*LIGO Laboratory / LIGO Scientific Collaboration*

LIGO-T1500001-v2 *LIGO* January 20, 2015

*Noise requirement for the test mass electro-static driver*

P. Fritschel

Distribution of this document:

LIGO Scientific Collaboration

This is an internal working note

of the LIGO Laboratory.

|  |  |
| --- | --- |
| **California Institute of Technology****LIGO Project** | **Massachusetts Institute of Technology****LIGO Project** |
| **LIGO Hanford Observatory** | **LIGO Livingston Observatory** |

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

# Introduction

A low-noise, lower range driver for the test mass electro-static actuator is being designed for use in interferometer low-noise operation (the UK high-voltage driver will continue to be used for lock acquisition). This note specifies the maximum voltage noise for this low-noise driver.

# Force noise per actuator quadrant

The voltage noise in the actuator quadrants will be independent of each other, so I start by defining the force noise per quadrant. The force coefficient for the ETM is still somewhat uncertain. John Miller’s FEA model gave 4e-10 N/V2, but measurements give factors of 2-4 smaller values (see LHO log entry 12220). It was recently suggested that the ring heater structure could be altering the field lines in a way that reduces the net force. I assume a force coefficient of 2e-10 N/V2 for the full ETM/ERM electrode pattern, or a force coefficient of ***a*** = **5e-11 N/V2 per quadrant**. The force noise per quadrant, assuming the bias path is sufficiently low-pass filtered that its noise is negligible, is thus:

# Force noise for both ETMs

Since the ESD force coefficient for the ITMs is about 30 times smaller than the ETMs, I neglect them in the calculation. The total force noise from the 8 ETM/ERM quadrants is:

# Maximum allowed force noise from ESD

For the maximum force noise, I use an Advanced LIGO configuration that is good for low frequency noise, namely with 25 W input power (other variable parameters do not significantly impact the noise below 30 Hz). The limiting strain noise in this case is 1.6e-23 Hz-1/2 at 20 Hz (see LIGO-T1200307, e.g.); the arm differential displacement noise is 6.5e-20 m/Hz1/2 at 20 Hz (this frequency is chosen because a 1/*f* 2 line is tangent with the strain noise spectrum at about 20 Hz).

The maximum displacement noise from ESD noise is 10 times smaller than this value, which gives a maximum (total differential) ESD force noise of:

# ESD signal path voltage noise

The maximum voltage noise on each ESD quadrant signal path comes from the previous two equations:

Between 10-20 Hz the interferometer strain noise falls a bit faster than *f* -2, so the noise at 10 Hz can be a bit higher; I set *vn* (10 Hz) < 250 nV/Hz1/2.