- System controls are defined as that hardware and software necessary to provide control and monitoring for a functional grouping of devices (in this case the detector).
- LEVEL 3: Subsystem- Subsystem controls are defined as that hardware and software which provide control and monitoring for a logical subset of a system (in this case the PSL).

- LEVEL 2: Local Control Unit (LCU)- LCU is defined as that hardware and software necessary to provide control and monitoring for a functional grouping of devices within a subsystem and usually within a geographic area.
- LEVEL 1: Device- A logical grouping (within a LCU) of sensors and controllers typically associated with a physical piece of hardware such as a mirror, power supply, pockels cell, etc.
- LEVEL 0: Sensor- The physical sensors and electro-mechanical operators associated with a level 1 device.

1.4.2 CIM Model for PSL Controls

The figure below shows the CIM model applied to the LIGO Prestabilized Laser. The areas covered by this document are shown within the dark background. Level 1 and 0 have been omitted for clarity, but will be shown in the following sections.

Figure 2 LIGO PSL CIM Model



1.5 Acronyms

ai — analog input
ao — analog output
AOM — Acousto-Optic Modulator
bi — binary input

bo — binary output
CDS — Control and Data System
DEMO — Demodulated output of RF Photodetector
FSS — Frequency Stabilization Servo
IF — Intermediate Frequency
kHz — Kilo Hertz
LCU — Local Control Unit
LO — Local Oscillator
LRU — Line Replaceable Unit
mbbi — multiple bit binary input
mbbo — multiple bit binary output
MHz — Mega Hertz
MOD — Phase Modulation System
OSA — Optical Spectrum Analyzer
PC — Pockels Cell
PSL — Pre-Stabilized Laser
PSS — Power Stabilization Servo
PZT — Piezo-electric Transducer
RF — Radio Frequency
SDP — Software Development Plan
VME — VERSAmodule Eurocards

2.0 Applicable Documents

CDS_N_007: Functional Description for the Prestabilized Laser Subsystem
DWG #1206002–3: Laser PZT Driver
DWG #1206075–3: Laser Loop Amplifier
DWG # 1206012–3: Visibility Monitor and Lockup Discriminator Production Version
DWG #1206017–3: Five Watt 12.3 MHz Amplifier. Note that 10.7 MHz will be used for the PSL
DWG #1206062–3: Power Monitoring Photodiode
DWG #1206065–3: Laser Power Stabilizer Amplifier for Spectra Physics Laser

DWG #1206054-3: 12.3 MHz Digital Control Phase Shifter. Note that 10.7 MHz will be used for the PSL

DWG #1206061-3: Pockels Cell Matching Network

Doc. No. TBD: LIGO Global CDS Requirements Specification

Doc. No. CG0001-STD: Technical Note on CDS Document Numbering

3.0 Requirements

3.1 Item Definition

3.1.1 System Diagrams and Description

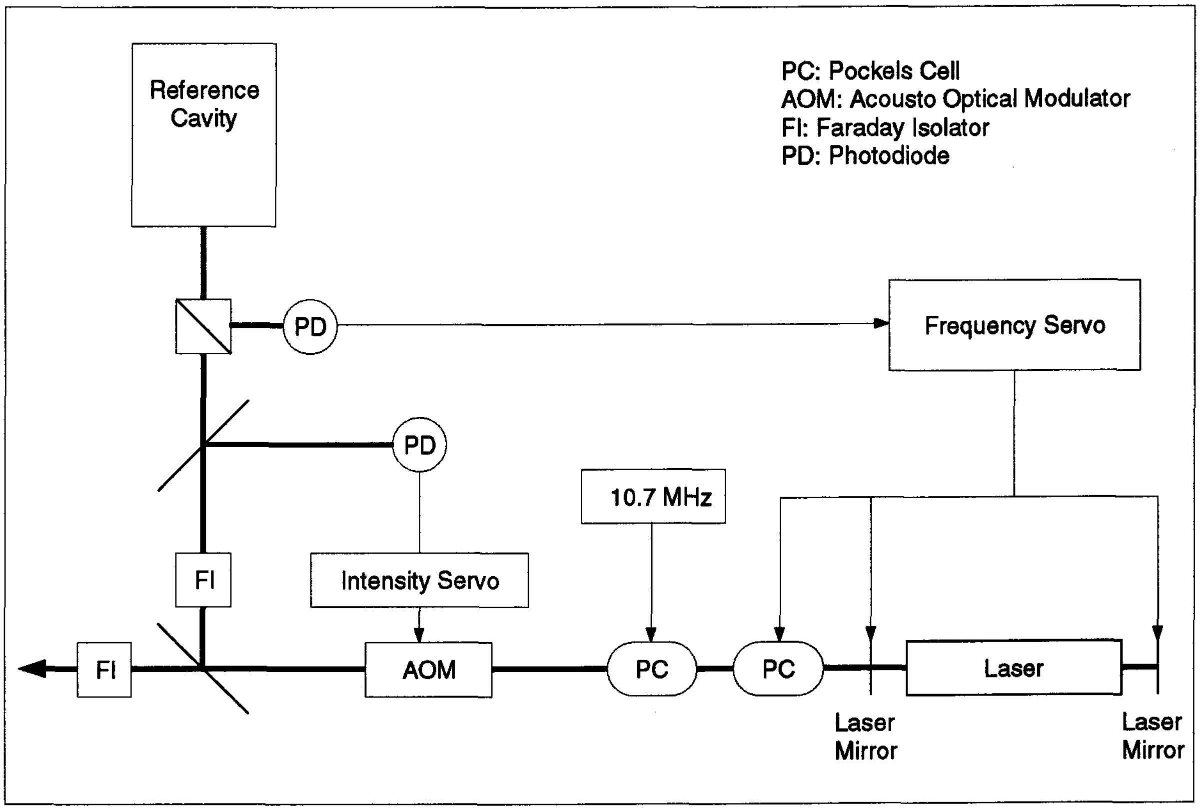
The PSL subsystem includes the laser, the optical elements and electronic hardware and software required to provide single mode, frequency and power prestabilized laser light from a modified commercial argon ion laser. For the purposes of control, it consists of the following major components (LCUs):

1. Argon Ion Laser
2. Phase Modulation
3. Power Stabilization Servo
4. Frequency Stabilization Servo
5. Laser Beam Steering

CDS_N_007 entitled "Functional Description for the Prestabilized Laser Subsystem" provides an overview of the present prestabilized laser used at Caltech. The schematics of the present circuits and modules listed in section 1.2 above are included in Appendix C.

A conceptual design of the prestabilized laser system is shown below.

Figure 3 PSL Block Diagram



3.1.2 Interface Definition

3.1.2.1 Interface to LIGO Global CDS

The interface to the LIGO CDS is through the CDS ethernet for the LIGO interferometer. Addressing hardware and software shall be as described in the LIGO Global CDS Requirements Specification.

3.1.2.2 Interface to CDS Data Acquisition

The interface to the LIGO CDS data acquisition system will be at the output connector for each signal listed below. These signals are a subset of the signals required for control and monitoring of the PSL.

The PSL subsystem controls shall provide separate buffered outputs for each of the signals listed. These outputs are in addition to those required for control and monitoring and the LIGO remote diagnostic system. Each output shall be capable of driving 50 ohms to full scale over a bandwidth equivalent to 10 times the respective sampling frequencies listed.

The following table is an estimate of the PSL channels and their respective rates that need to be digitized and stored by the CDS Data Acquisition system.

Table 1 PSL Data Acquisition Channels

Channel	Description	Sample Rate (sample/sec)
TBD	Power Stab. Servo Output Monitor	20 K
TBD	Power Stab Servo Ref Photodiode DC Out	2 K
TBD	Freq. Stab. Servo RF Photodiode Bias Supply Output Voltage Monitor	200
TBD	Freq Stab Servo RF Photodiode DC Out	2 K
TBD	Freq.Stab. Servo. Laser Loop Amplifier Pockels Cells (neg) Output Monitor	20 K
TBD	Freq.Stab. Servo. Laser Loop Amplifier Pockels Cells (pos) Output Monitor	20 K
TBD	Freq Stab. Servo Laser Loop Ampl. RF Photodetector Demodulated Output	20 K
TBD	Freq. Stab. Servo slow/fast PZT Driver Slow Piezo Monitor	20 K
TBD	Freq. Stab. Servo slow/fast PZT Driver Fast Piezo Monitor	20 K
TBD	Freq. Stab. Servo Slow PZT Power Supply Output Voltage Monitor	200
TBD	Freq. Stab. Servo Fast PZT Power Supply Output Voltage Monitor	200

Table 1 (Continued) PSL Data Acquisition Channels

TBD	Freq. Stab. Servo Pockels Cell Power Supply Output Voltage Monitor	200
TBD	Freq. Stab. Servo Pockels Cell Power Supply Output Current Monitor	200
TOTAL	13 Channels	125 K

3.1.2.3 Interface to LIGO CDS Remote Diagnostics

The interface to the LIGO CDS remote diagnostics system will be at the output connector for each signal listed below. These signals are a subset of the PSL signals that are used for laser tune up and diagnostics. During tune up and system diagnostic these signals are routed to high bandwidth scopes and spectrum analyzers. The operator then uses these signals to adjust such things as servo loop gain, mirror orientation and circuit DC offsets. The oscilloscope, spectrum analyzers, other test equipment and cabling to the equipment are to be provided by the CDS Remote Diagnostics subsystem.

The PSL subsystem controls shall provide separate buffered outputs for each of the signals listed below. These outputs are in addition to those required for control and monitoring and the LIGO data acquisition system. Each output shall be capable of driving 50 ohms to full scale over the bandwidth specified in the table below.

Table 2 PSL Remote Diagnostic Signals

Channel Name	Signal	Location	Bandwidth (3 dB)
TBD	LLA Pockels Cell Neg Output	Freq Stab Servo	0-5 MHz
TBD	LLA Pockels Cell Pos Output	Freq Stab Servo	0-5 MHz
TBD	LLA RF Photodetector Demod Output	Freq Stab Servo	0-5 MHz
TBD	LLA PZT Out Monitor	Freq Stab Servo	0-5 MHz

Table 2 (Continued) PSL Remote Diagnostic Signals

Channel Name	Signal	Location	Bandwidth (3 dB)
TBD	RF Photodetector DC Output	Freq Stab Servo	0-100 KHz
TBD	Slow PZT Driver Output Monitor	Freq Stab Servo	0-1MHz
TBD	Fast PZT Driver Output Monitor	Freq Stab Servo	0-2 MHz
TBD	Reference Photodetector DC Output	Power Stab Servo	0-100 KHz
TBD	Power Stab Servo Ampl Output	Power Stab Servo	0-5 MHz
TBD	Reference cavity mirror 1 X output	Laser Steering	0-100 KHz
TBD	Reference cavity mirror 1 Y output	Laser Steering	0-100 KHz
TBD	Reference cavity mirror 2 X output	Laser Steering	0-100 KHz
TBD	Reference cavity mirror 2 Y output	Laser Steering	0-100 KHz

The output of the optical spectrum analyzer (OSA) is monitored by the operator during tune up and operation. The output of the OSA consists of a signal proportional to the ramp voltage used to drive the analyzer cavity PZT and the analyzer photodetector output signal. When these signals are viewed on an oscilloscope running in X-Y mode the operator is able to distinguish the laser carrier frequency and any sidebands that exist due to modulation and/or higher order modes.

In addition to the signals listed above the operator must be able to view (video image) the beam spot at the output of the reference cavity. The video camera is to be provided by the PSL Controls system. Video monitors, multiplexers and cabling to the operator control areas are to be provided by the CDS Remote Diagnostics system.

3.1.2.4 Interface to LIGO PSL Components

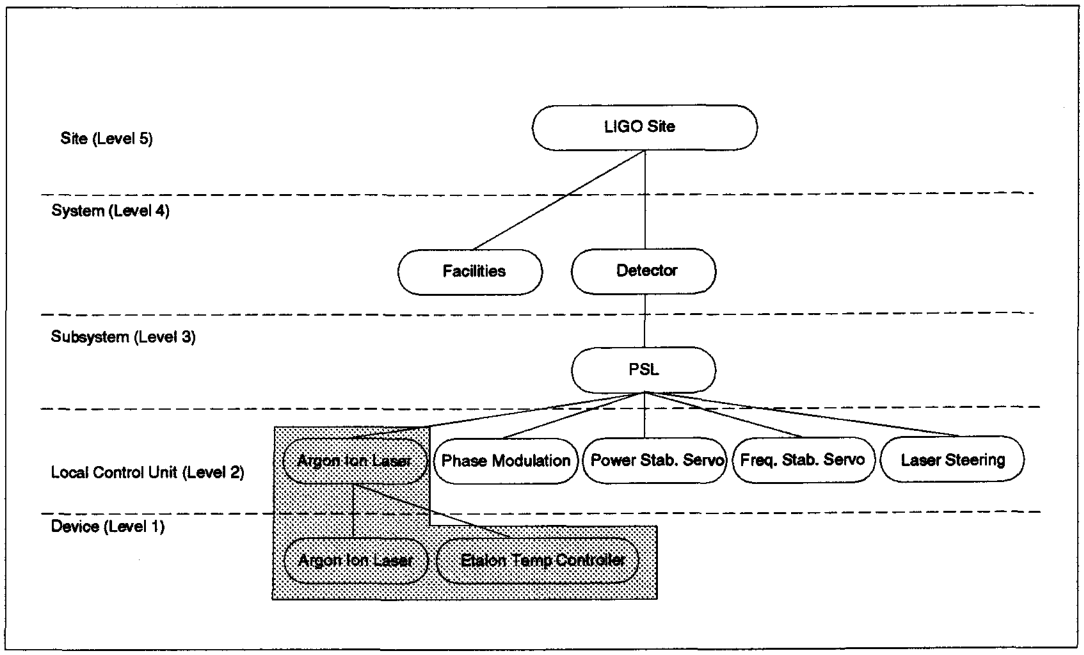
The interface to the PSL equipment shall be at the input and output connectors of the PSL equipment or device. PSL equipment is defined as pockels cells, Acousto-Optic Modulators, laser, etc.

3.1.3 Major Component Characteristics

3.1.3.1 Argon Ion Laser LCU

The figure below highlights the levels of the PSL CIM model that are covered by this section. The laser is a commercial SPECTRA PHYSICS 2040 E argon ion laser. The laser has been modified so that the cavity mirrors are mounted on piezo-electric actuated mounts. This allows for active length control of the laser cavity. The output mirror is attached to a "slow piezo mount" with a mechanical resonant frequency of about 5 kHz. The reflector mirror is mounted on a "fast

Figure 4 LIGO PSL Argon Ion Laser CIM Model



piezo mount" with a mechanical resonance of about 200 kHz. It should be noted that although the mirrors are physically part of the laser assembly, the control of each mirror is part of the PSL frequency stabilization servo LCU.

3.1.3.1.1 Argon Ion Laser Level 2 Performance

The Spectra Physics laser can be operated as a fully stand alone unit. All interlocks necessary for protection of the laser and its components are incorporated into the control unit supplied with the device. The function of the level 2 controls is to provide the operator and CDS interface to the unit. Update rates and reaction times for the controls are as follows:

1. Temperature and pressure monitors- once per second maximum
2. Laser power, voltage and current monitors- 10 samples per second maximum
3. On/Off selects and level adjustments- 1 second maximum for operator or CDS initiation
4. Interlock reaction time- 1 second maximum

3.1.3.1.2 Argon Ion Laser Level 2 Controls

Connection to the laser shall be made through the remote connector interface provided on the back of the model 2570 power supply. A list of the functions that are available and the pin assignments for the connector are described in the manual for the laser. A copy of table 4–2, "Remote Connector Pin Assignments", from the manual is included in Appendix A of this specification.

3.1.3.1.2.1 Sequences and Functions

The following sequences and functions shall be incorporated:

1. The level 2 controls shall be capable of selecting the control source for the laser, i.e. Computer/Remote. The default selection shall be remote (CDS control through remote connector). It should be noted that computer control in this case refers to local computer control of the laser via an RS-232 or GPIB interface.
2. Laser cooling water shall be allowed to flow through the laser after it has been turned off until the cooling water return temperature is less than TBD.

3.1.3.1.2.2 Alarms

Argon Ion laser LCU (level 2) alarms shall be generated for the following:

Table 3 Argon Ion Laser LCU Alarms

ALARM CONDITION	SEVERITY	ACTION
Laser is on and no laser cooling flow	Major	Turn off Laser
The laser has been off for more than 15 minutes and laser cooling water is flowing (prevent condensation)	Minor	Operator Warning
The laser control selection is "computer"	Minor	Operator Warning
The laser is on and there is no gas purge flow	Major	Turn off Laser

3.1.3.1.2.3 Permits

There are no interlocks outside of those incorporated into the laser control unit.

3.1.3.1.2.4 Level 1 Devices

For the purposes of control and monitoring the Laser LCU contains two devices, the laser which includes the laser cooling unit and the etalon temperature controller. The minimum required performance and signals for each device are described in the following figures and tables.

3.1.3.1.3 Laser Device

3.1.3.1.3.1 Performance

TBD

3.1.3.1.3.2 Control Signals

Figure 5 Laser Device Interface Signals

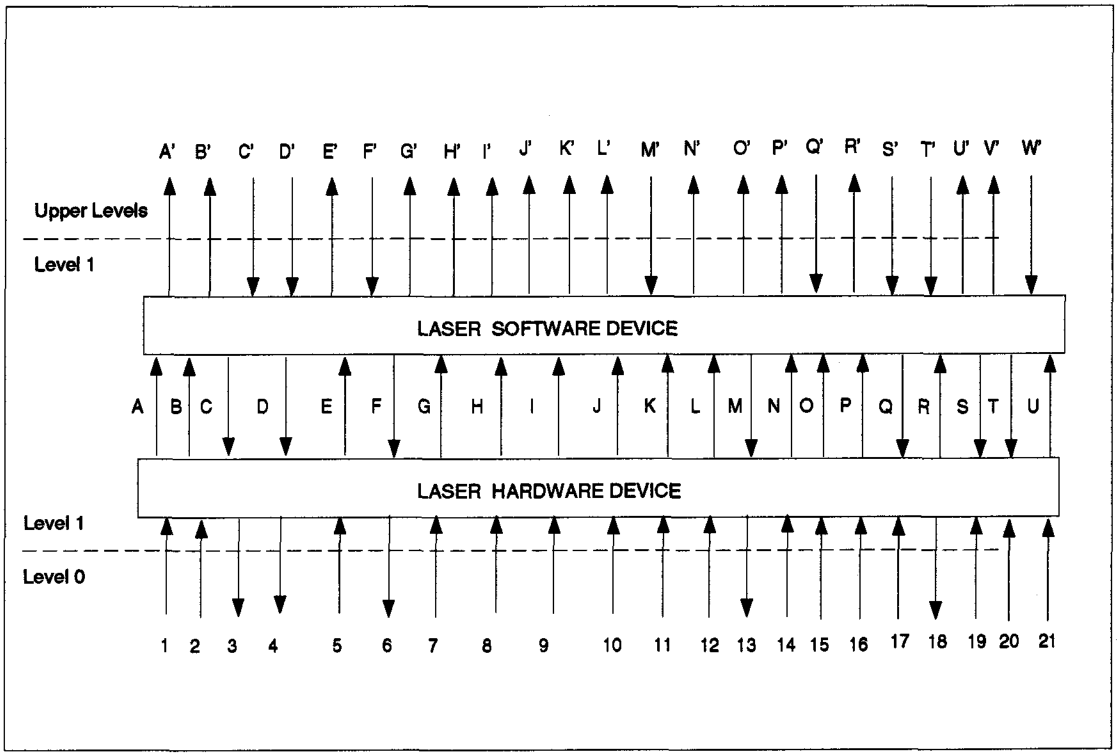


Table 4 Laser Device Level 1 to Upper Levels Interface Signals

Label	Description	Signal Type
A	Laser Temperature Monitor	0-10 VDC
B	Purge Gas Pressure Monitor	0-10 VDC
C	Laser On/Off Select	TTL
D	Purge Gas On/Off Select	TTL
E	Laser On/Off Status (Remote Emission Indicator)	TTL
F	Control Mode Select	TTL
G	Regulator Fault Readback	TTL
H	Head Cover Interlock	TTL

Table 4 (Continued) Laser Device Level 1 to Upper Levels Interface Signals

Label	Description	Signal Type
I	Tube Voltage Monitor	0-10 VDC
J	Tube Current Monitor	0-10 VDC
K	Tube Power Monitor	0-10 VDC
L	Power Range Selection Monitor	TTL, multi-bit
M	Power Range Select	TTL, multi-bit
N	Tube Fill Status	TTL
O	Head Outlet Temperature Interlock	TTL
P	Low Water Flow Indicator	TTL
Q	Control Source Select	TTL
R	AUX Interlock Status	TTL
S	Tube Current Select	0-5 VDC
T	Tube Power Select	0-5 VDC
U	Control Mode Monitor	TTL, Multi-bit
A’	Laser Temperature Monitor	ai
B’	Purge Gas Pressure Monitor	ai
C’	Laser On/Off Select (Remote Emission Indiocator)	bi
D’	Purge Gas On/Off Select	bo
E’	Laser On/Off Status	bi
F’	Control Mode Select	bo
G’	Regulator Fault Readback	bi
H’	Head Cover Interlock	bi
I’	Tube Voltage Monitor	ai
J’	Tube Current Monitor	ai
K’	Tube Power Monitor	ai
L	Power Range Selection Monitor	mbbi

Table 4 (Continued) Laser Device Level 1 to Upper Levels Interface Signals

Label	Description	Signal Type
M’	Power Range Select	mbbo
N’	Tube Fill Status	bi
O’	Head Outlet Temperature Interlock	bi
P’	Low Water Flow Indicator	bi
Q’	Control Source Select	bo
R’	AUX Interlock Status	bi
S’	Tube Current Select	ao
T’	Tube Power Select	ao
U’	Control Mode Monitor	bi
V’	Laser Device Alarms	alarm
W’	Laser Device Permits	Software

Table 5 Laser Device Level 1 to Level 0 Interface Signals

Label	Description	Signal Type
1	Laser Temperature Monitor	0-10 VDC
2	Laser Pressure Monitor	0-10 VDC
3	Laser On/Off Select	TTL
4	Laser Gas On/Off Select	TTL
5	Laser On/Off Status	TTL
6	Control Mode Select	TTL
7	Regulator Fault Readback	TTL
8	Head Cover Interlock	TTL
9	Tube Voltage Monitor	0-10 VDC
10	Tube Current Monitor	0-10 VDC
11	Tube Power Monitor	0-10 VDC
12	Power Range Selection Monitor	TTL, multi-bit

Table 5 (Continued) Laser Device Level 1 to Level 0 Interface Signals

Label	Description	Signal Type
13	Power Range Select	TTL, multi-bit
14	Tube Fill Status	TTL
15	Head Outlet Temperature Interlock	TTL
16	Low Water Flow Indicator	TTL
17	Control Source Select	TTL
18	AUX Interlock Status	TTL
19	Tube Current Select	0-5 VDC
20	Tube Power Select	0-5 VDC
21	Control Mode Monitor	TTL

3.1.3.1.3.3 Sequences and Functions

The default control mode for the laser shall be power regulation. The power up and reset conditions for the laser shall be:

1. Laser- disabled
2. Mode- power regulation
3. Power Level- 0 watts
4. Gas- Off
5. Water Flow- Off
6. All other- don't care

3.1.3.1.3.4 Alarms

Laser device alarms shall be generated for the following:

Table 6 Laser Device Alarms

ALARM CONDITION	SEVERITY	ACTION
Laser temperature is greater than TBD (HIHI)	Major	Turn Off Laser
Laser temperature is greater than TBD (HI)	Minor	Operator Warning

Table 6 (Continued) Laser Device Alarms

ALARM CONDITION	SEVERITY	ACTION
Laser purge gas pressure is less than TBD (LO)	Minor	Operator Warning
Laser purge gas pressure is less than TBD (LOLO)	Major	Turn Off Laser
Laser Regulator Fault	Minor	Operator Warning
Laser Head Cover Interlock Open	Minor	Operator Warning
Low Water Flow to Head	Minor	Operator Warning
Outlet Head Water Temp greater than TBD	Major	Turn Off Laser
Laser Tube Voltage Below Gas Fill Threshold. Threshold voltage= 553 Volts	Minor	Operator Warning

3.1.3.1.3.5 Permits

The following laser device interlocks and permits shall be incorporated:

- The laser shall be disabled until a regulator fault is cleared.

3.1.3.1.4 Etalon Temperature Control Device

3.1.3.1.4.1 Performance

The temperature of the etalon shall be regulated to better than 0.1 deg C.

3.1.3.1.4.2 Control Signals

The etalon temperature regulator is a self contained commercial unit. There are currently no provisions for control or monitoring of temperature via the CDS.

Figure 6 Etalon Temperature Control Device Interface Signals

Label	Description	Signal Type
	None	

Table 7 Etalon Temperature Control Device Level 1 to Upper Levels Interface Signals

Label	Description	Signal Type
	None	

Table 8 Etalon Temperature Control Device Level 1 to Level 0 Interface Signals

Label	Description	Signal Type
	None	

3.1.3.1.4.3 Sequences and Functions

None

3.1.3.1.4.4 Alarms

None

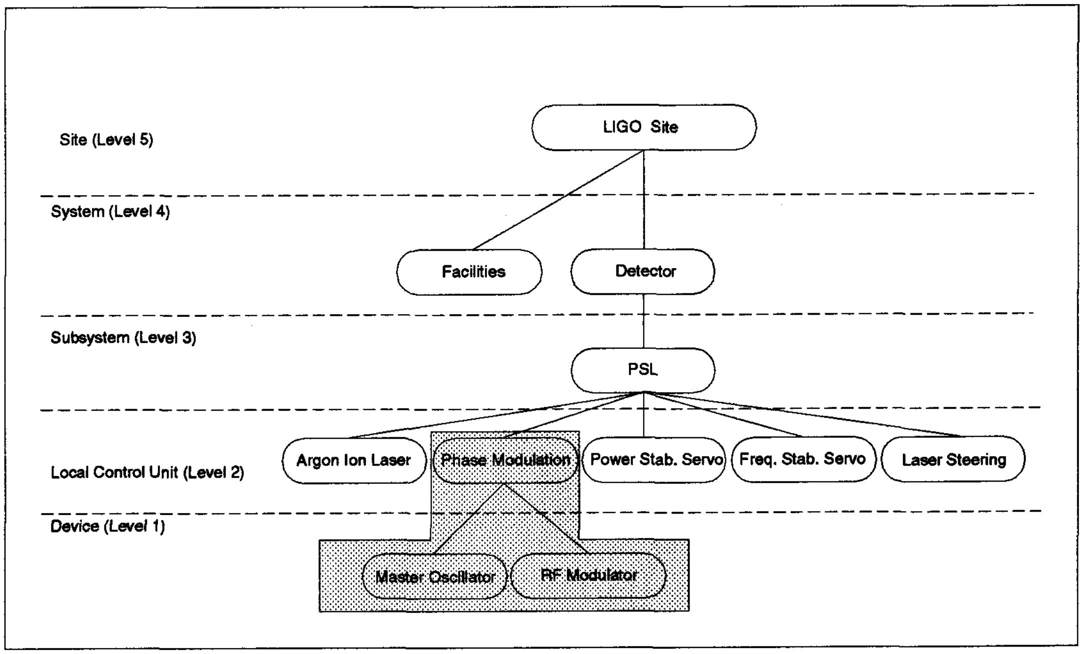
3.1.3.1.4.5 Permits

None

3.1.3.2 Laser Phase Modulation (MOD)

The figure below highlights the levels of the PSL CIM model that are covered by this section. The phase modulation LCU uses Pockels Cells to phase modulate the laser light with amplitude ~1 rad and frequency 10.7 MHz, which is large compared to the bandwidth of the reference cavity. The phase modulation LCU is made up of several components. They are a 10.7 MHz master oscillator and power splitter, a 5 watt minimum power RF amplifier whose output power is adjustable, a pockels cell matching network (step-up transformer) and the phase modulation pockels cell. A block diagram of the system is shown in the figure below.

Figure 7 LIGO PSL Laser Light Modulation CIM Model



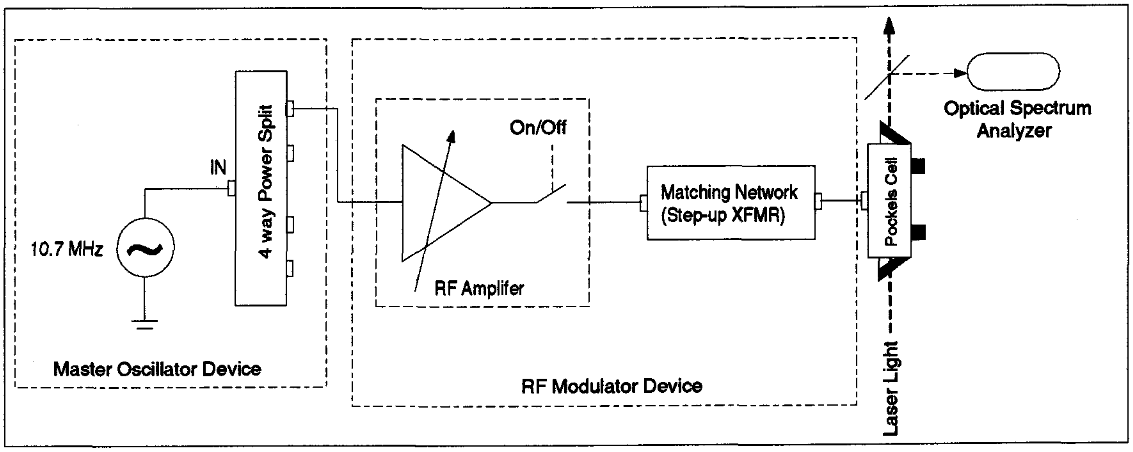


Figure 8 Phase Modulation LCU Block Diagram

3.1.3.2.1 Phase Modulation Level 2 Performance Requirements

The phase noise of the laser phase modulation system shall be less than TBD. The amplitude stability of the laser phase modulation system shall be better than TBD.

Update rates and reaction times for the controls are as follows:

1. RF power monitor- 10 samples per second maximum
2. On/Off Selects and Level Adjustments- 1 second maximum for operator or CDS initiation.

3.1.3.2.2 Phase Modulation Level 2 Controls

3.1.3.2.2.1 Sequences and Functions

The modes of operation for the phase modulation LCU are:

1. Modulation Off
2. Modulation On

The default, power up and reset mode of operation for the phase modulation LCU is “Modulator Off”.

3.1.3.2.2.2 Alarms

None

3.1.3.2.2.3 Permits

None

3.1.3.2.2.4 Level 1 Devices

For the purposes of control and monitoring, the phase modulation LCU has been broken into two devices. These are the master oscillator and the RF modulator devices shown in the figure above. The interface to the phase modulation pockels cell is at the input connector of the pockels cell. The minimum required performance and signals for each device are described in the following figures and tables.

3.1.3.2.3 Master Oscillator Device

3.1.3.2.3.1 Performance

The master oscillator shall provide at least 4 output connectors (BNC or SMA) for master oscillator distribution with the following characteristics:

1. Output power- +23 dBm
2. Output impedance- 50 ohms

3.1.3.2.3.2 Control Signals

Figure 9 Master Oscillator Device Interface Signals

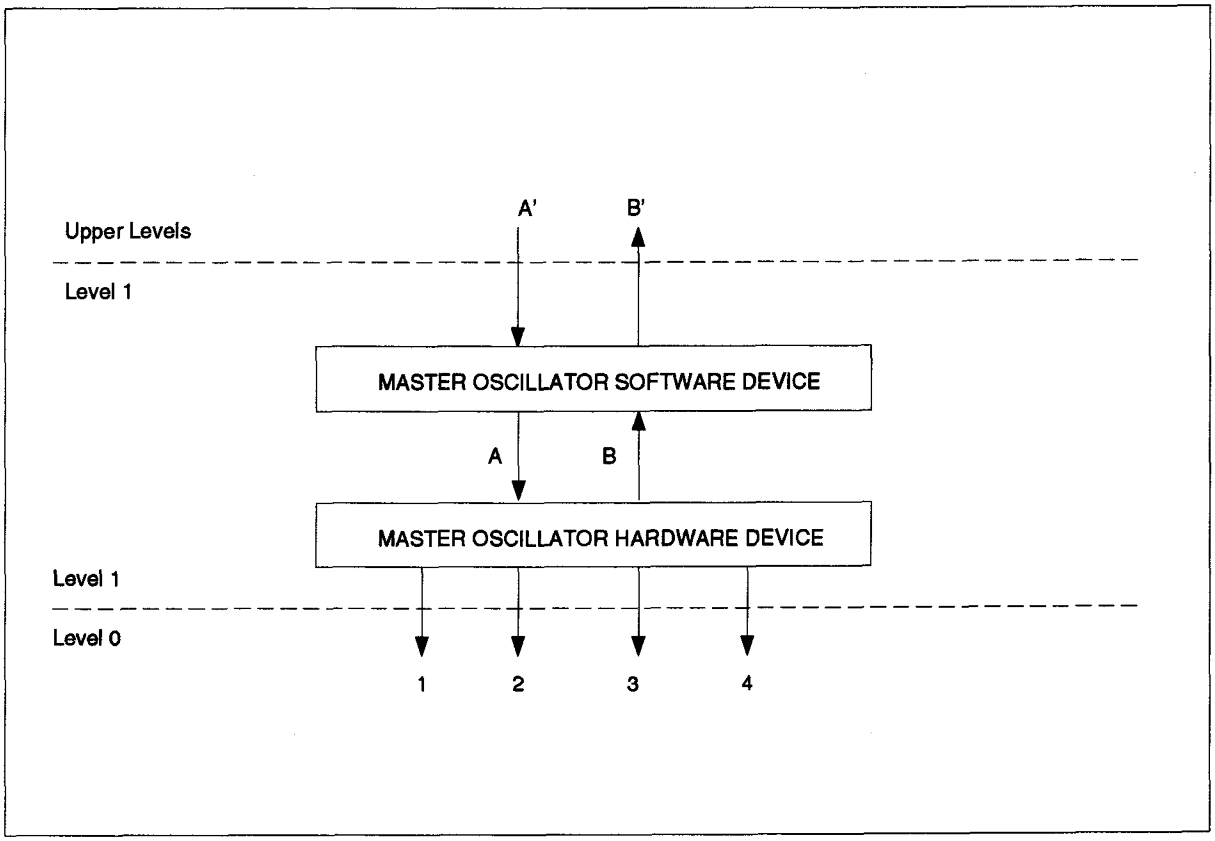


Table 9 Master Oscillator Device Level 1 to Upper Levels Interface Signals

Label	Description	Signal Type
A	Master Oscillator On/Off Select	TTL
B	Master Oscillator On/Off Status	TTL
A'	Master Oscillator On/Off Select	bo
B'	Master Oscillator On/Off Status	bi

Table 10 Master Oscillator Device Level 1 to Level 0 Interface Signals

Label	Description	Signal Type
1	Master Oscillator Output	+23 dBm
2	Master Oscillator Output	+23 dBm

Table 10 (Continued) Master Oscillator Device Level 1 to Level 0 Interface Signals

Label	Description	Signal Type
3	Master Oscillator Output	+23 dBm
4	Master Oscillator Output	+23 dBm

3.1.3.2.3.3 Sequences and Functions

None

3.1.3.2.3.4 Alarms

None

3.1.3.2.3.5 Permits

None

3.1.3.2.4 RF Modulator Device

3.1.3.2.4.1 Performance

The RF power amplifier shall have connectors for RF input and RF output.

The pockels cells matching network shall have connections for:

1. Input: Zin = 50 ohms, Pin = 5 watt min.
2. Output to Pockels Cells: Vout = 500 Vrms, max.

The matching network shall match the input impedance of the pockels cell to 50 ohms real ±TBD at 10.7 MHz and over the entire input power range of 0 to 5 Watts (+37 dBm). The stability of the match shall be better than TBD. The matching network circuitry includes any cabling and connectors required to connect to the pockels cell.

3.1.3.2.4.2 Control Signals

Controls for the modulator shall be:

1. Output Power Selection- The output power of the amplifier shall be selectable from 0 to +37 dBm in TBD increments.
2. Output On/Off Select- The On/Off status of the amplifier output shall be selectable from the VME bus. The On/Off status of the amplifier shall be readable from the VME bus.

Figure 10 RF Modulator Device Interface Signals

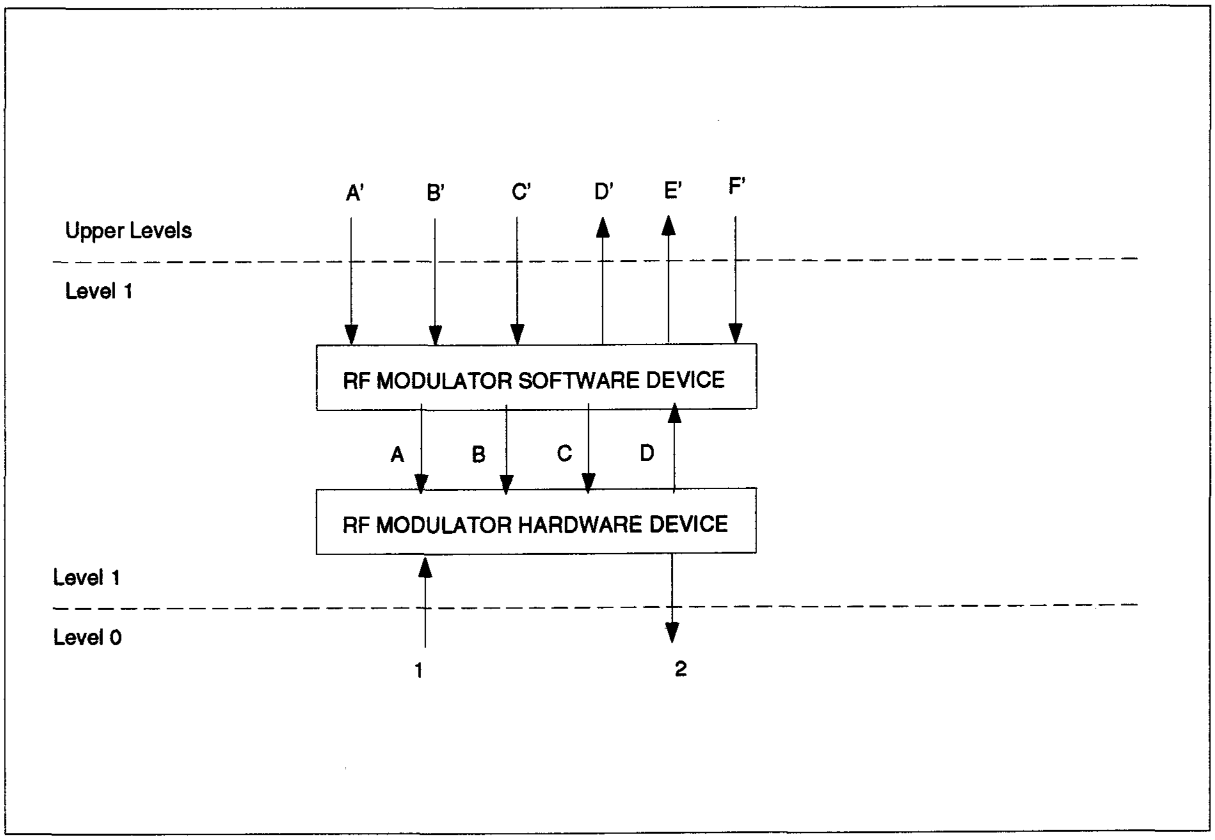


Table 11 RF Modulator Device Level 1 to Upper Levels Interface Signals

Label	Description	Signal Type
A	RF Modulator On/Off Select	TTL
B	RF Attenuator Range Select	TTL, multi-bit
C	RF Power Select	TTL, multi-bit
D	RF Output Power Monitor	0-10 VDC
A’	RF Modulator On/Off Select	bo
B’	RF Attenuator Range Select	mbbo

Table 11 (Continued) RF Modulator Device Level 1 to Upper Levels Interface Signals

Label	Description	Signal Type
C’	RF Power Select	mbbo
D’	RF Output Power Monitor	ai
E’	RF Modulator Device Alarms	alarm
F’	RF Modulator Device Permits	Software

Table 12 RF Modulator Device Level 1 Level 0 Interface Signals

Label	Description	Signal Type
1	RF Input	TBD
2	RF Output	5 Watts max.

