New Folder Name Noise caused by fluctuations

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INTERFEROMETER NOISE CAUSED BY FLUCTUATIONS IN MIRROR POINTING. (Interim report)

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Noise from the pointing system, seismic noise, or other sources can cause fluctuations in the pointing angles of the test mass mirrors. The angle variations will then induce noise in the interferometer output. Presented were a plausible model and confirming experimental results as to how the angle variation of the cavity mirrors can be converted into interferometer displacement noise.

(1) The model

There are seemingly two parameters which affect the coupling coefficient from the mirror angle variation to the mirror displacement variation measured by the interferometer: one is the distance between the beam axis and the mass center d; the other is the static mass angle θ.

The d-dependence of the coupling coefficient can be understood by the simple geometrical model as shown in Fig.1 (a). For small variations,

$$\delta x / \delta \theta = d,$$

where δx is the mirror displacement measured by the interferometer, and $\delta\theta$ is the mirror angle variation.

The θ-dependence of the coupling coefficient can be attributed to the above-mentioned model, because θ can only determine the mode axis of the cavity, and thus will determine d. The key point is that the mirror displacement measured by the interferometer is always along the excited mode , therefore the cavity axis. For example, as shown in Fig.1 (b), the change θ of the static angle of the concave mirror (the other mirror is flat) caused a lateral shift of the cavity axis by d:

$$d = r\theta$$

where r is the curvature radius of the concave mirror.

Therefore there is only one substantial parameter, that is d, for the coupling coefficient. And in this particular case, which is in fact the case of the 40 m prototype in Caltech,

$$\delta x / \delta \theta = r\theta$$

(2) Experimental results

The east end mirror of the 40 m prototype was used in tilt to investigate the problem.

Figure 2 shows the amplitude transfer function from the tilt coil voltages to the mirror angle and Fig.3 shows that from the tilt coil voltages to the mirror displacement as measured by the interferometer. The two response functions are proportional at all measured frequencies, in good agreement with the d-dependence model. They predict that d is roughly 2 mm for this test mass, a plausible figure.

θ-dependence of the coupling coefficient is shown in Fig.4. The linearity of the dependence indicates agreement with the θ-dependence model, and moreover the slope can be interpreted, using the model, as prediction that the curvature radius of the end mirror is roughly 50 m. This number is consistent with the actual value of 62 m, within the errors assosiated with the angle measurements.

(3) Predicted noise of the pointing system

The actual tilt coil voltage of the pointing system is shown in Fig.5. Using this measurement and the coupling coefficient measurement of Fig.3, the predicted noise due to pointing system fluctuations is shown in Fig.6, along with the typical interferometer noise. The prediction indicates that the pointing system-caused noise is not dominant for the current prototype.

(4) Suggestion (not yet conclusion !)

The model was verified to some extent. It provides the following guidance for keeping the pointing system-induced noise small.

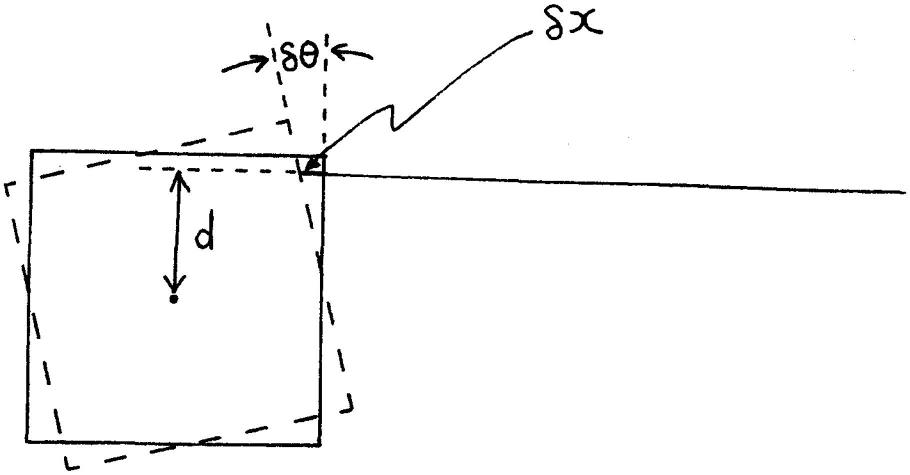
First of all, some provision for moving the mirror (and/or the incident laser beam) laterally and vertically is necessary in order to make the distance d between the beam axis and the center of mass zero. Although we can do that by changing the mirror angle, the method is not preferable, because, of course, it will degrade the visibility of the cavity.

Secondly, the residual rms fluctuation of the mirror angle should be made as small as possible by the feedback system with high gain at low frequencies. This will also help to reduce the d-fluctuation.

Finally, the gain and the electronic noise of the feedback circuit in the interesting frequency range should, of course, be kept small enough.

