Lab 2: FIRST-ORDER SYSTEM RESPONSE

Section 1 -- Background Information

This lab will introduce the ECP Model 205 Torsion Control Plant. The plant essentially consists of a motor-driven weighted disk that can be rotated in either direction. An incremental encoder is attached to the weighted-disk to measure its position as it rotates. Figure 1 shows a Simulink model for the weighted disk and motor. Through experiment, the parameters for the model will be estimated.
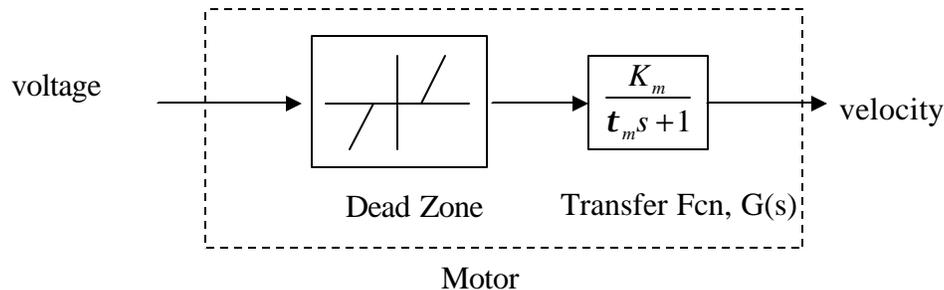

Figure 1. Simulink model of control plant.

Section 2 – Procedure

2.1 Setup of Control Plant
2.1.1 Logon.
a. Turn on the computer and log on to your NPS account.
b. Start the ECP Program. The shortcut is in the SERVO LAB APPS folder on the Windows desktop.

2.1.2 Record the ECP Station Number. Note that different stations will have different system characteristics.
ECP Station Number:_____

2.1.3 Configure the Mechanical Control plant as follows:
a. Single disk on the bottom encoder (encoder #1).
b. Two weights connected to the disk, mounted 180 degrees apart. The outside edge of the weight should be tangent to the 9-cm line (last line on disk). Weights are connected to the disk by the 3/16" hex screw and nut. Screw goes through the top of the weight; nut is placed on the bottom side of the disk in the slot. The nut has a flat and rounded side. Flat side goes towards the bottom of disk. Slot holds the nut from rotating. An access hole located on the front of the plant under the bottom disk can be used to hold the nut in place while assembling.
c. Middle and upper disks are NOT assembled into system at this time.
d. Ensure the bottom disk is securely fastened to the system and the weights are securely fastened to the bottom disk. The disk will be rotated at potentially high speeds in this experiment. It is important that the weights or disks do not come apart. For proper operation ensure that the disk can rotate by hand prior to energizing the control system. Two (2) weights must be at 180 degrees otherwise the system will be unbalanced.

2.1.4 Energize the control system by pushing the "ON" button on the ECP controller. The controller is the black and white box located next to the torsion control plant.

WARNING
The system is now energized and will rotate at potentially high speeds when a
control voltage is applied to the motor of the torsion system. At any point the motion

of the system can be stopped by pressing the OFF (red) button on the ECP controller box.

2.2 Determine the Dead Zone

A voltage that is applied to the motor will not result in motor rotation if the voltage is not of sufficient magnitude to overcome the plant's friction. The Dead Zone in the Simulink model accounts for the friction that exists in the real plant. In this part of the procedure, the student will seek an estimate of this dead zone voltage, V_{DZ}. To determine V_{DZ}, a voltage sufficient to cause rotation will be applied to the motor and its final velocity will be noted. The voltage will be reduced incrementally, noting the final velocity at each step. Continue reducing the applied voltage and recording the motor velocity until the point that the applied voltage does not cause the motor to rotate. Make a plot of these data similar to Figure 2. Extrapolate the data by a straight line through to the horizontal axis and note this voltage value. This will be V_{DZ} that is to be used in the Simulink model, which will be constructed in Lab 3.
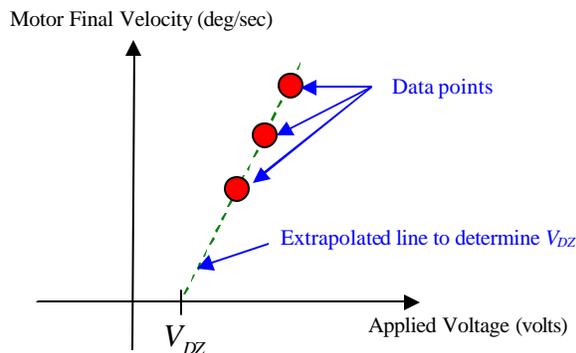