3.1.3.2.4.3 Sequences and Functions

The status of the RF amplifier device for each modulator LCU mode of operation is:

1. “Modulator Off”- RF amplifier disabled
2. “Modulator On”- RF amplifier enabled

3.1.3.2.4.4 Alarms

None

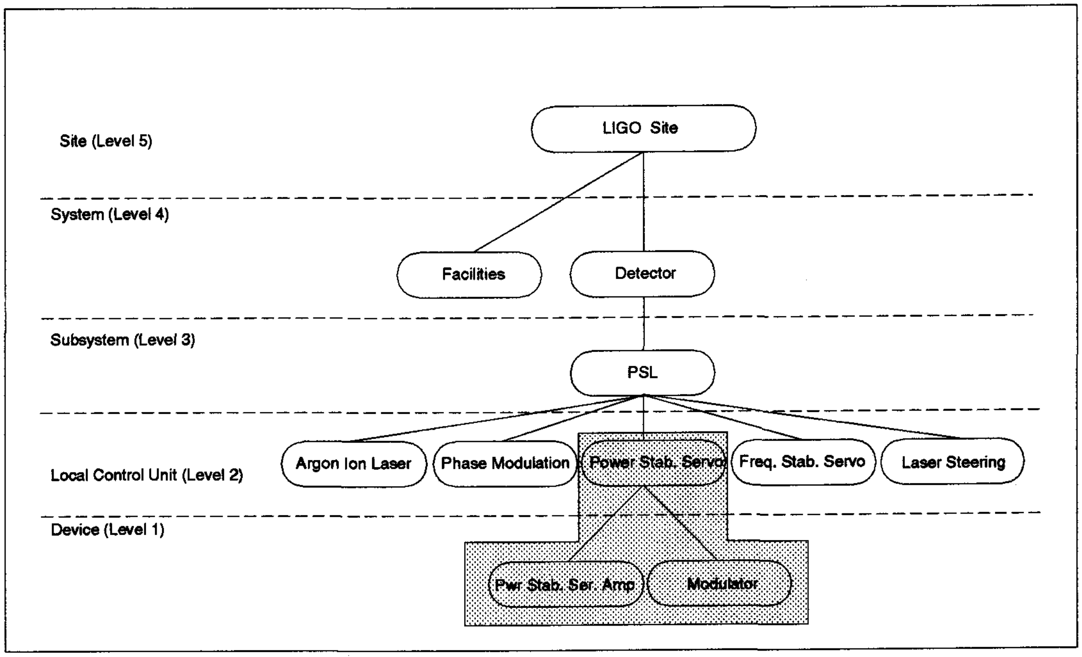
3.1.3.2.4.5 Permits

None

3.1.3.3 Laser Power Stabilization Servo (PSS)

The figure below highlights the levels of the PSL CIM model that are covered by this section. The power stabilization servo uses an Acousto-Optic Modulator (AOM) to stabilize the laser power. Stabilization is achieved by controlling the ratio of laser power in the zero order and first order beams at the output of the AOM. The PSS is made up of several components. They are:

Figure 11 LIGO PSL Power Stabilization Servo CIM Model



1. reference photodetector- used to monitor the laser power transmitted by the 12 meter mode cleaner. The photodiode is part of the Input Optics subsystem.
2. power stabilization servo amplifier- the servo amplifier that regulates the zero order beam power
3. VCO Deflector Driver- the driver for the Acousto-Optic Modulator
4. Acousto-Optic Modulator- used to transfer power from the zero order beam to the first order beam. The AOM is part of the PSL subsystem.

A block diagram of the PSS is shown in the figure below.

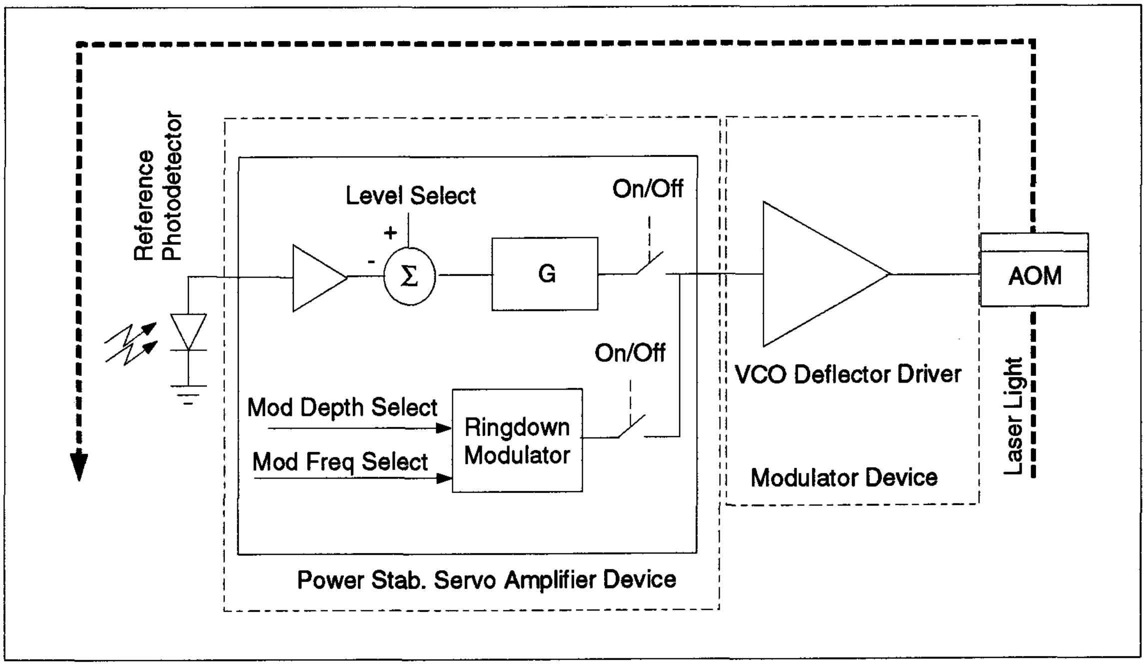


Figure 12 Power Stabilization Servo Block Diagram

3.1.3.3.1 Power Stabilization Servo Level 2 Performance

The power stabilization servo system shall have an open loop spectral noise voltage, referenced to the input:

$V(f) < 5\ nV/(Hz)^{1/2}$
for, $30\ Hz \leq f \leq 100\ KHz$.

Also, to assure linear operation, all of the amplifier stages should not approach their maximum output or slew rates limits under normal operating conditions.

Update rates and reaction times for controls are as follows:

1. On/Off and Level Selects- 1 second maximum for operator or CDS initiation
2. Power Stab. Amplifier Output Level Indicators (discrete)- 1 second from change of state to indication
3. Power Stab. Amplifier Output Monitor- 10 samples per second maximum

3.1.3.3.2 Power Stabilization Servo Level 2 Controls

3.1.3.3.2.1 Sequences and Functions

The modes of operation for the power stabilization servo LCU shall be:

1. Servo Off
2. Servo Locking
3. Servo Locked
4. Cavity Ringdown.

In cavity ringdown mode the light power level shall be modulated. The modulation waveform shall be a square wave with rise and fall times less than 100 nanoseconds. The depth (referenced from 100% power) of the modulation shall be selectable from 10% to 100% in 5% steps. The nominal modulation depth shall be 10%. The accuracy of the modulation depth shall be better than ±2%. The modulation frequency shall be selectable from 32 to 4096 Hz in at least 8 steps. The default modulation frequency shall be 1024 Hz. The accuracy of the modulation frequency shall be better than 10% of the selected frequency.

The default, power up and reset mode of operation for the power stabilization servo LCU is “Servo Off”.

3.1.3.3.2.2 Alarms

TBD

3.1.3.3.2.3 Permits

TBD

3.1.3.3.2.4 Level 1 Devices

For the purposes of control and monitoring, the power stabilization LCU has been broken into two devices. These are the power stabilization amplifier and the modulator devices shown in the figure above. The interface to the reference photodetector is at the output connector of the photodetector. Any conditioning electronics used to condition or transmit the photodetector signal are included as part of the power stabilization amplifier device. The interface to the AOM is at the input connector of the AOM. The minimum required performance and signals for each device are described in the following figures and tables.

3.1.3.3.3 Power Stabilization Amplifier Device

3.1.3.3.3.1 Performance

The power stabilization servo amplifier shall have connections for the following:

1. Input- input signal to amplifier from reference photo detector
2. Reference Photodetector Output- Remote Diag.
3. Reference Photodetector Output- Data Acq.
4. Output- Output to AOM driver AM input. Zout = 50 ohms. 0<Vout<1volt.
5. Output Monitor- Data Acquisition
6. Output Monitor- Remote Diagnostics

3.1.3.3.3.2 Control Signals

The controls and monitors for the amplifier shall be:

1. Gain Select- The amplifier DC gain shall selectable from94 to 124 dB in 12 steps.
2. Vernier Bias Adjust- Fine power level control, continuously adjustable with minimum 12 bit resolution.
3. Output Enable/Disable Select- The output of the amplifier shall be capable of being enabled or disabled. The present selection shall be monitored through the VME bus.
4. Output Monitor- The output of the amplifier shall have a monitor available to the VME bus.
5. Output Level Indicator- Discrete monitors of the output level corresponding to full scale, 3/4 full scale, —3/4 full scale, and —full scale shall be monitored through the VME bus. The indication shall be latching and be reset through the VME bus.
6. Ringdown Level Select- High and low selection from 0 to 100 percent modulation
7. Ringdown Frequency Select- Ringdown modulation frequency

Figure 13 Power Stabilization Amplifier Device Interface Signals

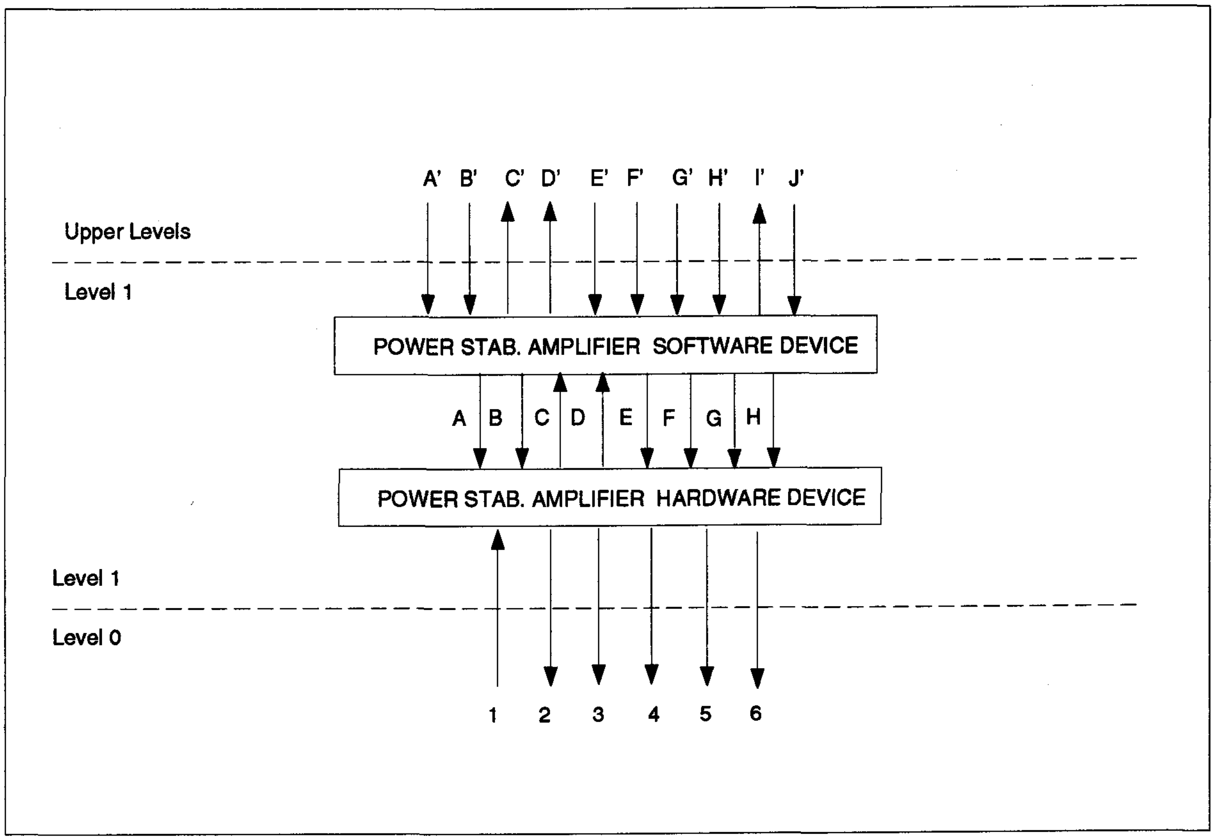


Table 13 Power Stabilization Amplifier Device Level 1 to Upper Levels Interface Signals

Label	Description	Signal Type
A	Gain Select	TTL, multi-bit
B	Output Enable/Disable Select	TTL
C	Output Monitor	0-10 VDC
D	Output Level Indicator	TTL, multi-bit
E	Ringdown Modulator Level Select	0-10 VDC
F	Ringdown Frequency Select	TBD

Table 13 (Continued) Power Stabilization Amplifier Device Level 1 to Upper Levels Interface Signals

Label	Description	Signal Type
G	Ringdown Enable/Disable Select	TTL
H	Vernier Bias Adjust	0-10 VDC
A'	Power Level Select	Software, TBD
B'	Output Enable/Disable Select	bo
C'	Output Monitor	ai
D'	Output Level Indicator	mbbi
E'	Ringdown Modulator Level Select	ao
F'	Ringdown Frequency Select	Software, TBD
G'	Ringdown Enable/Disable Select	bo
H'	Vernier Bias Adjust	ao
I'	Power Stabilization Ampl. Device Alarms	alarm
J'	Power Stabilation Ampl. Device Permits	Software

Table 14 Power Stabilization Amplifier Device Level 1 Level 0 Interface Signals

Label	Description	Signal Type
1	Reference Photodetector Input	-10 to +10 VDC
2	Reference Photodetector Output (Remote Diag)	-10 to +10 VDC
3	Reference Photodetector Output (Data Acq)	-5 to +5 VDC
4	Output	0 to 1 V
5	Output Monitor (Remote Diag)	-10 to +10 VDC
6	Output Monitor (Data Acq)	-5 to +5 VDC

3.1.3.3.3.3 Sequences and Functions

The status of each signal in each operating mode shall be as listed below. Signals not listed are assumed to be unaffected by operating mode.

Figure 14 Power Stabilization Amplifier Signal Status vs. Operating Mode

Operating Mode/ Signal	Servo Off	Servo Locking	Servo Locked	Cavity Ringdown
Output Enable/Disable Select	Disable	Enable	Enable	Disable
Ringdown Enable/Disable Select	Disable	Disable	Disable	Enable

3.1.3.3.3.4 Alarms

Power stabilization amplifier alarms shall be generated for the following:

Figure 15 Power Stabilization Amplifier Device Alarms

ALARM CONDITION	SEVERITY	ACTION
Output Power Greater Than 3/4 Power	Minor	Operator Warning
Output Power Less Than 1/4 Power and Amplifier Enabled	Minor	Operator Warning

3.1.3.3.3.5 Permits

The following device interlocks and permits shall be incorporated:

1. The power stabilization amplifier servo shall be disabled when the power stabilization LCU is in the "Ringdown" mode of operation.

3.1.3.3.4 Modulator Device

3.1.3.3.4.1 Performance

The AOM driver is a commercial unit (IntraAction Corporation model DE-40M). It has front panel controls for on/off select switch, carrier frequency adjust and carrier level adjust. The unit has BNC connectors for:

1. Analog Input: Zin= 50 ohms, 0–1volt = 30–50 MHz carrier
2. Modulation Input: Zin= 50 ohms, 0–1 volt = 0–4 watts output power
3. RF Output: 4 watts maximum, Zout= 50 ohms

The AOM has an input BNC connector.

3.1.3.3.4.2 Control Signals

The acoustic driver is a commercial unit (IntraAction Corporation model DE-40M). Controls for the DE-40M shall be:

1. TBD

Figure 16 Modulator Device Interface Signals

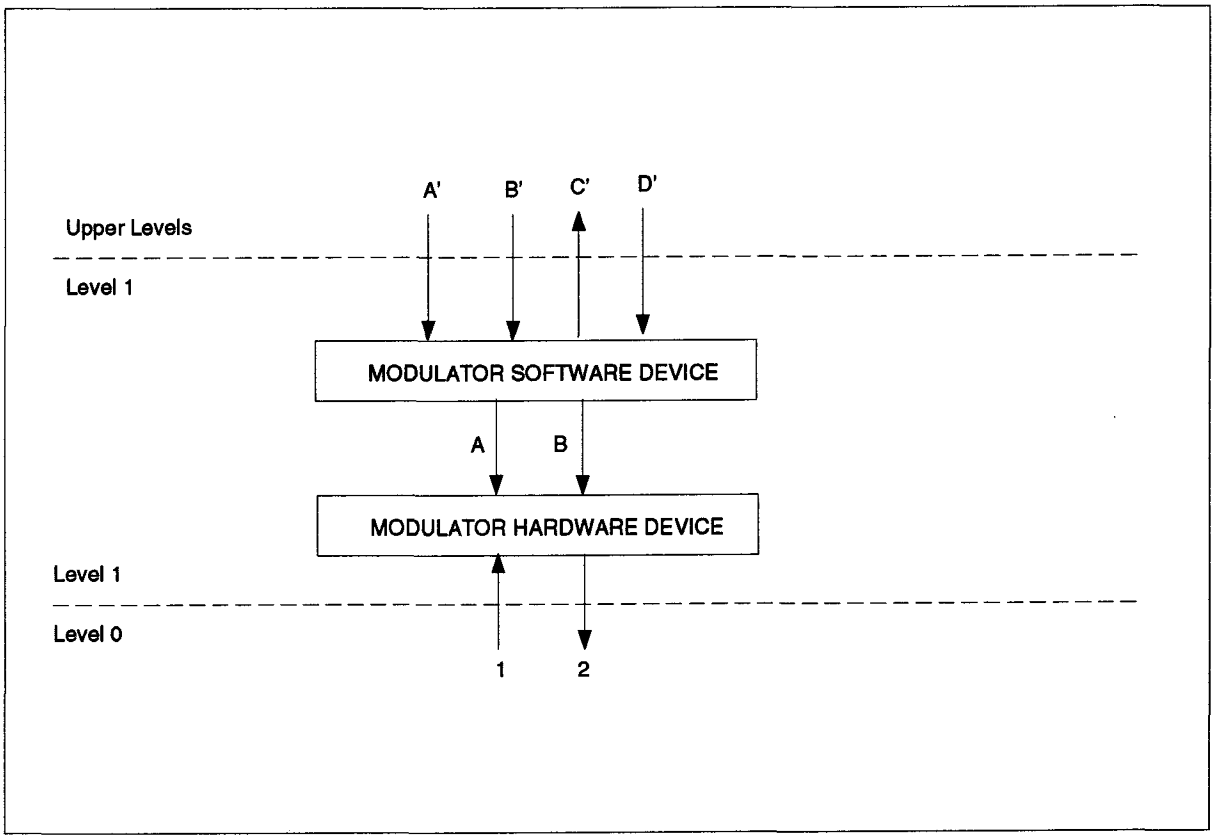


Table 15 Modulator Device Level 1 to Upper Levels Interface Signals

Label	Description	Signal Type
A	Modulator On/Off Select	TTL
B	Carrier Frequency Adjust	0-10 VDC
A’	Modulator On/Off Select	bo
B’	Carrier Frequency Adjust	ao
C’	Modulator Device Alarms	alarm
D’	Modulator Device Permits	Software

Table 16 Modulator Device Level 1 to Level 0 Interface Signals

Label	Description	Signal Type
1	Modulator Input to AOM Driver	0 to 1 V
2	Modulator Output to AOM	Matched to unit by manufacturer. (See manual).

3.1.3.3.4.3 Sequences and Functions

None

3.1.3.3.4.4 Alarms

None

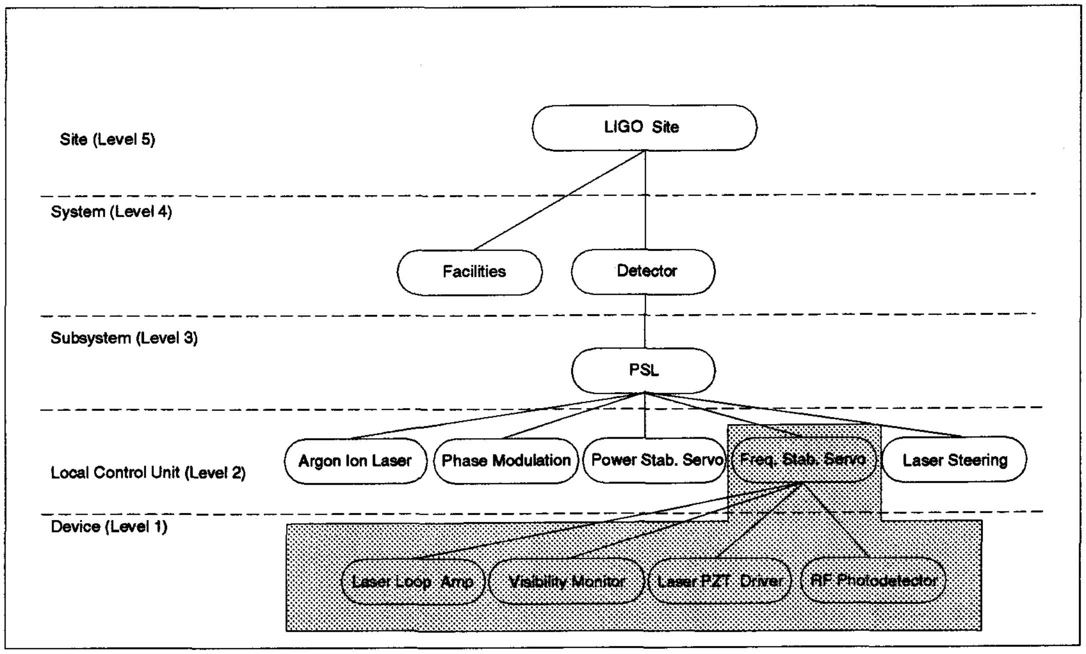
3.1.3.3.4.5 Permits

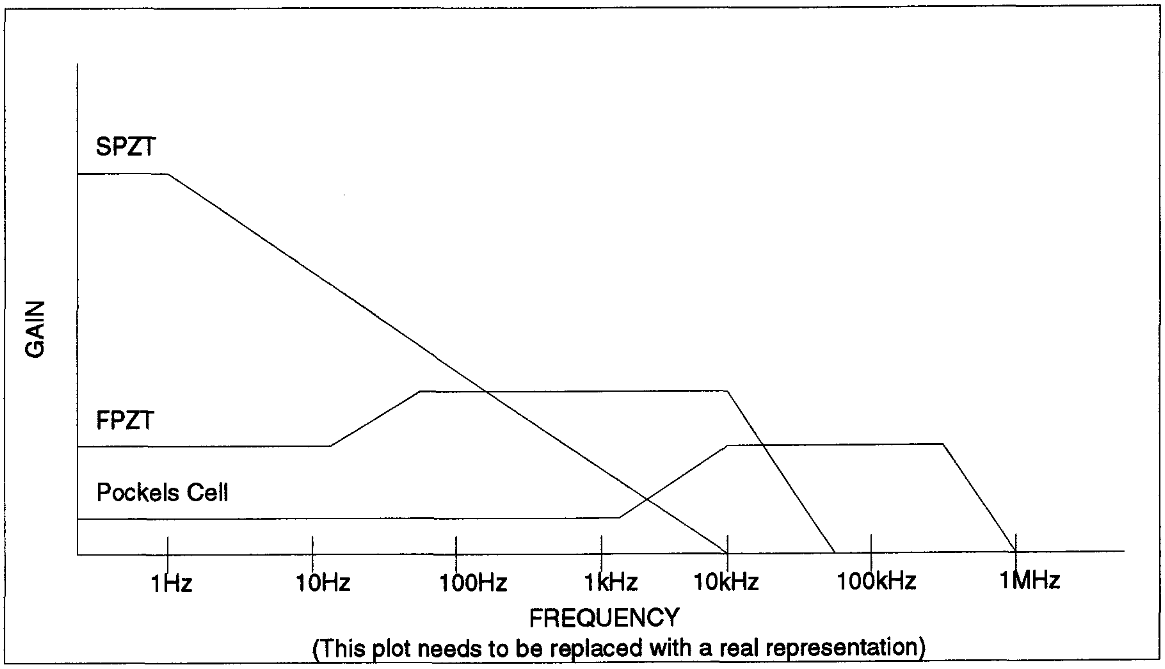
None

3.1.3.4 Laser Frequency Stabilization Servo (FSS)

The figure below highlights the levels of the PSL CIM model that are covered by this section. The frequency stabilization servo uses pockels cells, piezo mounted laser mirrors and a rigid spacer Fabry-Perot cavity to prestabilize the laser light frequency. Three different devices are used: phase correcting pockels cells, the "fast" PZT and the "slow" PZT. In general the slow PZT is used for loop response frequencies less than 500 Hz. The fast PZT is used for loop response frequencies between 500 Hz and 50 kHz. The pockels cells are used for loop response frequencies greater than 50 kHz. An approximation of the response of each device versus frequency is shown in the figure below. The gain and transfer function requirements for the frequency stabilization servo electronics are specified in document number TBD.

Figure 17 LIGO PSL Frequency Stabilization Servo CIM Model





(This plot needs to be replaced with a real representation)

Figure 18 Frequency Stabilization Device Response versus Frequency

Prestabilization of the laser is achieved by locking the laser frequency to a resonance of the reference cavity. The PSL FSS is made up of four devices. They are:

1. RF Photodetector- provides DC and RF outputs for light reflected from the reference cavity input mirror. The DC output signal is sent to the visibility monitor. The demodulated RF signal output is sent to the laser loop amplifier where it is used for frequency stabilization.
2. Laser loop amplifier-is the main frequency stabilization servo amplifier with outputs to the Pockels cells and PZT driver.
3. PZT driver- controls the high voltage drive to the fast and slow PZTs used to adjust the laser frequency.
4. Visibility monitor- provides a measure of the "visibility" of a cavity. When the cavity is in lock the visibility will be maximum. Visibility is defined as:

$V= (I_{in}-I_{refl})/I_{in}$

where, I_{in} is the input power to the reference cavity and I_{refl} is the reflected power (at the input to the reference cavity)measured by the RF photodetector (DC output).

A block diagram of the FSS is shown in the figure below.

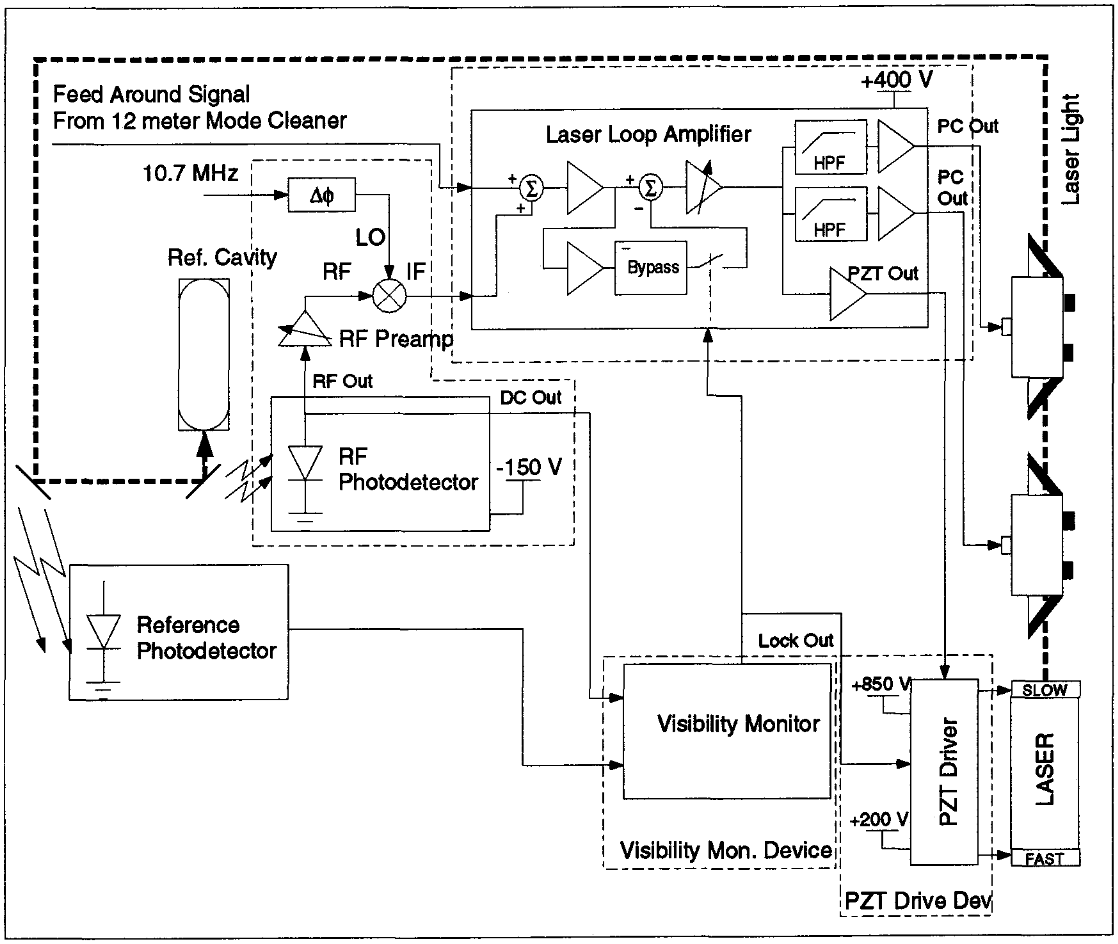


Figure 19 Frequency Stabilization Servo Block Diagram

3.1.3.4.1 Frequency Stabilization Servo Level 2 Performance

The frequency stabilization servo system shall have an open loop spectral noise voltage, referenced to the input:

$$V(f) < 5 \text{ nV}/(\text{Hz})^{1/2}$$

for, 30 Hz $\leq f \leq$ 100 KHz.

Also, to assure linear operation, all of the amplifier stages should not approach their maximum output or slew rates limits under normal operating conditions.

Update rates and reaction times for the controls are as follows:

1. On/Off Selects and Level Adjustments- 1 second maximum for operator or CDS initiation.
2. Pockels Cell, Visibility and PZT Output Monitors- 10 samples per second maximum
3. RF Photodetector and Laser Loop Amplifier Demodulated Output Monitor- 10 samples per second maximum
4. Power Supply Voltage and Current Monitors- 1 sample per second maximum
5. Slow PZT Scanning Disable on Lock Indication- 1 millisecond

3.1.3.4.2 Frequency Stabilization Servo Level 2 Controls

3.1.3.4.2.1 Sequences and Functions

The modes of operation of the frequency stabilization servo shall be:

1. Servo Off
2. Servo Acquiring
3. Servo Locked
4. Manual Scanning

In the “Servo Off” mode the laser loop amplifier output shall be disabled. The output shall be enabled in the “Servo Acquiring” and “Servo Locked” modes. In the “Manual Scanning” mode the output may be enabled or disabled.

In the “Servo Acquiring” mode the laser slow PZT shall scan. The range of the scan shall be 0–800 volts and the frequency of the scan shall be 1 Hz. The time to disable PZT scanning when the operating mode changes from “Servo Acquiring” to “Servo Locked” shall be less than 2 milliseconds. In the “Manual Scanning” mode the laser slow PZT shall scan continuously.

The “Servo Locked” mode of operation is achieved when the visibility monitor Lock Indicator Output is set to “TRUE”. This indicates a cavity visibility greater than the visibility threshold.

The default, power up and reset mode of operation shall be “Servo Off”

3.1.3.4.2.2 Alarms

TBD

3.1.3.4.2.3 Permits

The following permits shall be incorporated:

1. Laser slow PZT scanning shall be disabled when the laser is off.

3.1.3.4.2.4 Level 1 Devices

For the purposes of control and monitoring, the frequency stabilization LCU has been broken into four devices. These are the laser loop amplifier, visibility monitor, laser PZT driver and the RF photodetector/down converter devices shown in the figure above. The interface to the RF photodetector is at the output connector of the photodetector. The interface to the pockels cells is at the input connector of each pockels cell. The interface to the laser is at the input connector of the mirror PZTs. The minimum required performance and signals for each device are described in the following figures and tables. Note that each device also includes its respective power supplies.

3.1.3.4.3 Laser Loop Amplifier Device

3.1.3.4.3.1 Performance

The laser loop amplifier shall have BNC (SMA) connections for:

1. Local Oscillator In- +23 dBm max., +7 dBm min., Zin = 50 ohms
2. RF Photodetector In- +15 dBm max., Zin = 50 ohms
3. Feed around in: Zin = 50 ohms
4. PZT Out: Zout = 50 ohms
5. PZT Out: Remote Diag.
6. PZT Out: Data Acquisition
7. DEMO out: Remote Diag.
8. DEMO out: Data Acq..
9. —PC Drive: 400 Vp-p
10. —PC drive monitor: 1Volt/100 Volts, Remote Diag.
11. +PC Drive: 400 Vp-p
12. +PC Drive monitor: 1V/100V, Remote Diag.

The pockels cell (400 Volt) power supply shall have BNC (SHV) connections for:

1. High Voltage Output: SHV connector providing 400 volt power to laser loop amplifier.

The front panel controls and indicators shall be:

1. On/Off Select: High voltage on and off shall be selectable. The current selection shall be indicated.

The stability of supply shall be better than TBD. The output ripple shall be better than TBD.

The input connector on the phase corrector pockels cells are SHV. The input impedance is TBD.

3.1.3.4.3.2 Control Signals

Controls and indicators for the Laser Loop Amplifier shall be:

1. Mode select- The mode of operation shall be selectable. The selections will be Auto, Bypass Off and Bypass On. The current selection shall be readable from the VME bus.
2. Wideband DC Adjust- The wideband DC (Bypass Off) shall be adjustable from the VME bus. The range of the adjustment shall be TBD. The resolution of adjustment shall be TBD. Accuracy shall be TBD. The current selection shall be readable through the VME bus. Wideband DC adjustments are made to compensate for such things as electronic offsets and drifts.
3. Bypass DC Adjust- The bypass DC shall be adjustable from the VME bus. The range of the adjustment shall be TBD. The resolution of adjustment shall be TBD. Accuracy shall be TBD. The current selection shall be readable through the VME bus. Bypass DC adjustments are made to compensate for such things as electronic offsets and drifts.
4. Loop Gain Select- The loop gain of the amplifier shall be selectable. The selections shall be 12 different settings between 0.1 mA and 1.0 mA corresponding to the programming currents of the programmable gain amplifier used in the circuit. The current selection shall be readable from the VME bus.
5. DEMO out monitor-

6. —PC monitor- 1V/100V, 12 bit +/-1 bit FS
7. +PC monitor- 1V/100V, 12 bit +/-1 bit FS
8. Lock Indication- Lock Indication from visibility monitor

Pockels Cells power supply controls and indicators shall be:

1. Output Voltage Monitor: The supply shall have an output monitor. The scaling for the monitor shall be 1volt/100 volt.
2. On/Off select: The on/off status of the power supply shall be selectable. The current selection shall be readable through the VME bus.

Figure 20 Laser Loop Amplifier Device Interface Signals

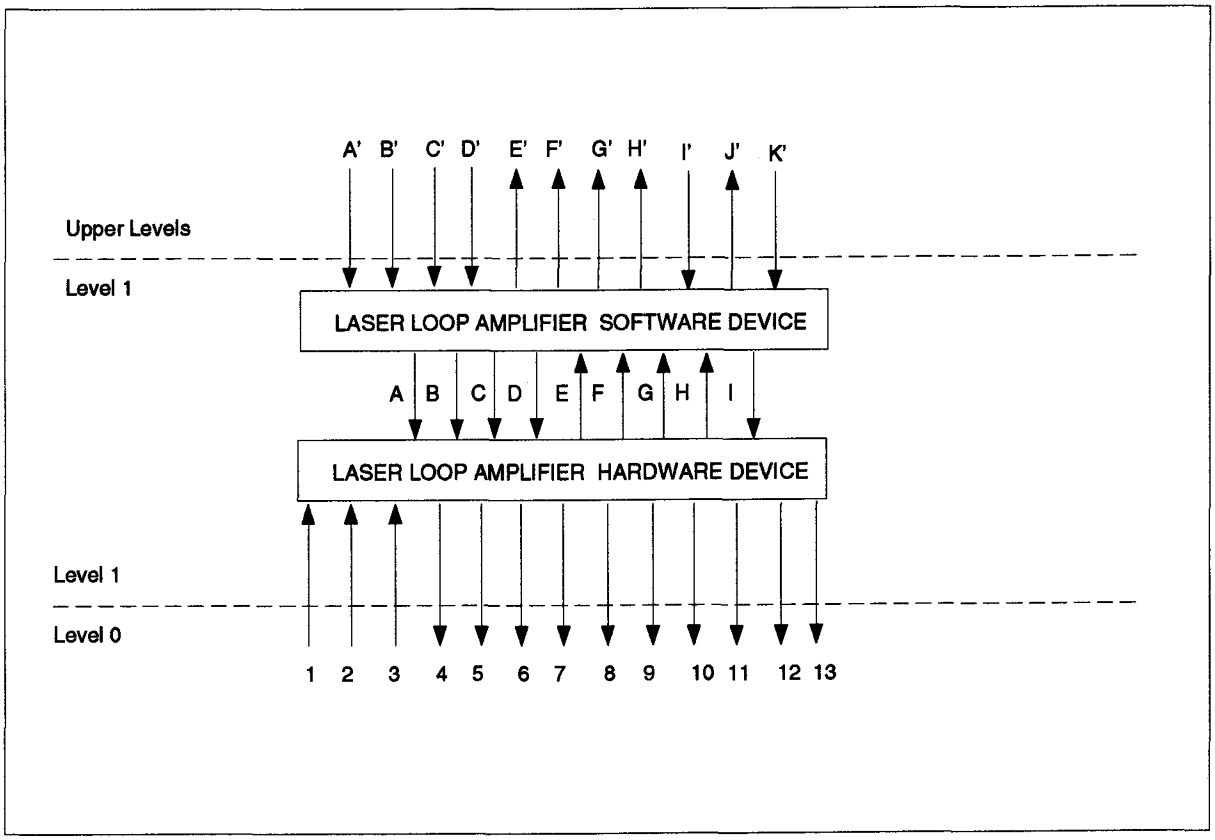


Table 17 Laser Loop Amplifier Device Level 1 to Upper Levels Interface Signals

Label	Description	Signal Type
A	Mode Select	TTL, Multi-bit
B	Wideband DC Adjust	0-10 VDC
C	Bypass DC Adjust	0-10 VDC
D	Loop Gain Select	0-10 VDC
E	DEMO Out Monitor	0-10 VDC
F	-PC Monitor	0-10 VDC
G	+PC Monitor	0-10 VDC
H	PC P.S. Output Voltage Monitor	0-10 VDC
I	PC P.S. On/Off Select	TTL
A'	Mode Select	mbbo
B'	Wideband DC Adjust	ao
C'	Bypass DC Adjust	ao
D'	Loop Gain Select	ao
E'	DEMO Out Monitor	ai
F'	-PC Monitor	ai
G'	+PC Monitor	ai
H'	PC P.S. Output Voltage Monitor	ai
I'	PC P.S. On/Off Select	bo
J'	Laser Loop Ampl. Device Alarms	alarm
K'	Laser Loop Ampl. Device Permits	Software

Table 18 Laser Loop Amplifier Device Level 1 to Level 0 Interface Signals

Label	Description	Signal Type
1	Local Oscillator Input	+ 23 dBm
2	RF Photodetector Input	+15 dBm max.