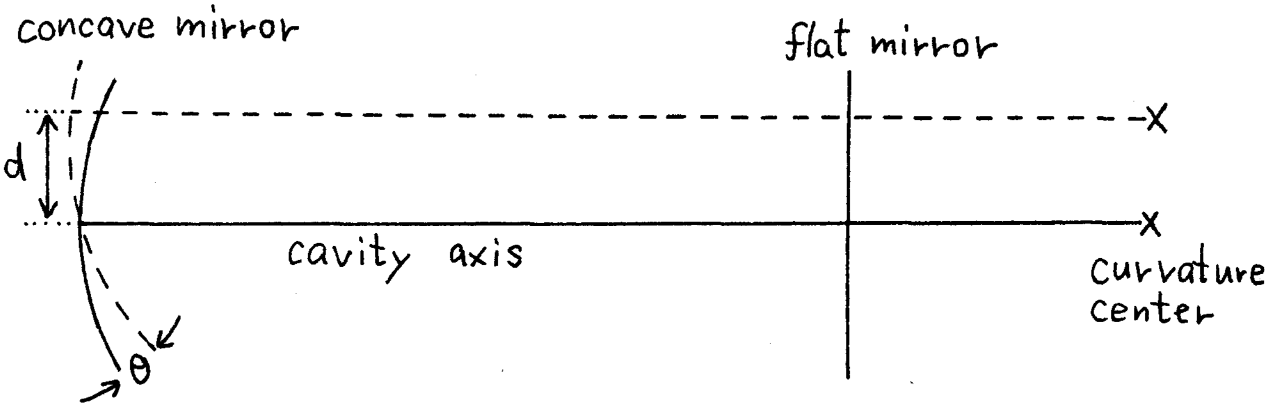
APPENDIX

Figure 7 to Fig.10 show performance of the new circuit for the pointing system.



$$\delta x/\delta\theta = d$$

(a) d-dependence model



$$d = r\theta$$

r: curvature radius

(b) θ-dependence model

Fig. 1 Model indicating how the mirror angle variation can be converted into the mirror displacement variation.

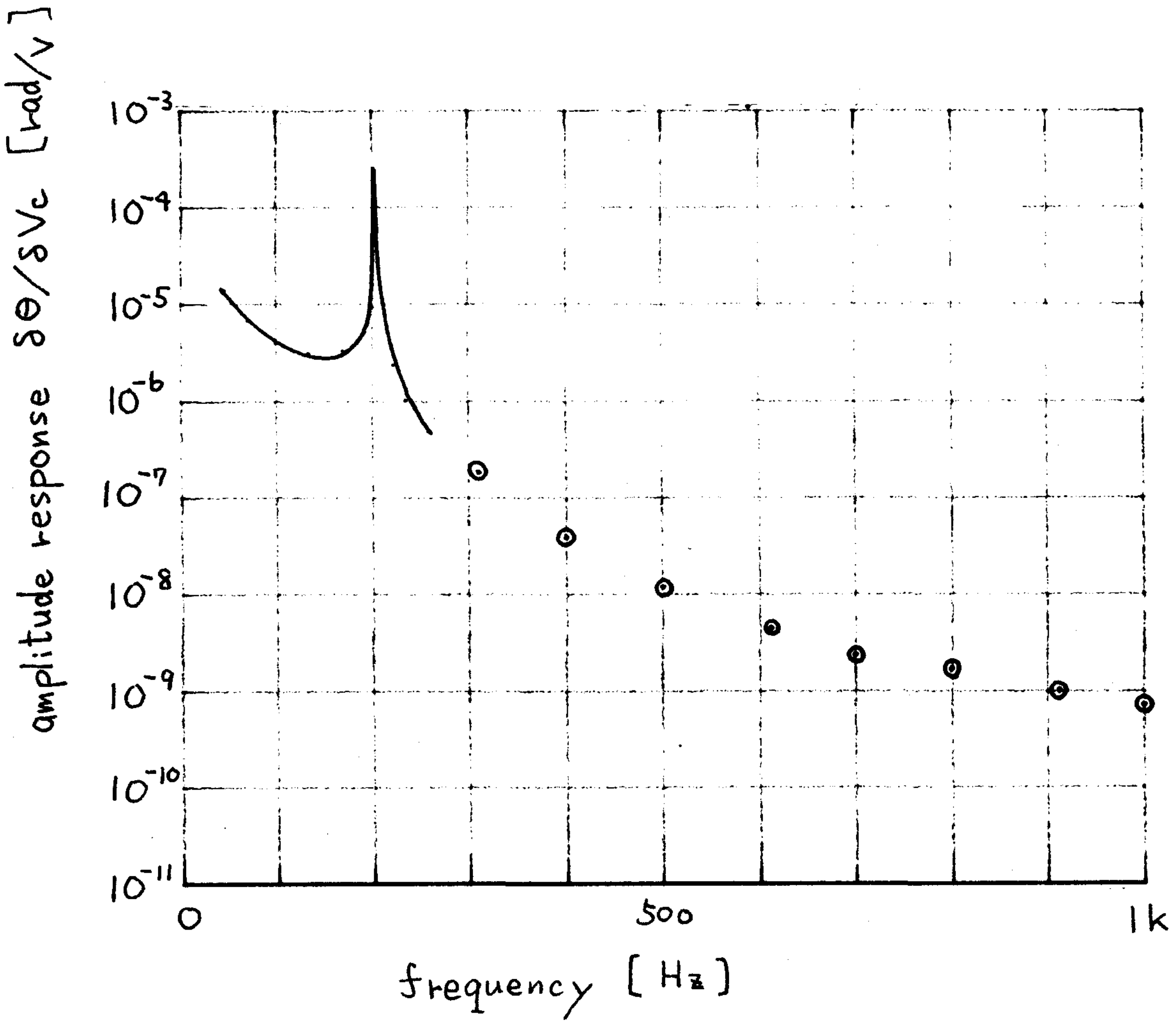


Fig. 2 Amplitude response $\delta\theta/\delta V_c$ from the tilt coil voltage to the mirror angle variation.

