

ECE411 Lab 3

1 Objectives

The primary objectives of this lab are:

- Identifying changes in system properties versus their observed response.
- Understanding the connection between open-loop and closed-loop response.
- Familiarize the student with the correlating real world data with modeling and simulation.

2 Setup of the ECP lab Station.

2.1 Safety

Familiarize yourself with section 2.3 Safety in the blue user's manual (pages 34-36).

2.2 The Setup for the Model 220 Servo Trainer Lab Station (Motor Gear Drive System)

Start the ECP program by finding the ECP32 icon on the Start/Programs menu on the Desktop.

Turn on power to the ECP lab station.

Under Setup, select the User Units to be counts

Use the Setup menu to locate and select Control Algorithm. When Algorithm is selected, select the following:

Set control Algorithm to:

Type=Continuous Time

Control Algorithm=PID

Click on Setup Algorithm and set the constants $K_d=0.0$, $K_i=0.0$.

In this laboratory we will be seeing the effect of varying the gain K_p . You can start with $K_p=0.05$ (the value we used in Lab 2).

Select feedback to be from Encoder 1 and click OK

Select Implement Algorithm. This will load the algorithm into the ECP work station.

Click OK to close window

Select Trajectory from the Command menu.

Select a Step input as the reference input to the system. Setup the Step Size to 4000 counts with a Dwell time of 2000 msec. Number of repetitions is 1. It will be a closed loop step. Click OK to close the window. Click OK to exit Trajectory settings.

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2.3 Setting up the Plots

Select Data and Setup Data Acquisition from the menu. Use the Add Item buttons to add items to the plot. Choose the Commanded Position and Encoder 1 Position. Set the sample period to 2 Servo cycles. Click OK

Under Plotting, select Setup Plot. Using the Add to Left Axis button, select the Commanded Position and the Encoder 1 Position. Click OK.

Note that later you can use Axis Scaling to zoom in and out on given portions of the plot for more accurate data recording.

2.4 Initializing the Lab Station

Under Utility, select Zero Position.

2.5 Running the Control

Choose Command, Execute (select Normal Data Sampling, if not checked), Run.

Plot the data using the Plotting menu. Include this plot with your report.

Measure the height of the first overshoot compared to the steady state value.

Calculate Percentage overshoot _____%.

You should see a damped oscillation in the step response. Measure the time period between successive overshoots and record. Convert this value to frequency:

Time between successive overshoots _____ seconds, equates to a frequency of ____Hz, or ____rad/s.

3 Varying the Controller Gain and Analyzing the Closed-Loop System

In lab2 we considered the (open-loop) DC servomotor model developed in class which is of the form:

$$G(s) = \frac{Y(s)}{U(s)} = \frac{K_{mot}}{s(s+a)}$$

For some open-loop plant parameters K_{mot} and a . We identified those open-loop parameters and you should have developed a model similar to (here $K_{mot} = 1710$ and $a = 2.2$):

$$G(s) = \frac{Y(s)}{U(s)} = \frac{1710}{s(s+2.2)}$$

Note – these are just approximate example numbers, but should be pretty close to what you obtained in lab 2. For the rest of this lab please use the model results (K_{mot} and a) you developed in lab 2. The closed loop plant can now be calculated as

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$$M(s) = \frac{Y(s)}{R(s)} = \frac{K_p G(s)}{1 + K_p G(s)} = \frac{K_p K_{mot}}{s^2 + as + K_p K_{mot}} = \frac{85.5}{s^2 + 2.2s + 85.5} = \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$$

for controller gain K_P and some values of the closed-loop parameters ζ and ω_n (here we used $K_P=0.05$ and for these example numbers you would obtain $\zeta = 0.12$ and $\omega_n = 9.2\text{rad/s}$).

Note that the damping ratio ζ and natural frequency ω_n determine the overshoot and frequency of oscillation of the closed-loop system step response via the formulae:

$$\%MaxOvershoot = 100e^{\frac{-\pi\zeta}{\sqrt{1-\zeta^2}}}$$

$$\omega_d = \omega_n \sqrt{1-\zeta^2}$$

For example the numbers above would yield 68% overshoot and a damped oscillation at $\omega_d = 9.1\text{rad/s}$ in the closed-loop system step response.

You now have a mathematical model of both the open-loop ($G(s)$) and closed-loop ($M(s)$) systems (developed in lab 2), with the ability to predict the system performance (step response). You can also easily modify the Simulink model you developed in lab 1 to simulate the system for any choice of parameter values, and furthermore you can implement any desired value of the controller gain K_P on the actual experimental ECP system.

Use these tools to perform the following controller design studies. In each case you consider the closed-loop system step response and give the results from:

- Analytic predictions for overshoot and oscillation (i.e., using the formulae given above)
 - Simulation response (using your Simulink model)
 - Actual experimental data (using the ECP system)
- i) Consider the closed-loop system step response for K_P varying between 0.01 and 0.1 (examine several values in this range). Describe what is happening to the closed-loop response as the controller gain varies.
 - ii) Design a controller K_P to achieve overshoots of:
 - a. 75%
 - b. 50%
 - c. 20%
 - d. 5%

Describe how well the designs perform in simulation and on the actual ECP system.
 - iii) Design a controller to achieve critical damping. How well does this design perform on the ECP system? Would you consider it an acceptable design?
 - iv) The analysis and simulation models for all of the above designs should predict zero steady state error (note that $M(0)=1$ for any choice of parameter values). Does that match what you see on the actual ECP system? Can you think why?
 - v) All of the above designs utilize simple proportional control. Do you think any of them have yielded good closed-loop performance? In the class we will learn how to design dynamic controllers (i.e., the controller itself has a transfer function description). As an example implement a true PID controller with PID controller gains of $K_P=1.0$, $K_I=0.1$, $K_D=0.02$ and comment on the results (compare to proportional control).

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4 Remember To Turn Off Power To ECP Box When Finished.

Note: You may want to save the setup of the ECP controller to your network drive.

5 Writing the Report.

Please include the items listed above. Label each item, and number each item (including commentaries) according to its section.