Table 18 (Continued) Laser Loop Amplifier Device Level 1 to Level 0 Interface Signals

Label	Description	Signal Type
3	Feedaround Signal Input	-12 to +12 VDC
4	PZT Output	-10 to +10 VDC
5	PZT Output, Remote Diag	-10 to +10 VDC
6	PZT Output, Data Acq.	-10 to +10 VDC
7	DEMO Output (Remote Diag)	-10 to +10 VDC
8	DEMO Output (Data Acq.)	-10 to +10 VDC
9	+PC Output Monitor (Remote Diag)	-10 to +10 VDC
10	-PC Output Monitor (Remote Diag)	-10 to +10 VDC
11	-PC Drive	400 Vp-p
12	+PC Drive	400 Vp-p
13	Lock Indication Input	TTL

3.1.3.4.3.3 Sequences and Functions

The modes of operation of the laser loop amplifier device shall be:

1. Bypass Off
2. Bypass On
3. Auto

In the "Bypass Off" mode the low frequency gain of the laser loop amplifier is suppressed. In the "Bypass On" mode the low frequency gain is boosted. The exact details of the gain characteristics for each are described in document number TBD.

In the "Auto" mode of operation the decision as to which level (i.e. bypass off or bypass on) of low frequency gain is selected is determined by an external input from the visibility lock indication. If the operating mode of the frequency stabilization LCU is "Servo Acquiring" then the laser amplifier mode is "Bypass Off", when the LCU mode switches to "Servo Locked" the laser amplifier mode is "Bypass On".

3.1.3.4.3.4 Alarms

Laser loop amplifier alarms shall be generated for the following:

Figure 21 Laser Loop Amplifier Device Alarms

ALARM CONDITION	SEVERITY	ACTION
Pockel Cell Power Supply Transient Detection Alarm	Minor	Operator Warning

3.1.3.4.3.5 Permits

None

3.1.3.4.4 Visibility Monitor Device

3.1.3.4.4.1 Performance

The visibility monitor shall be capable of calculating the visibility while the LCU is in the "locked" mode in a time not to exceed 100 milliseconds. This time includes the time required to measure the appropriate voltage, perform the calculation and determine the lock condition. The accuracy of the calculation shall be better than ±5% full scale. The time to calculate the visibility when the LCU is the "servo acquiring" mode shall not exceed 1 millisecond.

3.1.3.4.4.2 Control Signals

Controls and indicators shall be:

1. RF Photodiode DC Gain: The photodiode gain shall be selectable. The selections shall be x1, x3, x10, x30, x100. The current selection shall be readable through the VME bus.
2. Reference Photodiode DC Gain: The reference gain shall be selectable. The selections shall be x1, x3, x10, x30, x100. The current selection shall be readable through the VME bus.
3. Threshold adjust: The threshold shall be adjustable from 0 to 1 in a minimum of 100 steps.

Figure 22 Visibility Monitor Device Interface Signals

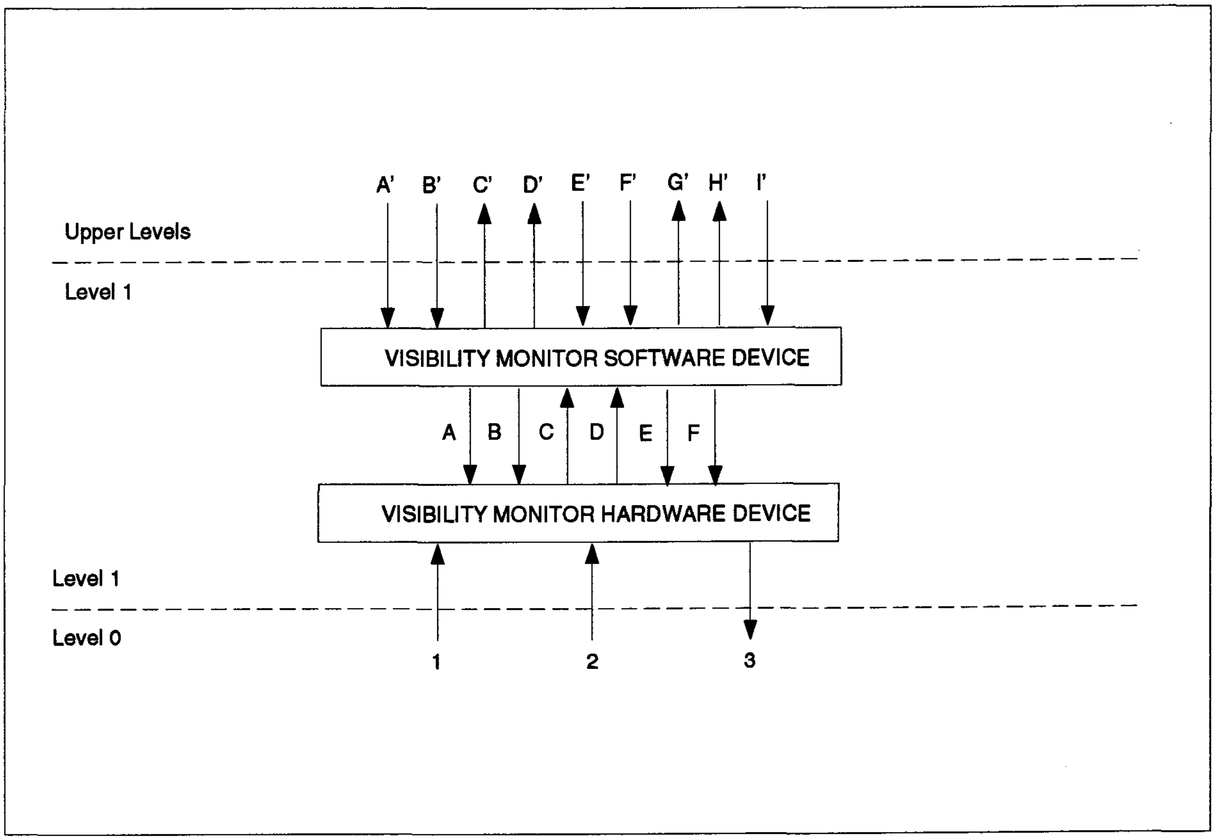


Table 19 Visibility Monitor Device Level 1 to Upper Levels Interface Signals

Label	Description	Signal Type
A	RF (DC) Photodiode Gain Select	TBD
B	Reference Gain Select	TBD
C	Reference Photodiode Input Monitor	0-10 VDC
D	RF (DC) Photodiode Input Monitor	0-10 VDC
E	Lock (bar) Indicator	TTL
F	Threshold Adjust	TBD

Table 19 (Continued) Visibility Monitor Device Level 1 to Upper Levels Interface Signals

Label	Description	Signal Type
A’	RF (DC) Photodiode Gain Select	TBD
B’	Reference Gain Select	TBD
C’	Reference Photodiode Input Monitor	ai
D’	RF (DC) Photodiode Input Monitor	ai
E’	Lock (bar) Indicator	bo
F’	Threshold Adjust	TBD
G’	Visibility Monitor Output	ao
H’	Visibility Monitor Device Alarms	alarm
I’	Visbility Monitor Device Permits	Software

Table 20 Visibility Monitor Device Level 1 to Level 0 Interface Signals

Label	Description	Signal Type
1	Reference Photodetector Input	-10 to +10 V
2	RF Photodetector DC Input	-10 to +10 V
3	Lock (bar) Output	TTL

3.1.3.4.4.3 Sequences and Functions

The visibility monitor has two states: locked=”TRUE” and locked=”FALSE”. Locked=”TRUE” is defined as a calculated visibility greater than or equal to the visibility threshold. Locked=”FALSE” is defined as a calculated visibility less than the visibility threshold.

In the locked=”TRUE” state the Lock Output indicator is set to “TRUE” and the visibility must be calculated at least once every 100 milliseconds.

In the locked=”FALSE” state the Lock Output indicator is set to “FALSE” and the visibility must be calculated at least once every millisecond. This time constraint is set by the necessity to disable the laser slow PZT scanning before the laser cavity is beyond the lock range of the laser loop amplifier.

3.1.3.4.4.4 Alarms

Visibility monitor device alarms shall be generated for the following:

Table 21 Visibility Monitor Driver Device Alarms

ALARM CONDITION	SEVERITY	ACTION
Visibility less than threshold	Minor	Operator warning, Set lock indicator output to "FALSE"
Visibility greater than or equal to threshold	Minor	Operator warning, Set lock indicator output to "TRUE"

3.1.3.4.4.5 Permits

None

3.1.3.4.5 PZT Driver Device

3.1.3.4.5.1 Performance

The PZT driver shall have connections for:

1. Input:
2. Fast Piezo out: Vout(min) = 180 Vp-p
3. Fast Piezo monitor: 1V/100V, Remote Diag.
4. Fast Piezo monitor: 1V/100V, Data Acq.
5. Slow Piezo out: Vout(min) = 700 V
6. Slow Piezo monitor: 1V/100V, Remote Diag.
7. Slow Piezo monitor: 1V/100V, Data Acq.

The slow PZT (850 Volt) power supply shall have connections for:

1. High Voltage Output: SHV connector providing +850 volt power to PZT driver module.
2. Output Voltage Monitor: The supply shall have an output monitor. The scaling for the monitor shall be 1volt/100 volt.

The slow PZT (850 Volt) power supply front panel controls and indicators shall be:

1. On/Off Select: High voltage on and off shall be selectable. The current selection shall be indicated.

The stability of slow PZT supply shall be better than TBD. The output ripple shall be better than TBD.

The fast PZT (200 Volt) power supply shall have connections for:

1. High Voltage Output: SHV connector providing +200 volt power to PZT driver module.
2. Output Voltage Monitor: The supply shall have an output monitor. The scaling for the monitor shall be 1volt/100 volt.

The fast PZT (200 Volt) power supply front panel controls and indicators shall be:

1. On/Off Select: High voltage on and off shall be selectable. The current selection shall be indicated.

The stability of fast PZT supply shall be better than TBD. The output ripple shall be better than TBD.

3.1.3.4.5.2 Control Signals

PZT Driver controls and indicators shall be:

1. Output too low: Output below threshold shall be latching and reset from the VME bus.
2. Output too high: Output above threshold shall be latching and reset from the VME bus.
3. SPZT Mode select- The SPZT mode shall be selectable. The selections shall be AUTO, SCAN, and SERVO (DC). The current selection shall be readable from the VME bus.
4. Fast Piezo monitor- 1V/100V
5. Slow Piezo monitor- 1V/100V
6. Output too Low/High Reset- Reset for Output too Low and Output to High latches.

Slow PZT power supply controls and indicators shall be:

1. Output Voltage Monitor: The supply shall have an output monitor. The scaling for the monitor shall be 1volt/100 volt.
2. On/Off select: The on/off status of the power supply shall be selectable. The current selection shall be readable through the VME bus.

Fast PZT power supply controls and indicators shall be:

1. Output Voltage Monitor: The supply shall have an output monitor. The scaling for the monitor shall be 1volt/100 volt.
2. On/Off select: The on/off status of the power supply shall be selectable. The current selection shall be readable through the VME bus.

Figure 23 PZT Driver Device Interface Signals

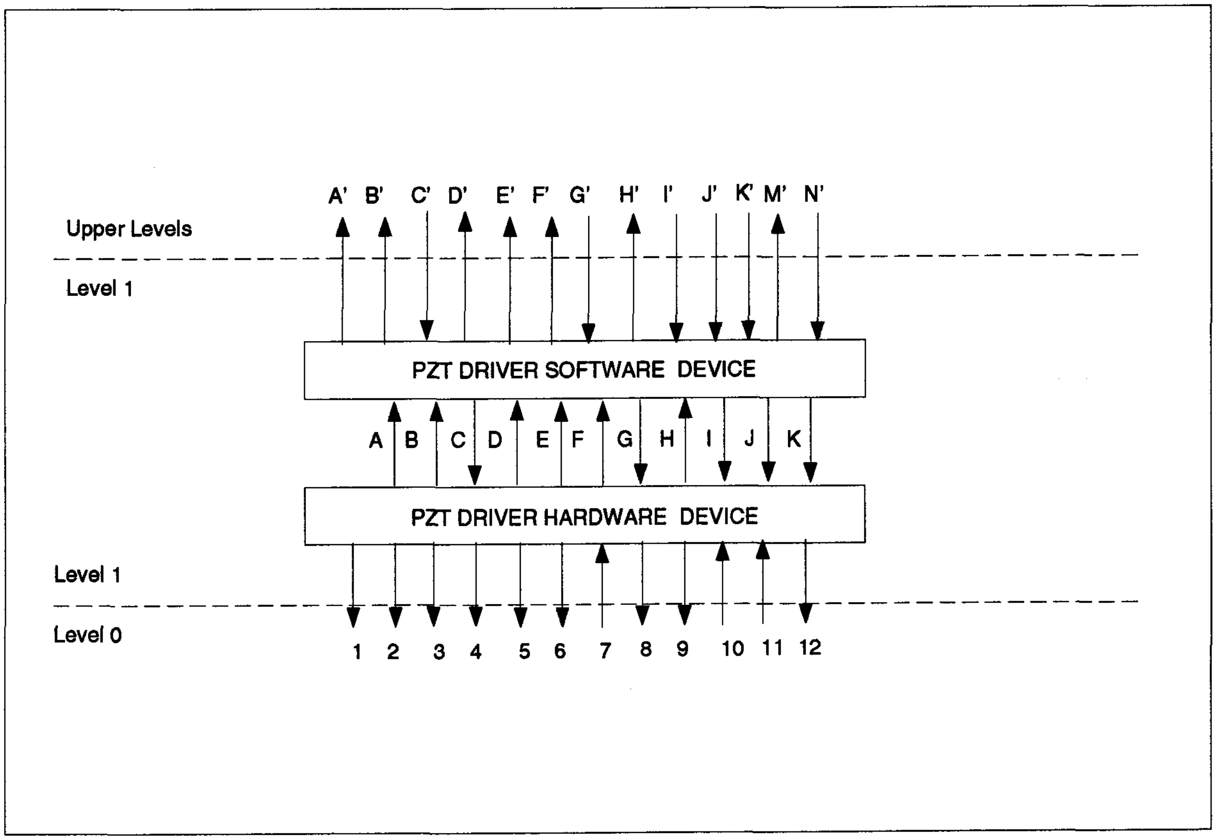


Table 22 PZT Driver Device Level 1 to Upper Levels Interface Signals

Label	Description	Signal Type
A	Drive Output Too Low	TTL
B	Drive Output Too High	TTL
C	SPZT Mode Select	TTL, Multi-bit
D	Slow PZT Output Monitor	0-10 VDC
E	Fast PZT Output Monitor	0-10 VDC
F	Slow PZT P.S. Voltage Monitor	0-10 VDC
G	Slow PZT P.S. On/Off Select	TTL
H	Fast PZT P.S. Voltage Monitor	0-10 VDC
I	Fast PZT P.S. On/Off Select	TTL
J	Output too Low/High Reset	TTL
K	Slow PZT Scan Reference	0-10 VDC
A’	Drive Output Too Low	bi
B’	Drive Output Too High	bi
C’	SPZT Mode Select	mbbo
D’	Slow PZT Output Monitor	ai
E’	Fast PZT Output Monitor	ai
F’	Slow PZT P.S. Voltage Monitor	ai
G’	Slow PZT P.S. On/Off Select	bo
H’	Fast PZT P.S. Voltage Monitor	ai
I’	Fast PZT P.S. On/Off Select	bo
J’	Output too Low/High Reset	bo
K’	Slow PZT Scan Reference	ao
L’	PZT Driver Device Alarms	alarm
M’	PZT Driver Device Permits	Software

Table 23 PZT Driver Device Level 1 to Level 0 Interface Signals

Label	Description	Signal Type
1	Slow PZT Drive Output	0 to 850 V
2	Fast PZT Drive Output	0 to 200 V
3	Slow PZT Monitor (Remote Diag)	0 to 10 V
4	Fast PZT Monitor (Remote Diag)	0 to 10 V
5	Slow PZT Monitor (Data Acq.)	0 to 10 V
6	Fast PZT Monitor (Data Acq.)	0 to 10 V
7	PZT Input	-12 to +12 V
8	Slow PZT P.S. On/Off Select	TTL
9	Fast PZT P.S. On/Off Select	TTL
10	Slow PZT P.S. Voltage Monitor In	0-10 VDC
11	Fast PZT P.S. Voltage Monitor In	0-10 VDC
12	Output too High/Low alarm reset	TTL

3.1.3.4.5.3 Sequences and Functions

None

3.1.3.4.5.4 Alarms

PZT driver device alarms shall be generated for the following:

Table 24 PZT Driver Device Alarms

ALARM CONDITION	SEVERITY	ACTION
Drive output too high	Minor	Operator Warning
Drive output too low	Minor	Operator Warning
Slow PZT Power Supply Transient Detection Alarm	Minor	Operator Warning
Fast PZT Power Supply Transient Detection Alarm	Minor	Operator Warning

3.1.3.4.5.5 Permits

None

3.1.3.4.6 RF Photodetector Device

3.1.3.4.6.1 Performance

The RF photodetector shall have connections for:

1. RF output- Zout= 50 ohms
2. DC output- Remote Diag.
3. DC output- Data Acq.
4. HV Bias Input- Vin max= —150 VDC
5. RF Photodiode Input: Input from photodiode supplied by interferometer group

The photodiode bias (-150 volt) supply shall have connections for:

1. High Voltage Output: SHV connector providing –150 volt power to the RF photodetector.
2. Output Voltage Monitor: The supply shall have an output monitor. The scaling for the monitor shall be 1volt/100 volt.

The photodiode bias supply front panel controls and indicators shall be:

1. On/Off Select: High voltage on and off shall be selectable. The current selection shall be indicated.

The stability of photodiode bias supply shall be better than TBD. The output ripple shall be better than TBD.

The RF phase shifter shall have connections for:

1. Input: Zin = 50 ohm, +23 dBm nominal
2. Output 1: Zout = 50 ohm, +23 dBm nominal

The phase shifter shall be capable of covering a full 360 degrees of phase shift at 10.7 MHz in steps no larger than 4.5 degrees.

3.1.3.4.6.2 Control Signals

Photodiode Bias Supply Controls and indicators shall be:

1. Output Voltage Monitor: The supply shall have an output monitor. The scaling for the monitor shall be 1volt/100 volt.

2. On/Off select: The on/off status of the power supply shall be selectable. The current selection shall be readable through the VME bus.

RF phase shifter controls and indicators shall be:

1. Local Oscillator Phase Shift Select: 0 to 360 degrees in 4.5 degree steps minimum. The current selection shall be readable through the VME bus.

Figure 24 RF Photodetector Device Interface Signals

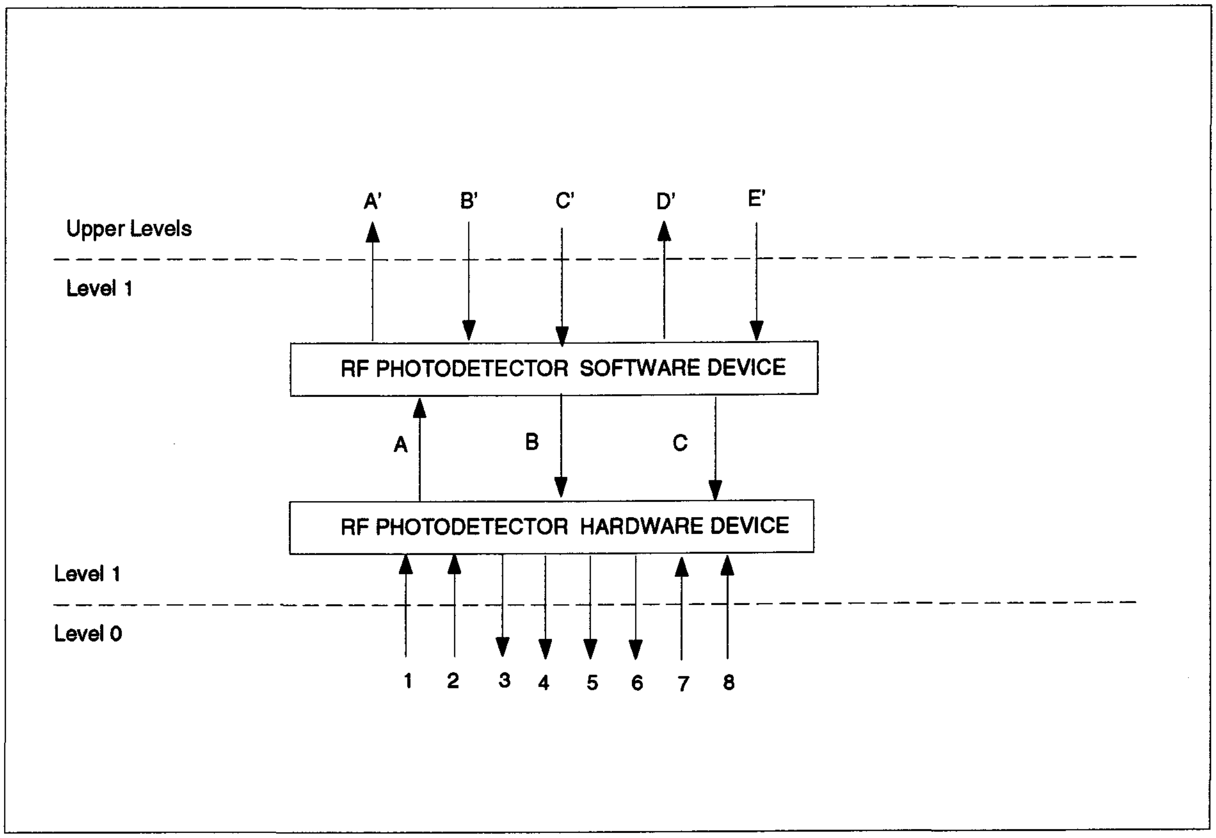


Table 25 RF Photodetector Device Level 1 to Upper Levels Interface Signals

Label	Description	Signal Type
A	Photodiode Bias Supply Voltage Monitor	0-10 VDC
B	Photodiode Bias Supply On/Off Select	TTL

Table 25 (Continued) RF Photodetector Device Level 1 to Upper Levels Interface Signals

Label	Description	Signal Type
C	RF L.O. Phase Select	0-10 VDC
A'	Photodiode Bias Supply Voltage Monitor	ai
B'	Photodiode Bias Supply On/Off Select	bo
C'	RF L.O. Phase Select	ao
D'	RF Photodiode Device Alarms	alarm
E'	RF Photodiode Device Permits	Software

Table 26 RF Photodetector Device Level 1 to Level 0 Interface Signals

Label	Description	Signal Type
1	RF Photodetector Input	-10 to +10 V
2	Detector RF Output	+ 15 dBm max.
3	Detector DC Output	-10 to +10 V
4	Detector DC Out (Remote Diag)	-10 to +10 V
5	Detector DC Out (Data Acq.)	-10 to +10 V
6	RF Photodetector Bias Supply On/Off Select	TTL
7	RF Photodiode Bias Supply Voltage Monitor	0-10 VDC
8	LO Input	+23 dBm

3.1.3.4.6.3 Sequences and Functions

The operator shall have the ability to flip the local oscillator phase select 180 degrees in one step.

3.1.3.4.6.4 Alarms

RF photodetector device alarms shall be generated for the following:

Table 27 RF Photodetector Device Alarms

ALARM CONDITION	SEVERITY	ACTION
Photodiode Bias Power Supply Transient Detection Alarm	Minor	Operator Warning

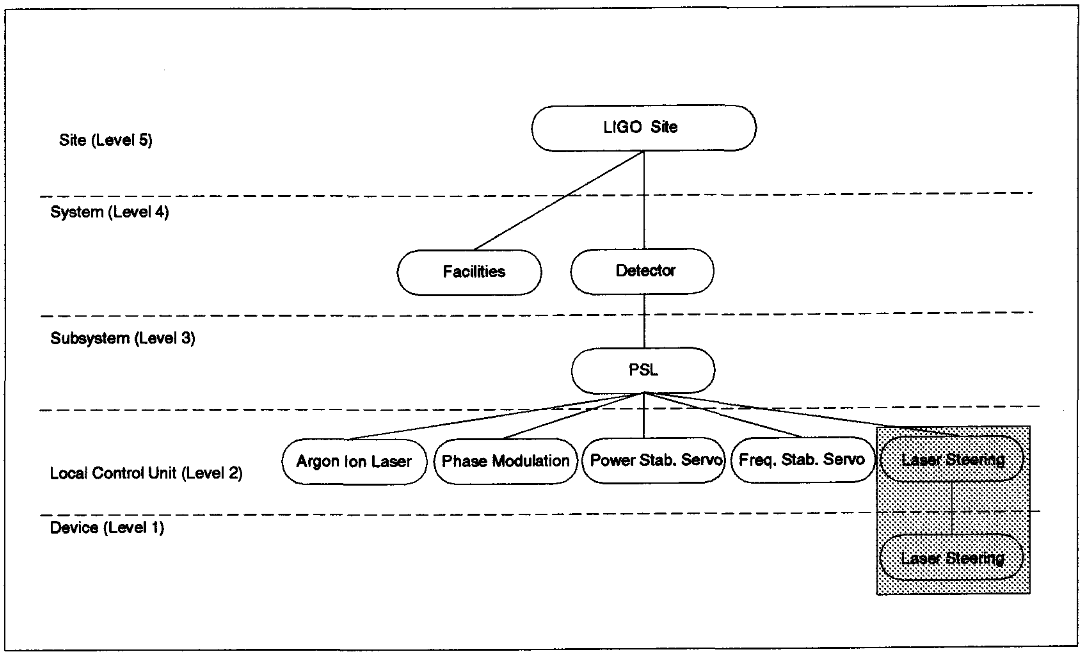
3.1.3.4.6.5 Permits

None

3.1.3.5 Laser Beam Steering

The figure below highlights the levels of the PSL CIM model that are covered by this section. The laser steering system uses piezo mounted mirrors to steer the laser light to the reference cavity in both the x and y axis in order to compensate for slow variations in alignment of input llight to the reference cavity. The primary components used in the steering systems are:

Figure 25 LIGO PSL Laser Steering CIM Model



1. Piezo mounted mirrors: deflect beam in x and y directions, part of the interferometer system.

2. Steering Mirror PZT Driver: provides high voltage drive to steering mirror PZTs
3. Steering Mirror PZT Power Supplies: provide +150 volt DC to PZT driver

3.1.3.5.1 Laser Steering Level 2 Performance

The output voltage ripple of the mirror piezo output shall be less than 1 mV peak, i.e. 1 part in 10^5 full scale.

Update rates and reaction times for the controls are as follows:

1. On/Off Selects and Level Adjustments- 1 second maximum for operator or CDS initiation.
2. PZT Output Monitors- 10 samples per second maximum
3. Power Supply Voltage and Current Monitors- 1 sample per second maximum.

3.1.3.5.2 Laser Steering Level 2 Controls

3.1.3.5.2.1 Sequences and Functions

None

3.1.3.5.2.2 Alarms

None

3.1.3.5.2.3 Permits

None

3.1.3.5.2.4 Level 1 Devices

For the purposes of control and monitoring the Laser Steering LCU has been grouped into one device which includes both mirror steering PZT drivers and the PZT power supply. The minimum performance and signals for this device are shown in the figure and table below.

3.1.3.5.3 Laser Steering Device

3.1.3.5.3.1 Performance

The steering mirror PZT driver shall have connections for:

1. Mirror 1 X Piezo out: Vout = 140 volts max.
2. Mirror 1 Y Piezo out: Vout = 140 volts max.
3. Mirror 2 X Piezo out: Vout = 140 volts max.
4. Mirror 2 Y Piezo out: Vout = 140 volts max.

The PZT (150 Volt) power supply shall have BNC (SHV) connections for:

1. High Voltage Output: SHV connector providing +150 volt power to PZT driver module.
2. Output Voltage Monitor: The supply shall have an output monitor. The scaling for the monitor shall be 1volt/100 volt.

The front panel controls and indicators shall be:

1. On/Off Select: High voltage on and off shall be selectable. The current selection shall be indicated.

The stability of supply shall be better than TBD. The output ripple shall be better than TBD.

3.1.3.5.3.2 Control Signals

Steering mirror PZT driver controls and indicators shall be:

1. Mirror 1 X Piezo monitor- 1V/100V
2. Mirror 1 Y Piezo monitor- 1V/100V
3. Mirror 2 X Piezo monitor- 1V/100V
4. Mirror 2 Y Piezo monitor- 1V/100V

PZT Power Supply controls and indicators shall be:

1. Output Voltage Monitor: The supply shall have an output monitor. The scaling for the monitor shall be 1volt/100 volt.
2. On/Off select: The on/off status of the power supply shall be selectable. The current selection shall be readable through the VME bus.

Figure 26 Laser Steering Device Interface Signals

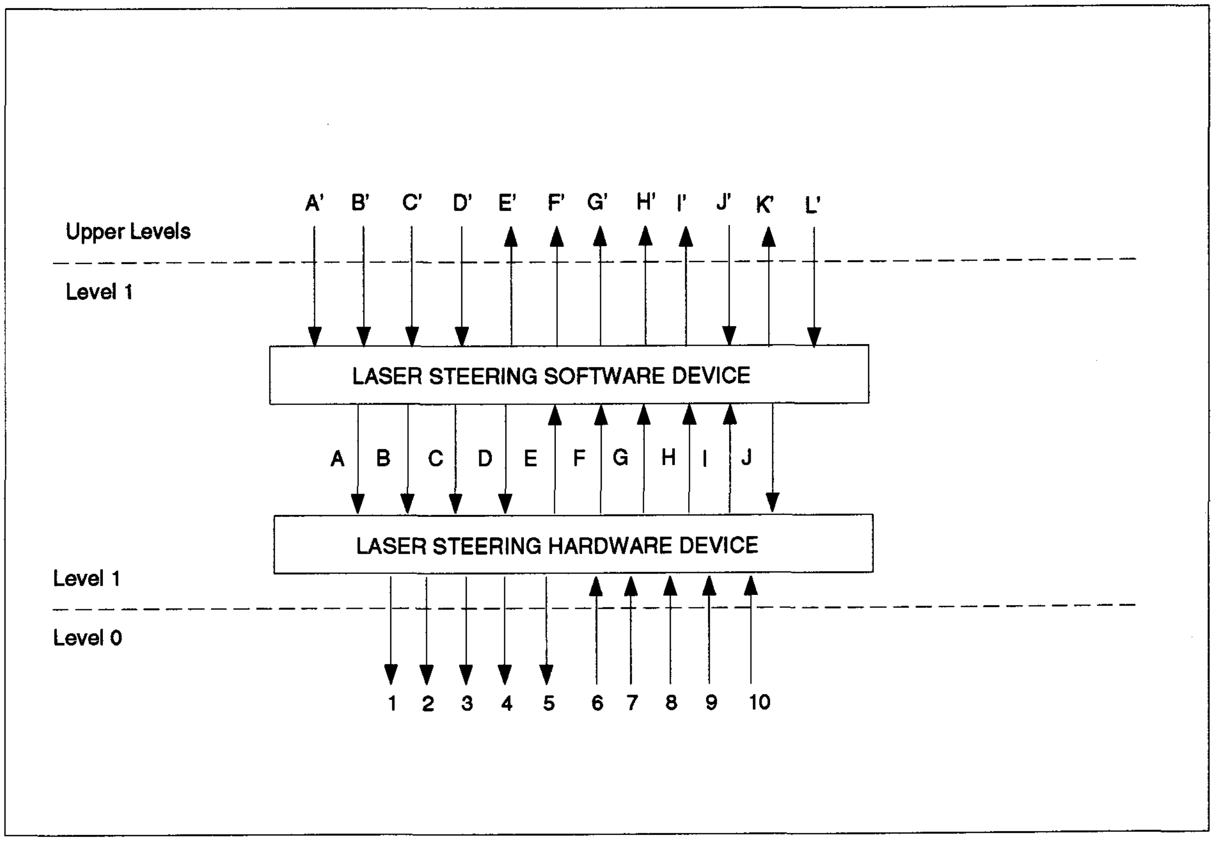


Table 28 Laser Steering Device Level 1 to Upper Levels Interface Signals

Label	Description	Signal Type
A	Ref Cavity Mirror 1 X Position Select	0-10 VDC
B	Ref Cavity Mirror 1 Y Position Select	0-10 VDC
C	Ref Cavity Mirror 2 X Position Select	0-10 VDC
D	Ref Cavity Mirror 2 Y Position Select	0-10 VDC
E	Ref Cavity X PZT 1 Output Voltage Monitor	0-10 VDC

Table 28 (Continued) Laser Steering Device Level 1 to Upper Levels Interface Signals

Label	Description	Signal Type
F	Ref Cavity Y PZT 1 Output Voltage Monitor	0-10 VDC
G	Ref Cavity X PZT 2 Output Voltage Monitor	0-10 VDC
H	Ref Cavity X PZT 2 Output Voltage Monitor	0-10 VDC
I	PZT P.S. Voltage Monitor	0-10 VDC
J	PZT P.S. On/Off Select	TTL
A’	Ref Cavity Mirror 1 X Position Select	ao
B’	Ref Cavity Mirror 1 Y Position Select	ao
C’	Ref Cavity Mirror 2 X Position Select	ao
D’	Ref Cavity Mirror 2 Y Position Select	ao
E’	Ref Cavity X PZT 1 Output Voltage Monitor	ai
F’	Ref Cavity Y PZT 1 Output Voltage Monitor	ai
G’	Ref Cavity X PZT 2 Output Voltage Monitor	ai
H’	Ref Cavity X PZT 2 Output Voltage Monitor	ai
I’	PZT P.S. Voltage Monitor	ai
J’	PZT P.S. On/Off Select	bo
K’	Laser Steering Device Alarms	alarm
L’	Laser Steering Device Permits	Software

Table 29 Laser Steering Device Level 1 to Level 0 Interface Signals

Label	Description	Signal Type
1	X PZT Output Mirror 1	0-140 volts
2	Y PZT Output Mirror 1	0-140 volts
3	X PZT Output Mirror 2	0-140 volts
4	Y PZT Output Mirror 2	0-140 volts
5	PZT P.S. On/Off Select	TTL
6	PZT P.S. Voltage Monitor	0-10 VDC
7	X PZT Output Mirror 1 Voltage Monitor	0-10 VDC
8	Y PZT Output Mirror 1 Voltage Monitor	0-10 VDC
9	X PZT Output Mirror 2 Voltage Monitor	0-10 VDC
10	Y PZT Output Mirror 2 Voltage Monitor	0-10 VDC

3.1.3.5.3.3 Sequences and Functions

None

3.1.3.5.3.4 Alarms

Laser steering device alarms shall be generated for the following:

Table 30 Laser Steering Device Alarms

ALARM CONDITION	SEVERITY	ACTION
PZT Power Supply Transient Detection Alarm	Minor	Operator Warning

3.1.3.5.3.5 Permits

None

3.2 Characteristics

3.2.1 Performance

3.2.1.1 Analog Resolution and Accuracy

All analog to digital and digital to analog conversions shall have a resolution of 12 bits +/- 1 bit full scale unless specified otherwise.

3.2.1.2 Power Supply Transient Monitoring

To as great an extent as possible, all high voltage and bias power supplies shall be equipped with transient detection circuitry. This circuitry shall be capable of detecting transients of greater than 50 microseconds and larger that TBD% full scale. Upon transient detection, the circuit will latch until the transient has cleared and a reset from the CDS has been issued. The detection of a transient shall also generate an operator warning.

3.2.1.3 Calibration and Compensation

In general, all components used within the system shall have no requirement for local front panel gain calibration and offset correction during normal interferometer operations. To this end, all components shall contain provisions for any or all of the following:

1. Self calibration and compensation
2. remote adjustment and monitoring of all calibration and compensation devices

3.2.2 Physical Characteristics

All PSL controls shall be designed in accordance with the VME specification unless specified otherwise. VME modules shall be standard 6U modules using multiple slots if necessary.

VME modules currently supported by EPICS shall be utilized to implement the PSL controls to the greatest extent possible.

3.2.3 Reliability

TBD

3.2.4 Maintainability

TBD

3.2.5 Environmental Conditions

All subsystem controls shall meet all performance requirements when exposed to all specified natural and induced environments.

3.2.5.1 Temperature and Humidity

The ambient environmental design range shall be as follows:

1. Operating: +40 C/20–90% RH to 0C/20–90% RH
2. Non-operating: +70C/20–90% RH to —40C/20–90% RH
3. Transport only: +70C/10–90% RH to —40C/10–90% RH

3.2.5.2 Atmospheric Pressure

The subsystem controls design must accommodate atmospheric pressure changes from a maximum of 15.2 psia to a minimum of 14.2 psia.

3.2.5.3 Background Electromagnetic Radiation

The subsystem controls shall not degrade due to background electromagnetic emissions as specified by IEEE C95.1–1991.

3.2.6 Transportability

All items shall be transportable without degradation in performance. As necessary, provisions shall be made for measuring and controlling environmental conditions (temperature and acceleration) during transport and handling. Special shipping containers, shipping and handling mechanical restraints, and shock isolation shall be utilized to prevent damage. All containers must be movable by a forklift.

3.3 Design and Construction

3.3.1 Materials, Processes and Parts

TBD

3.3.2 Electromagnetic Radiation

TBD

3.3.3 Identification and Marking

All components shall be uniquely identified. Commercial components shall be identified by manufacturers name, model number and component serial number. Custom LIGO components shall be identified by model number and component serial number. To as great an extent as possible, component markings shall be in a visible location such as the component front panel or face plate.

All channel names, rack names, cable numbers and device names shall be in accordance with the appropriate LIGO standards.

All software signal channel names developed for the PSL controls shall follow the LIGO CDS naming convention.

3.3.4 Workmanship

All details of workmanship shall be of the highest grade appropriate to the methods and level of fabrication and consistent with the requirements specified herein. There shall be no evidence of poor workmanship that would make the components unsuitable for the purpose intended. All electronic circuits, modules and wiring shall be consistent with good engineering practice and fabricated to best commercial standards.

3.3.5 Interchangeability

The CDS PSL controls shall be designed to maximize interchangeability and replaceability of mating components. Using the Line Replaceable Unit (LRU) concept, the designs shall be such that mating assemblies may be exchanged without selection for fit or performance and without modification to the section, the unit being replaced or adjacent equipment. Mature, performance proven, standard, commercially available equipment shall not be modified unless it impacts safety.

3.3.6 Expansion Capabilities

The PSL controls shall be designed and implemented to allow maximum flexibility for future expansion. At minimum, the system shall be capable of 100% signal expansion.

3.3.7 Safety

The PSL controls shall meet all California Institute of Technology, LIGO, state and federal safety regulations. A hazard analysis shall be conducted in conjunction with the design. Particular emphasis shall be placed on:

- Restricting the use of hazardous materials where possible
- Personnel access
- Grounding and electrical systems
- RF radiation emission
- Cleanliness

3.3.8 Human Performance/Human Engineering

The PSL controls shall be designed to meet the requirements of labeling, work space design requirements, environmental and applicable human engineering requirements.

3.3.9 Standard of Manufacture

TBD

3.4 Documentation

3.4.1 Engineering Drawings and Associated Lists

Engineering drawings, schematics, wire lists and cable routing lists shall be produced for the subsystem and all components installed as part of the subsystem. To the greatest extent possible, electronic copies shall be maintained and available on-line.

3.4.2 Software

The following documentation shall be provided for all software.

1. Software Development Plan (SDP)
2. Software design data and control flow diagrams by CIM model level
3. Sequences using the Grafcet standards
4. Timing charts
5. Data/code directory structures

3.4.3 Technical Manuals and Procedures

3.4.3.1 Procedures

At a minimum, procedures shall be provided for:

1. Initial installation and set up of equipment
2. normal operation of equipment, including applicable flow control diagrams
3. normal and/or preventative maintenance
4. troubleshooting guide for any anticipated potential malfunctions
5. commissioning of equipment

3.4.3.2 Manuals

Manuals shall be provided, at a minimum, for all purchased components and equipment.

3.4.3.3 Documentation and Numbering

Documentation and numbering shall comply with the LIGO documentation numbering system.

3.4.3.4 Test Plans

Hardware and software test plans shall be provided for the system and all components utilized in the system.

3.5 Logistics

List of recommended spare parts and special purpose test equipment.

3.6 Personnel and Training

Analysis shall be performed to determine the personnel and training requirements for operation, maintenance, and safety of the major components of the PSL subsystem controls , identifying the numbers, types, skill levels and duty cycles, with respect to operational mode and phase, both normal and emergency.