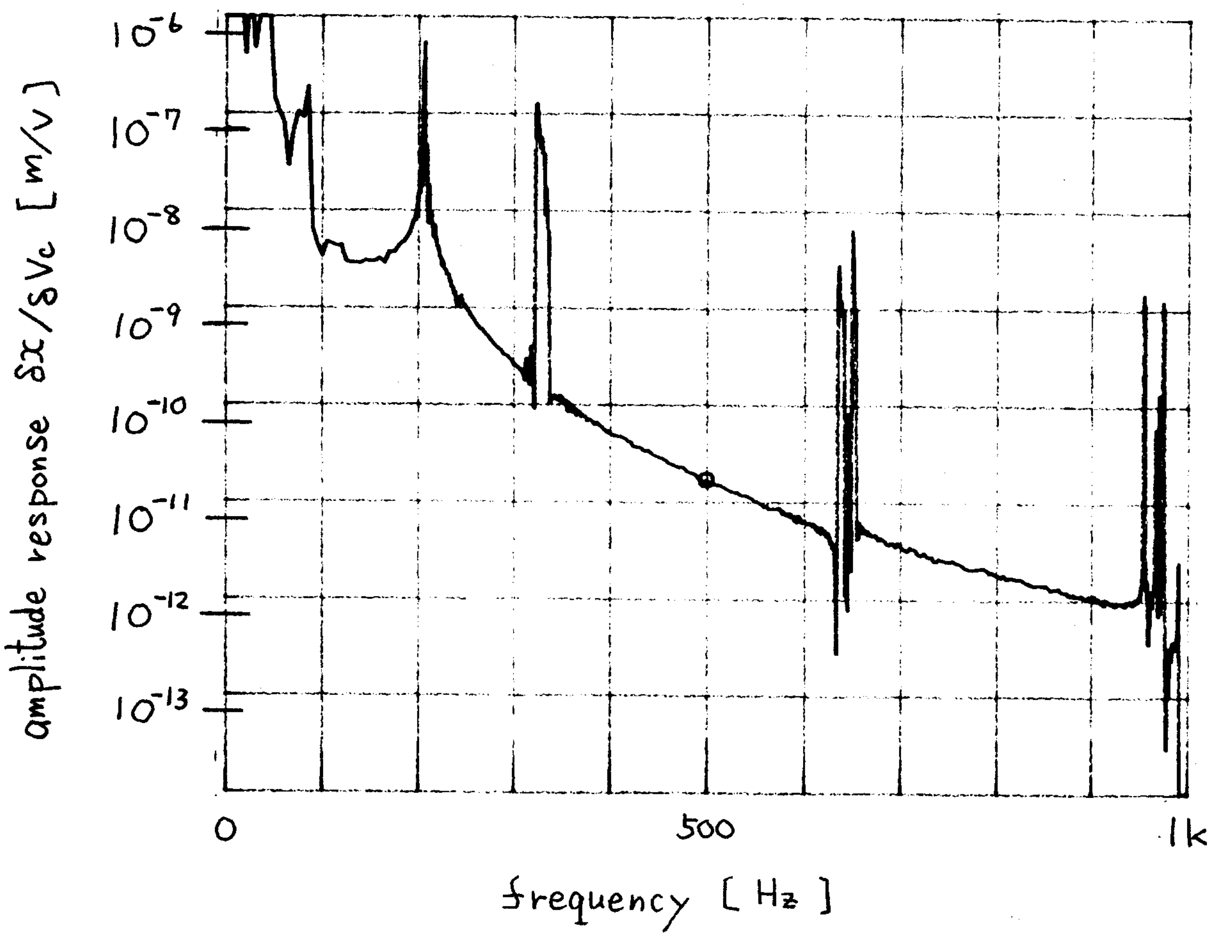


Fig. 3 Amplitude response $\delta x/\delta V_c$ from the tilt coil voltage to the mirror displacement measured by the interferometer.

