1 DC Motor Calibration

1.1 Introduction

The output of the DC-motor system in the lab is the angle $\theta$ of its shaft. This angle is measured by a potentiometer. This potentiometer has a gain of $g_p$ and an offset of $o_p$.

\[ v = o_p + g_p \cdot \theta. \]

That is, $v = o_p + g_p \cdot \theta$.

The values of $g_p$ and $o_p$ are related to the voltage of the internal power supply and mechanical coupling. To have a correct value of $\theta$ for control purposes, you have to compensate for the effect of the potentiometer.

\[ K_0 = \frac{\theta_2 v_1 - \theta_1 v_2}{\theta_1 - \theta_2} \]
\[ K_3 = \frac{\theta_1 - \theta_2}{v_1 - v_2}. \]
1.2 Potentiometer Calibration Procedure

Note: Please do not attempt to connect the ribbon cable from the bench-top interface board to the computer. If the ribbon is disconnected, please ask your TA to connect it.

1. Supply the potentiometer with a voltage of +12V and −12V. Disconnect the motor wiring, or apply a zero voltage to the D/A so that the motor does not move. Connect the output of the potentiometer to an A/D channel (Channel 0 is recommended since it is a default channel).

2. In Matlab, open init.m and run it to initialize the variables. Then open control.mdl and build it by choosing build under WinCon in the Simulink pull down menu.

3. If there is no error, a WinCon server will be launched automatically and you can choose values or signals to view from this server. Open the subsystem Calibrator Solver. Go to WinCon and select the four display signals showing K_0, K_3, Voltage, and Angle. Then start the program by pushing the Start button. Now you should be able to read a reasonable voltage value from the A/D when you move the shaft of the potentiometer.

4. Move the shaft to a specific angle, say +60 degrees. Then set the value of Theta1 inside the calibrator block to the same value you have set physically. Then apply a rising edge at Set1 by forcing it to zero and then forcing it to one. At this point, you have latched the information for one of the calibration points.

5. Move the shaft to another angle, say −60 degrees. Then set the value of Theta2 inside the calibrator block to the same physical value and apply a rising edge signal to Set2 to latch the information of the second point for calibration.

6. Now you can observe the appropriate values for K_0 and K_3 inside the display boxes. To confirm that these values are correct, you must observe the same physical angle of the shaft in the Angle display box when you move the rotor. Record the value of K_0 and K_3 right away to use for your next experiments. These values must be updated in the workspace. To do so, stop WinCon, copy these numbers in the init.m file, and run init.m to update the workspace. Keep in mind that this recording will not be done automatically and if you lose this information, you have to calibrate the potentiometer again.

2 DC Motor Model Identification

In this experiment, you will identify the parameters of a servomotor system, i.e. compute the numerical values for the two parameters K_p and T that completely characterize the system. These values will be used for control design.

2.1 Preparation

The servomotor system is given as follows:
1. Let the controller \( C(s) \) in the figure above be a positive gain: \( C(s) = K \). Write down the closed-loop transfer function \( G(s) = \frac{Y(s)}{R(s)} \) in terms of \( K, K_p, \) and \( T \).

2. Since \( K_p \) and \( T \) are positive constants, \( G(s) \) is a stable second-order system with no zeros. It can in fact be written in the form \( G(s) = \frac{G_0\omega_n^2}{s^2 + 2\delta\omega_n s + \omega_n^2} \) for positive constants \( G_0, \delta, \) and \( \omega_n \). Determine the relationship between the triple \((\delta, \omega_n, G_0)\) and \((K, K_p, T)\).

3. Suppose that the damping ratio \( \delta \) for the closed loop servomotor system is less than 1 (for a certain value of \( K \)). Given a step response, we know how to compute \( \omega_n \) and \( \delta \) from the maximum overshoot and peak time. Combined with the results from Step 2, you can determine the values of \( K_p \) and \( T \) from the step response. Write down the formulas for \( K_p \) and \( T \). You can also show the details of the step response on a plot.

4. Sketch a root locus of \( G(s) \) as a function of \( K > 0 \), for fixed, positive values of \( K_p \) and \( T \). What happens to the poles of the closed-loop system as \( K \) is increased from 0?

5. Read the Laboratory Procedure so that you will know what to do before coming to the lab.

### 2.2 Laboratory Procedure

Note: Please do not attempt to connect the ribbon cable from the bench-top interface board to the computer. If the ribbon is disconnected, please ask your TA to connect it.

1. Modify your control.mdl file such that the controller of the DC motor be a simple gain \( K \).

2. Build and run your control.mdl simulink file to close the control loop. (You should have already calibrated the potentiometer and your \( K_0 \) and \( K_3 \) parameters must be valid in the workspace.).

3. Experimentally determine a value of \( K > 0 \) (beginning from a small value such as 0.01) for which the step response has a percent overshoot of approximately 40% and collect the data. Because each of the servomotors has a different amount of inertia, gain \( K \) will differ from each servomotor to another. (Don’t copy your neighbor’s values!).

4. Plot the step response data collected in Step 3 into Matlab and determine \( \omega_n \) and \( \delta \), by measuring the peak time and percentage overshoot from your graph. Then determine the physical values of \( K_p \) and \( T \). Do a good job here, because your measurements will be used in subsequent labs, and your numbers are unique to your workstation. Save the collected data from your Simulink model in your workspace.

5. Plot the simulated response of \( G(s) \) for the identified values of \( \omega_n \) and \( \delta \) on the same axes that you have plotted the experimental data and keep the plot for your report. The two plots should be close to one another (see the figure below).
2.3 Questions

1. Why use a value of $K$ that gives an overshoot of 40%? Can other values work? What if you use a value of $K$ so that the closed-loop system is over-damped? What if you use a value that gives 100% overshoot?

2. What are some of the reasons for the discrepancy between the measured step response and the simulated one? For example, there is static friction in the motor, which is not modelled by the second order system. Why and how does static friction make the responses differ?

2.4 Report

Please refer to the Lab 1 report format template for your write-up.