3.7 Precedence

In the event of conflict between the provisions of this specification and other documents, the following precedence shall apply:

1. The LIGO Site Controls Specification

2. This specification
3. Documents referenced herein

4.0 Quality Assurance

4.1 Quality Conformance Inspection

Acceptance testing shall be performed on the PSL subsystem controls in accordance with an approved test plan and procedure(s). Verification shall be by one or more of the following methods:

- Inspection: Inspection shall be used to verify conformity with requirements that are neither qualitative or quantitative such as markings, workmanship, etc.
- Analysis: Analysis shall be used to verify conformity with requirements that are impractical or prohibitive in time or cost to verify using other methods.
- Demonstration: Demonstration shall be used to verify conformity with qualitative requirements.
- Test: Test shall be used to verify conformity with quantitative requirements.

5.0 Packaging, Handling and Transportability

All equipment shall be packaged in a manner to ensure arrival at the destination delivery point in an undamaged condition. The equipment shall not be damaged or performance degraded by normal handling during installation and maintenance.

Appendix A Argon Ion Laser Remote Connector Pin Assignments

Appendix B Table of TBDs

Section	Description	Comment
2.0	Document No. for Global CDS Specification	Global CDS specification and requirements documents will be developed prior to CDS DRR scheduled for 10/95.
3.1.2.2	Data Acquistion Channel Names	Names will be assigned according to the LIGO naming convention as part of the preliminary design.
3.1.2.3	Remote Diagnostics Channel Names	Names will be assigned according to the LIGO naming convention as part of the preliminary design.
3.1.3.1.2.1	Laser cooling water return temperature interlock	The return temperature threshold for maintaining cooling flow to laser after the laser has be turned off will be determined as part of the preliminary design.
3.1.3.1.3.1	Laser device performance	Performance requirements beyond those described in the PSL requirements specification and this document will be determined as part of the preliminary design.
3.1.3.2.1	Phase modulation performance requirements	Performance requirements are currently being developed and will be completed prior to the DRR (2/95).
3.1.3.2.4.1	Pockels cell matching network requirements	The accuracy and stability of the match to the pockels cell will be developed as part of the preliminary design.

Section	Description	Comment
3.1.3.2.4.2	RF modulator output power selections	The actual number of output power selections for the RF modulator will be developed as part of the preliminary design. The number being used in the conceptual design is 8.
3.1.3.2.4.2 Table 12	RF modulator input power	The input power to the RF modulator will be selected during the preliminary design. The selection will be based on the availablity of low noise power amplifiers.
3.1.3.3.2.2	Power stabilization Level 2 alarms	The alarms will be determined as part of the preliminary design. Currently there are no level 2 alarms.
3.1.3.3.2.3	Power stabilization Level 2 permits	The permits will be determined as part of the preliminary design. Currently there are no level 2 permits.
3.1.3.3.3.2	Power stabilization amplifier power level selections	The current number of selections is 12. This number has been used in the conceptual design. The required number of selections will probably be lower.
3.1.3.3.3.2 Table 13	Power stabilization amplifier power level selections, signal type	See above.
3.1.3.3.3.2 Table 13	Power stabilization ringdown level selections, signal type	Actual signal parameters will be developed during the preliminary design.

Section	Description	Comment
3.1.3.3.4.2	Acouto driver controls	The DE-40M driver is a stand alone unit with front panel knobs. The feasibility of connecting remote controls or replacing the unit with an equivalent model with remote connections will be investigated during the preliminary design.
3.1.3.4	Document number for description of the transfer function characteristics of the frequency stabilization electronics	The transfer function of the existing electronics are being analyzed as part of the conceptual and preliminary designs. The analysis will be documented in a technical note.
3.1.3.4.2.2	Frequency stabilization Level 2 alarms	The alarms will be determined as part of the preliminary design. Currently there are no level 2 alarms.
3.1.3.4.3.1	Pockel cells power supply stability requirements	The stability requirements for the power supply will be developed during the preliminary design and will be consistent with the performance requirements of the laser loop amplifier device.
3.1.3.4.3.1	Pockels cells input impedance	The input impedance of the pockels cell will be determined during the preliminary design.
3.1.3.4.3.2	Wideband DC adjust range and accuracy	The conceptual design calls for a range of -10 to +10 volts with min 12 bit resolution. The actual specification will be determined during the preliminary design.

Section	Description	Comment
3.1.3.4.3.2	Bypass DC adjust range and accuracy	The conceptual design calls for a range of -10 to +10 volts with min 12 bit resolution. The actual specification will be determined during the preliminary design.
3.1.3.4.3.3	Document number for description of the transfer function characteristics of the laser loop amplifier	The transfer function of the existing laser loop amplifier are being analyzed as part of the conceptual and preliminary designs. The analysis will be documented in a technical note.
3.1.3.4.4.2 Table 19	RF and Reference Photodiode gain select and visbility monitor threshold adjust signal types	The signal types will be determined as part of the preliminary design
3.1.3.4.5.1	Slow PZT power supply stability requirements	The stability requirements for the power supply will be developed during the preliminary design and will be consistent with the performance requirements of the laser loop amplifier device.
3.1.3.4.5.1	Fast PZT power supply stability requirements	The stability requirements for the power supply will be developed during the preliminary design and will be consistent with the performance requirements of the laser loop amplifier device.
3.1.3.4.6.1	RF photodetector bias power supply stability requirements	The stability requirements for the power supply will be developed during the preliminary design and will be consistent with the performance requirements of the frequency stabilization LCU.

Section	Description	Comment
3.1.3.5.3.1	Laser steering power supply stability requirements	The stability requirements for the power supply will be developed during the preliminary design and will be consistent with the performance requirements of the laser steering LCU.
3.2.1.2	Power supply transient amplitude	The requirements for the amplitude of the transients that will be detected by the circuitry will be determined during the preliminary design.
3.2.3	Reliability	Reliability requirements for LIGO in general need to be developed.
3.2.4	Maintainability	Maintainability requirements for LIGO in general need to be developed.
3.3	Design and Construction guidelines	Standards for design and construction within the project need to be developed.

Appendix C Existing PSL Schematics

CALIFORNIA INSTITUTE OF TECHNOLOGY
Laser Interferometer Gravitational Wave Observatory (LIGO) Project

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Refer to: LIGO-T950001-1-C
Date: January 30, 1995

Subject: LIGO PSL Controls Requirements Document

Attached please find a copy of the LIGO Prestabilized Laser Controls Requirements document. I have incorporated comments received on the January 19 version of this document. Significant changes (i.e. not typos or spelling corrections) to the January 19 document are listed below. This document will be used as the basis for the conceptual designs presented at the Design Requirements Review scheduled for February 6, 1995.

Location	Change
Table 6	Removed laser tube fill pressure low alarm (redundant with auto fill)
3.1.3.2	Changed max to min in description of 5 watt power amplifier
3.1.3.2.4.1	Changed input power to matching network to 5 watts minimum and output voltage to 500 volts maximum
Figure 12	Added ringdown circuit to diagram.
3.1.3.3.3.3.2	Changed power level select to vernier bias adjust (consistent with current schematics), added amplifier gain select and corrected table 13 and figure 13 to be consistent.
3.1.3.3.4.2	Corrected figure 16 and tables 15 and 16 to be consistent with DE-40M controls and connections.
3.1.3.4	Added a reference to the TBD document that describes the required transfer function of the frequency stabilization electronics.
Figure 19	Corrected figure to show bypass and correct light path.
Table 17	Corrected loop gain selection signal type.

Location	Change
Table 19	RF and Reference Photodetector gain select signal types changed to TBD to allow for software implementation of visibility monitor
Figure 23, Table 22	Added omitted scan reference signal to table and figure.
3.1.3.4.6.1	Removed phase shifter accuracy requirement.
Table 2	Added LLA PZT output monitor to the list of remote diagnostic signals.
3.1.3.4	Removed incorrect references to the sensitivities of the reference and RF photodetectors.
3.1.3.4.3.2	Changed LLA modes of operation to Auto, Bypass Off and Bypass On
3.1.3.4.3.3	See above.

Thank you,

Jay Heefner

jh

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Contents

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LIGO-T950001-1-C

Prestabilized Laser (PSL) Subsystem Controls

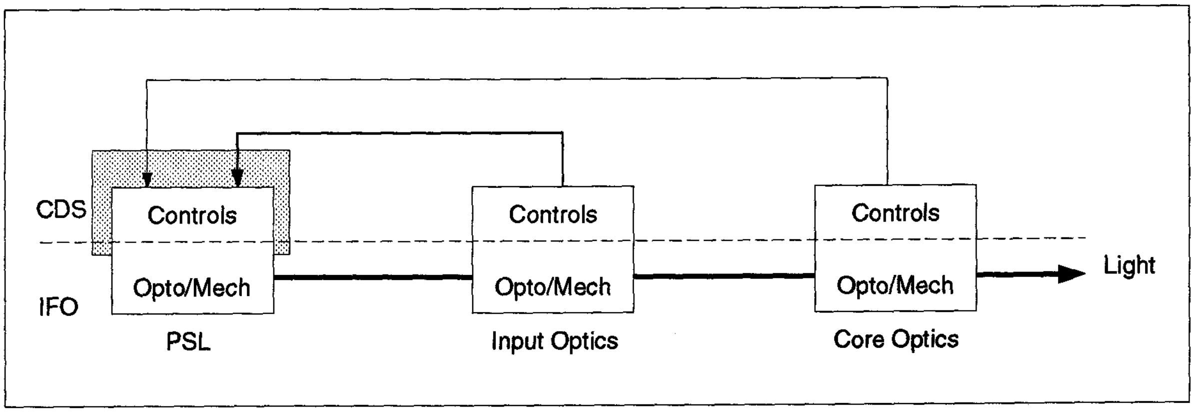
DRAFT January 30, 1995

1.0 Introduction

1.1 Scope

This document covers the development specifications and requirements for the Prestabilized Laser Controls necessary for operation on the LIGO interferometer. The Prestabilized Laser Subsystem provides frequency and power prestabilized laser light in a single mode from a modified commercial argon ion laser. A block diagram of the prestabilized laser, input optics and core optics for LIGO is shown in the figure below. As can be seen from the figure, each of these systems are composed of components that can be classified as optical/mechanical devices, provided by the interferometer group or controls devices, provided by the Control and Data System (CDS) group. Controls devices consist of the hardware (electronics, cabling, etc.) and software elements required to complete the system. The scope of this requirements document is back highlighted in the figure. Note that the scope of the requirements covers not only the control components, but the interfaces to optical/mechanical devices and other systems including other components of the CDS (not shown).

Figure 1 PSL Controls Scope Diagram



1.2 Purpose

The purpose of this document is to provide the requirements for development of a control and monitor system for the Prestabilized Laser (PSL) installed on the LIGO interferometer. The starting point for the design and the basis of many of the requirements are the existing analog control modules and optical hardware. It is intended to be a living document that will evolve through the life cycle of the project and eventually become the final requirements document for the LIGO PSL. The document will be the subject of review and sign off procedures according to standard LIGO document control.

1.3 Document Organization

The document is organized into the following sections:

1. Introduction
2. Applicable Documents
3. Requirements

    3.1 Item Definition- The item definition contains the system diagrams and descriptions, block diagrams and interface definitions. Each of the major components, in this case the subsystem LCUs (Local Control Units) are described. In addition, the minimum performance and signals required for control and monitoring of each LCU are described including alarm limits and permits.

    3.2 Characteristics- The characteristics section describes the general physical, reliability, maintainability, environmental and performance requirements that pertain to the subsystem and all components utilized for the control and monitoring of the subsystem.

    3.3 Design and Construction- The design and construction section outlines the minimum requirements and standards for materials, safety, electromagnetic radiation, workmanship and expansion capabilities.

    3.4 Documentation- The documentation section outlines the minimum requirements for subsystem and component documentation, testing, manuals and procedures.

    3.5 through 3.7 Logistics, Personnel and Training, and Precedence- These sections outline the minimum requirements for such things as spare parts, personnel requirements, and personnel training. The precedence section outlines the guidelines for determining the order of consideration that should be used in the event of conflict between this document and others.

4. Quality Assurance
5. Packaging, Handling and Transportability
6. Appendix A: Argon Ion Laser Remote Connector Pin Assignments- A copy of Table 4–2 of the laser manual is included. This table details the connector pin assignments used to interface the laser control unit to CDS.
7. Appendix B: Table of TBDs- A table of the requirements that are TBD is included. A description and comment on resolution are given for each.
8. Appendix C: Existing PSL Schematics- These schematics will be used a basis for the design of the LIGO PSL Controls.

1.4 Definitions

1.4.1 Computer Integrated Manufacturing (CIM) Model

In developing controls specifications and designs, a standard model of control levels (commonly referred to as a CIM model) has been designed for use by the LIGO CDS group. These levels are defined below.

In accordance with these definitions, the "site" is LIGO site, the "system" is Detector, and Prestabilized Laser is a "subsystem".

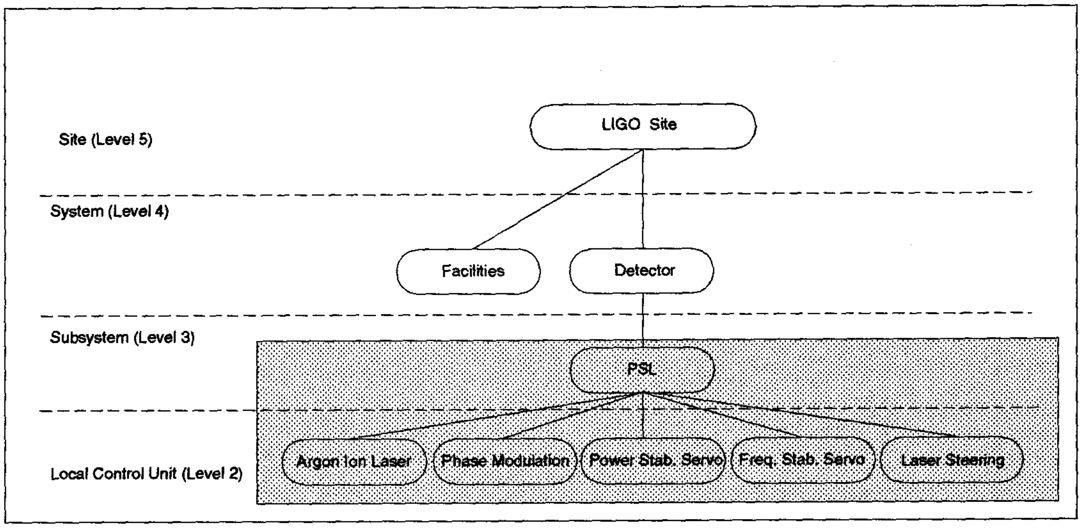
- LEVEL 6: General Computing Facilities- This is outside the scope of controls. This level is typically the interface to the control system from outside users.
- LEVEL 5: Site- A site is defined as a geographic location with a LIGO interferometer facility. These are Washington, Louisiana, Caltech Mark II and MIT 5 meter. Site controls are all hardware and software which are common to all LIGO control systems at a site and, in general, provides for Supervisory Control And Data Acquisition (SCADA) functions for a LIGO site.
- LEVEL 4: System- System controls are defined as that hardware and software necessary to provide control and monitoring for a functional grouping of devices (in this case the detector).
- LEVEL 3: Subsystem- Subsystem controls are defined as that hardware and software which provide control and monitoring for a logical subset of a system (in this case the PSL).

- LEVEL 2: Local Control Unit (LCU)- LCU is defined as that hardware and software necessary to provide control and monitoring for a functional grouping of devices within a subsystem and usually within a geographic area.
- LEVEL 1: Device- A logical grouping (within a LCU) of sensors and controllers typically associated with a physical piece of hardware such as a mirror, power supply, pockels cell, etc.
- LEVEL 0: Sensor- The physical sensors and electro-mechanical operators associated with a level 1 device.

1.4.2 CIM Model for PSL Controls

The figure below shows the CIM model applied to the LIGO Prestabilized Laser. The areas covered by this document are shown within the dark background. Level 1 and 0 have been omitted for clarity, but will be shown in the following sections.

Figure 2 LIGO PSL CIM Model



1.5 Acronyms

ai — analog input
ao — analog output
AOM — Acousto-Optic Modulator
bi — binary input

bo — binary output
CDS — Control and Data System
DEMO — Demodulated output of RF Photodetector
FSS — Frequency Stabilization Servo
IF — Intermediate Frequency
kHz — Kilo Hertz
LCU — Local Control Unit
LO — Local Oscillator
LRU — Line Replaceable Unit
mbbi — multiple bit binary input
mbbo — multiple bit binary output
MHz — Mega Hertz
MOD — Phase Modulation System
OSA — Optical Spectrum Analyzer
PC — Pockels Cell
PSL — Pre-Stabilized Laser
PSS — Power Stabilization Servo
PZT — Piezo-electric Transducer
RF — Radio Frequency
SDP — Software Development Plan
VME — VERSAmodule Eurocards

2.0 Applicable Documents

CDS_N_007: Functional Description for the Prestabilized Laser Subsystem
DWG #1206002–3: Laser PZT Driver
DWG #1206075–3: Laser Loop Amplifier
DWG # 1206012–3: Visibility Monitor and Lockup Discriminator Production Version
DWG #1206017–3: Five Watt 12.3 MHz Amplifier. Note that 10.7 MHz will be used for the PSL
DWG #1206062–3: Power Monitoring Photodiode
DWG #1206065–3: Laser Power Stabilizer Amplifier for Spectra Physics Laser

DWG #1206054-3: 12.3 MHz Digital Control Phase Shifter. Note that 10.7 MHz will be used for the PSL

DWG #1206061-3: Pockels Cell Matching Network

Doc. No. TBD: LIGO Global CDS Requirements Specification

Doc. No. CG0001-STD: Technical Note on CDS Document Numbering

3.0 Requirements

3.1 Item Definition

3.1.1 System Diagrams and Description

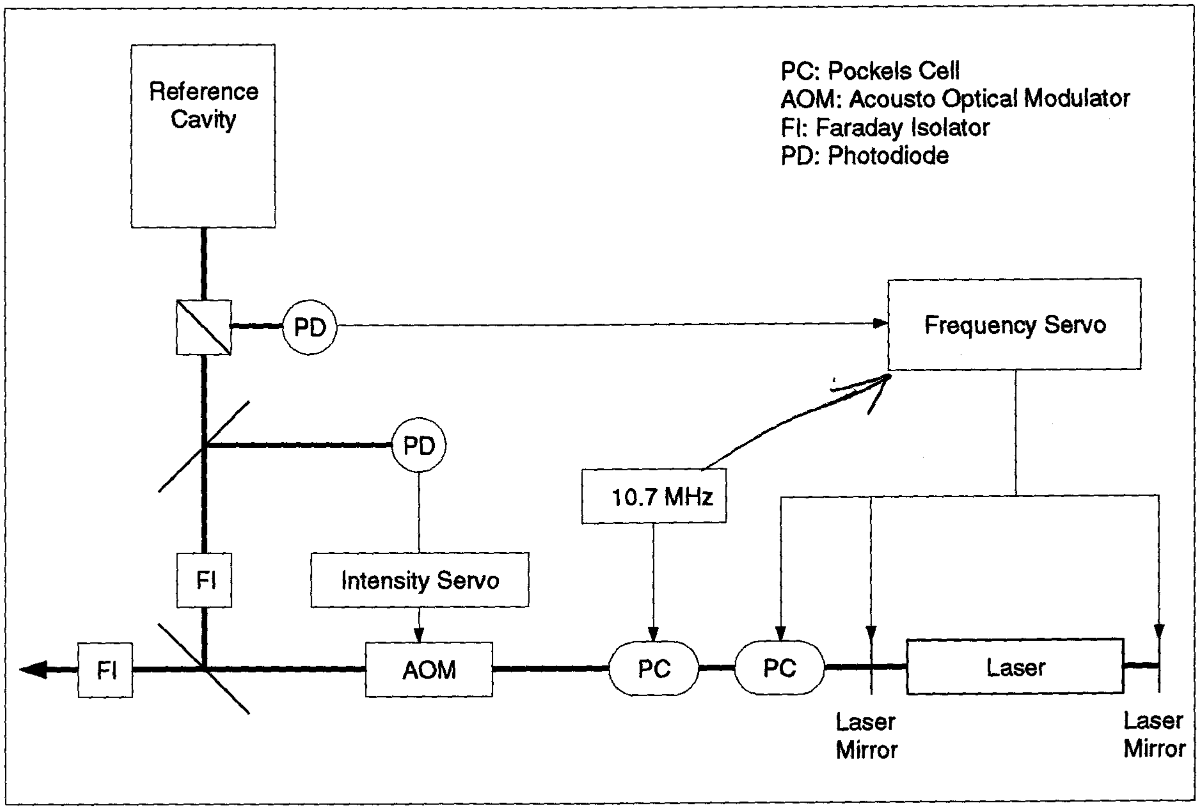
The PSL subsystem includes the laser, the optical elements and electronic hardware and software required to provide single mode, frequency and power prestabilized laser light from a modified commercial argon ion laser. For the purposes of control, it consists of the following major components (LCUs):

1. Argon Ion Laser
2. Phase Modulation
3. Power Stabilization Servo
4. Frequency Stabilization Servo
5. Laser Beam Steering

CDS_N_007 entitled "Functional Description for the Prestabilized Laser Subsystem" provides an overview of the present prestabilized laser used at Caltech. The schematics of the present circuits and modules listed in section 1.2 above are included in Appendix C.

A conceptual design of the prestabilized laser system is shown below.

Figure 3 PSL Block Diagram



3.1.2 Interface Definition

3.1.2.1 Interface to LIGO Global CDS

The interface to the LIGO CDS is through the CDS ethernet for the LIGO interferometer. Addressing hardware and software shall be as described in the LIGO Global CDS Requirements Specification.

3.1.2.2 Interface to CDS Data Acquisition

The interface to the LIGO CDS data acquisition system will be at the output connector for each signal listed below. These signals are a subset of the signals required for control and monitoring of the PSL.

The PSL subsystem controls shall provide separate buffered outputs for each of the signals listed. These outputs are in addition to those required for control and monitoring and the LIGO remote diagnostic system. Each output shall be capable of driving 50 ohms to full scale over a bandwidth equivalent to 10 times the respective sampling frequencies listed.

The following table is an estimate of the PSL channels and their respective rates that need to be digitized and stored by the CDS Data Acquisition system.

Table 1 PSL Data Acquisition Channels

Channel	Description	Sample Rate (sample/sec)
TBD	Power Stab. Servo Output Monitor	20 K
TBD	Power Stab Servo Ref Photodiode DC Out	2 K
TBD	Freq. Stab. Servo RF Photodiode Bias Supply Output Voltage Monitor	200
TBD	Freq Stab Servo RF Photodiode DC Out	2 K
TBD	Freq.Stab. Servo. Laser Loop Amplifier Pockels Cells (neg) Output Monitor	20 K
TBD	Freq.Stab. Servo. Laser Loop Amplifier Pockels Cells (pos) Output Monitor	20 K
TBD	Freq Stab. Servo Laser Loop Ampl. RF Photodetector Demodulated Output	20 K
TBD	Freq. Stab. Servo slow/fast PZT Driver Slow Piezo Monitor	20 K
TBD	Freq. Stab. Servo slow/fast PZT Driver Fast Piezo Monitor	20 K
TBD	Freq. Stab. Servo Slow PZT Power Supply Output Voltage Monitor	200
TBD	Freq. Stab. Servo Fast PZT Power Supply Output Voltage Monitor	200

Table 1 (Continued) PSL Data Acquisition Channels

TBD	Freq. Stab. Servo Pockels Cell Power Supply Output Voltage Monitor	200
TBD	Freq. Stab. Servo Pockels Cell Power Supply Output Current Monitor	200
TOTAL	13 Channels	125 K

3.1.2.3 Interface to LIGO CDS Remote Diagnostics

The interface to the LIGO CDS remote diagnostics system will be at the output connector for each signal listed below. These signals are a subset of the PSL signals that are used for laser tune up and diagnostics. During tune up and system diagnostic these signals are routed to high bandwidth scopes and spectrum analyzers. The operator then uses these signals to adjust such things as servo loop gain, mirror orientation and circuit DC offsets. The oscilloscope, spectrum analyzers, other test equipment and cabling to the equipment are to be provided by the CDS Remote Diagnostics subsystem.

The PSL subsystem controls shall provide separate buffered outputs for each of the signals listed below. These outputs are in addition to those required for control and monitoring and the LIGO data acquisition system. Each output shall be capable of driving 50 ohms to full scale over the bandwidth specified in the table below.

Table 2 PSL Remote Diagnostic Signals

Channel Name	Signal	Location	Bandwidth (3 dB)
TBD	LLA Pockels Cell Neg Output	Freq Stab Servo	0-5 MHz
TBD	LLA Pockels Cell Pos Output	Freq Stab Servo	0-5 MHz
TBD	LLA RF Photodetector Demod Output	Freq Stab Servo	0-5 MHz
TBD	LLA PZT Out Monitor	Freq Stab Servo	0-5 MHz

RF PD RFout

Table 2 (Continued) PSL Remote Diagnostic Signals

Channel Name	Signal	Location	Bandwidth (3 dB)
TBD	RF Photodetector DC Output	Freq Stab Servo	0-100 KHz
TBD	Slow PZT Driver Output Monitor	Freq Stab Servo	0-1MHz
TBD	Fast PZT Driver Output Monitor	Freq Stab Servo	0-2 MHz
TBD	Reference Photodetector DC Output	Power Stab Servo	0-100 KHz
TBD	Power Stab Servo Ampl Output	Power Stab Servo	0-5 MHz
TBD	Reference cavity mirror 1 X output	Laser Steering	0-100 KHz
TBD	Reference cavity mirror 1 Y output	Laser Steering	0-100 KHz
TBD	Reference cavity mirror 2 X output	Laser Steering	0-100 KHz
TBD	Reference cavity mirror 2 Y output	Laser Steering	0-100 KHz

The output of the optical spectrum analyzer (OSA) is monitored by the operator during tune up and operation. The output of the OSA consists of a signal proportional to the ramp voltage used to drive the analyzer cavity PZT and the analyzer photodetector output signal. When these signals are viewed on an oscilloscope running in X-Y mode the operator is able to distinguish the laser carrier frequency and any sidebands that exist due to modulation and/or higher order modes.

In addition to the signals listed above the operator must be able to view (video image) the beam spot at the output of the reference cavity. The video camera is to be provided by the PSL Controls system. Video monitors, multiplexers and cabling to the operator control areas are to be provided by the CDS Remote Diagnostics system.

3.1.2.4 Interface to LIGO PSL Components

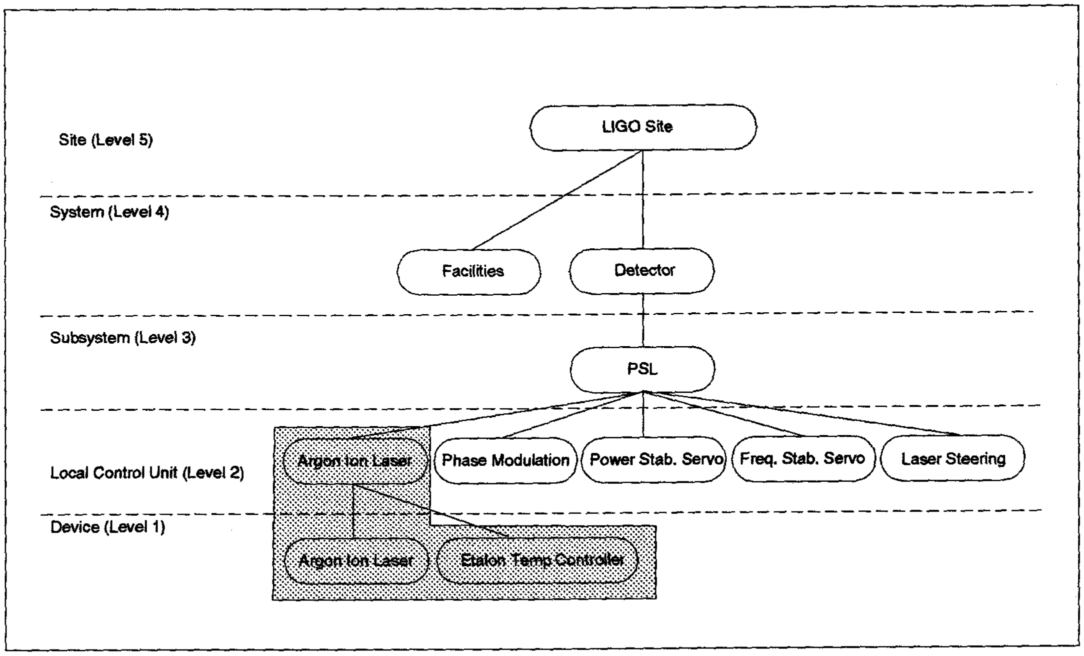
The interface to the PSL equipment shall be at the input and output connectors of the PSL equipment or device. PSL equipment is defined as pockels cells, Acousto-Optic Modulators, laser, etc.

3.1.3 Major Component Characteristics

3.1.3.1 Argon Ion Laser LCU

The figure below highlights the levels of the PSL CIM model that are covered by this section. The laser is a commercial SPECTRA PHYSICS 2040 E argon ion laser. The laser has been modified so that the cavity mirrors are mounted on piezo-electric actuated mounts. This allows for active length control of the laser cavity. The output mirror is attached to a "slow piezo mount" with a mechanical resonant frequency of about 5 kHz. The reflector mirror is mounted on a "fast

Figure 4 LIGO PSL Argon Ion Laser CIM Model



piezo mount" with a mechanical resonance of about 200 kHz. It should be noted that although the mirrors are physically part of the laser assembly, the control of each mirror is part of the PSL frequency stabilization servo LCU.

3.1.3.1.1 Argon Ion Laser Level 2 Performance

The Spectra Physics laser can be operated as a fully stand alone unit. All interlocks necessary for protection of the laser and its components are incorporated into the control unit supplied with the device. The function of the level 2 controls is to provide the operator and CDS interface to the unit. Update rates and reaction times for the controls are as follows:

1. Temperature and pressure monitors- once per second maximum
2. Laser power, voltage and current monitors- 10 samples per second maximum
3. On/Off selects and level adjustments- 1 second maximum for operator or CDS initiation
4. Interlock reaction time- 1 second maximum

3.1.3.1.2 Argon Ion Laser Level 2 Controls

Connection to the laser shall be made through the remote connector interface provided on the back of the model 2570 power supply. A list of the functions that are available and the pin assignments for the connector are described in the manual for the laser. A copy of table 4–2, "Remote Connector Pin Assignments", from the manual is included in Appendix A of this specification.

3.1.3.1.2.1 Sequences and Functions

The following sequences and functions shall be incorporated:

1. The level 2 controls shall be capable of selecting the control source for the laser, i.e. Computer/Remote. The default selection shall be remote (CDS control through remote connector). It should be noted that computer control in this case refers to local computer control of the laser via an RS-232 or GPIB interface.
2. Laser cooling water shall be allowed to flow through the laser after it has been turned off until the cooling water return temperature is less than TBD.

3.1.3.1.2.2 Alarms

Argon Ion laser LCU (level 2) alarms shall be generated for the following:

Table 3 Argon Ion Laser LCU Alarms

ALARM CONDITION	SEVERITY	ACTION
Laser is on and no laser cooling flow	Major	Turn off Laser
The laser has been off for more than 15 minutes and laser cooling water is flowing (prevent condensation)	Minor	Operator Warning
The laser control selection is "computer"	Minor	Operator Warning
The laser is on and there is no gas purge flow	Major	Turn off Laser

3.1.3.1.2.3 Permits

There are no interlocks outside of those incorporated into the laser control unit.

3.1.3.1.2.4 Level 1 Devices

For the purposes of control and monitoring the Laser LCU contains two devices, the laser which includes the laser cooling unit and the etalon temperature controller. The minimum required performance and signals for each device are described in the following figures and tables.

3.1.3.1.3 Laser Device

3.1.3.1.3.1 Performance

TBD

3.1.3.1.3.2 Control Signals

Figure 5 Laser Device Interface Signals

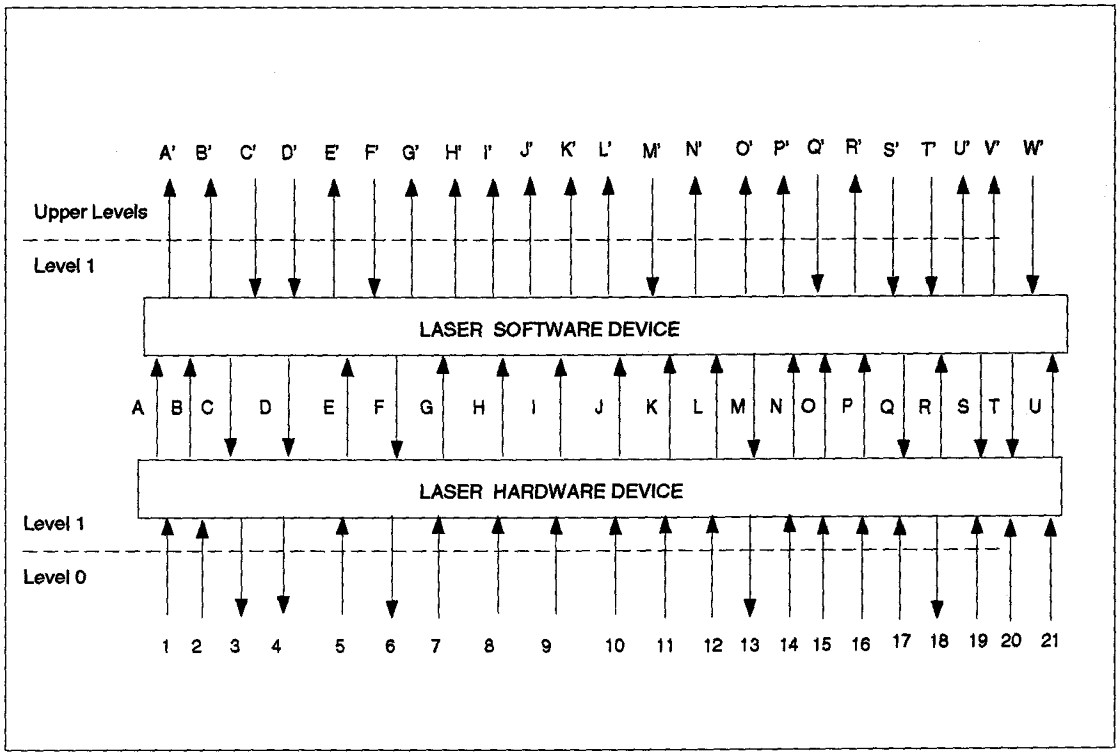


Table 4 Laser Device Level 1 to Upper Levels Interface Signals

Label	Description	Signal Type
A	Laser Temperature Monitor	0-10 VDC
B	Purge Gas Pressure Monitor	0-10 VDC
C	Laser On/Off Select	TTL
D	Purge Gas On/Off Select	TTL
E	Laser On/Off Status (Remote Emission Indicator)	TTL
F	Control Mode Select	TTL
G	Regulator Fault Readback	TTL
H	Head Cover Interlock	TTL

Table 4 (Continued) Laser Device Level 1 to Upper Levels Interface Signals

Label	Description	Signal Type
I	Tube Voltage Monitor	0-10 VDC
J	Tube Current Monitor	0-10 VDC
K	Tube Power Monitor	0-10 VDC
L	Power Range Selection Monitor	TTL, multi-bit
M	Power Range Select	TTL, multi-bit
N	Tube Fill Status	TTL
O	Head Outlet Temperature Interlock	TTL
P	Low Water Flow Indicator	TTL
Q	Control Source Select	TTL
R	AUX Interlock Status	TTL
S	Tube Current Select	0-5 VDC
T	Tube Power Select	0-5 VDC
U	Control Mode Monitor	TTL, Multi-bit
A’	Laser Temperature Monitor	ai
B’	Purge Gas Pressure Monitor	ai
C’	Laser On/Off Select (Remote Emission Indiocator)	bi
D’	Purge Gas On/Off Select	bo
E’	Laser On/Off Status	bi
F’	Control Mode Select	bo
G’	Regulator Fault Readback	bi
H’	Head Cover Interlock	bi
I’	Tube Voltage Monitor	ai
J’	Tube Current Monitor	ai
K’	Tube Power Monitor	ai
L	Power Range Selection Monitor	mbbi

Table 4 (Continued) Laser Device Level 1 to Upper Levels Interface Signals

Label	Description	Signal Type
M'	Power Range Select	mbbo
N'	Tube Fill Status	bi
O'	Head Outlet Temperature Interlock	bi
P'	Low Water Flow Indicator	bi
Q'	Control Source Select	bo
R'	AUX Interlock Status	bi
S'	Tube Current Select	ao
T'	Tube Power Select	ao
U'	Control Mode Monitor	bi
V'	Laser Device Alarms	alarm
W'	Laser Device Permits	Software

Table 5 Laser Device Level 1 to Level 0 Interface Signals

Label	Description	Signal Type
1	Laser Temperature Monitor	0-10 VDC
2	Laser Pressure Monitor	0-10 VDC
3	Laser On/Off Select	TTL
4	Laser Gas On/Off Select	TTL
5	Laser On/Off Status	TTL
6	Control Mode Select	TTL
7	Regulator Fault Readback	TTL
8	Head Cover Interlock	TTL
9	Tube Voltage Monitor	0-10 VDC
10	Tube Current Monitor	0-10 VDC
11	Tube Power Monitor	0-10 VDC
12	Power Range Selection Monitor	TTL, multi-bit

Table 5 (Continued) Laser Device Level 1 to Level 0 Interface Signals

Label	Description	Signal Type
13	Power Range Select	TTL, multi-bit
14	Tube Fill Status	TTL
15	Head Outlet Temperature Interlock	TTL
16	Low Water Flow Indicator	TTL
17	Control Source Select	TTL
18	AUX Interlock Status	TTL
19	Tube Current Select	0-5 VDC
20	Tube Power Select	0-5 VDC
21	Control Mode Monitor	TTL

3.1.3.1.3.3 Sequences and Functions

The default control mode for the laser shall be power regulation. The power up and reset conditions for the laser shall be:

1. Laser- disabled
2. Mode- power regulation
3. Power Level- 0 watts
4. Gas- Off
5. Water Flow- Off
6. All other- don't care

3.1.3.1.3.4 Alarms

Laser device alarms shall be generated for the following:

Table 6 Laser Device Alarms

ALARM CONDITION	SEVERITY	ACTION
Laser temperature is greater than TBD (HIHI)	Major	Turn Off Laser
Laser temperature is greater than TBD (HI)	Minor	Operator Warning

Table 6 (Continued) Laser Device Alarms

ALARM CONDITION	SEVERITY	ACTION
Laser purge gas pressure is less than TBD (LO)	Minor	Operator Warning
Laser purge gas pressure is less than TBD (LOLO)	Major	Turn Off Laser
Laser Regulator Fault	Minor	Operator Warning
Laser Head Cover Interlock Open	Minor	Operator Warning
Low Water Flow to Head	Minor	Operator Warning
Outlet Head Water Temp greater than TBD	Major	Turn Off Laser
Laser Tube Voltage Below Gas Fill Threshold. Threshold voltage= 553 Volts	Minor	Operator Warning

3.1.3.1.3.5 Permits

The following laser device interlocks and permits shall be incorporated:

- The laser shall be disabled until a regulator fault is cleared.

3.1.3.1.4 Etalon Temperature Control Device

3.1.3.1.4.1 Performance

The temperature of the etalon shall be regulated to better than 0.1 deg C.

3.1.3.1.4.2 Control Signals

The etalon temperature regulator is a self contained commercial unit. There are currently no provisions for control or monitoring of temperature via the CDS.