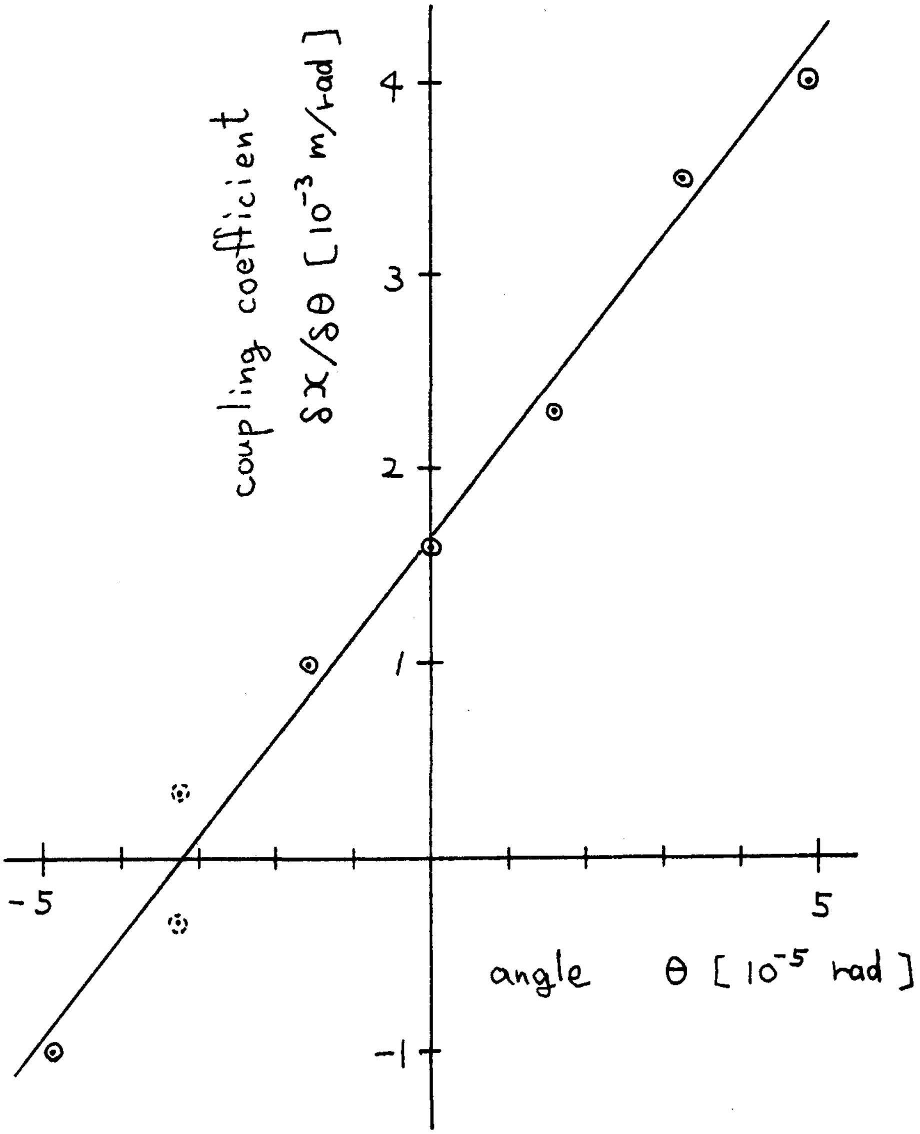


Fig. 4 Coupling coefficient from the mirror angle variation to the mirror displacement measured by the interferometer as a function of the static mirror angle θ.

