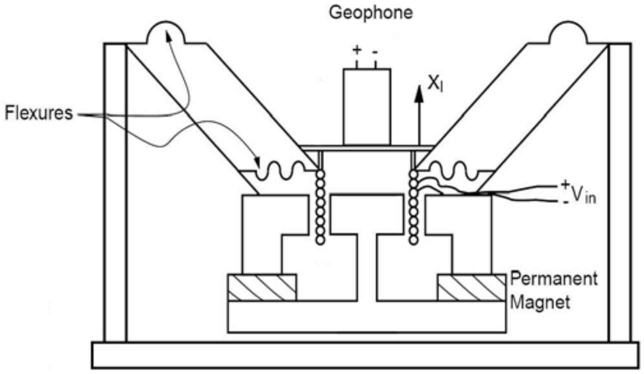
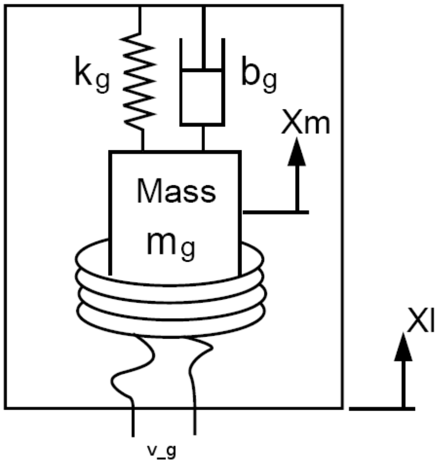
2.140: Week of 4/30
2.14: Week of 5/7

In this lab, we study a simple active vibration isolation system formed using a speaker and a geophone. The goal is to make the "platform" (i.e., the moving part of the speaker) have zero velocity, even if the base of the speaker moves. Geophones (and sometimes accelerometers) are commonly used as feedback sensors in such systems.



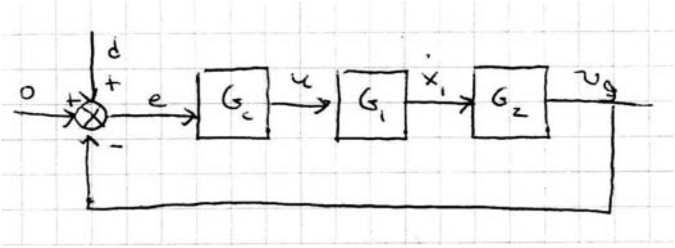
A sketch of the cross-section of the speaker system is shown above. As in Labs 2 and 3, we will implement the controller in dSpace, and designate the controller output voltage as u. A power op-amp (configured as in Labs 2 and 3) applies a voltage V_{in} of $2u$ to the speaker voice coil, whose resistance is $R_v = 18\ \Omega$.

The voice coil and speaker magnet are coupled with a force (and back emf) constant $K_f = 10$ N/A. The moving mass of the platform (including the geophone housing) is $m_1 = 0.14$ kg and the stiffness of the speaker mechanism relative to ground is $k_1 = 1300$ N/m. The speaker system also exhibits a damping force (with the voice coil circuit open) of $b_1 = 3$ N·s/m.



A diagram of the geophone is shown above. A permanent magnet of mass $m_g = 0.01$ kg is coupled to the housing by a spring of stiffness $k_g = 81$ N/m and open-circuit damping coefficient $b_g = 0.37$ N·m/s. The permanent magnet m_g and geophone coils interact with a foce (and back emf) constant $K_g = 42$ N/A. Above the natural frequency of the geophone mass m_g on the spring k_g, the geophone produces a voltage approximately equal to the velocity of its housing.

Because the mass m_2 of the permanent magnet in the geophone is small compared to the mass m_1 of the platform, we can make the approximation that the system behaves as indicated in the block diagram below, where G_c is the compensator transfer function and d is a disturbance signal.



1. Show that the transfer function from controller output u to platform velocity $\dot{x}_1$ is

$$\frac{\dot{x}_1}{u} = G_1 = \frac{(2K_f/R_v)s}{m_1 s^2 + (b_1 + K_f^2/R_v)s + k_1} \tag{1}$$

2. Show that the transfer function from platform velocity $\dot{x}_1$ to geophone output voltage v_g is

$$\frac{v_g}{\dot{x}_1} = G_2 = \frac{K_g m_g s^2}{m_g s^2 + b_g s + k_g} \tag{2}$$

3. Use Matlab to make a pole-zero diagram, Bode plot, and Nyquist diagram of the plant transfer function

$$\frac{v_g}{u} = G_1 G_2 \tag{3}$$

4. This system will have two crossover frequencies. We wish to design for a low-frequency crossover of 2 Hz or lower, wile maintaining a phase margin of at least 25 degrees at both the high-frequency and low-frequency crossovers. We have chosen to use a double lag compensator with the transfer function

$$K\left(\frac{Ts+1}{\alpha Ts+1}\right)^2 \tag{4}$$

   Please choose the design parameters to obtain the desired crossover specification.

5. Make Bode plots of the return ratio and the closed-loop response v_g/d.