Figure 2. Data points and extrapolated line used to estimate V_{DZ}

2.2.1 Start the ECP software program. Setup the ECP program to run the motor as follows:
a. Click on Setup→User Units, select degrees
b. Select Setup→Control Algorithm. Select Continuous Time. Click OK.
c. Select Data→ Setup Data Acquisition
- Sample Period (servo cycles) = 10
- Selected Items should be Commanded Position and Encoder 1 Position
- Click OK
d. Select Command→Trajectory
- Select Impulse and Unidirectional moves. Click Setup.
- Select Open Loop Impulse and set Amplitude (volts)=0.2; Pulse width (msec) = 10,000; Reps = 5; Dwell Time (msec)= 0;
e. Reset encoders to zero (Utility → Zero Position)

f. Select Command → Execute, Normal Data Sampling. Click Run to load and execute the program. Disk should move and data is recorded. With the trajectory set up as described above, the ECP controller will apply 0.2 volts to the DC motor for 10,000 msec (or 10 sec). Since the Dwell Time was set to zero, the applied voltage does not turn off, and the signal is repeated four more times.   So the voltage that is applied to the motor is essentially 0.2 volts for 50 seconds.

g. Observe that the motor rotates for 50 seconds and achieves some final velocity. If the motor does not run for the full 50 seconds, then the ECP software likely detected an overspeed condition and shut off the applied motor voltage. Reduce the applied voltage by 0.01 volts and repeat as necessary to achieve the full 50 seconds.

h. Plot Data: Select Plotting → Setup Plot.
   1. For the left axis chose Encoder 1 Velocity, and for the right axis choose Encoder 1 Position. Select Plot Data.
   2. Note the final velocity achieved by the motor. You can read it off the plot or you can select Plotting→Axis Scaling to see the range of data values.

2.2.2 Reduce the applied voltage by 0.01 volts and repeat steps 2.2.1d through 2.2.1h. Each time note the final velocity achieved by the motor. Continue until the voltage does not cause the motor to rotate is encountered.

2.2.3 Make a plot of your data similar to the one shown in Figure 2. Extrapolate a line from the data points to estimate the value of V_{DZ}.

2.3 Determine the Parameters for the Transfer Function
In this portion of the procedure, the student will determine the parameters for the Transfer Function (K_m and t_m) that will be used in the Simulink model. The plots generated in step 2.2.1h (velocity vs. time) are examples of a first-order system response. From a plot such as these, we can determine the values of K_m and t_m needed for the Simulink model.

2.3.1 Repeat steps 2.2.1d – f. Use the first voltage value you encountered that did not produce an overspeed condition. The motor should run for the entire 50 seconds so that a constant steady state velocity is achieved. Plot the data to verify that the motor achieved some steady final value.

2.3.2 Save the Data: Select Data→Export Raw Data. Save the data in your home directory (drive H:\). Be sure to use the *.txt extension. You can view the data with the Notepad utility. Also, before importing into Matlab, you'll need to delete the column headings at the first row of the data file, as well as the square brackets in the beginning and end of the file. Bring this data into Matlab for plotting and analysis using the **load** command. Note: Output data are encoder counts, and only for Commanded Position and Encoder 1 Position. Velocity data will need to be calculated from the position and time data. The calculation of velocity will need to include a conversion from encoder counts to degrees/sec. There are 16,000 encoder counts per 360 degrees revolution. Time is provided in seconds.