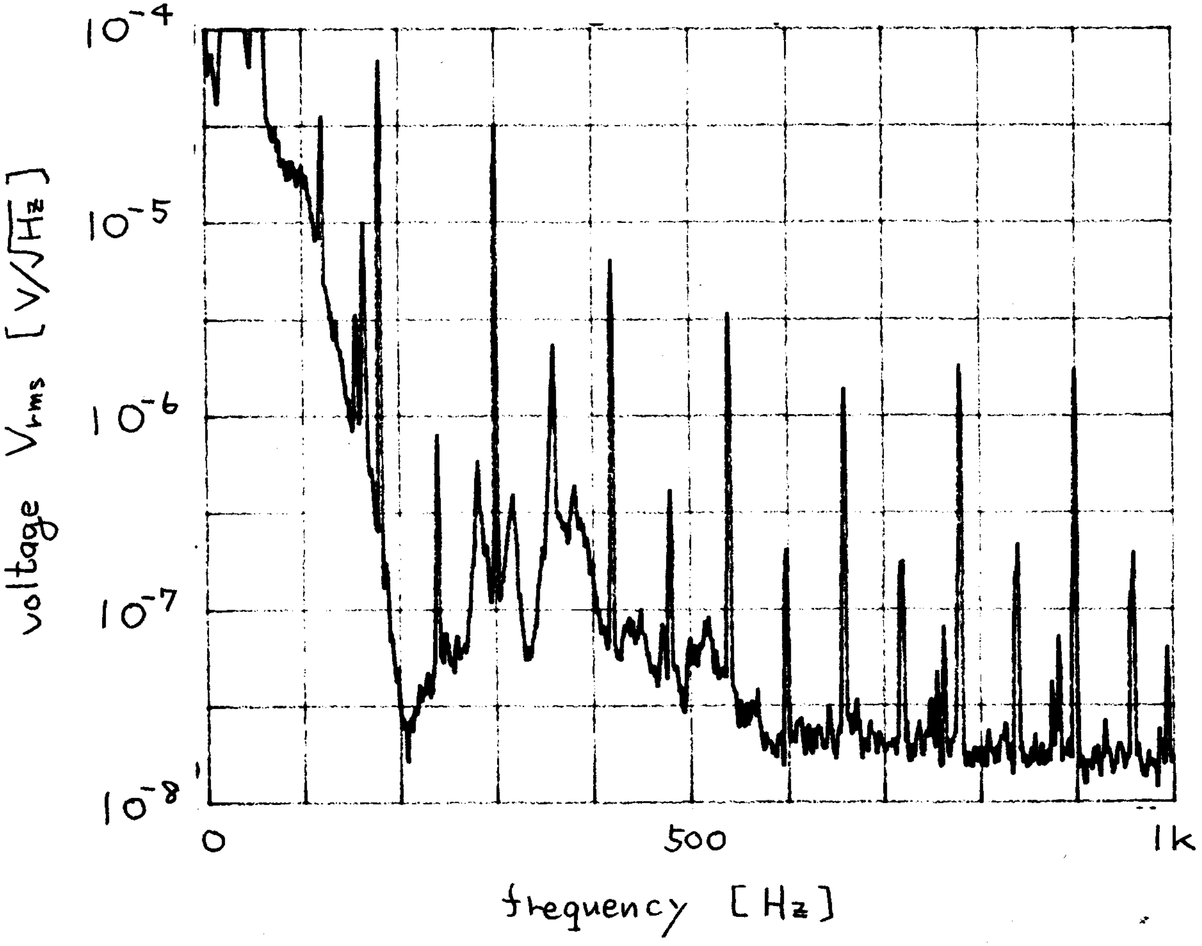


Fig. 5 Tilt coil voltage of the pointing system (the new circuit).

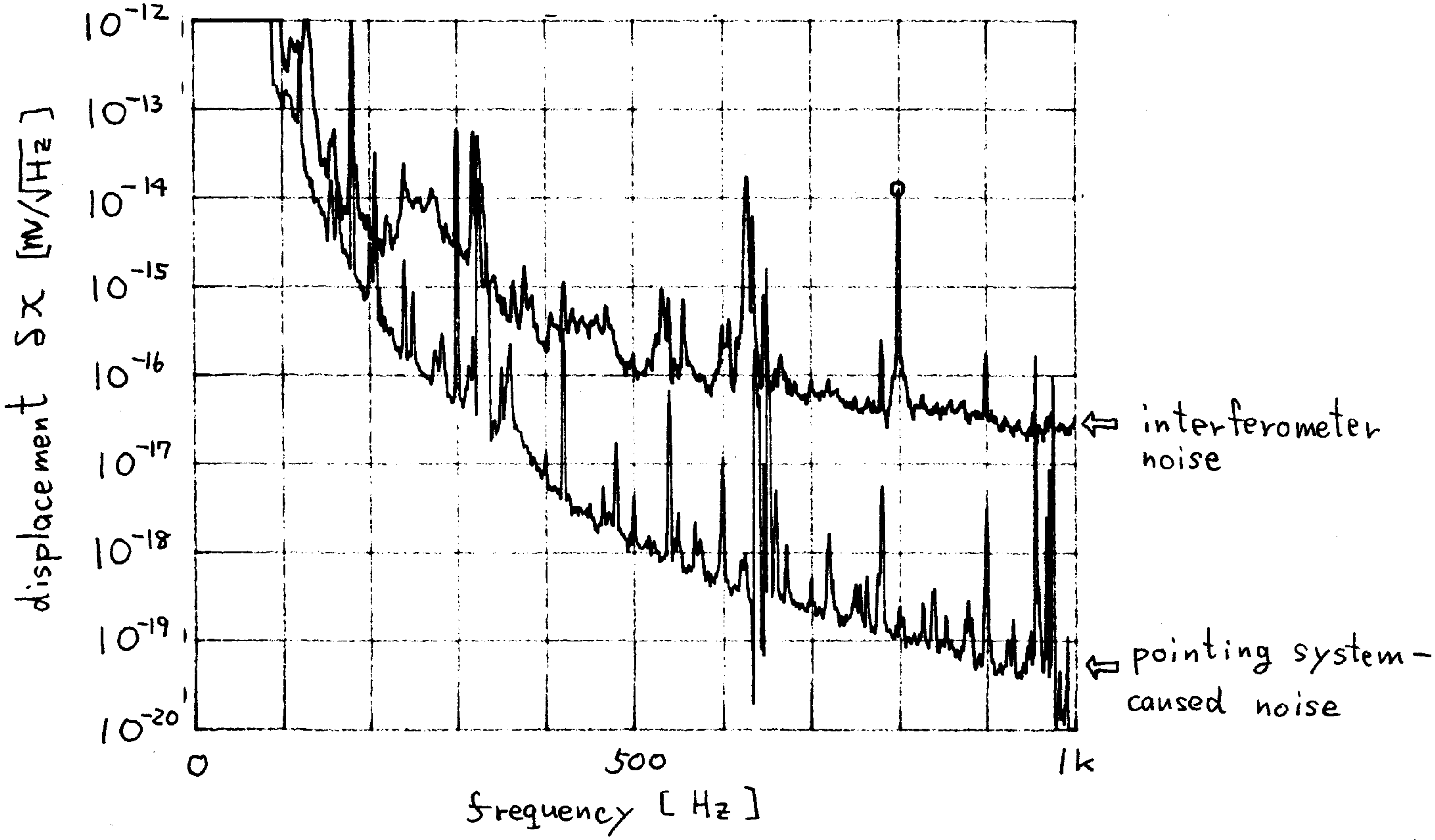


Fig. 6 Predicted displacement noise caused by the pointing system (the new circuit, tilt) with the typical interferometer noise.