Figure 6 Etalon Temperature Control Device Interface Signals

Label	Description	Signal Type
	None	

Table 7 Etalon Temperature Control Device Level 1 to Upper Levels Interface Signals

Label	Description	Signal Type
	None	

Table 8 Etalon Temperature Control Device Level 1 to Level 0 Interface Signals

Label	Description	Signal Type
	None	

3.1.3.1.4.3 Sequences and Functions

None

3.1.3.1.4.4 Alarms

None

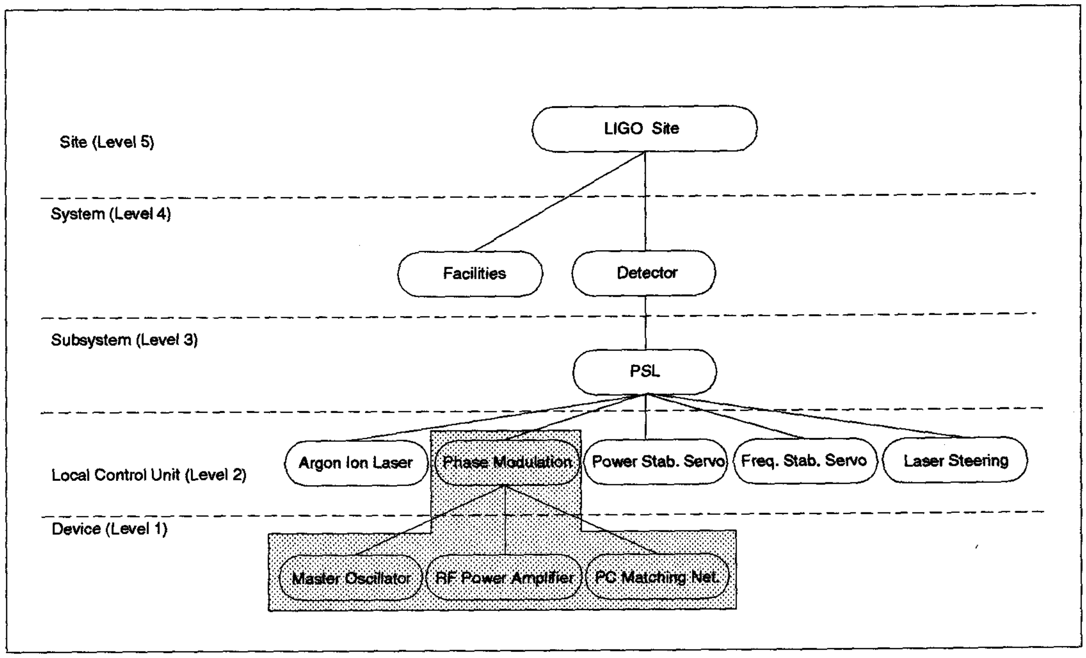
3.1.3.1.4.5 Permits

None

3.1.3.2 Laser Phase Modulation (MOD)

The figure below highlights the levels of the PSL CIM model that are covered by this section. The phase modulation LCU uses Pockels Cells to phase modulate the laser light with amplitude ~1 rad and frequency 10.7 MHz, which is large compared to the bandwidth of the reference cavity. The phase modulation LCU is made up of several components. They are a 10.7 MHz master oscillator and power splitter, a 5 watt minimum power RF amplifier whose output power is adjustable, a pockels cell matching network (step-up transformer) and the phase modulation pockels cell. A block diagram of the system is shown in the figure below.

Figure 7 LIGO PSL Laser Light Modulation CIM Model



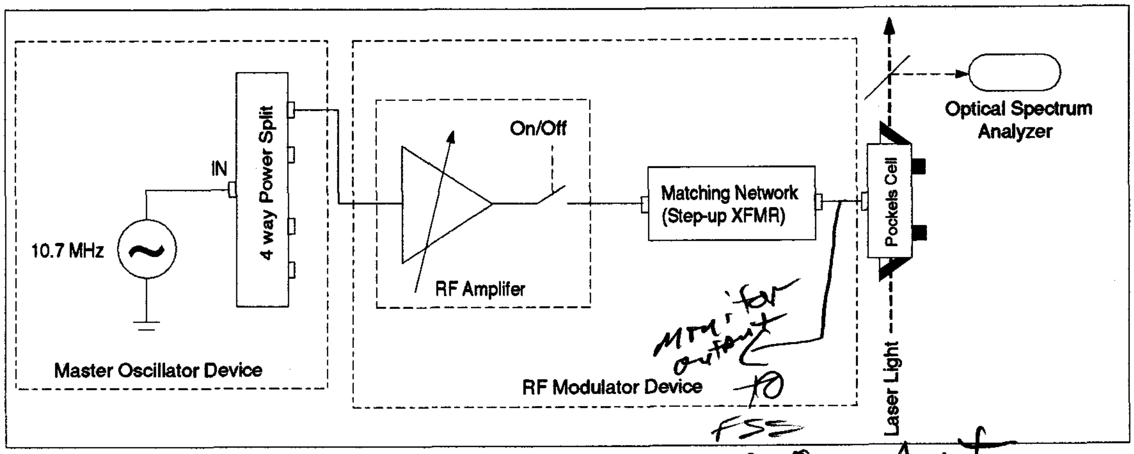


Figure 8 Phase Modulation LCU Block Diagram

3.1.3.2.1 Phase Modulation Level 2 Performance Requirements

The phase noise of the laser phase modulation system shall be less than TBD. The amplitude stability of the laser phase modulation system shall be better than TBD.

Update rates and reaction times for the controls are as follows:

1. RF power monitor- 10 samples per second maximum
2. On/Off Selects and Level Adjustments- 1 second maximum for operator or CDS initiation.

3.1.3.2.2 Phase Modulation Level 2 Controls

3.1.3.2.2.1 Sequences and Functions

The modes of operation for the phase modulation LCU are:

1. Modulation Off
2. Modulation On

The default, power up and reset mode of operation for the phase modulation LCU is "Modulator Off".

3.1.3.2.2.2 Alarms

None

3.1.3.2.2.3 Permits

None

3.1.3.2.2.4 Level 1 Devices

For the purposes of control and monitoring, the phase modulation LCU has been broken into two devices. These are the master oscillator and the RF modulator devices shown in the figure above. The interface to the phase modulation pockels cell is at the input connector of the pockels cell. The minimum required performance and signals for each device are described in the following figures and tables.

3.1.3.2.3 Master Oscillator Device

3.1.3.2.3.1 Performance

The master oscillator shall provide at least 4 output connectors (BNC or SMA) for master oscillator distribution with the following characteristics:

1. Output power- +23 dBm
2. Output impedance- 50 ohms

3.1.3.2.3.2 Control Signals

Figure 9 Master Oscillator Device Interface Signals

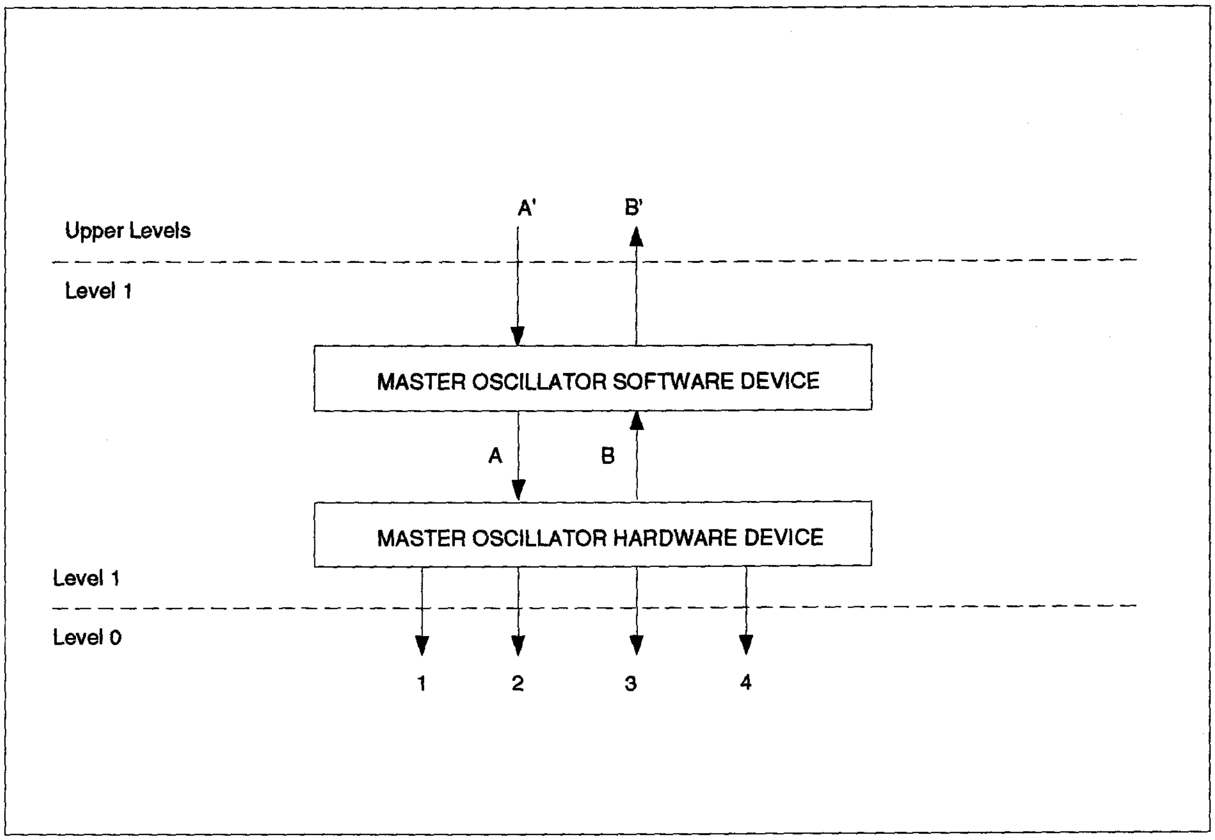


Table 9 Master Oscillator Device Level 1 to Upper Levels Interface Signals

Label	Description	Signal Type
A	Master Oscillator On/Off Select	TTL
B	Master Oscillator On/Off Status	TTL
A’	Master Oscillator On/Off Select	bo
B’	Master Oscillator On/Off Status	bi

Table 10 Master Oscillator Device Level 1 to Level 0 Interface Signals

Label	Description	Signal Type
1	Master Oscillator Output	+23 dBm
2	Master Oscillator Output	+23 dBm

Table 10 (Continued) Master Oscillator Device Level 1 to Level 0 Interface Signals

Label	Description	Signal Type
3	Master Oscillator Output	+23 dBm
4	Master Oscillator Output	+23 dBm

3.1.3.2.3.3 Sequences and Functions

None

3.1.3.2.3.4 Alarms

None

3.1.3.2.3.5 Permits

None

3.1.3.2.4 RF Modulator Device

3.1.3.2.4.1 Performance

The RF power amplifier shall have connectors for RF input and RF output.

The pockels cells matching network shall have connections for:

1. Input: Zin = 50 ohms, Pin = 5 watt min.
2. Output to Pockels Cells: Vout = 500 Vrms, max.

The matching network shall match the input impedance of the pockels cell to 50 ohms real ±TBD at 10.7 MHz and over the entire input power range of 0 to 5 Watts (+37 dBm). The stability of the match shall be better than TBD. The matching network circuitry includes any cabling and connectors required to connect to the pockels cell.

3.1.3.2.4.2 Control Signals

Controls for the modulator shall be:

1. Output Power Selection- The output power of the amplifier shall be selectable from 0 to +37 dBm in TBD increments.
2. Output On/Off Select- The On/Off status of the amplifier output shall be selectable from the VME bus. The On/Off status of the amplifier shall be readable from the VME bus.

Figure 10 RF Modulator Device Interface Signals

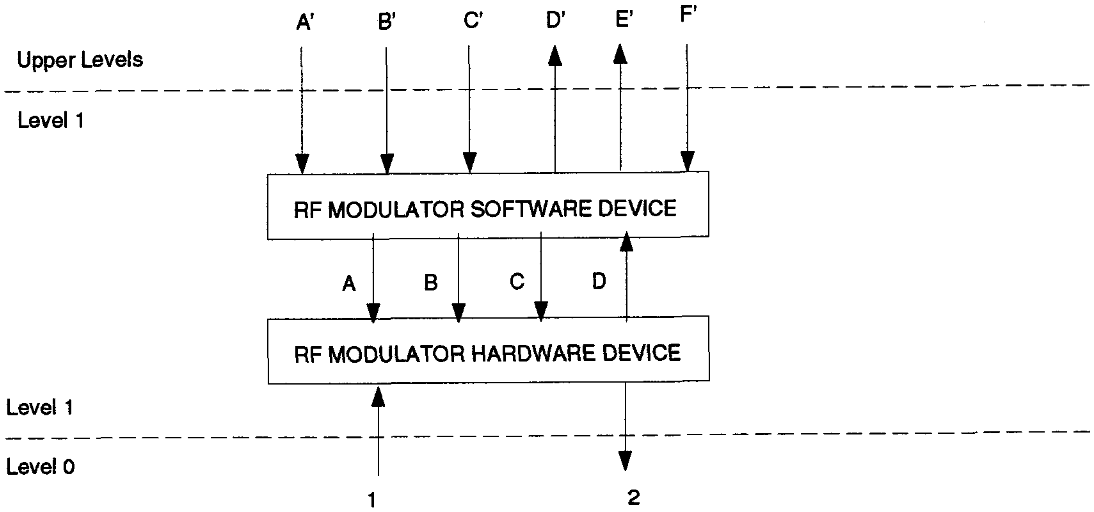


Table 11 RF Modulator Device Level 1 to Upper Levels Interface Signals

Label	Description	Signal Type
A	RF Modulator On/Off Select	TTL
B	RF Attenuator Range Select	TTL, multi-bit
C	RF Power Select	TTL, multi-bit
D	RF Output Power Monitor	0-10 VDC
A’	RF Modulator On/Off Select	bo
B’	RF Attenuator Range Select	mbbo

Table 11 (Continued) RF Modulator Device Level 1 to Upper Levels Interface Signals

Label	Description	Signal Type
C'	RF Power Select	mbbo
D'	RF Output Power Monitor	ai
E'	RF Modulator Device Alarms	alarm
F'	RF Modulator Device Permits	Software

Table 12 RF Modulator Device Level 1 Level 0 Interface Signals

Label	Description	Signal Type
1	RF Input	TBD
2	RF Output	5 Watts max.

3.1.3.2.4.3 Sequences and Functions

The status of the RF amplifier device for each modulator LCU mode of operation is:

1. "Modulator Off"- RF amplifier disabled
2. "Modulator On"- RF amplifier enabled

3.1.3.2.4.4 Alarms

None

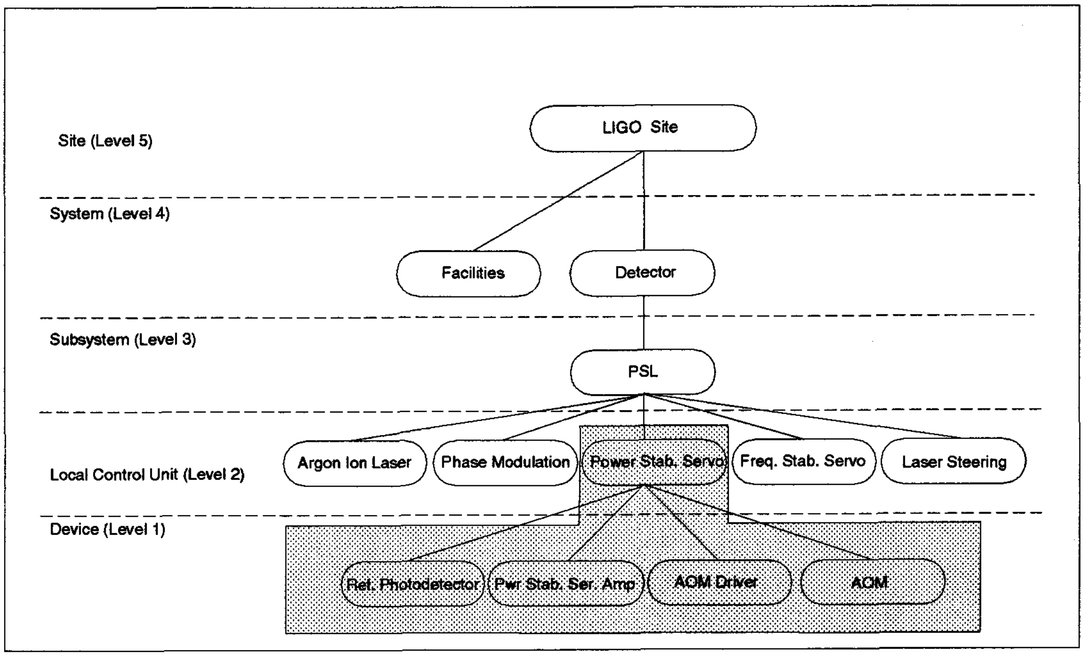
3.1.3.2.4.5 Permits

None

3.1.3.3 Laser Power Stabilization Servo (PSS)

The figure below highlights the levels of the PSL CIM model that are covered by this section. The power stabilization servo uses an Acousto-Optic Modulator (AOM) to stabilize the laser power. Stabilization is achieved by controlling the ratio of laser power in the zero order and first order beams at the output of the AOM. The PSS is made up of several components. They are:

Figure 11 LIGO PSL Power Stabilization Servo CIM Model



1. reference photodetector- used to monitor the laser power transmitted by the 12 meter mode cleaner. The photodiode is part of the ~~Input Optics~~ PSL IFO subsystem.
2. power stabilization servo amplifier- the servo amplifier that regulates the zero order beam power
3. VCO Deflector Driver- the driver for the Acousto-Optic Modulator
4. Acousto-Optic Modulator- used to transfer power from the zero order beam to the first order beam. The AOM is part of the PSL subsystem.

A block diagram of the PSS is shown in the figure below.

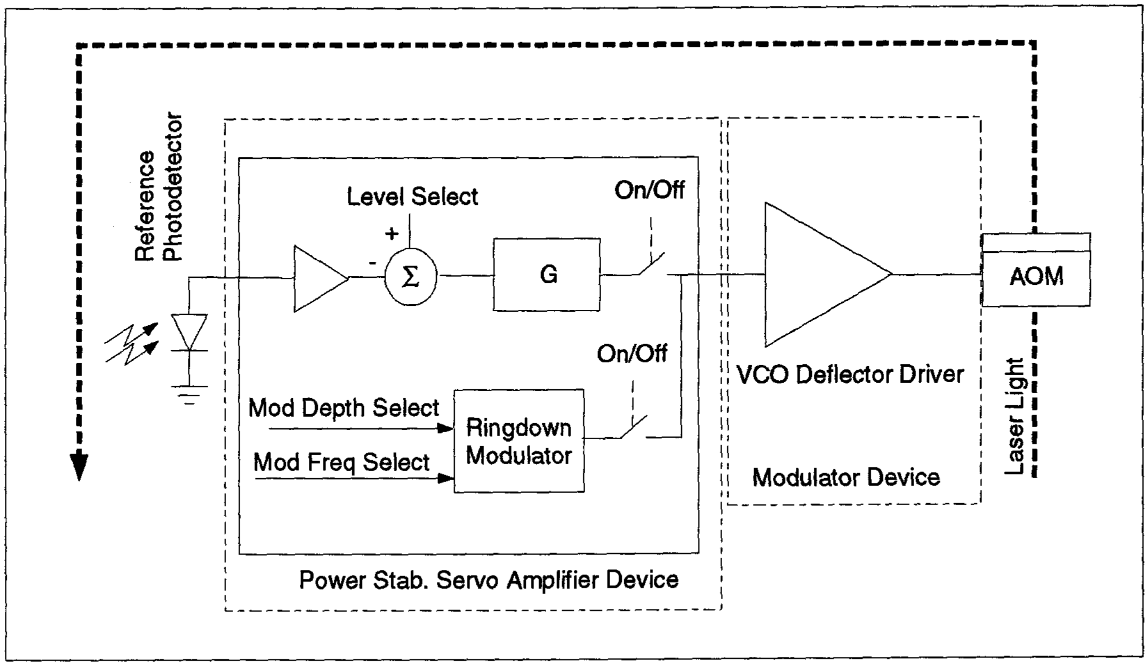


Figure 12 Power Stabilization Servo Block Diagram

3.1.3.3.1 Power Stabilization Servo Level 2 Performance

The power stabilization servo system shall have an open loop spectral noise voltage, referenced to the input:

$V(f) < 5\ nV/(Hz)^{1/2}$
for, $30\ Hz \leq f \leq 100\ KHz$.

Also, to assure linear operation, all of the amplifier stages should not approach their maximum output or slew rates limits under normal operating conditions.

Update rates and reaction times for controls are as follows:

1. On/Off and Level Selects- 1 second maximum for operator or CDS initiation
2. Power Stab. Amplifier Output Level Indicators (discrete)- 1 second from change of state to indication
3. Power Stab. Amplifier Output Monitor- 10 samples per second maximum

3.1.3.3.2 Power Stabilization Servo Level 2 Controls

3.1.3.3.2.1 Sequences and Functions

The modes of operation for the power stabilization servo LCU shall be:

1. Servo Off
2. Servo Locking
3. Servo Locked
4. Cavity Ringdown.

In cavity ringdown mode the light power level shall be modulated. The modulation waveform shall be a square wave with rise and fall times less than 100 nanoseconds. The depth (referenced from 100% power) of the modulation shall be selectable from 10% to 100% in 5% steps. The nominal modulation depth shall be 10%. The accuracy of the modulation depth shall be better than ±2%. The modulation frequency shall be selectable from 32 to 4096 Hz in at least 8 steps. The default modulation frequency shall be 1024 Hz. The accuracy of the modulation frequency shall be better than 10% of the selected frequency.

The default, power up and reset mode of operation for the power stabilization servo LCU is "Servo Off".

3.1.3.3.2.2 Alarms

TBD

3.1.3.3.2.3 Permits

TBD

3.1.3.3.2.4 Level 1 Devices

For the purposes of control and monitoring, the power stabilization LCU has been broken into two devices. These are the power stabilization amplifier and the modulator devices shown in the figure above. The interface to the reference photodetector is at the output connector of the photodetector. Any conditioning electronics used to condition or transmit the photodetector signal are included as part of the power stabilization amplifier device. The interface to the AOM is at the input connector of the AOM. The minimum required performance and signals for each device are described in the following figures and tables.

3.1.3.3.3 Power Stabilization Amplifier Device

3.1.3.3.3.1 Performance

The power stabilization servo amplifier shall have connections for the following:

1. Input- input signal to amplifier from reference photo detector
2. Reference Photodetector Output- Remote Diag.
3. Reference Photodetector Output- Data Acq.
4. Output- Output to AOM driver AM input. Zout = 50 ohms. 0<Vout<1volt.
5. Output Monitor- Data Acquisition
6. Output Monitor- Remote Diagnostics

3.1.3.3.3.2 Control Signals

The controls and monitors for the amplifier shall be:

1. Gain Select- The amplifier DC gain shall selectable from94 to 124 dB in 12 steps.
2. Vernier Bias Adjust- Fine power level control, continuously adjustable with minimum 12 bit resolution.
3. Output Enable/Disable Select- The output of the amplifier shall be capable of being enabled or disabled. The present selection shall be monitored through the VME bus.
4. Output Monitor- The output of the amplifier shall have a monitor available to the VME bus.
5. Output Level Indicator- Discrete monitors of the output level corresponding to full scale, 3/4 full scale, —3/4 full scale, and —full scale shall be monitored through the VME bus. The indication shall be latching and be reset through the VME bus.
6. Ringdown Level Select- High and low selection from 0 to 100 percent modulation
7. Ringdown Frequency Select- Ringdown modulation frequency

Figure 13 Power Stabilization Amplifier Device Interface Signals

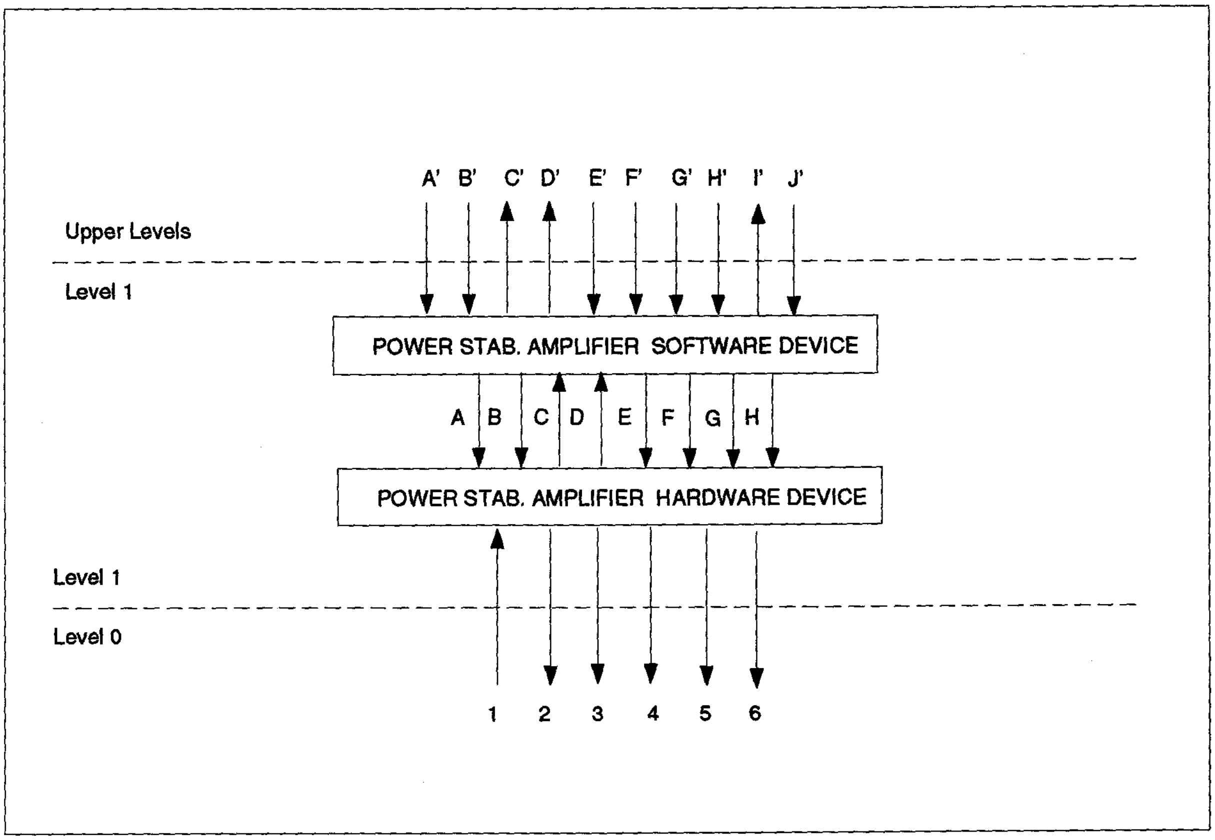


Table 13 Power Stabilization Amplifier Device Level 1 to Upper Levels Interface Signals

Label	Description	Signal Type
A	Gain Select	TTL, multi-bit
B	Output Enable/Disable Select	TTL
C	Output Monitor	0-10 VDC
D	Output Level Indicator	TTL, multi-bit
E	Ringdown Modulator Level Select	0-10 VDC
F	Ringdown Frequency Select	TBD

Table 13 (Continued) Power Stabilization Amplifier Device Level 1 to Upper Levels Interface Signals

Label	Description	Signal Type
G	Ringdown Enable/Disable Select	TTL
H	Vernier Bias Adjust	0-10 VDC
A'	Power Level Select	Software, TBD
B'	Output Enable/Disable Select	bo
C'	Output Monitor	ai
D'	Output Level Indicator	mbbi
E'	Ringdown Modulator Level Select	ao
F'	Ringdown Frequency Select	Software, TBD
G'	Ringdown Enable/Disable Select	bo
H'	Vernier Bias Adjust	ao
I'	Power Stabilization Ampl. Device Alarms	alarm
J'	Power Stabilation Ampl. Device Permits	Software

Table 14 Power Stabilization Amplifier Device Level 1 Level 0 Interface Signals

Label	Description	Signal Type
1	Reference Photodetector Input	-10 to +10 VDC
2	Reference Photodetector Output (Remote Diag)	-10 to +10 VDC
3	Reference Photodetector Output (Data Acq)	-5 to +5 VDC
4	Output	0 to 1 V
5	Output Monitor (Remote Diag)	-10 to +10 VDC
6	Output Monitor (Data Acq)	-5 to +5 VDC

3.1.3.3.3.3 Sequences and Functions

The status of each signal in each operating mode shall be as listed below. Signals not listed are assumed to be unaffected by operating mode.

Figure 14 Power Stabilization Amplifier Signal Status vs. Operating Mode

Operating Mode/ Signal	Servo Off	Servo Locking	Servo Locked	Cavity Ringdown
Output Enable/Disable Select	Disable	Enable	Enable	Disable
Ringdown Enable/Disable Select	Disable	Disable	Disable	Enable

3.1.3.3.3.4 Alarms

Power stabilization amplifier alarms shall be generated for the following:

Figure 15 Power Stabilization Amplifier Device Alarms

ALARM CONDITION	SEVERITY	ACTION
Output Power Greater Than 3/4 Power	Minor	Operator Warning
Output Power Less Than 1/4 Power and Amplifier Enabled	Minor	Operator Warning

3.1.3.3.3.5 Permits

The following device interlocks and permits shall be incorporated:

1. The power stabilization amplifier servo shall be disabled when the power stabilization LCU is in the "Ringdown" mode of operation.

3.1.3.3.4 Modulator Device

3.1.3.3.4.1 Performance

The AOM driver is a commercial unit (IntraAction Corporation model DE-40M). It has front panel controls for on/off select switch, carrier frequency adjust and carrier level adjust. The unit has BNC connectors for:

1. Analog Input: Zin= 50 ohms, 0–1volt = 30–50 MHz carrier
2. Modulation Input: Zin= 50 ohms, 0–1 volt = 0–4 watts output power
3. RF Output: 4 watts maximum, Zout= 50 ohms

The AOM has an input BNC connector.

3.1.3.3.4.2 Control Signals

The acoustic driver is a commercial unit (IntraAction Corporation model DE-40M). Controls for the DE-40M shall be:

1. TBD

Figure 16 Modulator Device Interface Signals

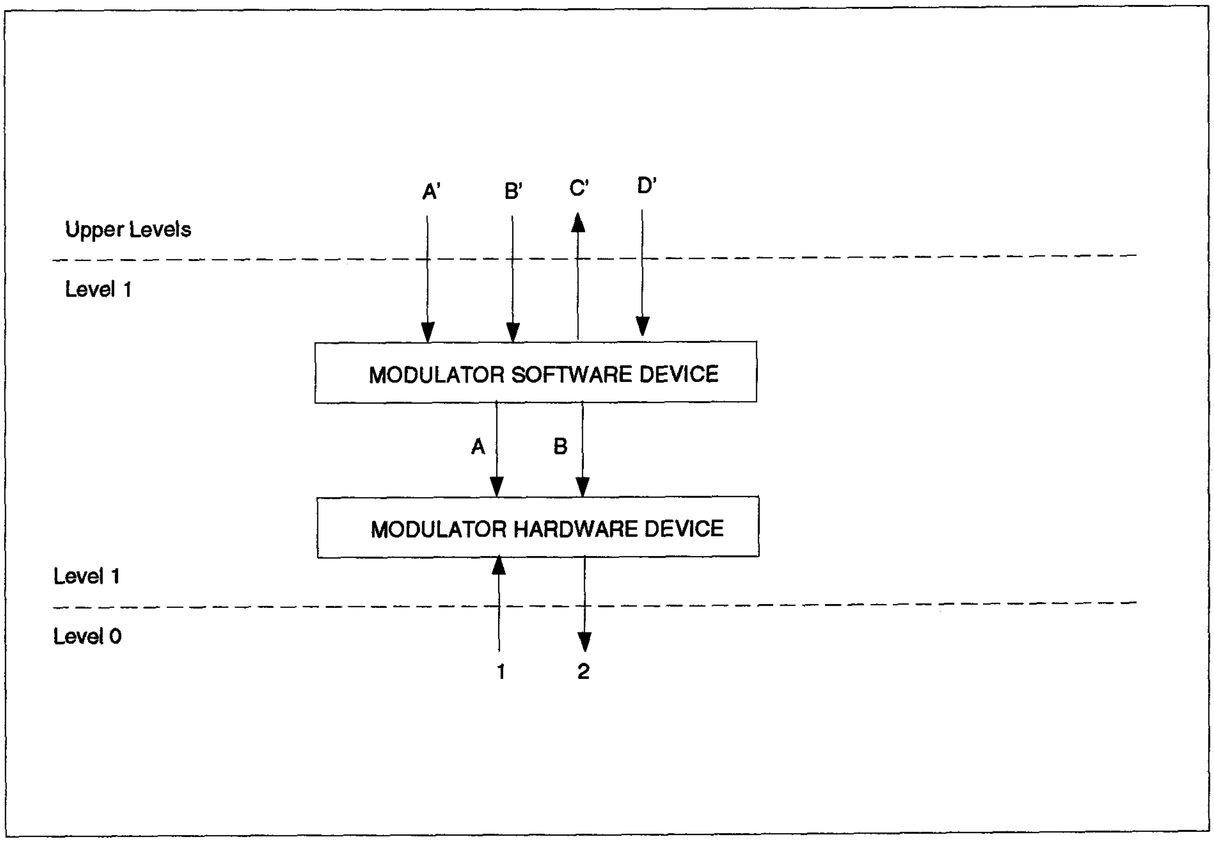


Table 15 Modulator Device Level 1 to Upper Levels Interface Signals

Label	Description	Signal Type
A	Modulator On/Off Select	TTL
B	Carrier Frequency Adjust	0-10 VDC
A'	Modulator On/Off Select	bo
B'	Carrier Frequency Adjust	ao
C'	Modulator Device Alarms	alarm
D'	Modulator Device Permits	Software

Table 16 Modulator Device Level 1 to Level 0 Interface Signals

Label	Description	Signal Type
1	Modulator Input to AOM Driver	0 to 1 V
2	Modulator Output to AOM	Matched to unit by manufacturer. (See manual).

3.1.3.3.4.3 Sequences and Functions

None

3.1.3.3.4.4 Alarms

None

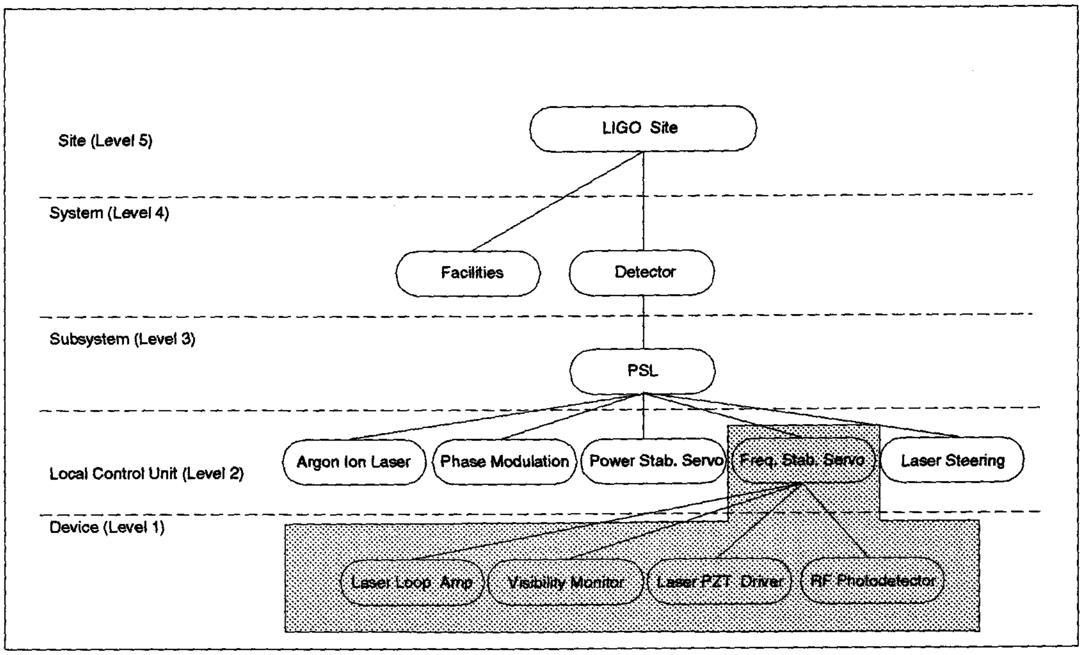
3.1.3.3.4.5 Permits

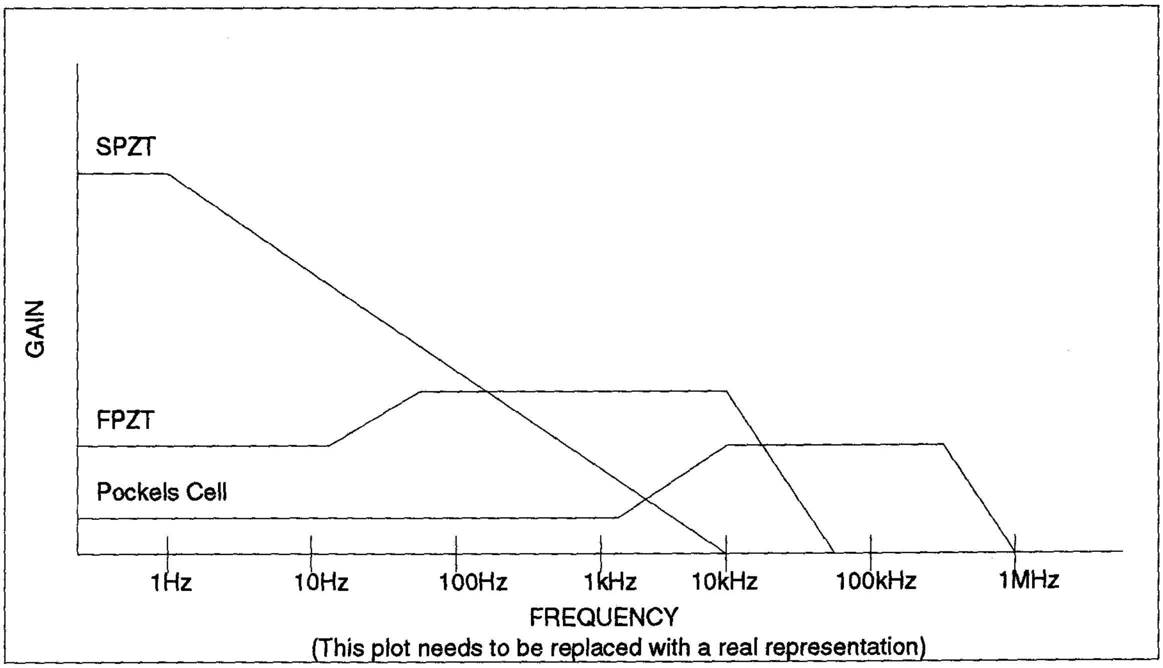
None

3.1.3.4 Laser Frequency Stabilization Servo (FSS)

The figure below highlights the levels of the PSL CIM model that are covered by this section. The frequency stabilization servo uses pockels cells, piezo mounted laser mirrors and a rigid spacer Fabry-Perot cavity to prestabilize the laser light frequency. Three different devices are used: phase correcting pockels cells, the “fast” PZT and the “slow” PZT. In general the slow PZT is used for loop response frequencies less than 500 Hz. The fast PZT is used for loop response frequencies between 500 Hz and 50 kHz. The pockels cells are used for loop response frequencies greater than 50 kHz. An approximation of the response of each device versus frequency is shown in the figure below. The gain and transfer function requirements for the frequency stabilization servo electronics are specified in document number TBD.

Figure 17 LIGO PSL Frequency Stabilization Servo CIM Model





(This plot needs to be replaced with a real representation)

Figure 18 Frequency Stabilization Device Response versus Frequency

Prestabilization of the laser is achieved by locking the laser frequency to a resonance of the reference cavity. The PSL FSS is made up of four devices. They are:

1. RF Photodetector- provides DC and RF outputs for light reflected from the reference cavity input mirror. The DC output signal is sent to the visibility monitor. The demodulated RF signal output is sent to the laser loop amplifier where it is used for frequency stabilization.
2. Laser loop amplifier-is the main frequency stabilization servo amplifier with outputs to the Pockels cells and PZT driver.
3. PZT driver- controls the high voltage drive to the fast and slow PZTs used to adjust the laser frequency.
4. Visibility monitor- provides a measure of the "visibility" of a cavity. When the cavity is in lock the visibility will be maximum. Visibility is defined as:

$V = (I_{in} - I_{refl})/I_{in}$

ref refl

where, I_{in} is the input power to the reference cavity and I_{refl} is the reflected power (at the input to the reference cavity)measured by the RF photodetector (DC output).

A block diagram of the FSS is shown in the figure below.