2.3.3 From the velocity plot, determine the first-order transfer function for the single disk system, namely K_m and t_m. Use the attached table to record some time and velocity data points from your plot. Using these data, you can calculate t_m with Equation 3 in the Notes section of the procedure. The Notes also show how to calculate K_m. You will need to take into account the amplitude of the step input used in step 2.3.1 of this procedure and V_{DZ}, which was determined earlier.

Section 3 -- Report

Submit a report in a format and with content similar to that of Lab 1. In the Introduction also discuss relevant theory that was presented and explored during the lab. In the Results and Analysis section show your calculations for the parameters of the first-order transfer function, as well as the Matlab velocity plot. Include the attached table as a cover for your report.

Finally, discuss the main points of the lab in the Conclusion of the report. Include any significant findings and recommendations you may have.

TEST DATA SUMMARY

Team Members: _____

                                     _____

                                     _____

                                     _____

Test Station Information	
ECP Station Number:	
Configuration:	
Number and location of disks	
Number and location of weights	

Test Data Summary		
Applied Voltage, V_A =		Final Velocity, $y(\infty)$ =
From Matlab Data Plot		Equation 3
Time	Velocity	Time Constant (calculated)

Test Data Results:

      Dead Zone Voltage, V_{DZ} =   _____

      Time Constant, t_m =   _____   average of all calculated

      Gain, K_m =   _____   computed from $y(\infty)$/A

      Transfer Function, G(s) =

Notes for Lab 2

The trasnfer function for the first-order system has the form

$$G(s) = \frac{K_m}{t_m s + 1}$$

where K_m is a constant and t_m is the system time constant, both of which will be determined from the experimental data. The time constant is defined as the time required for the system to reach 63% of its final value.
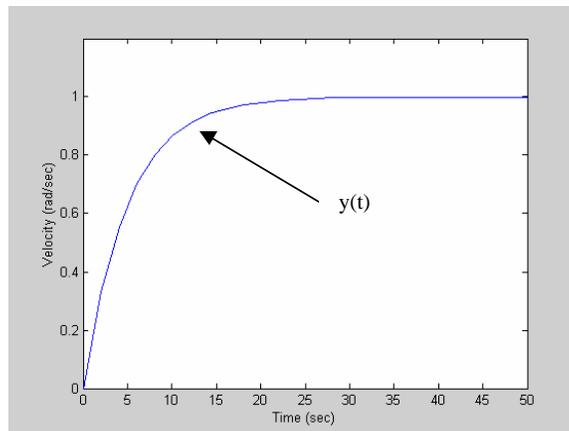
If the input to the system is a step function, U(s) with amplitude A, then the system response is given by

$$Y(s) = G(s) \cdot U(s) = \frac{K_m}{t_m s + 1} \cdot \frac{A}{s}$$

In the time domain, the system response is

$$y(t) = K_m A (1 - e^{-t/t_m}) \qquad\qquad \text{Equation 1}$$

and is shown in the figure.

By setting t = ∞ in Equation 1 and solving for K_m we have

$$K_m = \frac{y(\infty)}{A} \qquad\qquad \text{Equation 2}$$

where $A = V_A - V_{DZ}$, and $y(\infty)$ is the final velocity achieved by the motor. In our lab procedure, V_A is the applied motor voltage and V_{DZ} is the dead zone voltage. Substituting Equation 2 into Equation 1 and solving for t_m gives

$$t_m = -\frac{t}{\ln\left[1 - \frac{y(t)}{y(\infty)}\right]} \qquad\qquad \text{Equation 3}$$

Use the equation above and pick several samples of t and $y(t)$ from your measured data to calculate values for the time constant. Choose samples that lie along the transitional portion of the curve before the response settles to its final value. Average your calculated values of the time constant to get a more accurate reading for the time constant.

Lab 2r6.doc, 29 March 2006