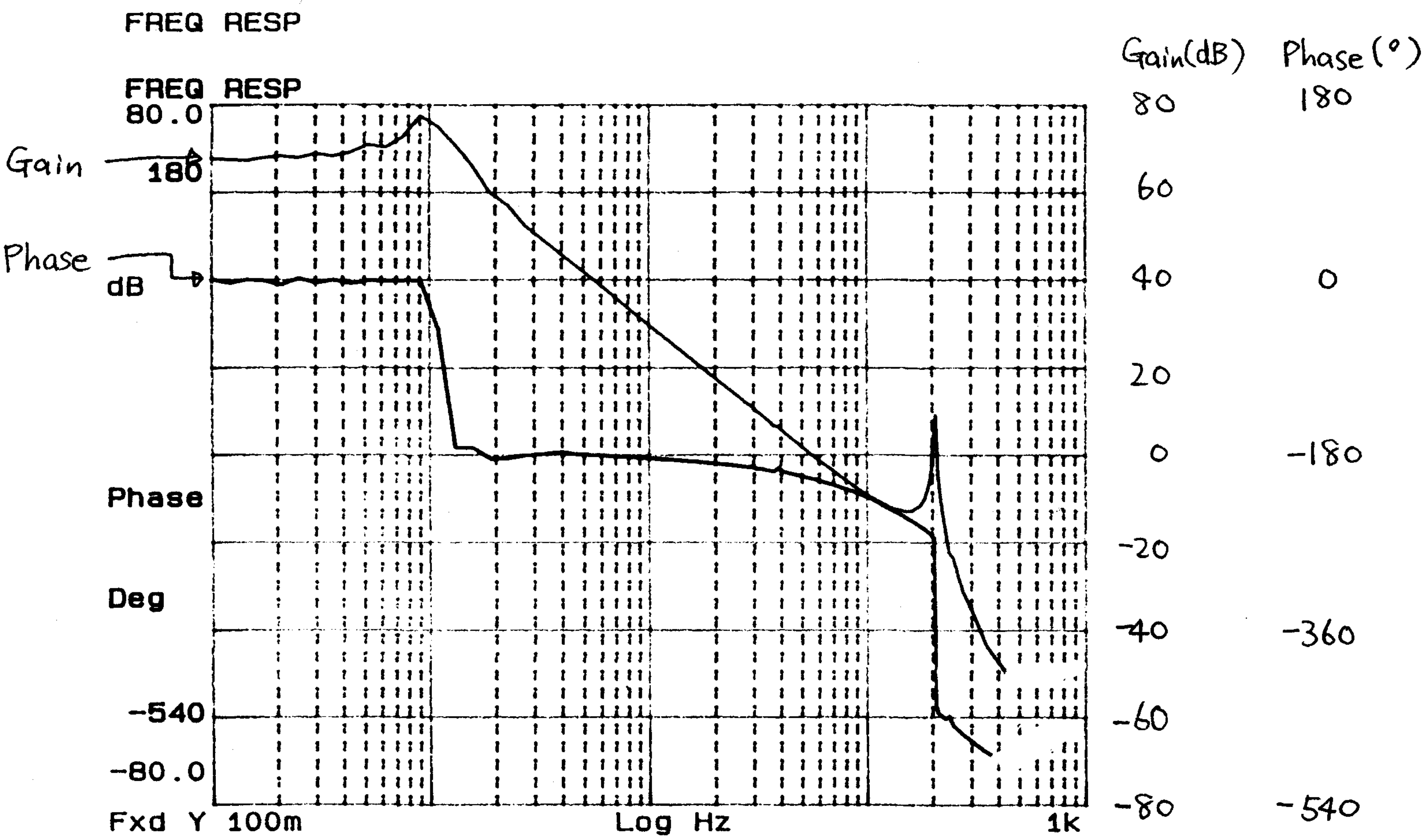


Fig. 7 Tranfer function from the coil voltage (tilt) to the output of XY processor

