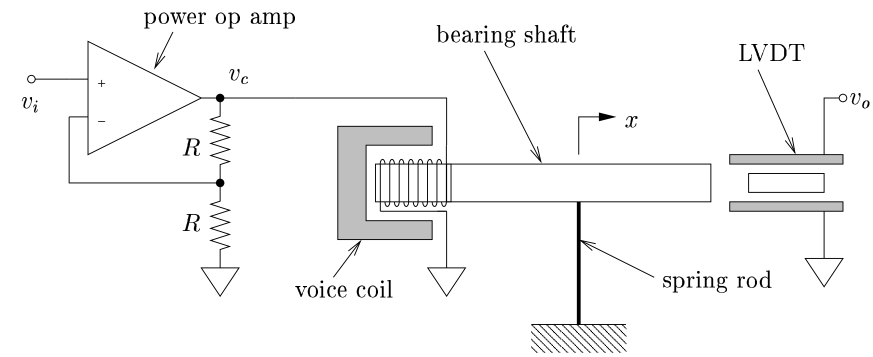


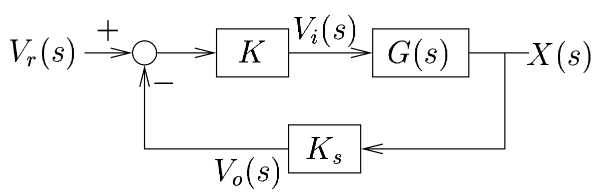
In this lab, we will use feedback to control the position of the second-order mechanical system that we studied in Labs 3 and 4. The spring rod has a stiffness k of 1.3 N/cm, the total moving mass m is 0.85 kg, and the LVDT has a gain K_s of 5 V/cm. The voice coil has a force constant K_f of 8.8 N/A and its coils have a resistance R_c of 5.5 Ω.

1. Assuming that the power op amp has a large constant gain, show that the voltage v_c at the input to the voice coil is given by $2v_i$.

2. Derive an expression for the transfer function $G(s)$ relating the input v_i of the power op amp to the position x of the bearing shaft. Be sure to write the full expression for $G(s)$ in terms of k, m, and so on before plugging in the numerical values.

3. Where are the poles and zeros of the system? Make an accurate sketch of the step response.

4. Design an op-amp circuit that can be used to obtain the block diagram shown below, where the constant gain K is set by adjusting resistances and the op-amp gain is modeled as a large constant.



In this system, v_r is an input "reference" voltage and v_o is the output voltage of the LVDT. The block $G(s)$ is the transfer function from v_i to x that was derived in Problem 1.

5. Make an s-plane plot showing how the poles of the system move as the gain K varies from 1 to 100.

6. Design an op-amp circuit that can be used to obtain the block diagram shown below, where K, α, and τ are set by adjusting values of resistors and capacitors. Take the op amp gain to be a large constant.