ECE411 Lab 4

1 Objectives

The primary objectives of this lab are:

- Correlating system response with system model/properties.
- Identifying changes in system properties versus their observed response.
- Giving the student a “hands-on feel” for adjusting PID parameters on a real system.
- Qualitative controller design (trial and error).

2 Safety

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

3 Model 205 Torsional Control Station

The Model 205 Torsional Control Station is controlled by the same ECP32 software as the Model 220 Servo Trainer Lab Station, with which you are already familiar. This station is essentially a rotational mass-spring-damper system with very little damping. Consisting of multiple masses and springs, it allows for more complex dynamics than the Servo Motor Station. In particular the lightly damped system allows for complex conjugate poles and zeros, with associated oscillatory response. Here you will explore the system response.

Start the ECP32 software (before turning the power on to the ECP Box). Load the provided **torsyspar.cfg** file via *File, Load Settings* (this file is located in C:\torsys, and also provided for download on the class webpage). This puts all the correct system settings into the ECP32 software and loads a stabilizing controller. Implement this default controller and set the trajectory to a (closed-loop) logarithmic frequency sweep between 1 Hz and 15 Hz over a time period of 30 seconds, with an amplitude of 250 counts. Perform the frequency sweep and observe the motion of the middle disk during the sweep. Now look at the amplitude versus frequency plot for the middle disk (encoder 2).

<u>Give an explanation for what you saw in terms of the system (consider the transfer function poles and zeros).</u>

<u>One of the following transfer functions models the relationship between the input and the output motion of the middle disk. Can you decide which one it is and explain why?</u>

$$\frac{\Theta(s)}{X(s)} = \frac{0.03372}{0.00000748s^4 + 0.0000795^3 + 0.03364s^2 + 0.173s + 13.92}$$

Figure 1: Transfer Function A

$$\frac{\Theta(s)}{X(s)} = \frac{0.038s^2 + 0.2144s + 120}{0.000007481s^4 + 0.0000795^3 + 0.03364s^2 + 0.173s + 13.92}$$

Figure 2: Transfer Function B

Don’t forget to turn off the ECP Box, and then the ECP32 software when you’re done.

ECE411 Lab 4

4 Model 220 Servo Trainer Lab Station

4.1 Experimenting with the Simulink Model

Note that in work to this point you have built a Matlab/Simulink simulation model of the closed-loop servo motor system with PID controller, looking something like Figure 3 below:

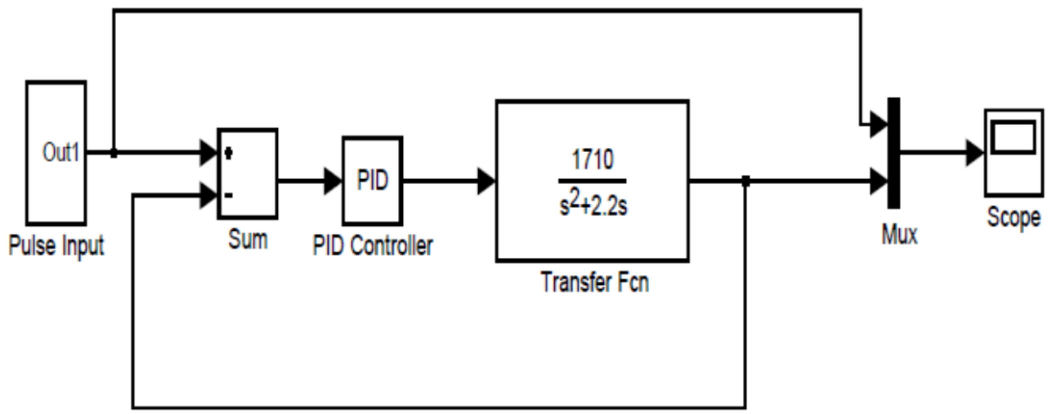

Figure 3: Simulink Simulation Model for Closed Loop Servo Control System

Note that the open-loop servo motor has a transfer function of the form:

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

Figure 4: Open Loop Plant Transfer Function

and the PID controller is of the form:

$$K_{PID}(s) = K_P + \frac{K_I}{s} + K_D s$$

Figure 5: PID Controller

where the gains KP, KI, KD are to be chosen by the controller designer.

Experiment with the PID controller gains in your Simulink model. Try to manually tune the controller for “optimal” settings (in your opinion) for each of the following types of controllers: P, PI, PD, PID. *Note that in order to remove any parameter from the control system, simply set its gain to zero, i.e., to make a PD controller, tune KI to zero.* Record your settings for comparison with the actual servo motor settings.

ECE411 Lab 4

4.2 Experimenting with the ECP Servo Motor

Now try experimenting with the PID controller gains in the actual ECP servo motor (you can be guided to good starting points by your studies with the simulation model). Try to manually tune the controller for "optimal" settings (in your opinion) for each of the following types of controllers: P, PI, PD, PID. Compare to your earlier settings for the simulation model.

Include relevant plots of your controller designs in both simulation and experiment. You should of course show step responses but you should also experiment with other types of inputs (e.g., sine sweeps).

5 Questions on Your Experimentation

1. Describe the process of creating a control input to the servo motor from the point where the feedback goes to the summing junction (see Figure 3). Address each term P, I, D in terms of the *error*. Use mathematical descriptions as appropriate (e.g., what does the integration term actually do?).

2. Give an explanation of the role of each of the P, I, and D terms for maintaining the stability and performance of the system. Relate the root locus plot for the plant (see the transfer functions in figures 4 and 5) to your explanation.

3. Were the optimal settings similar between the model and the actual device? What are some physical items that could cause a difference?

4. Comment on the effectiveness of the P, PI, PD, and PID controllers in this application.

5. Comment on the response of the controllers as the frequency/speed of the set point signal (to be tracked) increases. Specifically, look at tracking sine waves at various frequencies.

6. Why would an engineer use one particular type of controller over another?

6 Writing the Report

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