LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

LIGO Laboratory / LIGO Scientific Collaboration

LIGO- T060125-00-C *LIGO* June, 2006

DC Readout Chain Piezo Driver Requirements

Richard Abbott

Distribution of this document:
LIGO Science Collaboration
LIGO Laboratory

This is an internal working note of the LIGO Project.

California Institute of Technology
LIGO Project – MS 18-34
1200 E. California Blvd.
Pasadena, CA 91125
Phone (626) 395-2129
Fax (626) 304-9834
E-mail: info@ligo.caltech.edu

Massachusetts Institute of Technology
LIGO Project – NW17-161
175 Albany St
Cambridge, MA 02139
Phone (617) 253-4824
Fax (617) 253-7014
E-mail: info@ligo.mit.edu

LIGO Hanford Observatory
P.O. Box 1970
Mail Stop S9-02
Richland WA 99352
Phone 509-372-8106
Fax 509-372-8137

LIGO Livingston Observatory
P.O. Box 940
Livingston, LA 70754
Phone 225-686-3100
Fax 225-686-7189

http://www.ligo.caltech.edu/

1 Overview

For the current version of the DC readout there are 4 axes of Piezo control used to correct angle and position in the optical chain leading up to the OMC cavity. There is also a need to drive a length control Piezo to lock the OMC cavity.

The DC Readout Chain Piezo driver amplifier provides the drive voltages and monitoring functions for 4 separate Piezo elements and potentially can combine functionality to provide an additional channel of OMC length control Piezo drive should that be advantageous from an implementation standpoint.

Each of the Piezos has a low frequency requirement for bulk actuation and a high frequency requirement dictated by the need to apply modulation signals in the 10 kHz to 20 kHz band.

This document captures the known parameters and the basis to permit design of the Piezo driver amplifiers.

2 Requirements and Specifications

The design parameters, manufacturer's specifications and a basis to justify each parameter are included below for the tip/tilt axes

Table 1, Fixed Specifications for Tip/Tilt PZT

Parameter	Specification	Information Source
PZT Manufacturer	Piezo Jena	-
PZT Model Number	PSH 5/2 SG-V	-
PZT Capacitance per axis	2uF +/- 20%	Manufacturers data sheet and actual measurement at 40m lab
PZT Self Resonant Frequency	3600 Hz	Manufacturer's data sheet. Should be verified by measurement.
PZT Electrical Interface	Three color coded wires. There is a ground, fixed bias and variable drive wire	Physical examination and manufacturers data sheet
PZT Monitoring	Via integral strain gage bridge circuit	Manufacturers data sheet

Table 2 Piezosystem jena Datasheet

multiaxis tip/tilting platform series PSH x/2 part no.		**unit**	**PSH 5/2** K-105-00
number of active axis		-	2
max. tilt**		mrad	± 2
operating voltage		V	-10…+150
capacitance per axis*** (± 20%)		nF	2000
resonant frequency (unloaded)**		Hz	3600
typ. scan frequency ****		Hz	210
stiffness in z		N/µm	20
dimensions	length L	mm	22
	width B	mm	22
	height H	mm	29.5
mounting	holes spacing	mm	11 x 11 / 17 x 17
	threads	mm	M2-6H x 3 / M3-6H x 4
connector	voltage	-	LEMO 0S.303
multiaxis tip/tilting platform series PSH x/2 with feed back sensor part. no.		**unit**	**PSH 5/2 SG** K-105-01
max. tilt**	open / closed loop	mrad	± 2
integrated measurement system		-	strain gauge
dimension	height H	mm	35
resolution*	open loop	µrad	0.01
	closed loop	µrad	0.1
non-linearity**		%	0.4
repeatability**		µrad	0.8
connector	sensor	-	LEMO 0S.304

* values are based on measurement with E-103-19 amplifier
** typ. value measured by –10 V to +150 V
*** typ. value for small electrical field strength
**** unloaded platform; with sinusoidal waveform

Figure 1 was derived from the Piezosystem Jena datasheet. Pin 1 is connected to ground. For zero command and to center the Piezo within its angular dynamic range, pins 2 and 3 are at their quiescent voltage of VCC/2 or ~75 volts.

Pins 2 and 3 are driven in a "differential" mode where at one extreme, pin 3 goes to 150 while pin 2 goes to ground and vice versa for the other extreme. There seems to be considerable ambiguity regarding the color code of each wire, so beware as depoling will occur if the wrong polarity drive is applied. Reverse polarity voltages can fracture the Piezo crystal.

This Piezo configuration is for one axis only. There are two axes in each Piezosystem Jena module, and two modules are used in the DC readout scheme.