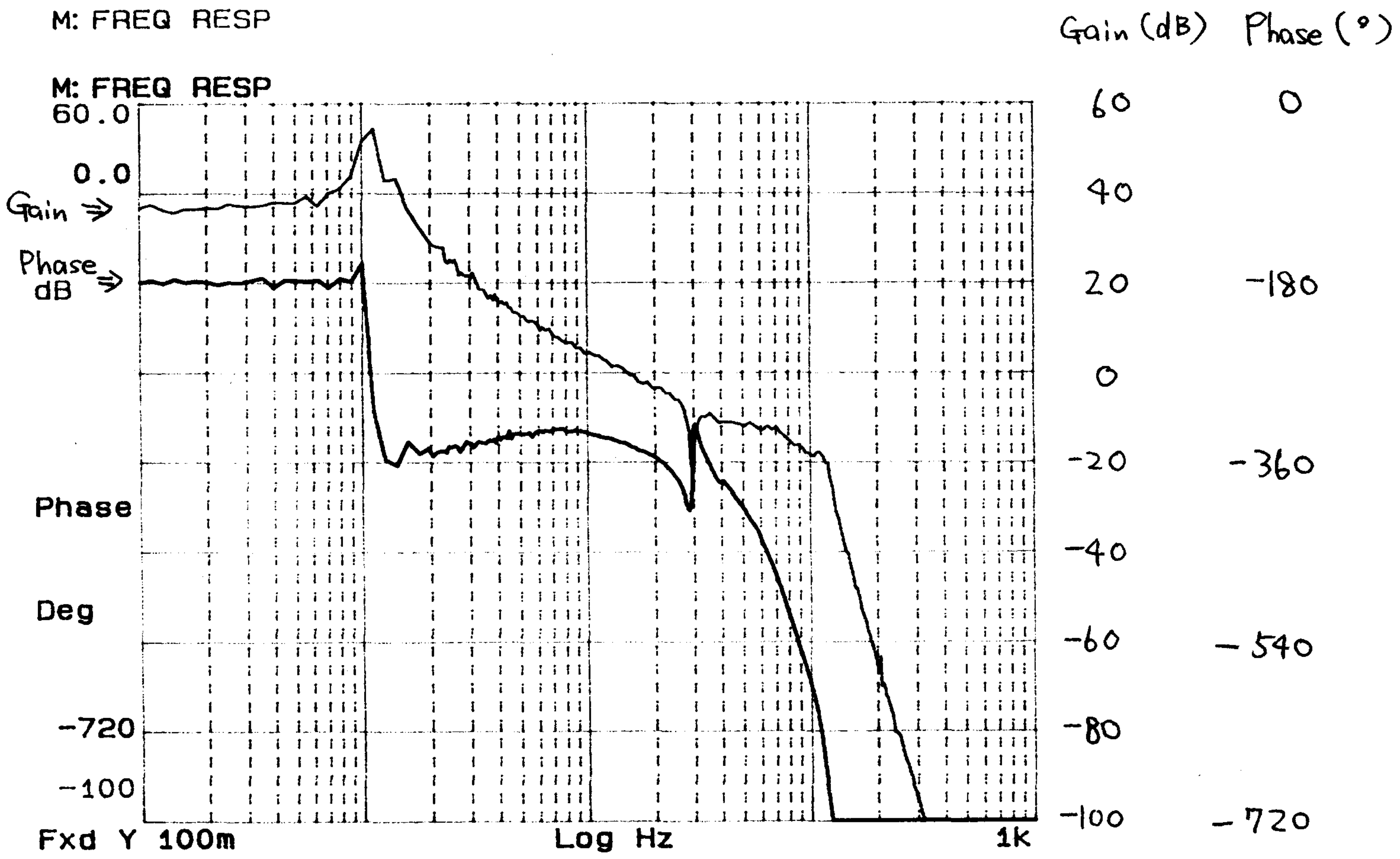


Fig. 8 Open loop transfer function for the pointing system (ver. 3.0 ; tilt)