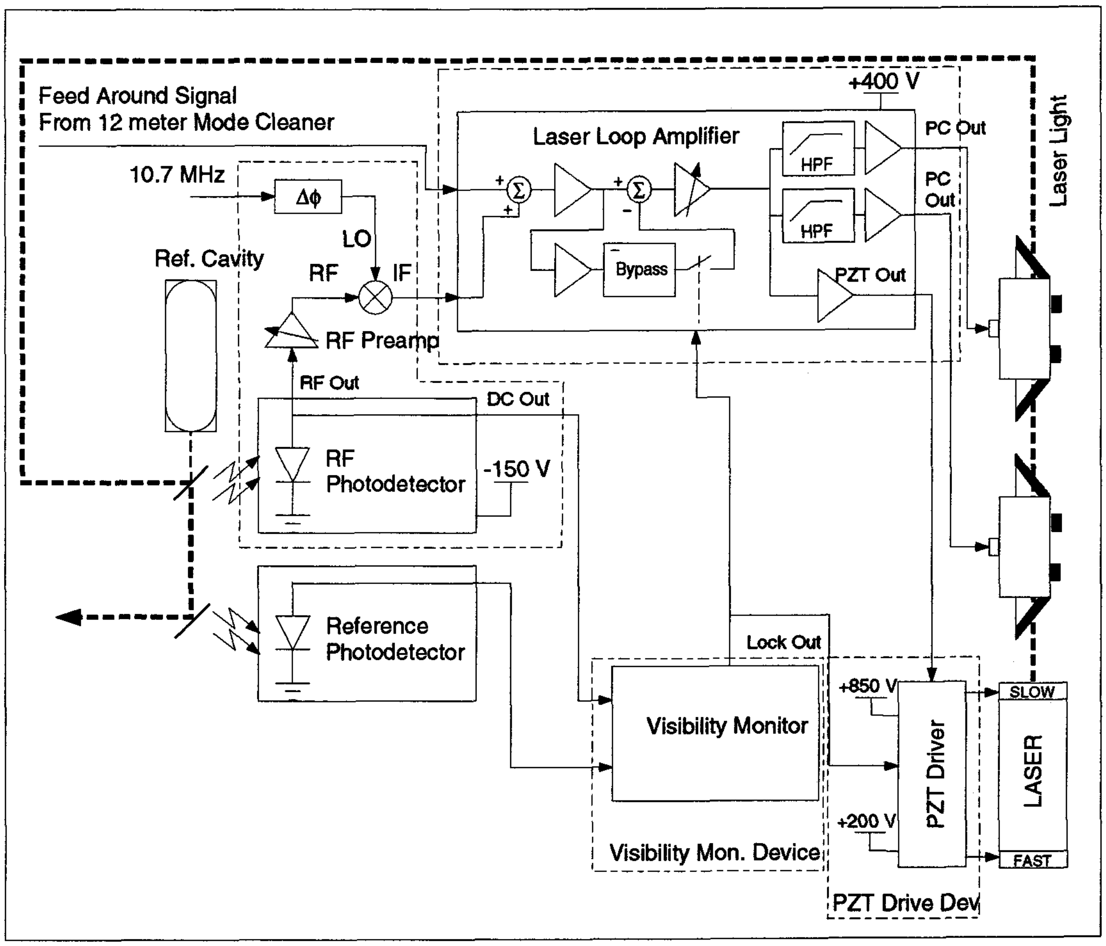


Figure 19 Frequency Stabilization Servo Block Diagram

3.1.3.4.1 Frequency Stabilization Servo Level 2 Performance

The frequency stabilization servo system shall have an open loop spectral noise voltage, referenced to the input:

$$V(f)< 5\ nV/(Hz)^{1/2}$$

for, 30 Hz ≤ f ≤ 100 KHz.

Also, to assure linear operation, all of the amplifier stages should not approach their maximum output or slew rates limits under normal operating conditions.

Update rates and reaction times for the controls are as follows:

1. On/Off Selects and Level Adjustments- 1 second maximum for operator or CDS initiation.
2. Pockels Cell, Visibility and PZT Output Monitors- 10 samples per second maximum
3. RF Photodetector and Laser Loop Amplifier Demodulated Output Monitor- 10 samples per second maximum
4. Power Supply Voltage and Current Monitors- 1 sample per second maximum
5. Slow PZT Scanning Disable on Lock Indication- 1 millisecond

3.1.3.4.2 Frequency Stabilization Servo Level 2 Controls

3.1.3.4.2.1 Sequences and Functions

The modes of operation of the frequency stabilization servo shall be:

1. Servo Off
2. Servo Acquiring
3. Servo Locked
4. Manual Scanning

In the "Servo Off" mode the laser loop amplifier output shall be disabled. The output shall be enabled in the "Servo Acquiring" and "Servo Locked" modes. In the "Manual Scanning" mode the output may be enabled or disabled.

In the "Servo Acquiring" mode the laser slow PZT shall scan. The range of the scan shall be 0–800 volts and the frequency of the scan shall be 1 Hz. The time to disable PZT scanning when the operating mode changes from "Servo Acquiring" to "Servo Locked" shall be less than 2 milliseconds. In the "Manual Scanning" mode the laser slow PZT shall scan continuously.

The "Servo Locked" mode of operation is achieved when the visibility monitor Lock Indicator Output is set to "TRUE". This indicates a cavity visibility greater than the visibility threshold.

The default, power up and reset mode of operation shall be "Servo Off"

3.1.3.4.2.2 Alarms

TBD

3.1.3.4.2.3 Permits

The following permits shall be incorporated:

1. Laser slow PZT scanning shall be disabled when the laser is off.

3.1.3.4.2.4 Level 1 Devices

For the purposes of control and monitoring, the frequency stabilization LCU has been broken into four devices. These are the laser loop amplifier, visibility monitor, laser PZT driver and the RF photodetector/down~~-converter devices~~ shown Demo in the figure above. The interface to the RF photodetector is at the output connector of the photodetector. The interface to the pockels cells is at the input connector of each pockels cell. The interface to the laser is at the input connector of the mirror PZTs. The minimum required performance and signals for each device are described in the following figures and tables. Note that each device also includes its respective power supplies.

3.1.3.4.3 Laser Loop Amplifier Device

3.1.3.4.3.1 Performance

The laser loop amplifier shall have BNC (SMA) connections for:

1. Local Oscillator In- +23 dBm max., +7 dBm min., Zin = 50 ohms
2. RF Photodetector In- +15 dBm max., Zin = 50 ohms
3. Feed around in: Zin = 50 ohms
4. PZT Out: Zout = 50 ohms
5. PZT Out: Remote Diag.
6. PZT Out: Data Acquisition
7. DEMO out: Remote Diag.
8. DEMO out: Data Acq..
9. —PC Drive: 400 Vp-p
10. —PC drive monitor: 1Volt/100 Volts, Remote Diag.
11. +PC Drive: 400 Vp-p
12. +PC Drive monitor: 1V/100V, Remote Diag.

The pockels cell (400 Volt) power supply shall have BNC (SHV) connections for:

1. High Voltage Output: SHV connector providing 400 volt power to laser loop amplifier.

The front panel controls and indicators shall be:

1. On/Off Select: High voltage on and off shall be selectable. The current selection shall be indicated.

The stability of supply shall be better than TBD. The output ripple shall be better than TBD.

The input connector on the phase corrector pockels cells are SHV. The input impedance is TBD.

3.1.3.4.3.2 Control Signals

Controls and indicators for the Laser Loop Amplifier shall be:

1. Mode select- The mode of operation shall be selectable. The selections will be Auto, Bypass Off and Bypass On. The current selection shall be readable from the VME bus.
2. Wideband DC Adjust- The wideband DC (Bypass Off) shall be adjustable from the VME bus. The range of the adjustment shall be TBD. The resolution of adjustment shall be TBD. Accuracy shall be TBD. The current selection shall be readable through the VME bus. Wideband DC adjustments are made to compensate for such things as electronic offsets and drifts.
3. Bypass DC Adjust- The bypass DC shall be adjustable from the VME bus. The range of the adjustment shall be TBD. The resolution of adjustment shall be TBD. Accuracy shall be TBD. The current selection shall be readable through the VME bus. Bypass DC adjustments are made to compensate for such things as electronic offsets and drifts.
4. Loop Gain Select- The loop gain of the amplifier shall be selectable. The selections shall be 12 different settings between 0.1 mA and 1.0 mA corresponding to the programming currents of the programmable gain amplifier used in the circuit. The current selection shall be readable from the VME bus.
5. DEMO out monitor-

6. —PC monitor- 1V/100V, 12 bit +/-1 bit FS
7. +PC monitor- 1V/100V, 12 bit +/-1 bit FS
8. Lock Indication- Lock Indication from visibility monitor

Pockels Cells power supply controls and indicators shall be:

1. Output Voltage Monitor: The supply shall have an output monitor. The scaling for the monitor shall be 1volt/100 volt.
2. On/Off select: The on/off status of the power supply shall be selectable. The current selection shall be readable through the VME bus.

Figure 20 Laser Loop Amplifier Device Interface Signals

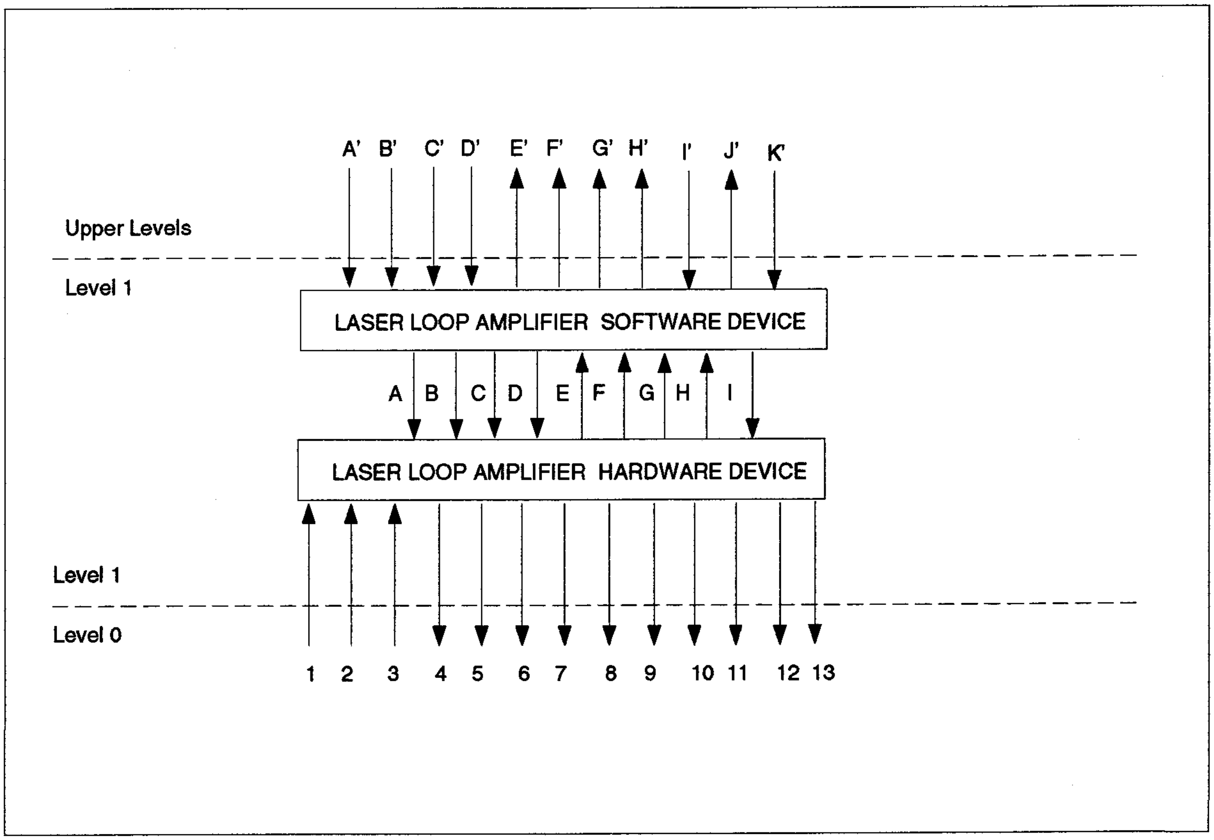


Table 17 Laser Loop Amplifier Device Level 1 to Upper Levels Interface Signals

Label	Description	Signal Type
A	Mode Select	TTL, Multi-bit
B	Wideband DC Adjust	0-10 VDC
C	Bypass DC Adjust	0-10 VDC
D	Loop Gain Select	0-10 VDC
E	DEMO Out Monitor	0-10 VDC
F	-PC Monitor	0-10 VDC
G	+PC Monitor	0-10 VDC
H	PC P.S. Output Voltage Monitor	0-10 VDC
I	PC P.S. On/Off Select	TTL
A’	Mode Select	mbbo
B’	Wideband DC Adjust	ao
C’	Bypass DC Adjust	ao
D’	Loop Gain Select	ao
E’	DEMO Out Monitor	ai
F’	-PC Monitor	ai
G’	+PC Monitor	ai
H’	PC P.S. Output Voltage Monitor	ai
I’	PC P.S. On/Off Select	bo
J’	Laser Loop Ampl. Device Alarms	alarm
K’	Laser Loop Ampl. Device Permits	Software

Table 18 Laser Loop Amplifier Device Level 1 to Level 0 Interface Signals

Label	Description	Signal Type
1	Local Oscillator Input	+ 23 dBm
2	RF Photodetector Input	+15 dBm max.

Table 18 (Continued) Laser Loop Amplifier Device Level 1 to Level 0 Interface Signals

Label	Description	Signal Type
3	Feedaround Signal Input	-12 to +12 VDC
4	PZT Output	-10 to +10 VDC
5	PZT Output, Remote Diag	-10 to +10 VDC
6	PZT Output, Data Acq.	-10 to +10 VDC
7	DEMO Output (Remote Diag)	-10 to +10 VDC
8	DEMO Output (Data Acq.)	-10 to +10 VDC
9	+PC Output Monitor (Remote Diag)	-10 to +10 VDC
10	-PC Output Monitor (Remote Diag)	-10 to +10 VDC
11	-PC Drive	400 Vp-p
12	+PC Drive	400 Vp-p
13	Lock Indication Input	TTL

3.1.3.4.3.3 Sequences and Functions

The modes of operation of the laser loop amplifier device shall be:

1. Bypass Off
2. Bypass On
3. Auto

In the “Bypass Off” mode the low frequency gain of the laser loop amplifier is suppressed. In the “Bypass On” mode the low frequency gain is boosted. The exact details of the gain characteristics for each are described in document number TBD.

In the “Auto” mode of operation the decision as to which level (i.e. bypass off or bypass on) of low frequency gain is selected is determined by an external input from the visibility lock indication. If the operating mode of the frequency stabilization LCU is “Servo Acquiring” then the laser amplifier mode is “Bypass Off”, when the LCU mode switches to “Servo Locked” the laser amplifier mode is “Bypass On”.

3.1.3.4.3.4 Alarms

Laser loop amplifier alarms shall be generated for the following:

Figure 21 Laser Loop Amplifier Device Alarms

ALARM CONDITION	SEVERITY	ACTION
Pockel Cell Power Supply Transient Detection Alarm	Minor	Operator Warning

3.1.3.4.3.5 Permits

None

3.1.3.4.4 Visibility Monitor Device

3.1.3.4.4.1 Performance

The visibility monitor shall be capable of calculating the visibility while the LCU is in the "locked" mode in a time not to exceed 100 milliseconds. This time includes the time required to measure the appropriate voltage, perform the calculation and determine the lock condition. The accuracy of the calculation shall be better than ±5% full scale. The time to calculate the visibility when the LCU is the "servo acquiring" mode shall not exceed 1 millisecond.

3.1.3.4.4.2 Control Signals

Controls and indicators shall be:

1. RF Photodiode DC Gain: The photodiode gain shall be selectable. The selections shall be x1, x3, x10, x30, x100. The current selection shall be readable through the VME bus.
2. Reference Photodiode DC Gain: The reference gain shall be selectable. The selections shall be x1, x3, x10, x30, x100. The current selection shall be readable through the VME bus.
3. Threshold adjust: The threshold shall be adjustable from 0 to 1 in a minimum of 100 steps.

Figure 22 Visibility Monitor Device Interface Signals

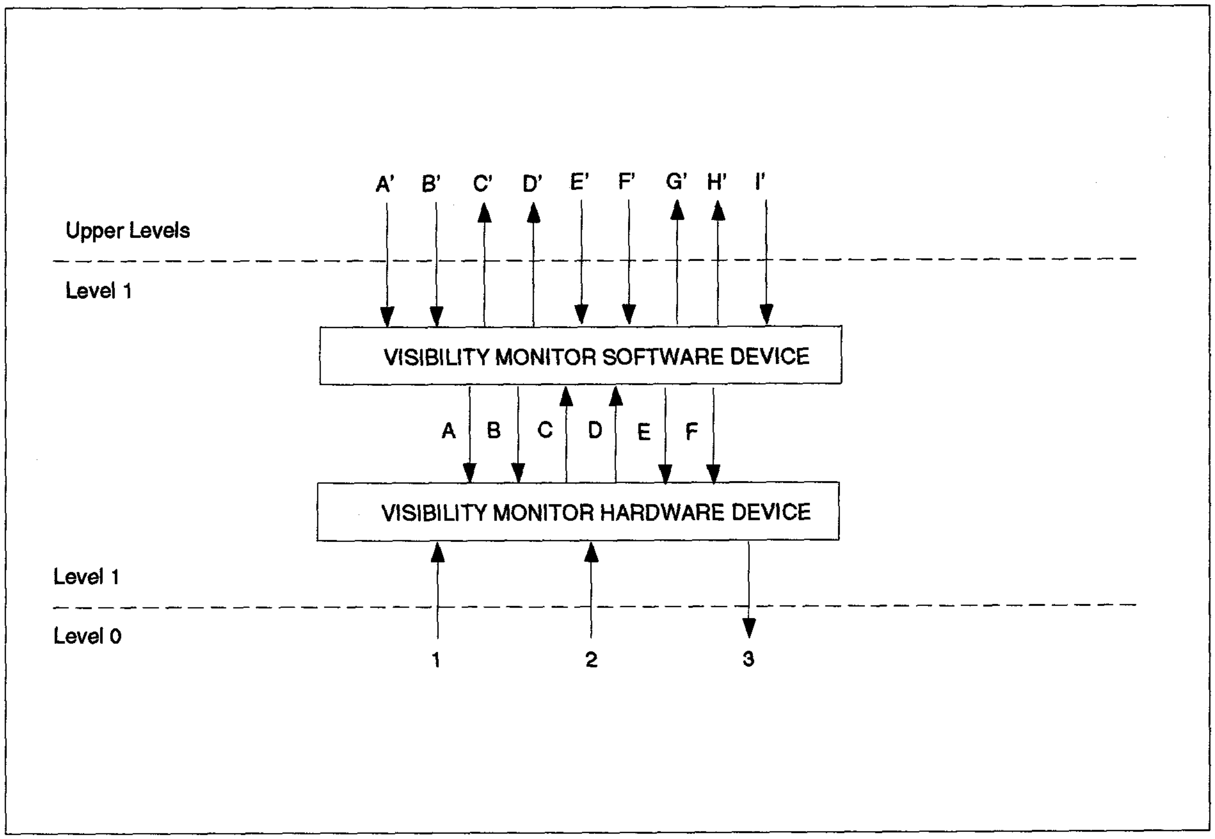


Table 19 Visibility Monitor Device Level 1 to Upper Levels Interface Signals

Label	Description	Signal Type
A	RF (DC) Photodiode Gain Select	TBD
B	Reference Gain Select	TBD
C	Reference Photodiode Input Monitor	0-10 VDC
D	RF (DC) Photodiode Input Monitor	0-10 VDC
E	Lock (bar) Indicator	TTL
F	Threshold Adjust	TBD

Table 19 (Continued) Visibility Monitor Device Level 1 to Upper Levels Interface Signals

Label	Description	Signal Type
A'	RF (DC) Photodiode Gain Select	TBD
B'	Reference Gain Select	TBD
C'	Reference Photodiode Input Monitor	ai
D'	RF (DC) Photodiode Input Monitor	ai
E'	Lock (bar) Indicator	bo
F'	Threshold Adjust	TBD
G'	Visibility Monitor Output	ao
H'	Visibility Monitor Device Alarms	alarm
I'	Visbility Monitor Device Permits	Software

Table 20 Visibility Monitor Device Level 1 to Level 0 Interface Signals

Label	Description	Signal Type
1	Reference Photodetector Input	-10 to +10 V
2	RF Photodetector DC Input	-10 to +10 V
3	Lock (bar) Output	TTL

3.1.3.4.4.3 Sequences and Functions

The visibility monitor has two states: locked="TRUE" and locked="FALSE". Locked="TRUE" is defined as a calculated visibility greater than or equal to the visibility threshold. Locked="FALSE" is defined as a calculated visibility less than the visibility threshold.

In the locked="TRUE" state the Lock Output indicator is set to "TRUE" and the visibility must be calculated at least once every 100 milliseconds.

In the locked="FALSE" state the Lock Output indicator is set to "FALSE" and the visibility must be calculated at least once every millisecond. This time constraint is set by the necessity to disable the laser slow PZT scanning before the laser cavity is beyond the lock range of the laser loop amplifier.

3.1.3.4.4.4 Alarms

Visibility monitor device alarms shall be generated for the following:

Table 21 Visibility Monitor Driver Device Alarms

ALARM CONDITION	SEVERITY	ACTION
Visibility less than threshold	Minor	Operator warning, Set lock indicator output to "FALSE"
~~Visibility greater than or equal to threshold~~	~~Minor~~	~~Operator warning,~~ ~~Set lock indicator output to "TRUE"~~

3.1.3.4.4.5 Permits

None

3.1.3.4.5 PZT Driver Device

3.1.3.4.5.1 Performance

The PZT driver shall have connections for:

1. Input:
2. Fast Piezo out: Vout(min) = 180 Vp-p
3. Fast Piezo monitor: 1V/100V, Remote Diag.
4. Fast Piezo monitor: 1V/100V, Data Acq.
5. Slow Piezo out: Vout(min) = 700 V
6. Slow Piezo monitor: 1V/100V, Remote Diag.
7. Slow Piezo monitor: 1V/100V, Data Acq.

The slow PZT (850 Volt) power supply shall have connections for:

1. High Voltage Output: SHV connector providing +850 volt power to PZT driver module.
2. Output Voltage Monitor: The supply shall have an output monitor. The scaling for the monitor shall be 1volt/100 volt.

The slow PZT (850 Volt) power supply front panel controls and indicators shall be:

1. On/Off Select: High voltage on and off shall be selectable. The current selection shall be indicated.

The stability of slow PZT supply shall be better than TBD. The output ripple shall be better than TBD.

The fast PZT (200 Volt) power supply shall have connections for:

1. High Voltage Output: SHV connector providing +200 volt power to PZT driver module.
2. Output Voltage Monitor: The supply shall have an output monitor. The scaling for the monitor shall be 1volt/100 volt.

The fast PZT (200 Volt) power supply front panel controls and indicators shall be:

1. On/Off Select: High voltage on and off shall be selectable. The current selection shall be indicated.

The stability of fast PZT supply shall be better than TBD. The output ripple shall be better than TBD.

3.1.3.4.5.2 Control Signals

PZT Driver controls and indicators shall be:

1. Output too low: Output below threshold shall be latching and reset from the VME bus.
2. Output too high: Output above threshold shall be latching and reset from the VME bus.
3. SPZT Mode select- The SPZT mode shall be selectable. The selections shall be AUTO, SCAN, and SERVO (DC). The current selection shall be readable from the VME bus.
4. Fast Piezo monitor- 1V/100V
5. Slow Piezo monitor- 1V/100V
6. Output too Low/High Reset- Reset for Output too Low and Output to High latches.

Slow PZT power supply controls and indicators shall be:

1. Output Voltage Monitor: The supply shall have an output monitor. The scaling for the monitor shall be 1volt/100 volt.
2. On/Off select: The on/off status of the power supply shall be selectable. The current selection shall be readable through the VME bus.

Fast PZT power supply controls and indicators shall be:

1. Output Voltage Monitor: The supply shall have an output monitor. The scaling for the monitor shall be 1volt/100 volt.
2. On/Off select: The on/off status of the power supply shall be selectable. The current selection shall be readable through the VME bus.

Figure 23 PZT Driver Device Interface Signals

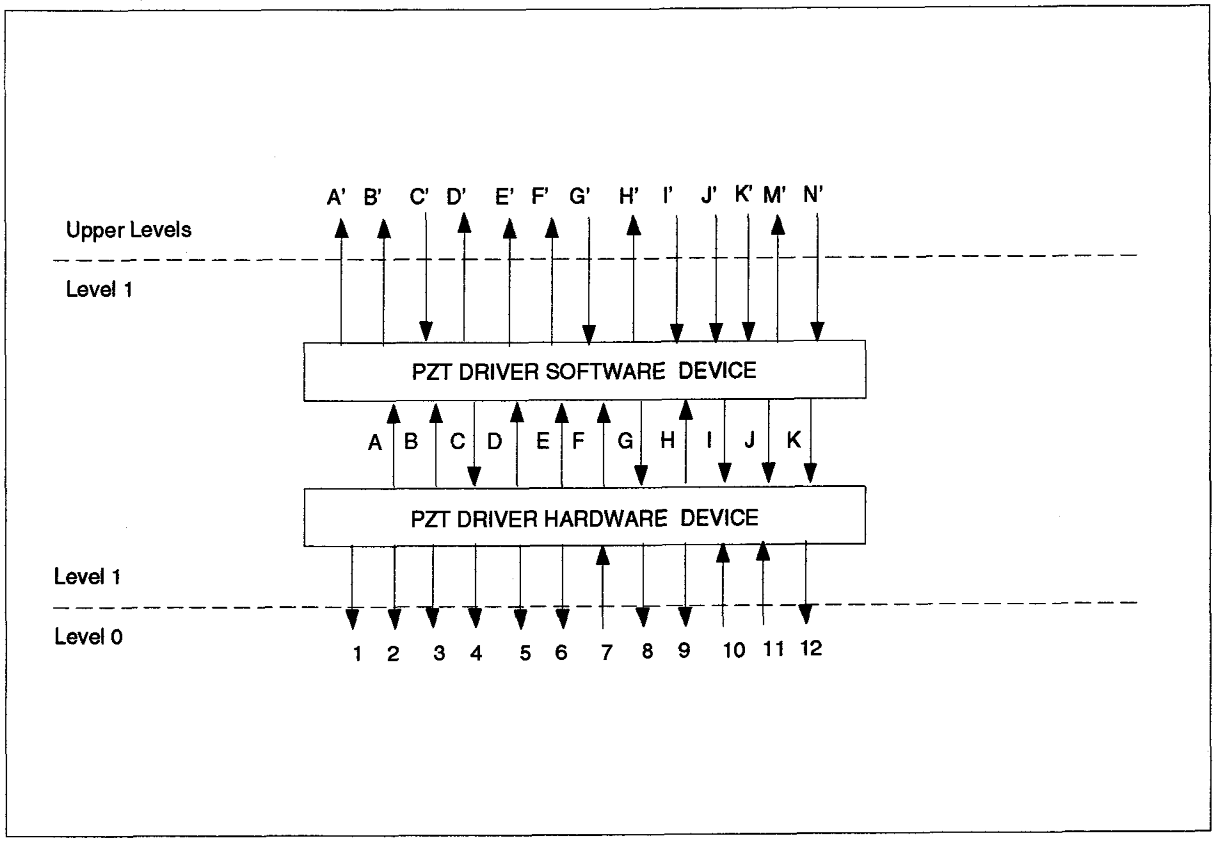


Table 22 PZT Driver Device Level 1 to Upper Levels Interface Signals

Label	Description	Signal Type
A	Drive Output Too Low	TTL
B	Drive Output Too High	TTL
C	SPZT Mode Select	TTL, Multi-bit
D	Slow PZT Output Monitor	0-10 VDC
E	Fast PZT Output Monitor	0-10 VDC
F	Slow PZT P.S. Voltage Monitor	0-10 VDC
G	Slow PZT P.S. On/Off Select	TTL
H	Fast PZT P.S. Voltage Monitor	0-10 VDC
I	Fast PZT P.S. On/Off Select	TTL
J	Output too Low/High Reset	TTL
K	Slow PZT Scan Reference	0-10 VDC
A'	Drive Output Too Low	bi
B'	Drive Output Too High	bi
C'	SPZT Mode Select	mbbo
D'	Slow PZT Output Monitor	ai
E'	Fast PZT Output Monitor	ai
F'	Slow PZT P.S. Voltage Monitor	ai
G'	Slow PZT P.S. On/Off Select	bo
H'	Fast PZT P.S. Voltage Monitor	ai
I'	Fast PZT P.S. On/Off Select	bo
J'	Output too Low/High Reset	bo
K'	Slow PZT Scan Reference	ao
L'	PZT Driver Device Alarms	alarm
M'	PZT Driver Device Permits	Software

Table 23 PZT Driver Device Level 1 to Level 0 Interface Signals

Label	Description	Signal Type
1	Slow PZT Drive Output	0 to 850 V
2	Fast PZT Drive Output	0 to 200 V
3	Slow PZT Monitor (Remote Diag)	0 to 10 V
4	Fast PZT Monitor (Remote Diag)	0 to 10 V
5	Slow PZT Monitor (Data Acq.)	0 to 10 V
6	Fast PZT Monitor (Data Acq.)	0 to 10 V
7	PZT Input	-12 to +12 V
8	Slow PZT P.S. On/Off Select	TTL
9	Fast PZT P.S. On/Off Select	TTL
10	Slow PZT P.S. Voltage Monitor In	0-10 VDC
11	Fast PZT P.S. Voltage Monitor In	0-10 VDC
12	Output too High/Low alarm reset	TTL

3.1.3.4.5.3 Sequences and Functions

None

3.1.3.4.5.4 Alarms

PZT driver device alarms shall be generated for the following:

Table 24 PZT Driver Device Alarms

ALARM CONDITION	SEVERITY	ACTION
Drive output too high	Minor	Operator Warning
Drive output too low	Minor	Operator Warning
Slow PZT Power Supply Transient Detection Alarm	Minor	Operator Warning
Fast PZT Power Supply Transient Detection Alarm	Minor	Operator Warning

3.1.3.4.5.5 Permits

None

3.1.3.4.6 RF Photodetector Device

3.1.3.4.6.1 Performance

The RF photodetector shall have connections for:

1. RF output- Zout= 50 ohms
2. DC output- Remote Diag.
3. DC output- Data Acq.
4. HV Bias Input- Vin max= —150 VDC
5. RF Photodiode Input: Input from photodiode supplied by interferometer group

The photodiode bias (-150 volt) supply shall have connections for:

1. High Voltage Output: SHV connector providing –150 volt power to the RF photodetector.
2. Output Voltage Monitor: The supply shall have an output monitor. The scaling for the monitor shall be 1volt/100 volt.

The photodiode bias supply front panel controls and indicators shall be:

1. On/Off Select: High voltage on and off shall be selectable. The current selection shall be indicated.

The stability of photodiode bias supply shall be better than TBD. The output ripple shall be better than TBD.

The RF phase shifter shall have connections for:

1. Input: Zin = 50 ohm, +23 dBm nominal
2. Output 1: Zout = 50 ohm, +23 dBm nominal

The phase shifter shall be capable of covering a full 360 degrees of phase shift at 10.7 MHz in steps no larger than 4.5 degrees.

3.1.3.4.6.2 Control Signals

Photodiode Bias Supply Controls and indicators shall be:

1. Output Voltage Monitor: The supply shall have an output monitor. The scaling for the monitor shall be 1volt/100 volt.

2. On/Off select: The on/off status of the power supply shall be selectable. The current selection shall be readable through the VME bus.

RF phase shifter controls and indicators shall be:

1. Local Oscillator Phase Shift Select: 0 to 360 degrees in 4.5 degree steps minimum. The current selection shall be readable through the VME bus.

Figure 24 RF Photodetector Device Interface Signals

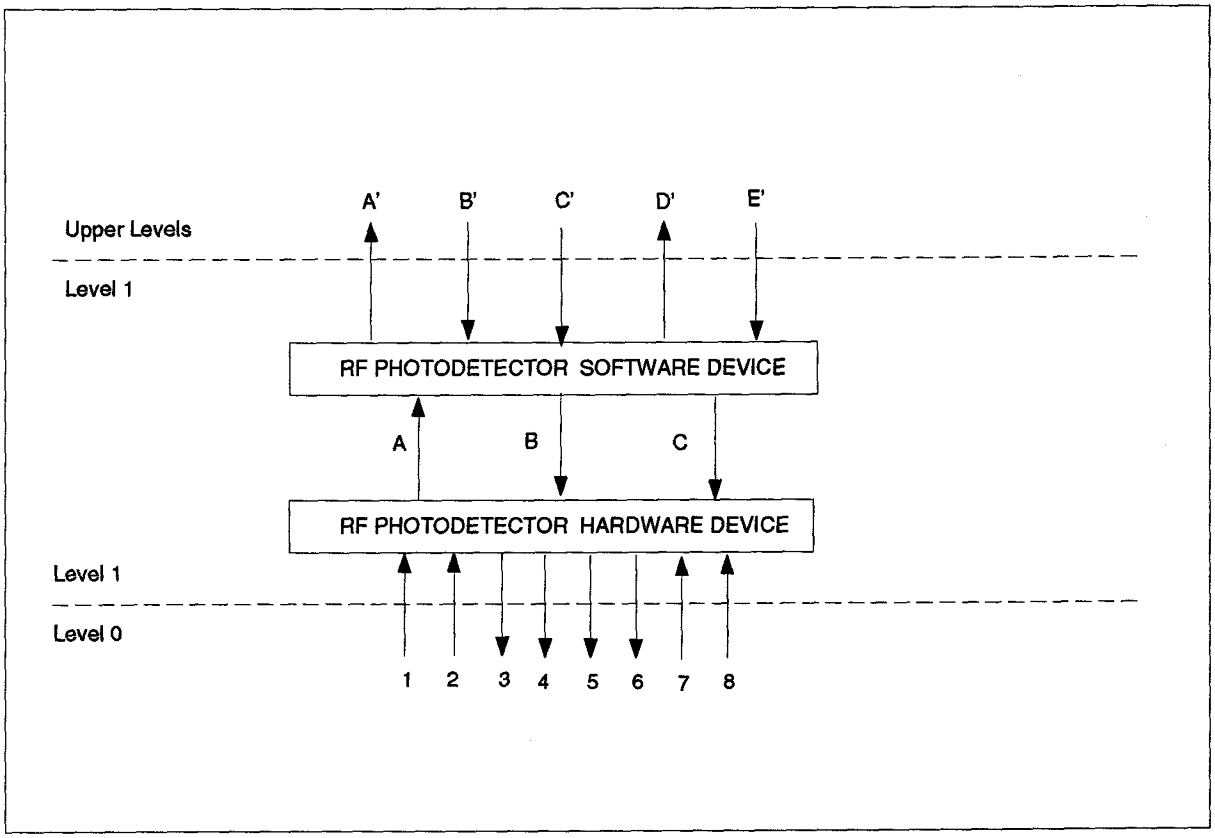


Table 25 RF Photodetector Device Level 1 to Upper Levels Interface Signals

Label	Description	Signal Type
A	Photodiode Bias Supply Voltage Monitor	0-10 VDC
B	Photodiode Bias Supply On/Off Select	TTL

Table 25 (Continued) RF Photodetector Device Level 1 to Upper Levels Interface Signals

Label	Description	Signal Type
C	RF L.O. Phase Select	0-10 VDC
A'	Photodiode Bias Supply Voltage Monitor	ai
B'	Photodiode Bias Supply On/Off Select	bo
C'	RF L.O. Phase Select	ao
D'	RF Photodiode Device Alarms	alarm
E'	RF Photodiode Device Permits	Software

Table 26 RF Photodetector Device Level 1 to Level 0 Interface Signals

Label	Description	Signal Type
1	RF Photodetector Input	-10 to +10 V
2	Detector RF Output	+ 15 dBm max.
3	Detector DC Output	-10 to +10 V
4	Detector DC Out (Remote Diag)	-10 to +10 V
5	Detector DC Out (Data Acq.)	-10 to +10 V
6	RF Photodetector Bias Supply On/Off Select	TTL
7	RF Photodiode Bias Supply Voltage Monitor	0-10 VDC
8	LO Input	+23 dBm

3.1.3.4.6.3 Sequences and Functions

The operator shall have the ability to flip the local oscillator phase select 180 degrees in one step.

3.1.3.4.6.4 Alarms

RF photodetector device alarms shall be generated for the following:

Table 27 RF Photodetector Device Alarms

ALARM CONDITION	SEVERITY	ACTION
Photodiode Bias Power Supply Transient Detection Alarm	Minor	Operator Warning

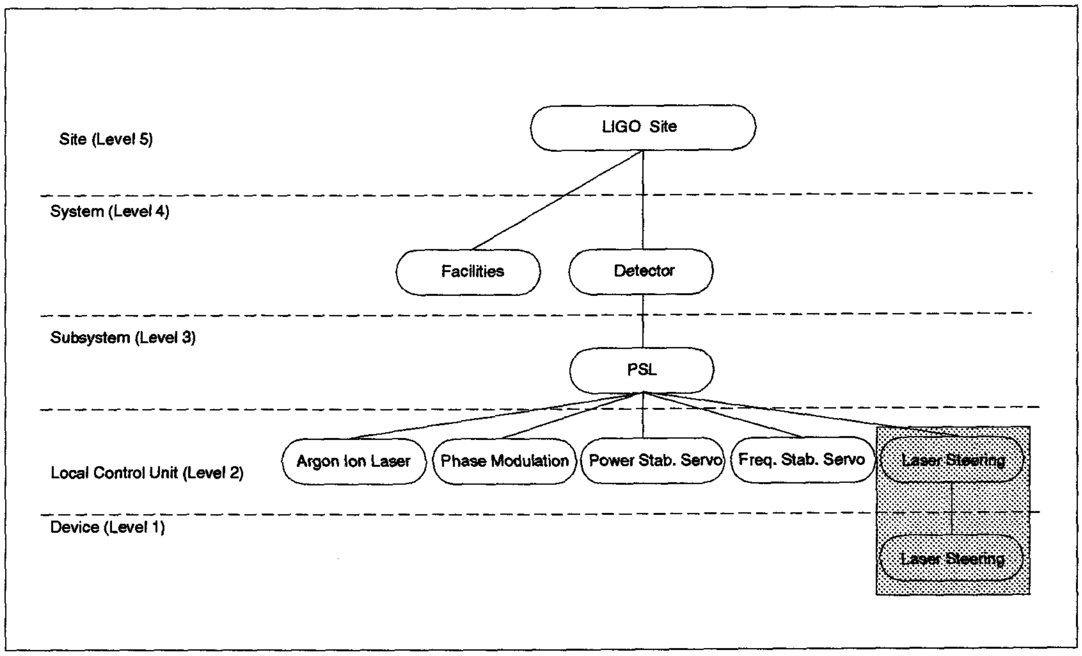
3.1.3.4.6.5 Permits

None

3.1.3.5 Laser Beam Steering

The figure below highlights the levels of the PSL CIM model that are covered by this section. The laser steering system uses piezo mounted mirrors to steer the laser light to the reference cavity in both the x and y axis in order to compensate for slow variations in alignment of input llight to the reference cavity. The primary components used in the steering systems are:

Figure 25 LIGO PSL Laser Steering CIM Model



1. Piezo mounted mirrors: deflect beam in x and y directions, part of the interferometer system.

2. Steering Mirror PZT Driver: provides high voltage drive to steering mirror PZTs
3. Steering Mirror PZT Power Supplies: provide +150 volt DC to PZT driver

3.1.3.5.1 Laser Steering Level 2 Performance

The output voltage ripple of the mirror piezo output shall be less than 1 mV peak, i.e. 1 part in 10^5 full scale.

Update rates and reaction times for the controls are as follows:

1. On/Off Selects and Level Adjustments- 1 second maximum for operator or CDS initiation.
2. PZT Output Monitors- 10 samples per second maximum
3. Power Supply Voltage and Current Monitors- 1 sample per second maximum.

