ECE411 Lab 2

1 Objectives

The primary objectives of this lab are:

- Familiarize you with the general setup of the ECP lab stations.
- Familiarize you with correlating real world data with modeling and simulation.

2 Getting Familiar with the General 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 Kp=0.05 Kd=0.0, Ki=0.0.

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 Plot

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.

2.6 Frequency Sweep

Set the PID parameters to Kp=1, Kd=0.005. Set the trajectory for a sine sweep between 5 and 20 Hz, over a 30 second timespan, with an amplitude of 50 counts. This should be a closed loop linear sweep. Plot the encoder 1data with linear time along the horizontal axis and linear amplitude along the vertical axis. Does what you're seeing make any sense to you? Now replot the data with linear frequency along the horizontal axis and linear amplitude along the vertical axis. Does this make more sense? OK, now plot the magnitude in dB along the vertical axis and logarithmic frequency along the x-axis (include this plot only). Explain what you're seeing in terms of the system.

2.7 Adjusting Parameters

Use a step trajectory as originally set up. Make the PID parameters Kp=0.2 and Kd=0.005. Run the step response and examine a plot of the commanded position and the encoder 1 output.

Now adjust Ki to 0.5 and re-run the step (don't forget to re-implement the algorithm). Examine a plot of the commanded position and the encoder 1 output.

Can you explain the difference you see between the steady state values of the system for the controller with and without the Ki gain term?

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2.8 Experiment with Control Parameters

Try adjusting the control parameters Kp, Ki, and Kd and observe the response to a step input. Include at least two plots with the reports, and state the Kp, Ki, and Kd values with the graph. Hint: don't make the changes too huge, or you'll exceed the system limits and will have to restart the controller. There should be a visible change in the system output response though.

3 Taking Data and Analysis

Use the results you measured in section 2.5 to do the analysis in this section, nothing that all formulae presented here assume that frequencies are in rad/s (not Hz). Note that we showed in class that the open-loop **plant** (motor gear drive, which is a DC servomotor) has a transfer function 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. If you apply a constant gain controller with constant gain Kp (note the PID controller with Ki=Kd=0 is just constant gain), then the total (closed-loop) system can be written in the general form:

$$M(s) = \frac{Y(s)}{R(s)} = \frac{K\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$$

for some values of the closed-loop parameters K, ζ, and ω_n (to see this, just calculate M(s) from G(s)). In particular you should note right away that here K=1. The parameter ζ is referred to as the damping ratio. We will show in class that for the closed loop step response, the damping ratio ζ obeys the following relationship:

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

The "%MaxOvershoot" is the peak of the first overshoot compared to the steady state value. Hence you can use the measured overshoot to solve for ζ. Note that the equation you derive for ζ from the above can be solved explicitly as a quadratic (where you choose the positive real root for stability), or you can solve it numerically using Matlab tools (e.g., fsolve).

The parameter ω_n is referred to as the natural frequency of the system. The closed loop step response shows a damped oscillation at a frequency we will call ω_d. We will show in class that this ω_d is related to the natural frequency ω_n of the system by the following equation:

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

Note that you have already calculated ω_d from the measured step response in section 2.5, and you have just calculated ζ from the previous formula. Hence you can now solve for the natural frequency ω_n. This means that you now know all the parameters K, ζ, and ω_n, and so you know the closed loop transfer function M(s). Knowing this, you can compare coefficients to solve for the open-loop parameters K_{mot} and a, and hence you have now identified the open loop plant model G(s).

Include your work showing your calculation of the overall system transfer function, with a proportional gain controller, Kp.

Calculate values for ω_n , K, ζ, K_{mot}, a from your measured data and include them, together with G(s) and M(s), in the report.

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4 Modeling the Lab in Matlab

Build a model of the system in Matlab Simulink using the parameters you have calculated. Note: this will be a modification of the simulink model you built in Lab 1. Run simulations of the model using the same step inputs and Kp parameters as in this lab. Use matlab to perform a frequency sweep of your model using the same settings as this lab system. Plot the frequency magnitude (dB) versus frequency and compare to your experimental results.

Compare the results from the physical system and comment on any similarities or differences (and their reasons) for both the step input and the frequency sweep.

Include in your report, a copy of your model, and the response of the model to a step and sine sweep.

5 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.

6 Writing the Report.

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

Can you give a brief explanation for the use of a step response or a frequency sweep on an unknown (unmodeled) system?