LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY
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Document Type	**LIGO-T960070-00 -**	**D**	Apr. 5, 96

Framework of Range Requirement of Suspension Actuator

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Distribution of this draft:

This is an internal working note
of the LIGO Project.

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1 INTRODUCTION

It turned out that it is not straightforward to describe the relation between the range requirement of the suspension actuator and the external disturbance motion requirement of the mass. This document provides a framework with which both requirements can be related to each other in a clarified way.

2 SIMPLE CASE

The difficulty comes from the fact that the range requirement described with a unit of displacement is not generally frequency-independent. If it were frequency-independent and were specified as, for example, 30 μm_p at any frequency, the external disturbance motion requirement of the mass would be simply related to that number, that is, the rms disturbance motion should be smaller than 50 μm_p by a factor of at least 15 (a factor of 5 for statistical fluctuation, and a factor of 3 for safety). In reality, however, the attainable range at higher frequencies should be rolled off, because of the slow pendulum response. Moreover the series impedance of the actuator is likely to be made frequency-dependent to suppress the driver noise significantly at higher frequencies. Therefore it is reasonable to require a frequency-dependent range, which makes the case rather complicated.

3 FRAMEWORK

Our attempt here is to provide a framework for this more realistic frequency-dependent range requirement of the actuator. This can be done by reducing this case to a frequency-independent case. The clue is that the range of the driver output voltage is usually frequency-independent.

Fig. 1 shows the actuating system for the suspended mass. The driver feeds the voltage V to the actuator via a series impedance, that causes the motion x_c on the mass. The mass also gets the motion x_e from the external source such as stack motion. x_t is the total motion of the mass.

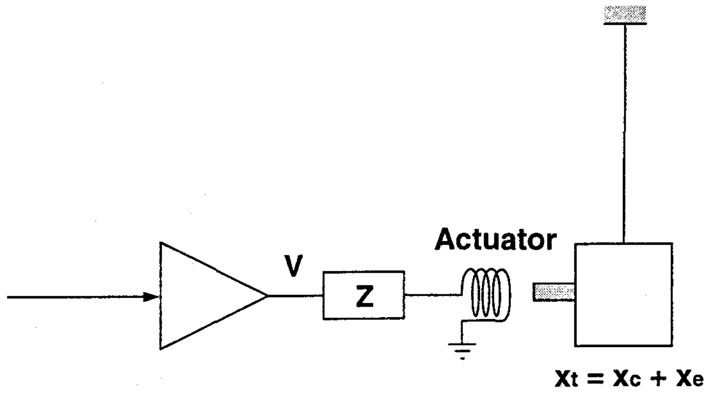

Figure 1: Actuating system for the suspended mass.

Fig. 2 shows the block diagram of the control system for the suspended mass with the external disturbance motion (a) and the modified diagram (b). Here G is the response transfer function of the sensor and amplifier, C is that of the actuator including the series impedance, and P is that of the pendulum response. F donates force. The diagram (a) is equivalent to the diagram (b) at the output of G. The diagram (b) indicates that the disturbance voltage comes in at the driver output as $\frac{X_e}{PC}$, whereas the voltage range is frequency-independent.

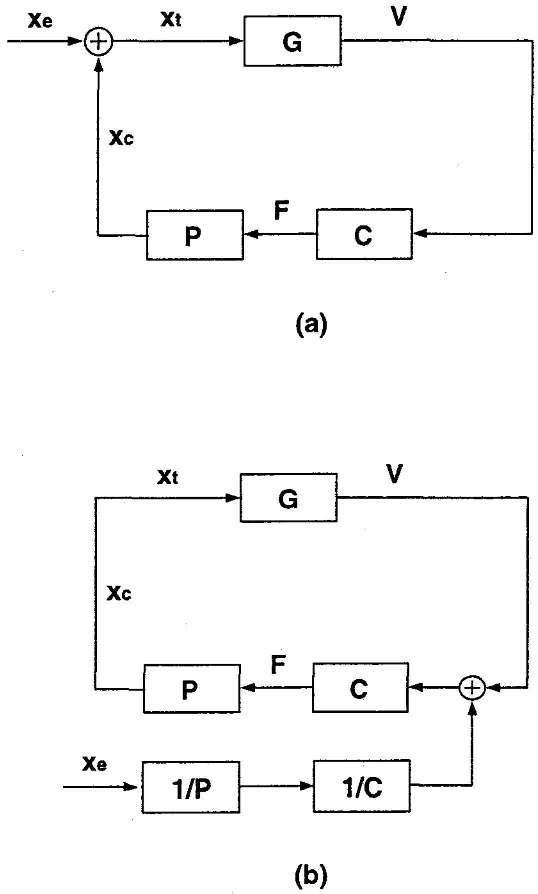

Figure 2: Block diagram of the control system for the suspended mass with disturbance motion (a) and the modified diagram (b).

Now we can specify the requirement simply as:

$$\left(\frac{X_e}{PC}\right)_{rms} \times 15 < V_p,$$

where V_p is the frequency-independent voltage range. In order to derive an equation for the actuator range, we multiply both side by $P_{DC}C_{DC}$. We obtain:

$$\left(\frac{x_e}{(P/P_{DC})(C/C_{DC})}\right)_{rms} \times 15 < x_{p,\,DC},$$

where $x_{p,DC}$ is the actuator range at DC. $(P/P_{DC})(C/C_{DC})$ is the normalized (unity at DC) transfer function from the driver voltage to the mass motion.

x_e normally originates from seismic excitation, and it is a product of the ground motion, the stack transfer function, and the suspension response. Therefore the external disturbance motion requirement of the mass consists of the stack isolation requirement and the suspension response requirement.

4 SUMMARY

The range requirement of the suspension actuator should be expressed in a DC actuator displacement range and the normalized (unity at DC) transfer function from the driver voltage to the mass motion. The external disturbance motion requirement of the mass should be expressed in the stack isolation and the suspension response. These requirements must satisfy the equation above.