HUEY-TILT(VER3.3):TT29.5;TT207;6,CH(2DB)4P110

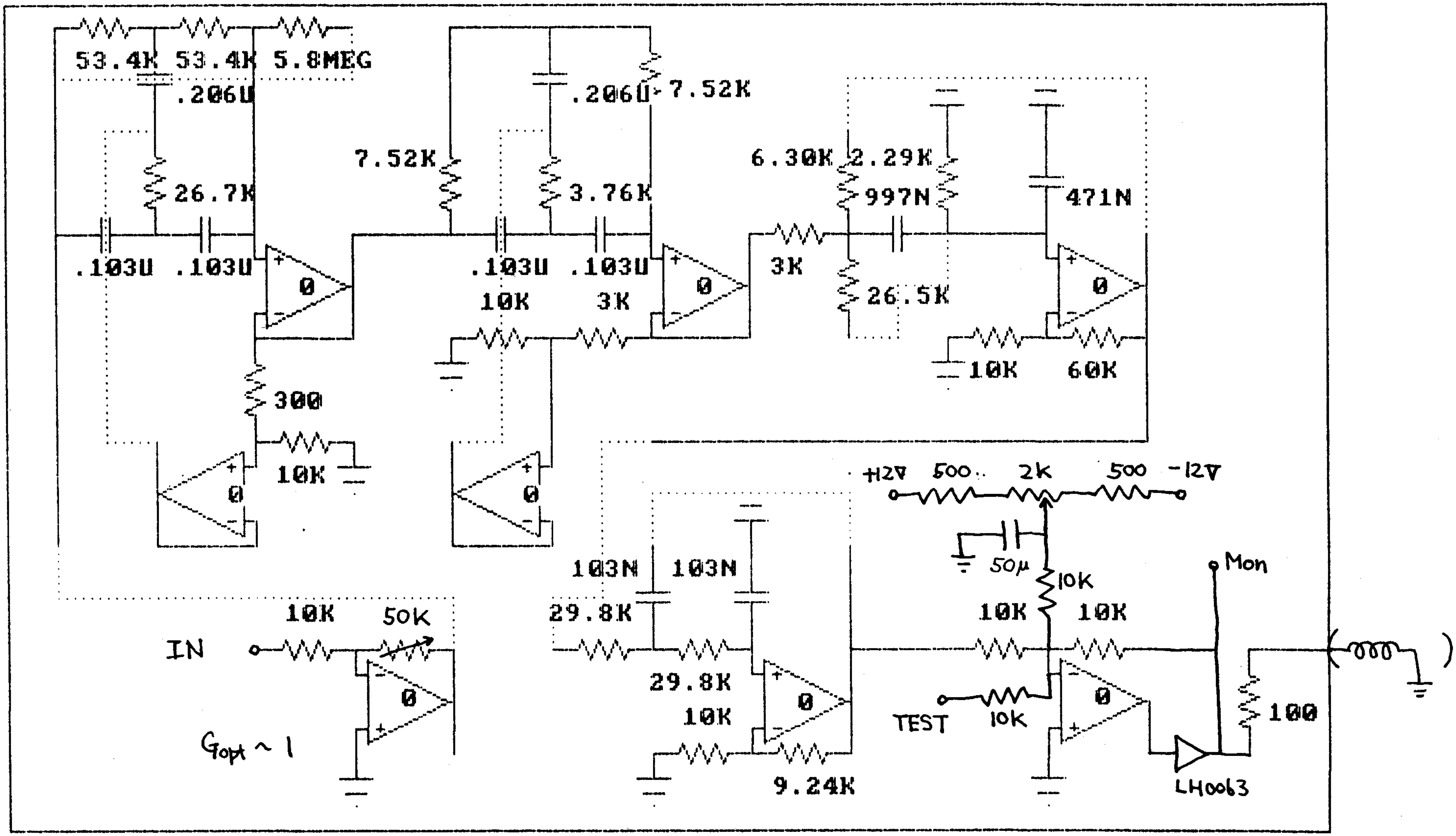


Fig. 9 Circuit diagram for the pointing system (tilt ; ver.3.3)

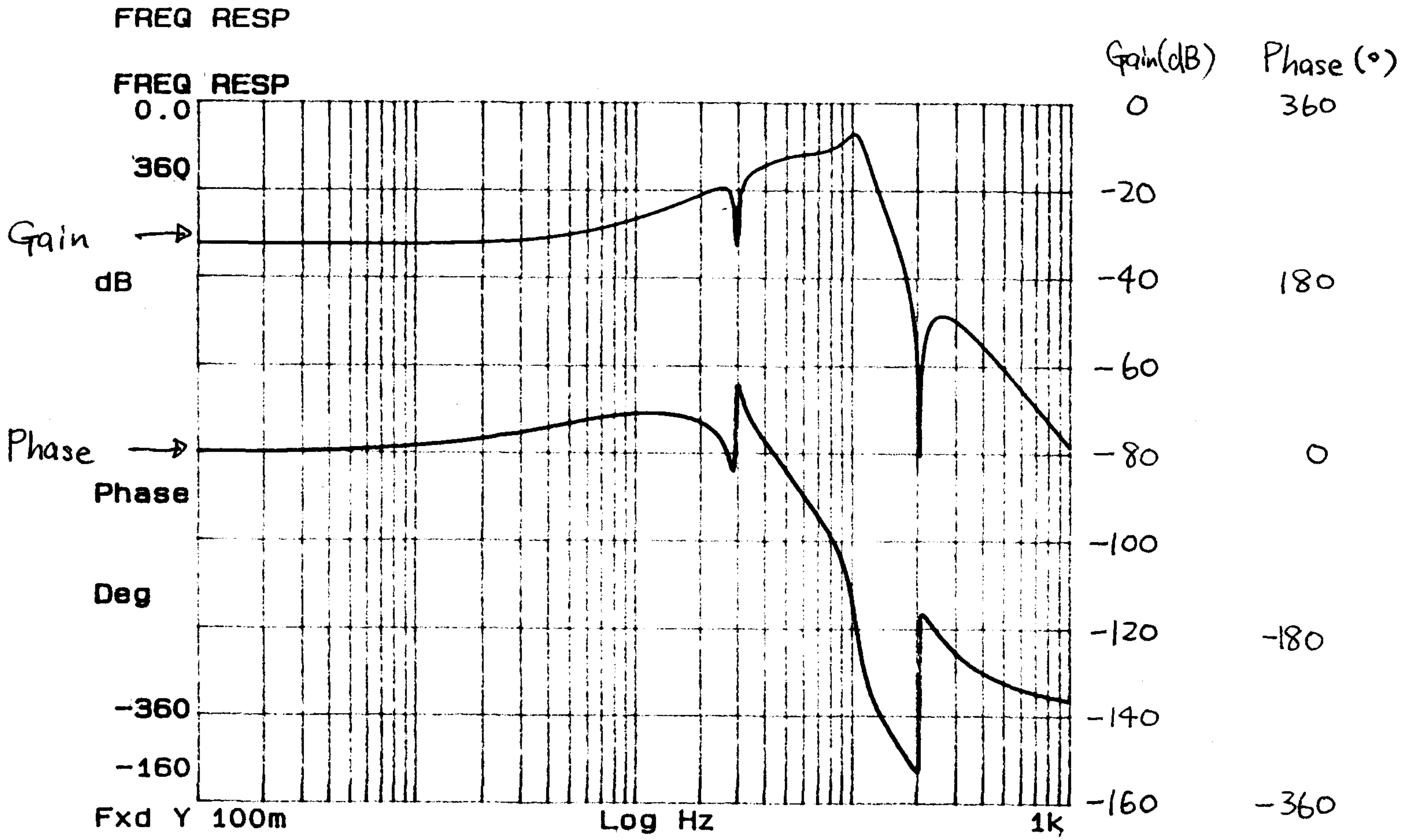


Fig. 10 Transfer function of the circuit for the pointing system (tilt ; ver. 3.3)