3.1.3.5.2 Laser Steering Level 2 Controls

3.1.3.5.2.1 Sequences and Functions

None

3.1.3.5.2.2 Alarms

None

3.1.3.5.2.3 Permits

None

3.1.3.5.2.4 Level 1 Devices

For the purposes of control and monitoring the Laser Steering LCU has been grouped into one device which includes both mirror steering PZT drivers and the PZT power supply. The minimum performance and signals for this device are shown in the figure and table below.

3.1.3.5.3 Laser Steering Device

3.1.3.5.3.1 Performance

The steering mirror PZT driver shall have connections for:

1. Mirror 1 X Piezo out: Vout = 140 volts max.
2. Mirror 1 Y Piezo out: Vout = 140 volts max.
3. Mirror 2 X Piezo out: Vout = 140 volts max.
4. Mirror 2 Y Piezo out: Vout = 140 volts max.

The PZT (150 Volt) power supply shall have BNC (SHV) connections for:

1. High Voltage Output: SHV connector providing +150 volt power to PZT driver module.
2. Output Voltage Monitor: The supply shall have an output monitor. The scaling for the monitor shall be 1volt/100 volt.

The front panel controls and indicators shall be:

1. On/Off Select: High voltage on and off shall be selectable. The current selection shall be indicated.

The stability of supply shall be better than TBD. The output ripple shall be better than TBD.

3.1.3.5.3.2 Control Signals

Steering mirror PZT driver controls and indicators shall be:

1. Mirror 1 X Piezo monitor- 1V/100V
2. Mirror 1 Y Piezo monitor- 1V/100V
3. Mirror 2 X Piezo monitor- 1V/100V
4. Mirror 2 Y Piezo monitor- 1V/100V

PZT Power Supply controls and indicators shall be:

1. Output Voltage Monitor: The supply shall have an output monitor. The scaling for the monitor shall be 1volt/100 volt.
2. On/Off select: The on/off status of the power supply shall be selectable. The current selection shall be readable through the VME bus.

Figure 26 Laser Steering Device Interface Signals

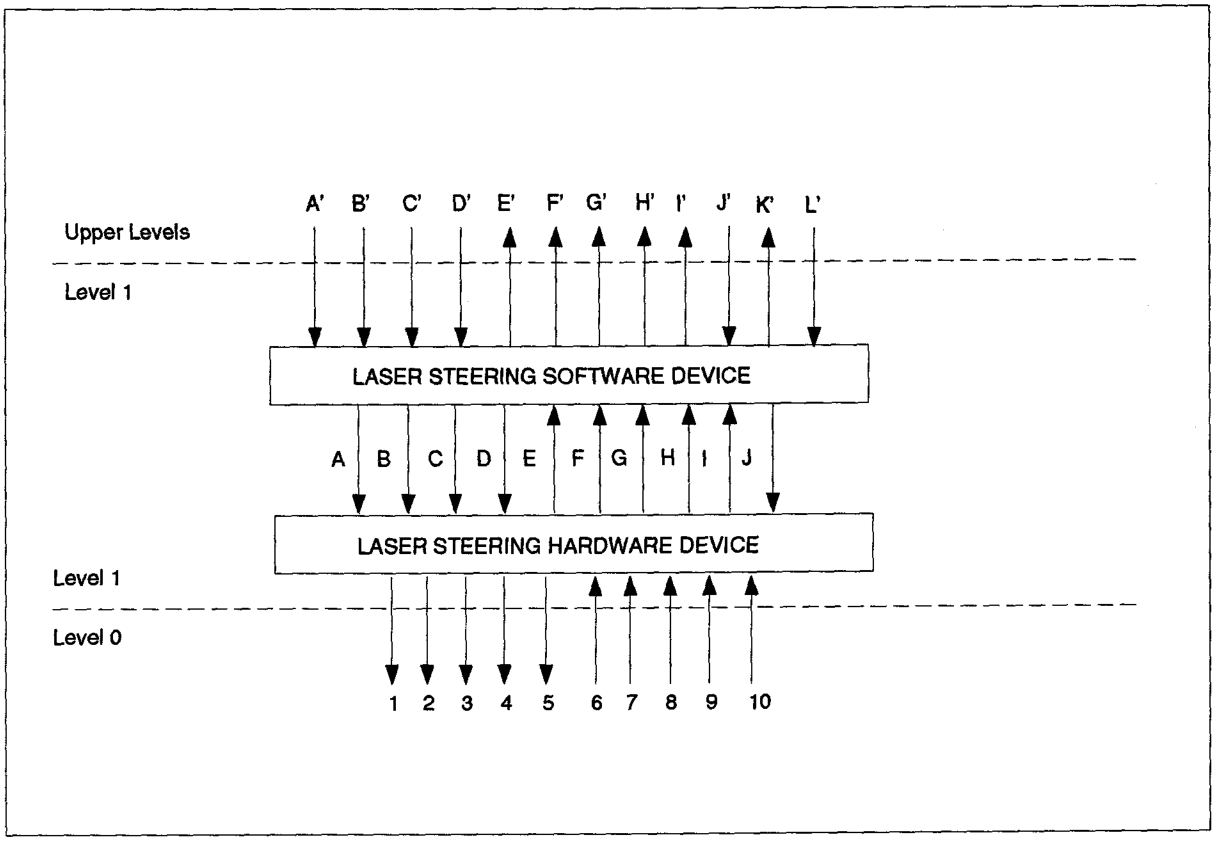


Table 28 Laser Steering Device Level 1 to Upper Levels Interface Signals

Label	Description	Signal Type
A	Ref Cavity Mirror 1 X Position Select	0-10 VDC
B	Ref Cavity Mirror 1 Y Position Select	0-10 VDC
C	Ref Cavity Mirror 2 X Position Select	0-10 VDC
D	Ref Cavity Mirror 2 Y Position Select	0-10 VDC
E	Ref Cavity X PZT 1 Output Voltage Monitor	0-10 VDC

Table 28 (Continued) Laser Steering Device Level 1 to Upper Levels Interface Signals

Label	Description	Signal Type
F	Ref Cavity Y PZT 1 Output Voltage Monitor	0-10 VDC
G	Ref Cavity X PZT 2 Output Voltage Monitor	0-10 VDC
H	Ref Cavity X PZT 2 Output Voltage Monitor	0-10 VDC
I	PZT P.S. Voltage Monitor	0-10 VDC
J	PZT P.S. On/Off Select	TTL
A'	Ref Cavity Mirror 1 X Position Select	ao
B'	Ref Cavity Mirror 1 Y Position Select	ao
C'	Ref Cavity Mirror 2 X Position Select	ao
D'	Ref Cavity Mirror 2 Y Position Select	ao
E'	Ref Cavity X PZT 1 Output Voltage Monitor	ai
F'	Ref Cavity Y PZT 1 Output Voltage Monitor	ai
G'	Ref Cavity X PZT 2 Output Voltage Monitor	ai
H'	Ref Cavity X PZT 2 Output Voltage Monitor	ai
I'	PZT P.S. Voltage Monitor	ai
J'	PZT P.S. On/Off Select	bo
K'	Laser Steering Device Alarms	alarm
L'	Laser Steering Device Permits	Software

Table 29 Laser Steering Device Level 1 to Level 0 Interface Signals

Label	Description	Signal Type
1	X PZT Output Mirror 1	0-140 volts
2	Y PZT Output Mirror 1	0-140 volts
3	X PZT Output Mirror 2	0-140 volts
4	Y PZT Output Mirror 2	0-140 volts
5	PZT P.S. On/Off Select	TTL
6	PZT P.S. Voltage Monitor	0-10 VDC
7	X PZT Output Mirror 1 Voltage Monitor	0-10 VDC
8	Y PZT Output Mirror 1 Voltage Monitor	0-10 VDC
9	X PZT Output Mirror 2 Voltage Monitor	0-10 VDC
10	Y PZT Output Mirror 2 Voltage Monitor	0-10 VDC

3.1.3.5.3.3 Sequences and Functions

None

3.1.3.5.3.4 Alarms

Laser steering device alarms shall be generated for the following:

Table 30 Laser Steering Device Alarms

ALARM CONDITION	SEVERITY	ACTION
PZT Power Supply Transient Detection Alarm	Minor	Operator Warning

mirrors nearing end of range

3.1.3.5.3.5 Permits

None

3.2 Characteristics

3.2.1 Performance

3.2.1.1 Analog Resolution and Accuracy

All analog to digital and digital to analog conversions shall have a resolution of 12 bits +/- 1 bit full scale unless specified otherwise.

3.2.1.2 Power Supply Transient Monitoring

To as great an extent as possible, all high voltage and bias power supplies shall be equipped with transient detection circuitry. This circuitry shall be capable of detecting transients of greater than 50 microseconds and larger that TBD% full scale. Upon transient detection, the circuit will latch until the transient has cleared and a reset from the CDS has been issued. The detection of a transient shall also generate an operator warning.

3.2.1.3 Calibration and Compensation

In general, all components used within the system shall have no requirement for local front panel gain calibration and offset correction during normal interferometer operations. To this end, all components shall contain provisions for any or all of the following:

1. Self calibration and compensation
2. remote adjustment and monitoring of all calibration and compensation devices

3.2.2 Physical Characteristics

All PSL controls shall be designed in accordance with the VME specification unless specified otherwise. VME modules shall be standard 6U modules using multiple slots if necessary.

VME modules currently supported by EPICS shall be utilized to implement the PSL controls to the greatest extent possible.

3.2.3 Reliability

TBD

3.2.4 Maintainability

TBD

3.2.5 Environmental Conditions

All subsystem controls shall meet all performance requirements when exposed to all specified natural and induced environments.

3.2.5.1 Temperature and Humidity

The ambient environmental design range shall be as follows:

1. Operating: +40 C/20–90% RH to 0C/20–90% RH
2. Non-operating: +70C/20–90% RH to —40C/20–90% RH
3. Transport only: +70C/10–90% RH to —40C/10–90% RH

3.2.5.2 Atmospheric Pressure

The subsystem controls design must accommodate atmospheric pressure changes from a maximum of 15.2 psia to a minimum of 14.2 psia.

3.2.5.3 Background Electromagnetic Radiation

The subsystem controls shall not degrade due to background electromagnetic emissions as specified by IEEE C95.1–1991.

3.2.6 Transportability

All items shall be transportable without degradation in performance. As necessary, provisions shall be made for measuring and controlling environmental conditions (temperature and acceleration) during transport and handling. Special shipping containers, shipping and handling mechanical restraints, and shock isolation shall be utilized to prevent damage. All containers must be movable by a forklift.

3.3 Design and Construction

3.3.1 Materials, Processes and Parts

TBD

3.3.2 Electromagnetic Radiation

TBD

3.3.3 Identification and Marking

All components shall be uniquely identified. Commercial components shall be identified by manufacturers name, model number and component serial number. Custom LIGO components shall be identified by model number and component serial number. To as great an extent as possible, component markings shall be in a visible location such as the component front panel or face plate.

All channel names, rack names, cable numbers and device names shall be in accordance with the appropriate LIGO standards.

All software signal channel names developed for the PSL controls shall follow the LIGO CDS naming convention.

3.3.4 Workmanship

All details of workmanship shall be of the highest grade appropriate to the methods and level of fabrication and consistent with the requirements specified herein. There shall be no evidence of poor workmanship that would make the components unsuitable for the purpose intended. All electronic circuits, modules and wiring shall be consistent with good engineering practice and fabricated to best commercial standards.

3.3.5 Interchangeability

The CDS PSL controls shall be designed to maximize interchangeability and replaceability of mating components. Using the Line Replaceable Unit (LRU) concept, the designs shall be such that mating assemblies may be exchanged without selection for fit or performance and without modification to the section, the unit being replaced or adjacent equipment. Mature, performance proven, standard, commercially available equipment shall not be modified unless it impacts safety.

3.3.6 Expansion Capabilities

The PSL controls shall be designed and implemented to allow maximum flexibility for future expansion. At minimum, the system shall be capable of 100% signal expansion.

3.3.7 Safety

The PSL controls shall meet all California Institute of Technology, LIGO, state and federal safety regulations. A hazard analysis shall be conducted in conjunction with the design. Particular emphasis shall be placed on:

- Restricting the use of hazardous materials where possible
- Personnel access
- Grounding and electrical systems
- RF radiation emission
- Cleanliness

3.3.8 Human Performance/Human Engineering

The PSL controls shall be designed to meet the requirements of labeling, work space design requirements, environmental and applicable human engineering requirements.

3.3.9 Standard of Manufacture

TBD

3.4 Documentation

3.4.1 Engineering Drawings and Associated Lists

Engineering drawings, schematics, wire lists and cable routing lists shall be produced for the subsystem and all components installed as part of the subsystem. To the greatest extent possible, electronic copies shall be maintained and available on-line.

3.4.2 Software

The following documentation shall be provided for all software.

1. Software Development Plan (SDP)
2. Software design data and control flow diagrams by CIM model level
3. Sequences using the Grafcet standards
4. Timing charts
5. Data/code directory structures

3.4.3 Technical Manuals and Procedures

3.4.3.1 Procedures

At a minimum, procedures shall be provided for:

1. Initial installation and set up of equipment
2. normal operation of equipment, including applicable flow control diagrams
3. normal and/or preventative maintenance
4. troubleshooting guide for any anticipated potential malfunctions
5. commissioning of equipment

3.4.3.2 Manuals

Manuals shall be provided, at a minimum, for all purchased components and equipment.

3.4.3.3 Documentation and Numbering

Documentation and numbering shall comply with the LIGO documentation numbering system.

3.4.3.4 Test Plans

Hardware and software test plans shall be provided for the system and all components utilized in the system.

3.5 Logistics

List of recommended spare parts and special purpose test equipment.

3.6 Personnel and Training

Analysis shall be performed to determine the personnel and training requirements for operation, maintenance, and safety of the major components of the PSL subsystem controls , identifying the numbers, types, skill levels and duty cycles, with respect to operational mode and phase, both normal and emergency.

3.7 Precedence

In the event of conflict between the provisions of this specification and other documents, the following precedence shall apply:

1. The LIGO Site Controls Specification

2. This specification
3. Documents referenced herein

4.0 Quality Assurance

4.1 Quality Conformance Inspection

Acceptance testing shall be performed on the PSL subsystem controls in accordance with an approved test plan and procedure(s). Verification shall be by one or more of the following methods:

- Inspection: Inspection shall be used to verify conformity with requirements that are neither qualitative or quantitative such as markings, workmanship, etc.
- Analysis: Analysis shall be used to verify conformity with requirements that are impractical or prohibitive in time or cost to verify using other methods.
- Demonstration: Demonstration shall be used to verify conformity with qualitative requirements.
- Test: Test shall be used to verify conformity with quantitative requirements.

5.0 Packaging, Handling and Transportability

All equipment shall be packaged in a manner to ensure arrival at the destination delivery point in an undamaged condition. The equipment shall not be damaged or performance degraded by normal handling during installation and maintenance.

Appendix A Argon Ion Laser Remote Connector Pin Assignments

Table 4–2: Remote Connector Pin Assignments

<table>
<tr><th>Pin</th><th>Name</th><th>Type</th><th>Description</th></tr>
<tr><td>1</td><td>GND</td><td>Output</td><td>Model 2570 power supply digital ground.</td></tr>
<tr><td>2</td><td>GND</td><td>Output</td><td>Model 2570 power supply digital ground.</td></tr>
<tr><td>3</td><td>Computer /Remote</td><td>Input</td><td>Selects control source. When this input is pulled low, control signals on input pins 4, 5, 6, 7, 8, 19, and 36 are enabled. When the input is inactive (high), signals on pins 4, 5, 6, 7, 8, 19, and 36 are ignored, and control inputs are taken from a computer connected to the power supply through the RS-232-C or IEEE 488 interfaces. The computer interface is an optional accessory.</td></tr>
<tr><td>4</td><td>Pre0</td><td>Input</td><td>One of three inputs used to select power range. Input signals on pins 4, 5, and 7 together select the power range according to the following table:
<table>
<tr><th>Pre2 (Pin 7)</th><th>Pre1 (Pin 5)</th><th>Pre0 (Pin 4)</th><th>Power Range</th></tr>
<tr><td>Low</td><td>Low</td><td>Low</td><td>0.3 W</td></tr>
<tr><td>Low</td><td>Low</td><td>High</td><td>0.3 W</td></tr>
<tr><td>Low</td><td>High</td><td>Low</td><td>1.0 W</td></tr>
<tr><td>Low</td><td>High</td><td>High</td><td>3.0 W</td></tr>
<tr><td>High</td><td>Low</td><td>Low</td><td>10 W</td></tr>
<tr><td>High</td><td>Low</td><td>High</td><td>30 W</td></tr>
<tr><td>High</td><td>High</td><td>Low</td><td>0.3 W</td></tr>
<tr><td>High</td><td>High</td><td>High</td><td>0.3 W</td></tr>
</table>
</td></tr>
<tr><td>5</td><td>Pre1</td><td>Input</td><td>One of the three inputs used to select power range (see pin 4 description).</td></tr>
<tr><td>6</td><td>Control Mode</td><td>Input</td><td>Selects feedback mode. When this input is pulled low, power mode is selected; when it is inactive (high), current mode is selected.</td></tr>
<tr><td>7</td><td>Pre2</td><td>Input</td><td>One of the three inputs used to select power range. (see pin 4 description).</td></tr>
<tr><td>8</td><td>Plasma On/Off</td><td>Input</td><td>The main laser on/off control. Pulling this input low closes the power contactor and begins to warm up the tube cathode. The laser will light after about 15 sec.</td></tr>
</table>

Table 4-2: Remote Connector Pin Assignments *(cont.)*

Pin	Name	Type	Description
9	AUX Interlock Open	Output	When the interlock is open, the output is inactive (high); if it is closed, the output is pulled low.
10	High Water Temp	Output	When the head outlet water temperature exceeds 78 deg C (172 deg F), the output is inactive (high); otherwise the output is pulled low.
11	Head Cover Interlock Open	Output	When the cover interlock switch in the head is open, the output is inactive (high); if it is closed, the output is pulled low.
12	Low Water Flow	Output	When the water flow rate through the head is less than 5 gpm, the output is inactive (high); otherwise, the output is pulled low.
13	Regulator Fault	Output	Under normal operating conditions, the output is pulled low. However, when the laser cannot be turned on because of faulty operation of the head or power supply, the output is inactive (high). Possible fault conditions are: current to the laser head had exceeded the maximum safe operating limit of 65 A; the plasma tube has run out of gas and cannot be filled; or, the power supply is defective.
14	Voltage Monitor	Output	This is a 0 to 5 V analog signal representing 0 to 1000 V plasma tube voltage.
15	Current Monitor	Output	This is a 0 to 5 V analog signal representing 0 to 100 A plasma tube current.
16	Power Monitor	Output	This is a 0 to 5 V analog signal representing optical output power from 0 W to a full scale value determined by the active power range (see following table).

Power Monitor (0 to 5 V)	**Power Range**
0 to .316 Watts	0.3 W
0 to 1.0 Watts	1.0 W
0 to 3.16 Watts	3.0 W
0 to 10.0 Watts	10 W
0 to 31.6 Watts	30 W

Table 4-2: Remote Connector Pin Assignments *(cont.)*

<table>
<tr><th>Pin</th><th>Name</th><th>Type</th><th>Description</th></tr>
<tr><td>17</td><td>Buffered +5VREF</td><td>Output</td><td>+5 V reference (10 mA maximum).</td></tr>
<tr><td>18</td><td>GND</td><td>Output</td><td>Model 2570 power supply digital ground.</td></tr>
<tr><td>19</td><td>Current Control</td><td>Input</td><td>This is a 0 to +5 V full scale command signal that selects the desired plasma tube current when the laser is operated in the current mode (pin 6 inactive) and under remote control (pin 3 low). The input may be used to manually select the current setpoint when it is connected to the wiper arm of a 10K Ω potentiometer. The other two terminals of the potentiometer should be connected to Buffered +5VREF (pin 17) and CMD CMN (pin 37). The full scale value of the command signal represents 100 A plasma tube current.</td></tr>
<tr><td>20</td><td>Premon0</td><td>Output</td><td>One of the three outputs that monitor the power range selection. Output signals on pins 20, 21, and 26 together indicate the power range according to the following table:
<table>
<tr><th>Premon2 (Pin 26)</th><th>Premon1 (Pin 21)</th><th>Premon0 (Pin 20)</th><th>Power Range</th></tr>
<tr><td>Low</td><td>Low</td><td>High</td><td>0.3 W</td></tr>
<tr><td>Low</td><td>High</td><td>Low</td><td>1.0 W</td></tr>
<tr><td>Low</td><td>High</td><td>High</td><td>3.0 W</td></tr>
<tr><td>High</td><td>Low</td><td>Low</td><td>10 W</td></tr>
<tr><td>High</td><td>Low</td><td>High</td><td>30 W</td></tr>
</table>
</td></tr>
<tr><td>21</td><td>Premon1</td><td>Output</td><td>One of the three outputs that monitor the power range selection (see pin 20 description).</td></tr>
<tr><td>22</td><td>Digital Input Common</td><td>Input</td><td>Current sources for optically coupled logic input signals on pins 3, 4, 5, 6, 7, and 8. Requires a +5 V pull-up at 50 mA, which may be taken from pins 23, 24, or 27.</td></tr>
<tr><td>23</td><td>+5V</td><td>Output</td><td>+5 Vdc at 500 mA (maximum current available to combined output pins 23, 24, and 27).</td></tr>
<tr><td>24</td><td>+5V</td><td>Output</td><td>(See pin 23 description).</td></tr>
<tr><td>25</td><td></td><td></td><td>Not used</td></tr>
</table>

Table 4-2: Remote Connector Pin Assignments *(cont.)*

Pin	Name	Type	Description
26	Premon2	Output	One of three outputs that monitor the power range selection (see pin 20 description).
27	+5V	Output	(See pin 23 description).
28	+12V	Output	+12 Vdc at 50 mA (max).
29	-12V	Output	-12 Vdc at 50 mA (max).
30	Tube Fill Status	Output	When this output is inactive (high), low gas pressure is indicated, and the plasma tube is in need of a fill. If the automatic fill system is on, or, if the gas pressure is lower than the fill safety level, the fill system will be filling the tube while the output is high. When the output is repeatedly pulled high and low (1 Hz square wave), an empty gas reservoir is indicated, and the tube can no longer be operated. When the output is held constantly low, the tube is maintaining sufficient gas pressure.
31	Remote Emission Indicator	Output	When this output is pulled low, the laser is turned on and (following an initial fifteen second warmup delay) is capable of emitting light. If it is inactive (high), the laser is turned off.
32	P.S. Type	Output	This output is always pulled low.
33	Modemon	Output	This output monitors the control mode selection. When it is pulled low, power mode is selected. If it is inactive (high), current mode is selected.
34	Monitor Jack	Input	Signal input to the monitor jack located on the Model 2570 power supply connector panel.
35	REF GND	Output	Common reference return line for output signals Voltage Monitor (pin 14), Current Monitor (pin 15), Power Monitor (pin 16), Buffered +5VREF (pin 17), and for Monitor Jack (pin 34).

Table 4-2: Remote Connector Pin Assignments *(cont.)*

Pin	Name	Type	Description
36	Power Control	Input	This is a 0 to +5 V full scale command signal that selects the desired optical output power when the laser is operated in the power mode (pin 6 low) and under remote control (pin 3 low). The input may be used to manually select the power setpoint when it is connected to the wiper arm of a 10K Ω potentiometer. The other two terminals of the potentiometer should be connected to Buffered +5VREF (pin 17) and CMD CMN (pin 37). The full scale value of the command signal is determined by the active power range (see following table).
			Power Control (0 to 5 V) / **Power Range** 0 to .316 Watts / 0.3 W 0 to 1.0 Watts / 1.0 W 0 to 3.16 Watts / 3.0 W 0 to 10.0 Watts / 10 W 0 to 31.6 Watts / 30 W
37	CMD CMN	Input	Common reference return line for command signals Current Control (pin 19) and Power Control (pin 36).

Appendix B Table of TBDs

Section	Description	Comment
2.0	Document No. for Global CDS Specification	Global CDS specification and requirements documents will be developed prior to CDS DRR scheduled for 10/95.
3.1.2.2	Data Acquistion Channel Names	Names will be assigned according to the LIGO naming convention as part of the preliminary design.
3.1.2.3	Remote Diagnostics Channel Names	Names will be assigned according to the LIGO naming convention as part of the preliminary design.
3.1.3.1.2.1	Laser cooling water return temperature interlock	The return temperature threshold for maintaining cooling flow to laser after the laser has be turned off will be determined as part of the preliminary design.
3.1.3.1.3.1	Laser device performance	Performance requirements beyond those described in the PSL requirements specification and this document will be determined as part of the preliminary design.
3.1.3.2.1	Phase modulation performance requirements	Performance requirements are currently being developed and will be completed prior to the DRR (2/95).
3.1.3.2.4.1	Pockels cell matching network requirements	The accuracy and stability of the match to the pockels cell will be developed as part of the preliminary design.

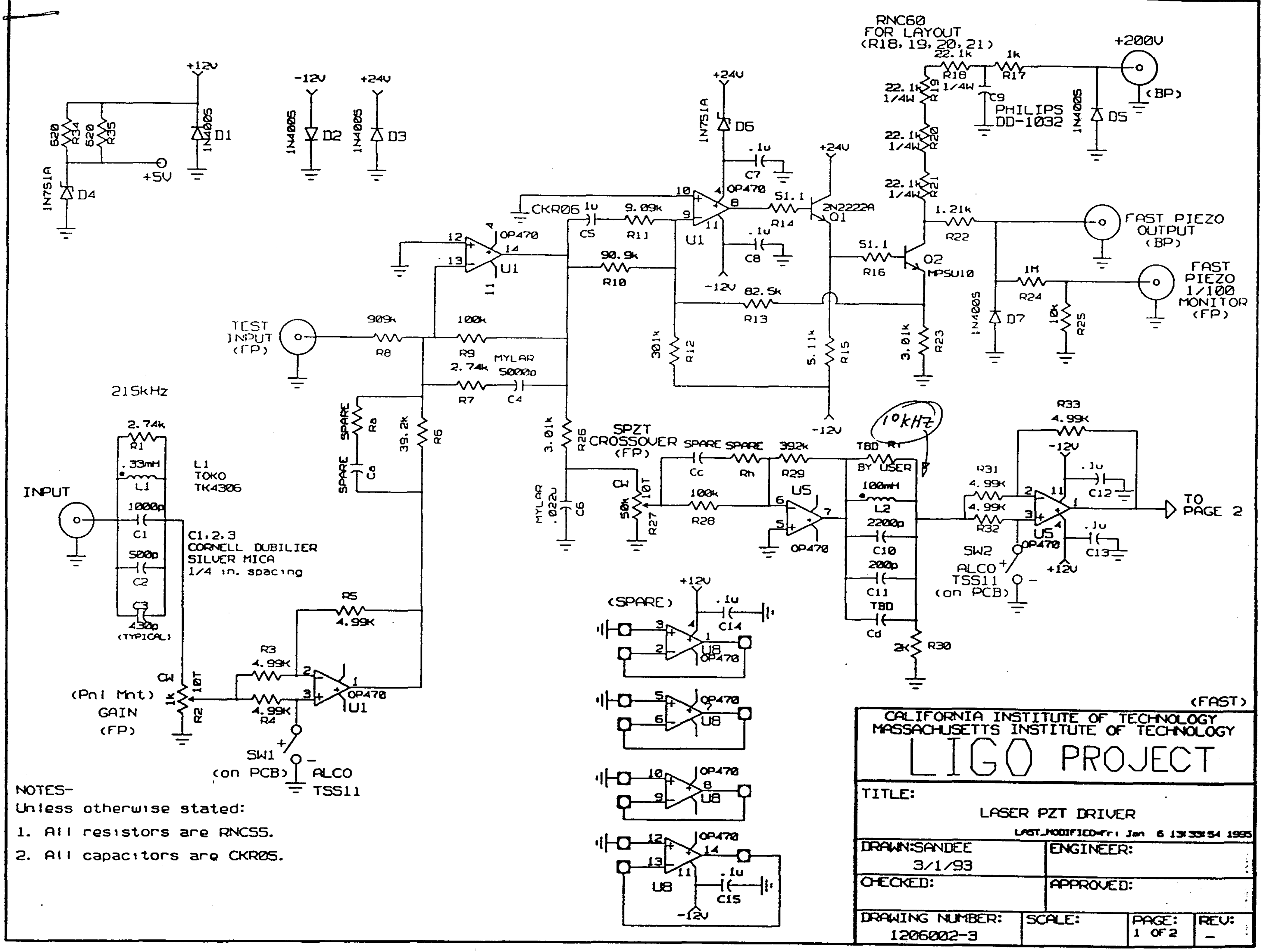
Section	Description	Comment
3.1.3.2.4.2	RF modulator output power selections	The actual number of output power selections for the RF modulator will be developed as part of the preliminary design. The number being used in the conceptual design is 8.
3.1.3.2.4.2 Table 12	RF modulator input power	The input power to the RF modulator will be selected during the preliminary design. The selection will be based on the availablity of low noise power amplifiers.
3.1.3.3.2.2	Power stabilization Level 2 alarms	The alarms will be determined as part of the preliminary design. Currently there are no level 2 alarms.
3.1.3.3.2.3	Power stabilization Level 2 permits	The permits will be determined as part of the preliminary design. Currently there are no level 2 permits.
3.1.3.3.3.2	Power stabilization amplifier power level selections	The current number of selections is 12. This number has been used in the conceptual design. The required number of selections will probably be lower.
3.1.3.3.3.2 Table 13	Power stabilization amplifier power level selections, signal type	See above.
3.1.3.3.3.2 Table 13	Power stabilization ringdown level selections, signal type	Actual signal parameters will be developed during the preliminary design.

Section	Description	Comment
3.1.3.3.4.2	Acouto driver controls	The DE-40M driver is a stand alone unit with front panel knobs. The feasibility of connecting remote controls or replacing the unit with an equivalent model with remote connections will be investigated during the preliminary design.
3.1.3.4	Document number for description of the transfer function characteristics of the frequency stabilization electronics	The transfer function of the existing electronics are being analyzed as part of the conceptual and preliminary designs. The analysis will be documented in a technical note.
3.1.3.4.2.2	Frequency stabilization Level 2 alarms	The alarms will be determined as part of the preliminary design. Currently there are no level 2 alarms.
3.1.3.4.3.1	Pockel cells power supply stability requirements	The stability requirements for the power supply will be developed during the preliminary design and will be consistent with the performance requirements of the laser loop amplifier device.
3.1.3.4.3.1	Pockels cells input impedance	The input impedance of the pockels cell will be determined during the preliminary design.
3.1.3.4.3.2	Wideband DC adjust range and accuracy	The conceptual design calls for a range of -10 to +10 volts with min 12 bit resolution. The actual specification will be determined during the preliminary design.

Section	Description	Comment
3.1.3.4.3.2	Bypass DC adjust range and accuracy	The conceptual design calls for a range of -10 to +10 volts with min 12 bit resolution. The actual specification will be determined during the preliminary design.
3.1.3.4.3.3	Document number for description of the transfer function characteristics of the laser loop amplifier	The transfer function of the existing laser loop amplifier are being analyzed as part of the conceptual and preliminary designs. The analysis will be documented in a technical note.
3.1.3.4.4.2 Table 19	RF and Reference Photodiode gain select and visbility monitor threshold adjust signal types	The signal types will be determined as part of the preliminary design
3.1.3.4.5.1	Slow PZT power supply stability requirements	The stability requirements for the power supply will be developed during the preliminary design and will be consistent with the performance requirements of the laser loop amplifier device.
3.1.3.4.5.1	Fast PZT power supply stability requirements	The stability requirements for the power supply will be developed during the preliminary design and will be consistent with the performance requirements of the laser loop amplifier device.
3.1.3.4.6.1	RF photodetector bias power supply stability requirements	The stability requirements for the power supply will be developed during the preliminary design and will be consistent with the performance requirements of the frequency stabilization LCU.

Section	Description	Comment
3.1.3.5.3.1	Laser steering power supply stability requirements	The stability requirements for the power supply will be developed during the preliminary design and will be consistent with the performance requirements of the laser steering LCU.
3.2.1.2	Power supply transient amplitude	The requirements for the amplitude of the transients that will be detected by the circuitry will be determined during the preliminary design.
3.2.3	Reliability	Reliability requirements for LIGO in general need to be developed.
3.2.4	Maintainability	Maintainability requirements for LIGO in general need to be developed.
3.3	Design and Construction guidelines	Standards for design and construction within the project need to be developed.

Appendix C Existing PSL Schematics



NOTES-
Unless otherwise stated:
1. All resistors are RNC55.
2. All capacitors are CKR05.

CALIFORNIA INSTITUTE OF TECHNOLOGY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LIGO PROJECT

TITLE:
LASER PZT DRIVER
LAST_MODIFIED=Fri Jan 6 13:33:54 1995

DRAWN:SANDEE
3/1/93
ENGINEER:
CHECKED:
APPROVED:
DRAWING NUMBER:
1206002-3
SCALE:
PAGE:
1 OF 2
REV:
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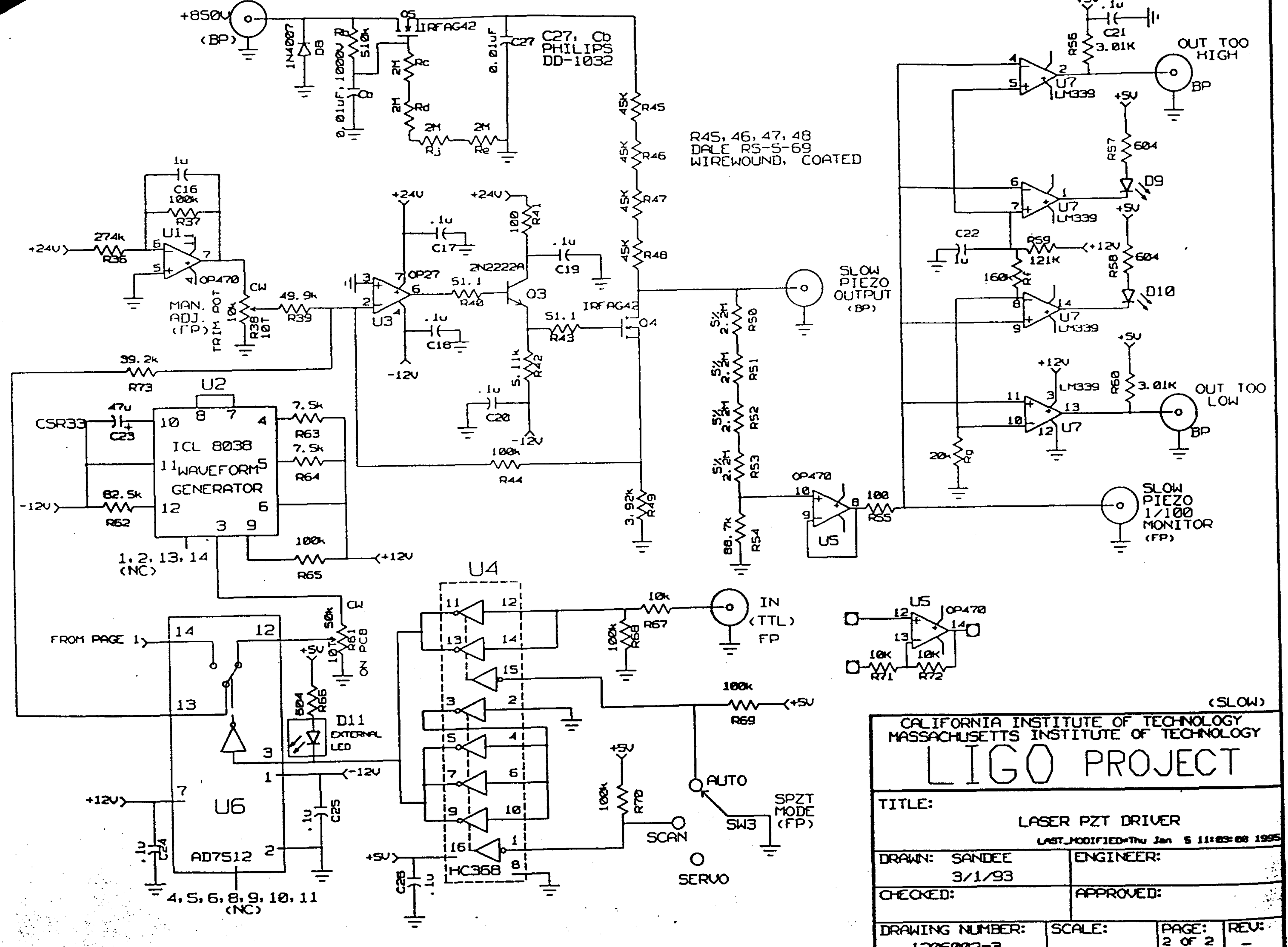

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MASSACHUSETTS INSTITUTE OF TECHNOLOGY

LIGO PROJECT

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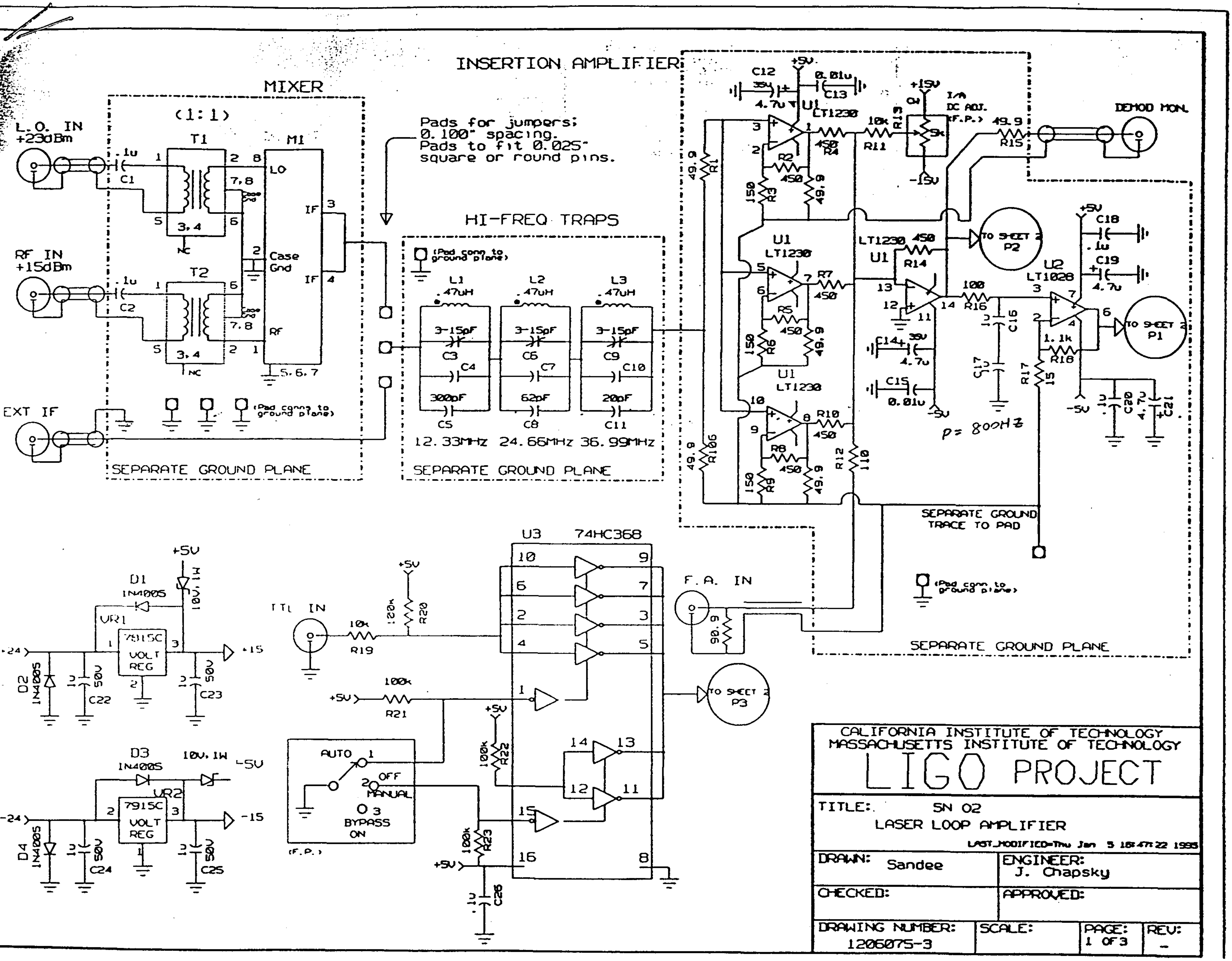
CHECKED:	APPROVED:
DRAWING NUMBER: 1206002-3	SCALE:
PAGE: 2 OF 2	REV: -