Figure 1

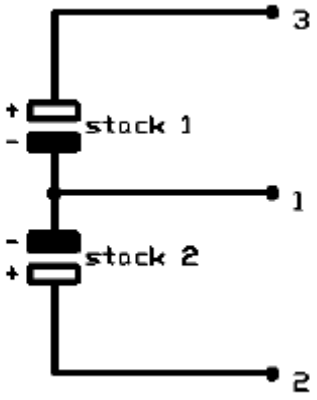

Table 3, OMC Length Piezo Specifications

Parameter	Specification	Information Source
PZT Manufacturer	Kinetic Ceramics	-
PZT Model Number	075010-022-3C	-
PZT Capacitance per axis	600nF +/- 20%	~230 nF was measured on the OMC PZT. The 600nF number came from the PSL PMC PZT measurement
PZT Self Resonant Frequency	65-70 kHz	Measurement on PMC PZT
PZT Electrical Interface	Two wires	Physical examination

Table 4 Piezo Driver Requirements for Piezosystem Jena PZT

Parameter	Requirement	Basis of Requirement
Number of Tip/Tilt axes to be driven	4 Individual Channels	The need to adjust horizontal and vertical angle and position
Main Drive Voltage Gain	15	0-10 volt input for a 0-150 volt output
Output DC Voltage Range	0 to 150 volts	Sufficient to drive the PZT over the full angular range
Output Voltage Noise	1/F in nature, 1uV/√Hz at 100 Hz	Not adding sensing noise to DC readout channel. Number derived from Vuk Mandic's study of angle and position jitter into the OMC cavity. The number assumes 1m lever-arm from position PZT to OMC
Electronics Packaging	19 inch rack mount	Consistent with Advanced LIGO packaging concepts
Built-in Monitoring	Strain Gauge and Output Voltage Monitor	The need to have EPICS read-back of position and Piezo drive voltage
Modulation Frequencies	10 kHz to 20 kHz	Based on current best estimate of suitable frequencies above the LIGO GW band
Modulation drive requirement	10 volts peak-to-peak across the Piezo actuator	Measurements done at the 40m lab indicated that the actual drive levels will probably be even lower
Dynamic Range vs. Frequency for the main output at lower frequencies (Numbers are referenced to the voltage across the Piezo Crystal itself)	< 10 Hz) < 300 mVrms 10-100 Hz its < 10 mVrms. These numbers can be suitably scaled by assuming we maximize the size of the resistor to get low noise on the alignment Piezos.	- The jitter of the test mass optics (in-lock) is < 1 urad/√Hz below 10 Hz and < 0.01 urad/√Hz above 10 Hz (limited by our optical lever sensing noise).

		The PZT amplifier may have 100 Ohms in series with the output. The ~1 uF of the PZT would create a 1.5 kHz pole which doesn't seriously restrict the dynamic range in the alignment servo band (f < 100 Hz).
Input Impedance	> 1k ohm	Sufficient to not be an excessive load to the source of drive voltage
Input Topology	Differential Input	Dictated by the desire to have good noise immunity in LIGO designs
Output Connections per axis	Ground and a differential 150Vp-p drive	Dictated by the drive needs of the Piezo
Main Piezo Drive Output Connector	Three terminal connector with integral strain relief. Suitable for use with voltages up to 300VDC	N/A

Table 5 Piezo driver requirements for OMC length Piezo

Parameter	Requirement	Basis of Requirement
Number of Piezos to be driven	1 channel	The need to adjust cavity length only
Main Drive Voltage Gain	30	0-10 volt input for a 0-300 volt output
Output DC Voltage Range	0 to 300 volts	The range must be sufficient to cover several free spectral ranges and track thermal drift
Output Voltage Noise	1/F in nature, 1uV/√Hz at 100 Hz	This is simply the same as the OMC alignment chain because there is no better information
Electronics Packaging	19 inch rack mount	Consistent with Advanced LIGO packaging concepts
Built-in Monitoring	Output Voltage Monitor	The need to have EPICS read-back of Piezo drive voltage
Modulation Frequencies	10 kHz to 20 kHz	Based on current best estimate of suitable frequencies above the LIGO GW band
Modulation drive requirement	10 volts peak-to-peak across the Piezo actuator	Measurements done at the 40m lab indicated that the actual drive levels will probably be even lower
Dynamic Range vs. Frequency (Numbers are referenced to the voltage across the Piezo Crystal itself)	< 10 Hz) < 300 mVrms 10-100 Hz its < 10 mVrms. These numbers can be scaled by assuming we maximize the size of the resistor for low noise on the Piezos.	Best guess at time of writing
Input Impedance	> 1k ohm	Sufficient to not be an excessive load to the source of drive voltage
Input Topology	Differential Input	Noise immunity

Output Connections per axis	Single-ended 300Vp-p drive	Dictated by the drive needs of the Piezo
Main Piezo Drive Output Connector	Coaxial cable connection suitable for use with voltages up to 300VDC	N/A