Lab 6: Magnetic Levitation Controller II

In the previous lab we obtained a linearized model for the magnetic levitation system. The model clearly indicated that the system is open-loop unstable and cannot be stabilized by a simple feedback gain (K). In this lab, we will design a feedback controller to stabilize this system. The following figure shows the block diagram of the controller.

![Block diagram of controller](image)

Figure 1 Controller block diagram

In Figure 1, the term Yo is the term that cancels the offset in the position signal y. In other words, the signal δy is zero if the ball is at the zero position (about 6mm from the base of the magnet). The term Io is the gravitational force cancellation term. This term is added to the compensator output (δi) so that the net force acting on the ball (at the zero position) is due to δi only. Both Yo and Io terms are the "offset" term and should not be included in the model. The term Ka represents the gain of the current power amplifier.

Figure 2 is an operational amplifier circuit realization of the block diagram (except the current amplifier).
Pre-Lab:

(1) Plot the Nyquist plot of the linearized model transfer function \( G(s) \). Based on the plot, explain why a lead compensator should be used to stabilize the system rather than a lag compensator.

(2) From Figure 1 it is easy to see that the DC gain of the transfer function of the compensator (including current amplifier) is \( K_p K_a \) where \( K_a \) is 1 (Amp/V). For the data obtained from Lab 4, determine the value of \( K_p \) so that the controller generates 1 Amp output for 1mm position error (i.e., ball displacement).

(3) Plot the Bode plot of the transfer function \( K_p K_a G(s) \) using the value of \( K_p \) determined in (2).

(4) Determine the cross over frequency and then find the transfer functions for two lead compensators so that the phase margins are 45 and 60 degrees.

(5) Determine two sets of values of \( R_1, R_2, \) and \( C \) in Figure 2 so that the transfer function of the circuit is \( K_p C(s) \) where \( C(s) \) represents the lead compensator transfer functions obtained in (4).

In-Lab Procedure:

(1) Verify that the gain of the current power amplifier \( K_a \) is 1 (Amp/V).

(2) Construct the circuit using the component values determined in (5) above for 45 degree phase margin.

(3) To set the value of \( Y_0 \), place the ball at the zero position and set \( V_R1 \) until the output of the first amplifier (\( y_1 \)) reads zero volts.

(4) To set \( I_o \), remove \( R_3 \) (10k resistor). Place the ball at the zero position and set \( V_R2 \) until the force reading reaches zero.

(5) Install \( R_3 \) in the circuit and place the ball at the zero position. Slowly remove the support. The ball should be levitated by the magnet at this point.

(6) Use a scope to monitor the voltage \( y_1 \). Record the system’s response to an impulse disturbance. The impulse disturbance input can be simulated by lightly taping the ball.

(7) Replace \( R_1, R_2, \) and \( C \) with the values that give 60 degree phase margin. Repeat step 6.