CALIFORNIA INSTITUTE OF TECHNOLOGY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

LIGO PROJECT

TITLE: SN 02
LASER LOOP AMPLIFIER
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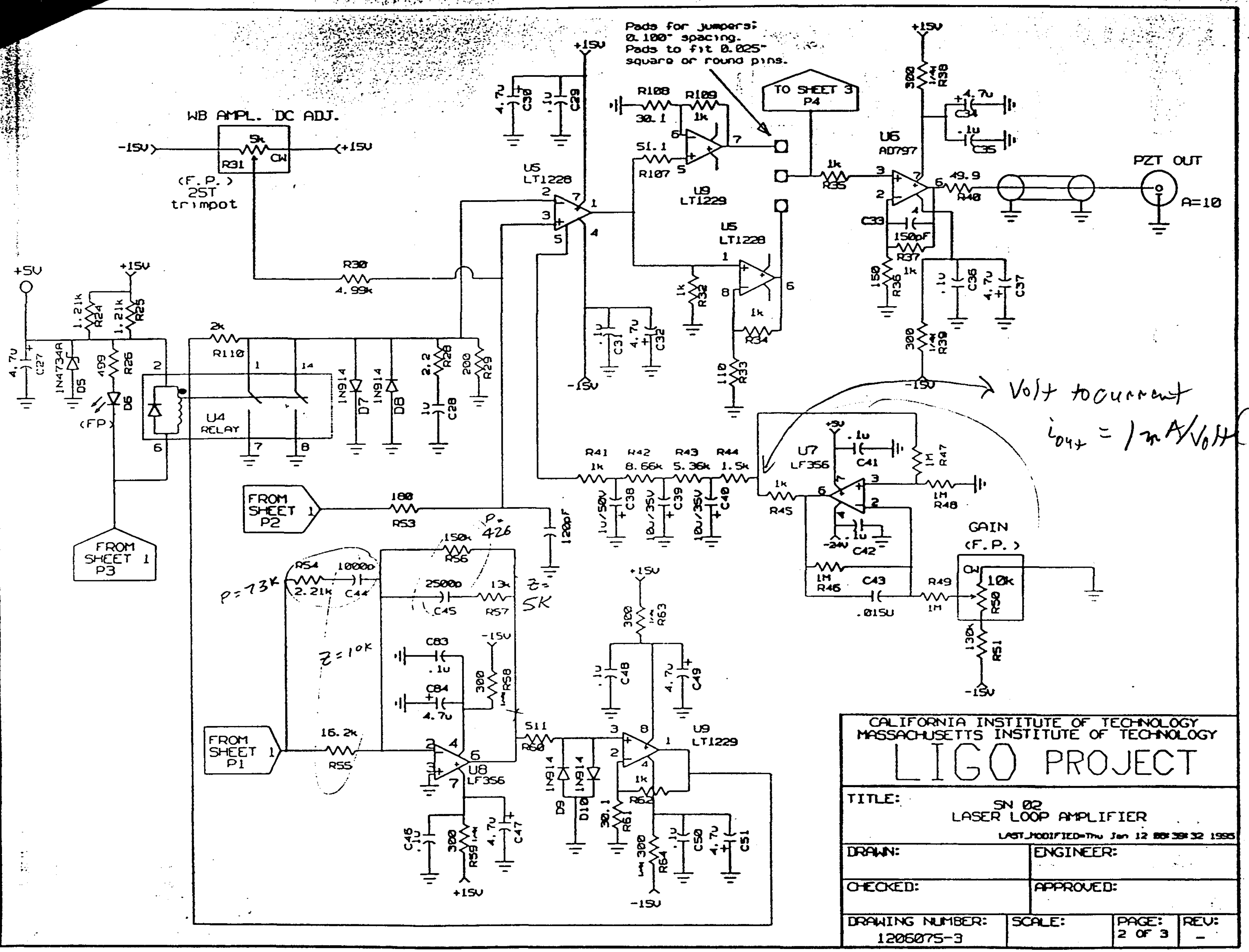
DRAWN: Sandee
ENGINEER: J. Chapsky
CHECKED:
APPROVED:
DRAWING NUMBER: 1206075-3
SCALE:
PAGE: 1 OF 3
REV: -



Volt to current

$i_{out} = 1mA/Volt$

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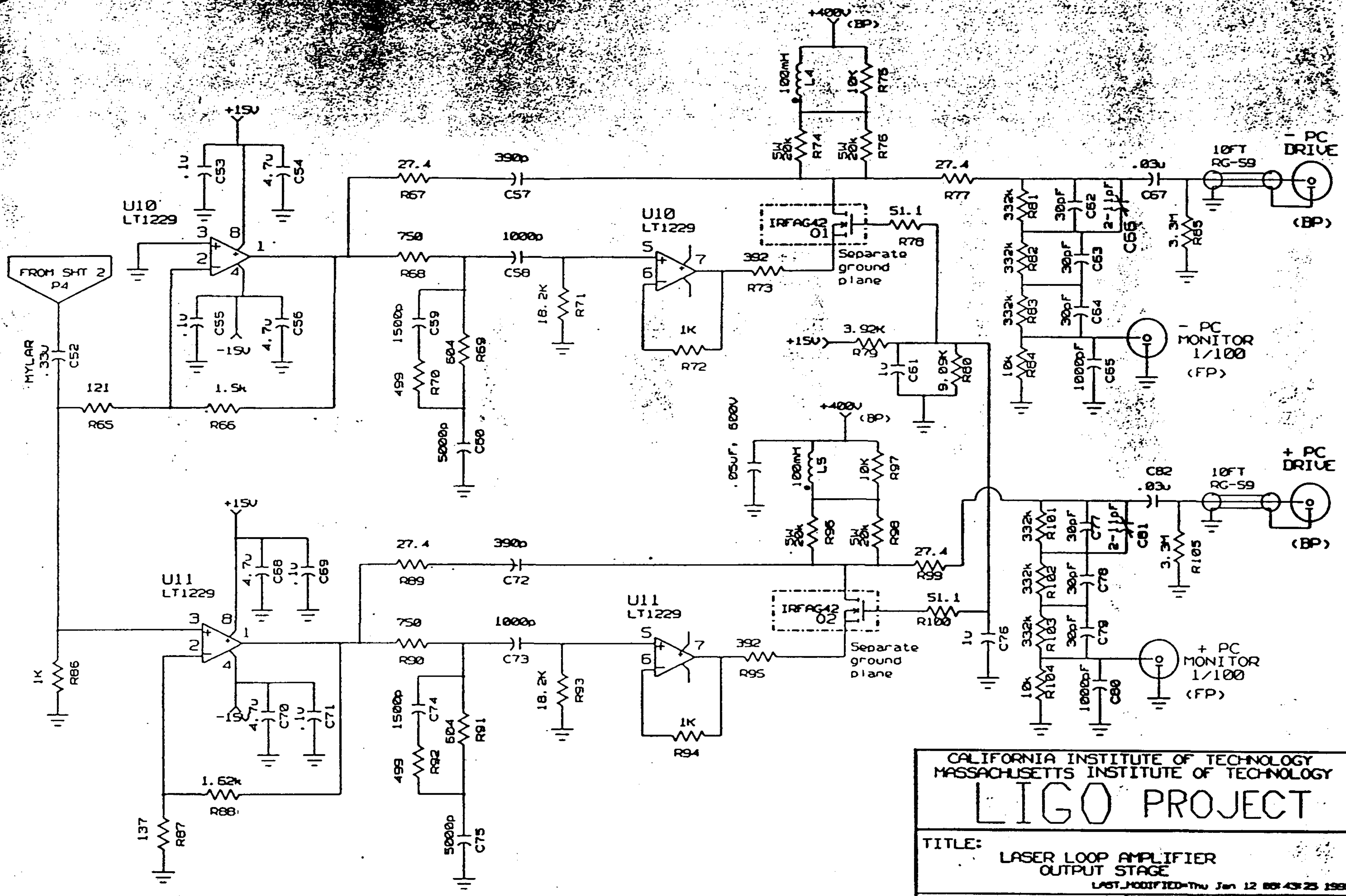
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LIGO PROJECT

TITLE: SN 02
LASER LOOP AMPLIFIER

LAST_MODIFIED=Thu Jan 12 08:38:32 1995

DRAWN:
ENGINEER:
CHECKED:
APPROVED:
DRAWING NUMBER: 1206075-3
SCALE:
PAGE: 2 OF 3
REV: -



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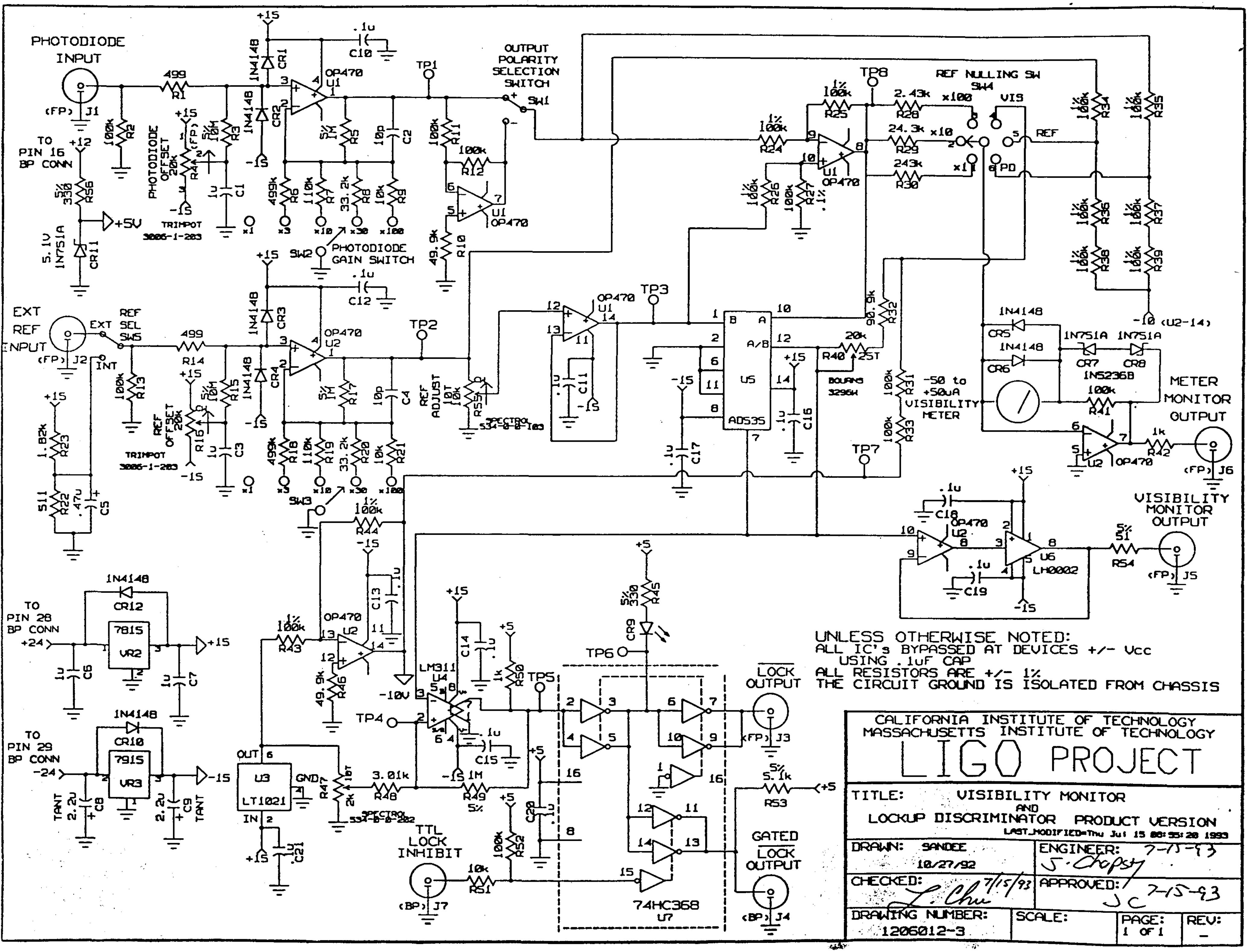
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

LIGO PROJECT

TITLE:
LASER LOOP AMPLIFIER
OUTPUT STAGE
LAST_MODIFIED=Thu Jan 12 08:43:25 1995

DRAWN:
ENGINEER:
CHECKED:
APPROVED:
DRAWING NUMBER: 1206075-3
SCALE:
PAGE: 3 OF 3
REV: -



UNLESS OTHERWISE NOTED:
ALL IC's BYPASSED AT DEVICES +/- Vcc
USING .1uF CAP
ALL RESISTORS ARE +/- 1%
THE CIRCUIT GROUND IS ISOLATED FROM CHASSIS

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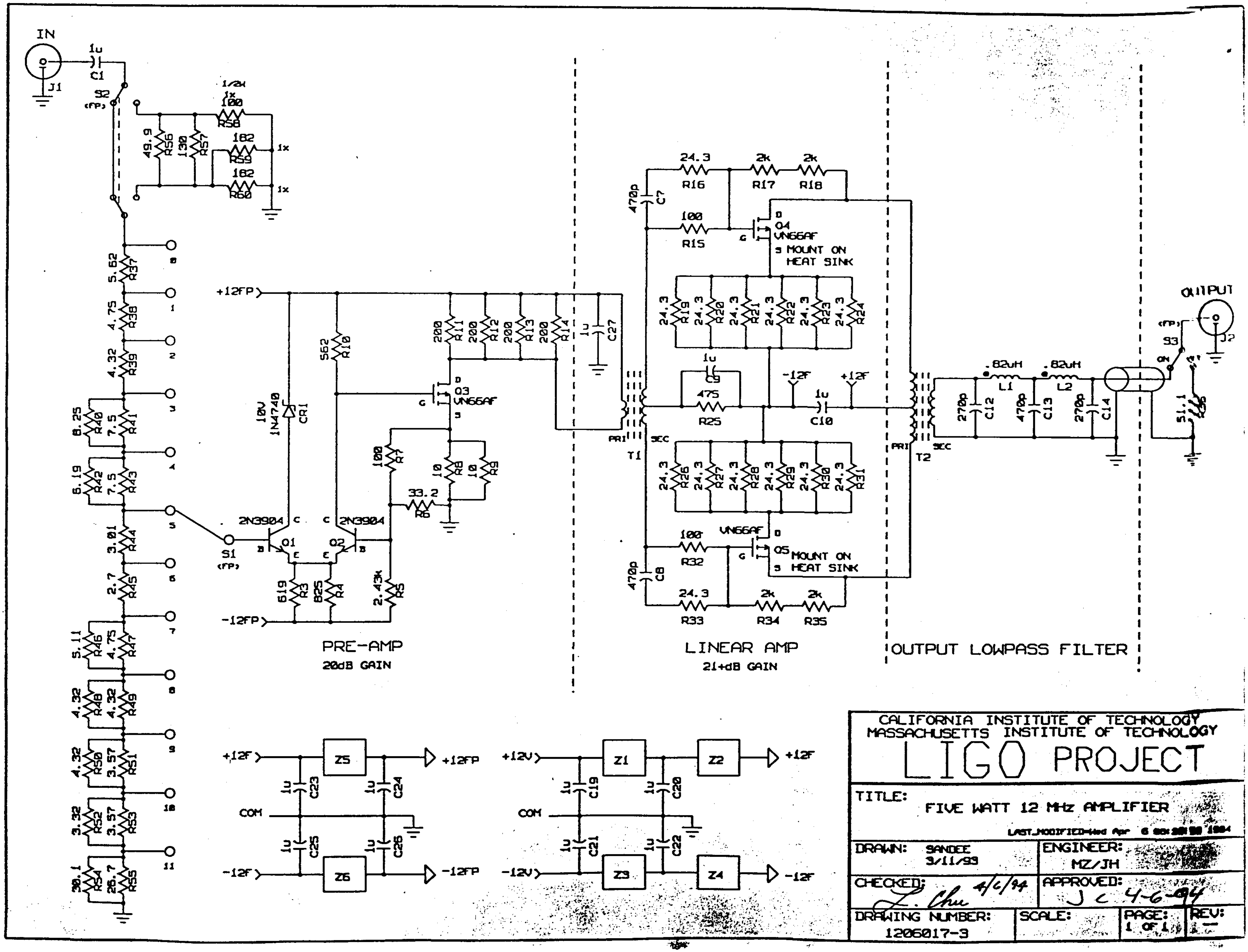
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

LIGO PROJECT

TITLE: VISIBILITY MONITOR AND LOCKUP DISCRIMINATOR PRODUCT VERSION

LAST_MODIFIED=Thu Jul 15 08:55:20 1993

DRAWN: SANDEE 10/27/92	ENGINEER: 7-15-93 S. Chopsy
CHECKED: L. Chu 7/15/93	APPROVED: JC 7-15-93
DRAWING NUMBER: 1206012-3	SCALE: · PAGE: 1 OF 1 · REV: -



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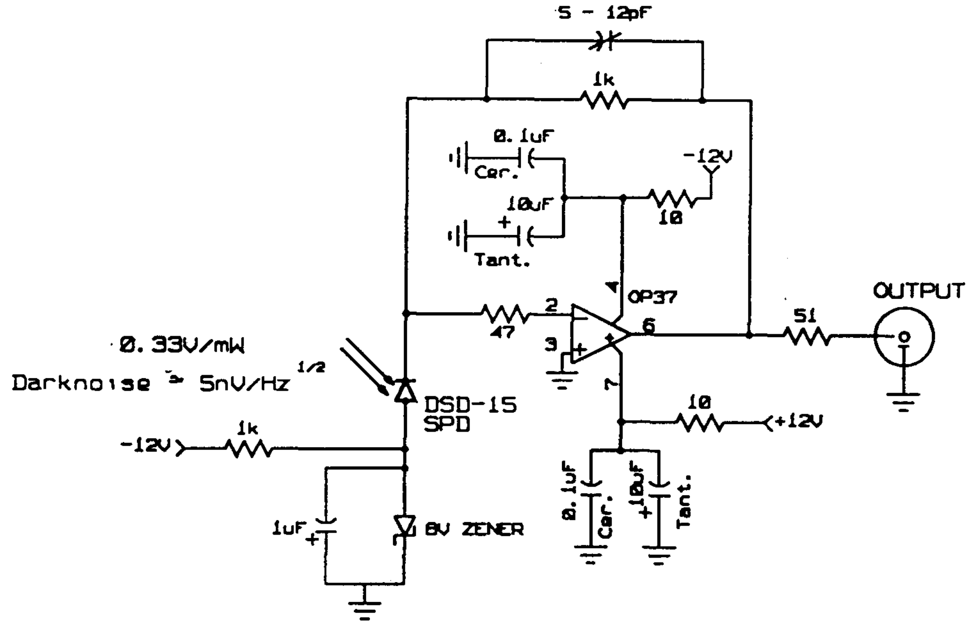
LIGO PROJECT

TITLE: FIVE WATT 12 MHz AMPLIFIER

LAST_MODIFIED-Wed Apr 6 08:38:58 1994

DRAWN: SANDEE 3/11/93	ENGINEER: MZ/JH
CHECKED: L. Chu 4/6/94	APPROVED: J C 4-6-94
DRAWING NUMBER: 1206017-3	SCALE:
PAGE: 1 OF 1	REV: —



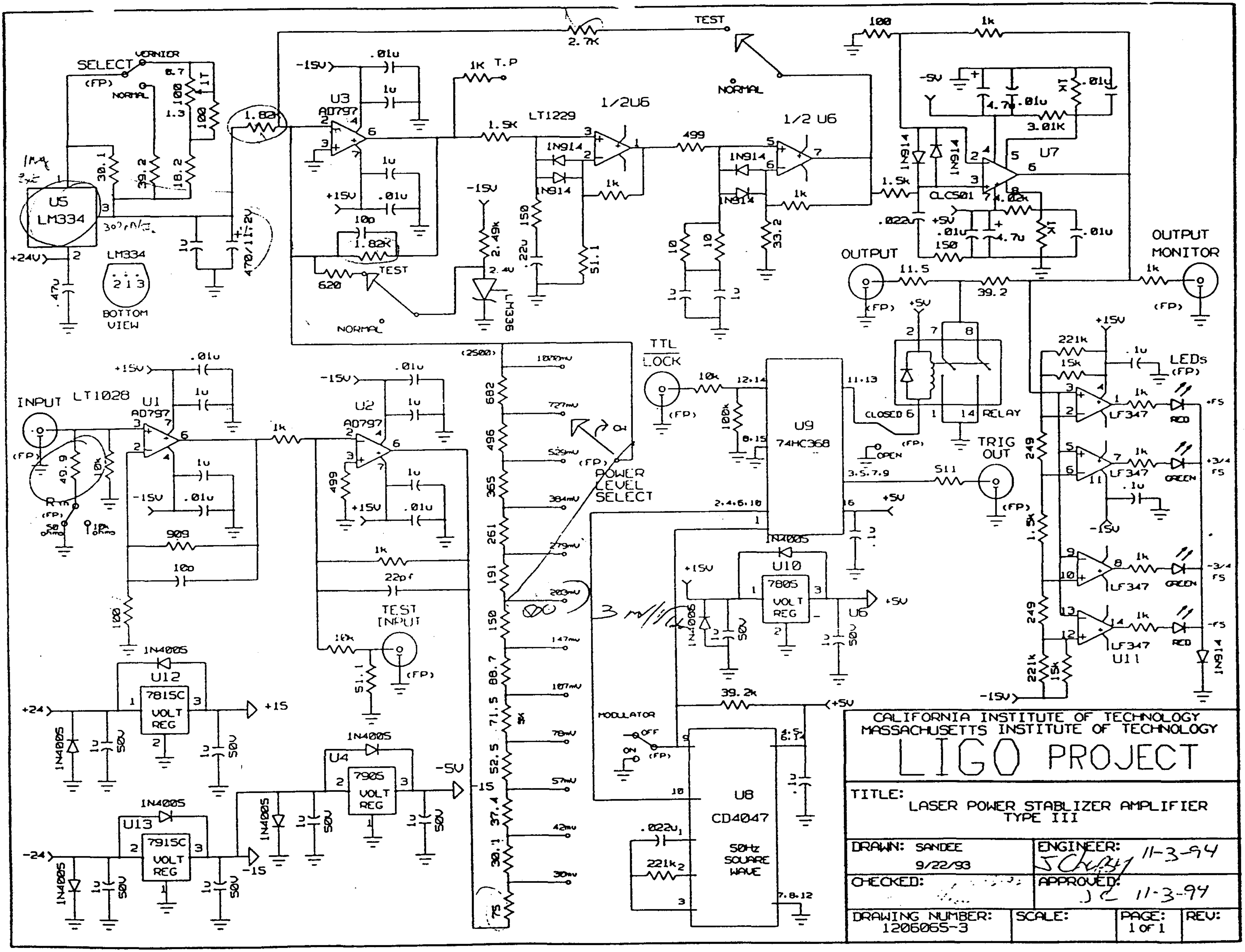
CALIFORNIA INSTITUTE OF TECHNOLOGY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LIGO PROJECT

TITLE:
POWER MONITORING PHOTODIODE
LAST_MODIFIED=Fri Feb 18 15:27:47 1994

DRAWN: 2/18/94
L. Chu
ENGINEER:

CHECKED:
APPROVED:

DRAWING NUMBER: 1206062-3
SCALE: --
PAGE: 1 OF 1
REV: -



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MASSACHUSETTS INSTITUTE OF TECHNOLOGY

LIGO PROJECT

TITLE: LASER POWER STABLIZER AMPLIFIER
TYPE III

DRAWN: SANDEE
9/22/93

ENGINEER: 11-3-94

CHECKED:

APPROVED: JC 11-3-94

DRAWING NUMBER: 1206065-3

SCALE:

PAGE: 1 OF 1

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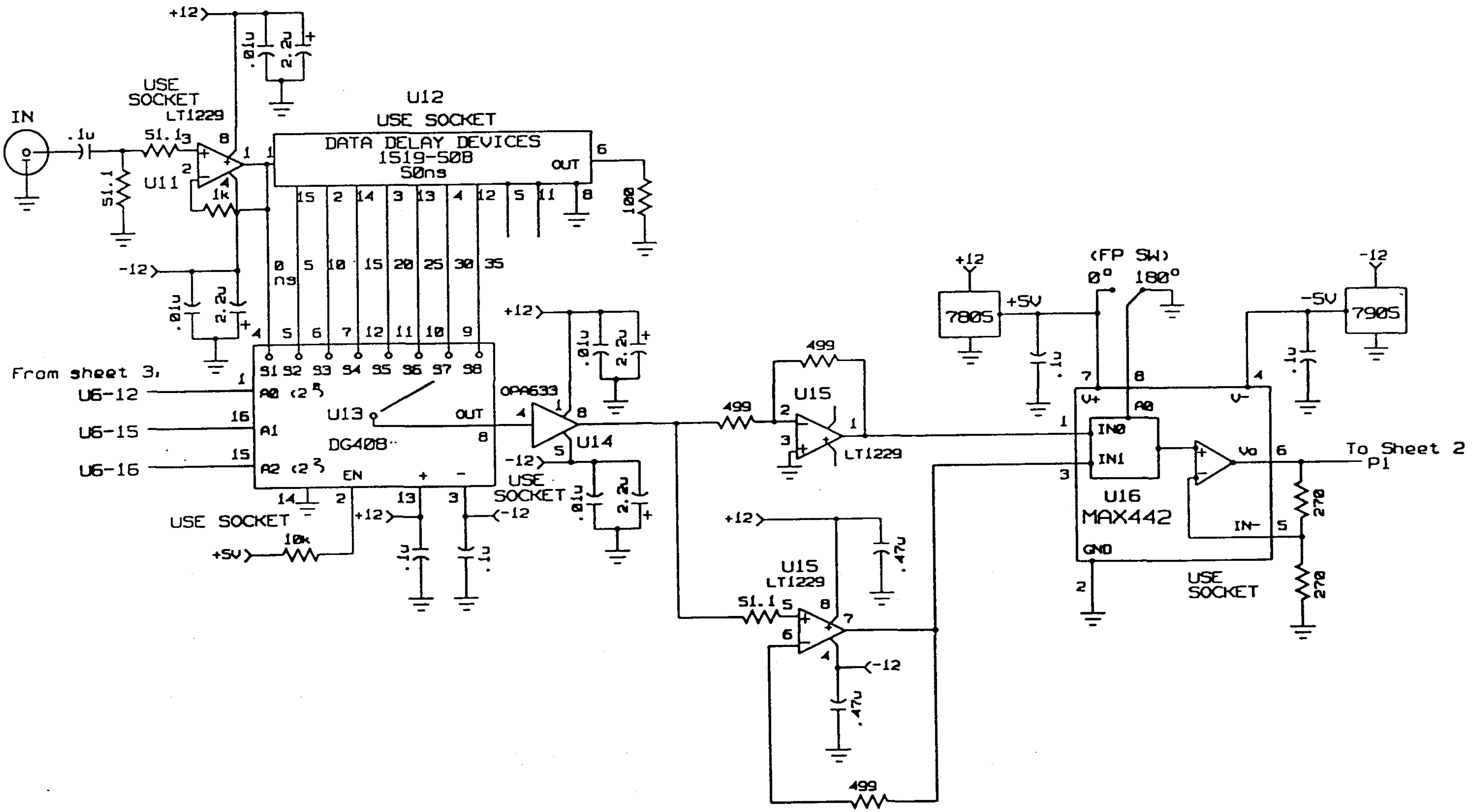

CALIFORNIA INSTITUTE OF TECHNOLOGY
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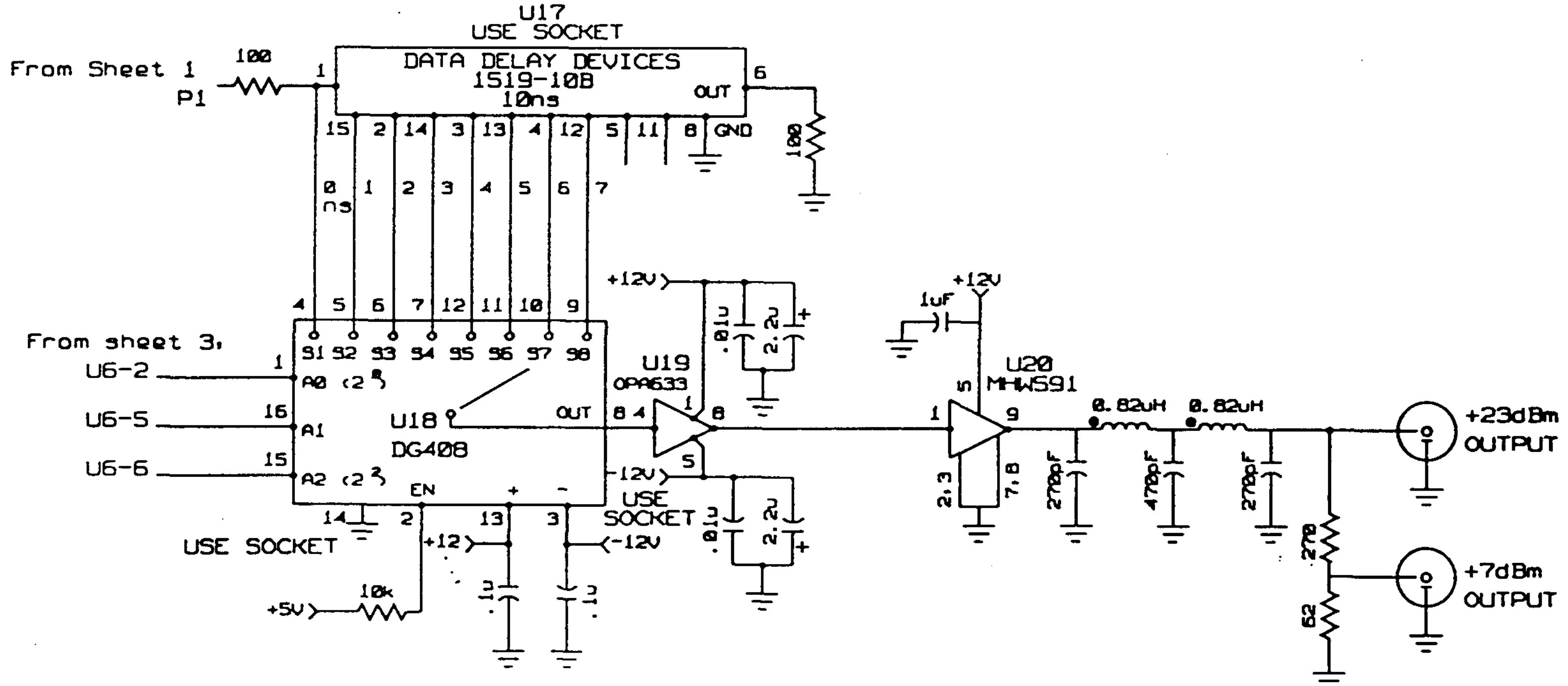
LIGO PROJECT

TITLE:
12.3 MHz DIGITAL CONTROL PHASE SHIFTER
LAST_MODIFIED=Wed Mar 16 16:54:52 1994

DRAWN: SANDEE 11/8/93
ENGINEER:
CHECKED:
APPROVED:
DRAWING NUMBER: 1206054-3
SCALE: __
PAGE: 1 OF 4
REV: -



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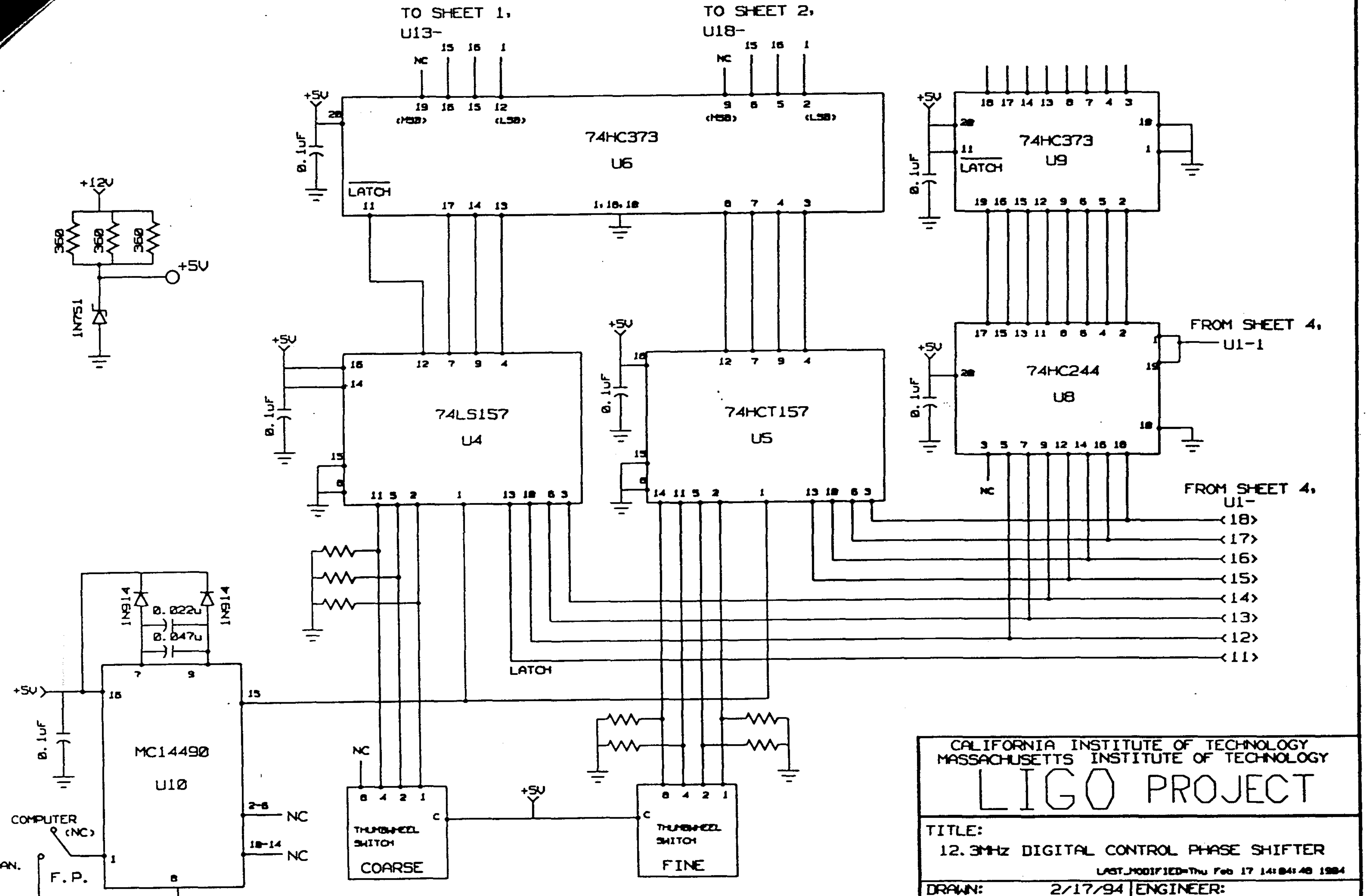
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

LIGO PROJECT

TITLE:
12.3 MHz DIGITAL CONTROL PHASE SHIFTER

LAST_MODIFIED=Wed Mar 16 16:56:07 1994

DRAWN: SANDEE 11/8/93		ENGINEER:	
CHECKED:		APPROVED:	
DRAWING NUMBER: 1206054-3	SCALE: __	PAGE: 2 OF 4	REV: -



NOTE: All resistors are 100kohm, and are part of a resistor network.

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LIGO PROJECT

TITLE:
12.3MHz DIGITAL CONTROL PHASE SHIFTER
LAST_MODIFIED=Thu Feb 17 14:04:40 1994

DRAWN: 2/17/94 L. Chu	ENGINEER:
CHECKED:	APPROVED:

DRAWING NUMBER:	SCALE:	PAGE:	REV:
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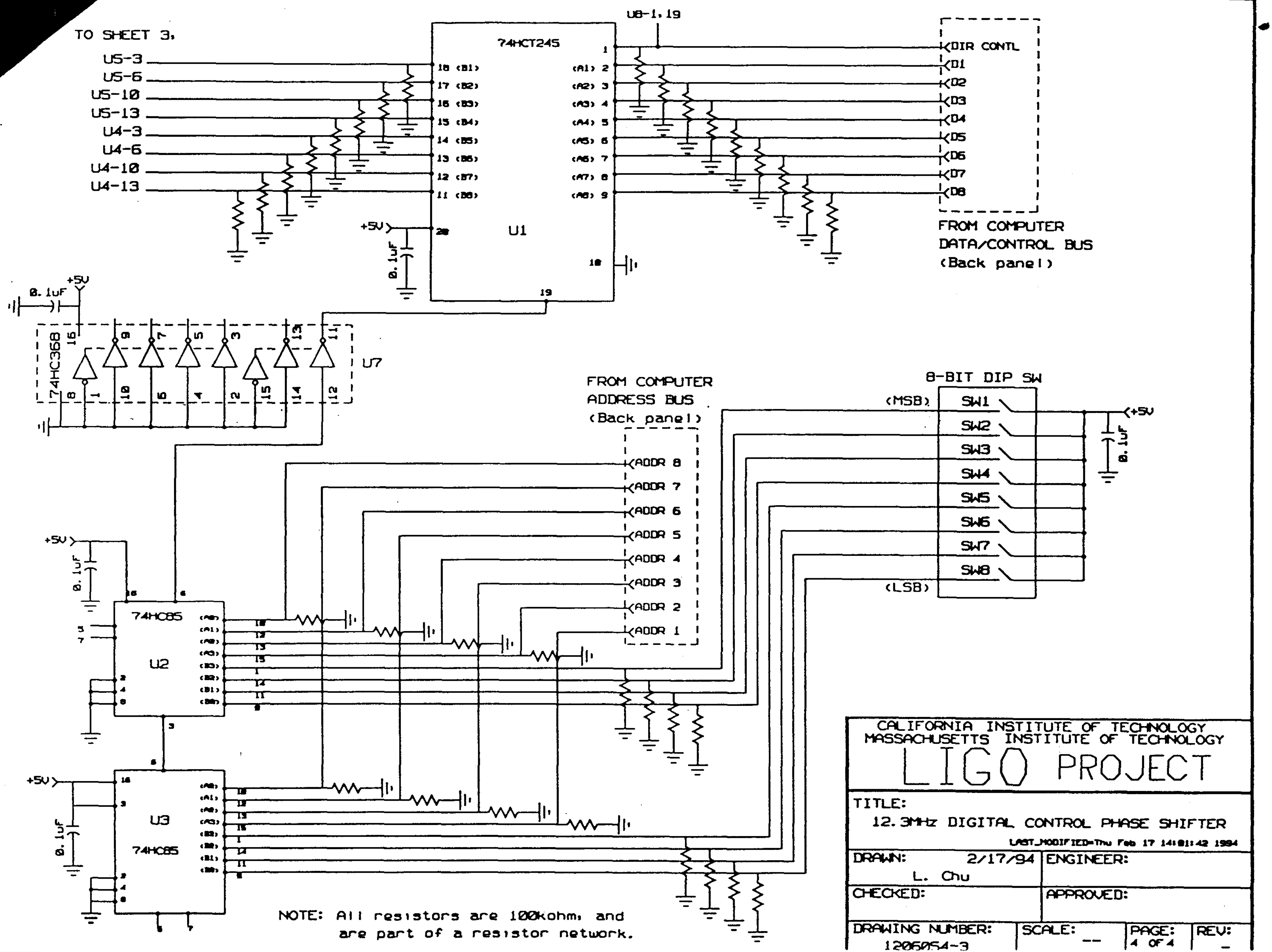

NOTE: All resistors are 100kohm, and are part of a resistor network.

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MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LIGO PROJECT

TITLE:
12.3MHz DIGITAL CONTROL PHASE SHIFTER
LAST_MODIFIED=Thu Feb 17 14:01:42 1994

DRAWN: 2/17/94 L. Chu
ENGINEER:
CHECKED:
APPROVED:
DRAWING NUMBER: 1206054-3
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PAGE: 4 OF 4
REV: -