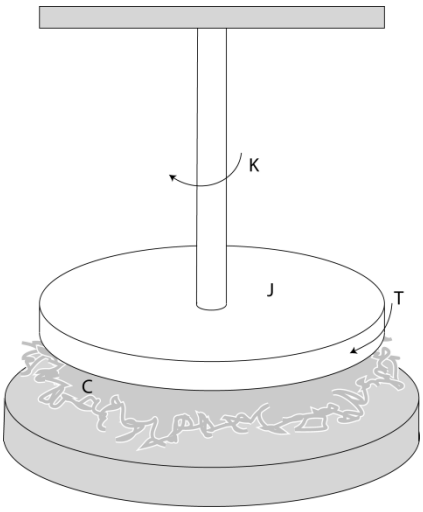
ECE-320 Lab 2
System Identification and Model Matching Control of a 1 dof Torsional System

In this lab you will be modeling and controlling a one degree of freedom torsional system. You will again fit the parameters of a transfer function model of your system using time-domain analysis and frequency domain analysis. We will utilize these models in later labs so do a good job in this lab, your results in later labs will be affected by how well you perform in this lab.

A one degree of freedom torsional mass-spring-damper system



can be modeled as

$$G(s) = \frac{K}{\frac{1}{\omega_n^2}s^2 + \frac{2\zeta}{\omega_n}s + 1}$$

Here K is the static gain, ω_n is the natural frequency, and ζ is the damping ratio. These are the parameters we need to determine to match the model to your system.

*You will need to copy and unzip all of the files from **Lab2 files.rar** from the class website and put the new files in the same folder you used for Lab1.*

*Your memo should include a detailed descriptions of your system (so you can set them up again), the name of your model file, a **table** comparing the estimated values of K, ω_n and ζ using the time domain and frequency domain estimates, and a brief comparison of the values. The damping ratios are often quite different, so that's OK. The other values should be close. You should include as attachments 6 graphs (log-decrement and frequency response graphs for the torsional system, and four model matching results), each with a Figure number and caption. You should also include the data used for estimating the static gain. However, do not include the data for constructing the Bode plot.*

Part A: Time Domain Modelling of a One degree of Freedom System

Step 1: Set Up the System. Only the first disk should move, the second disk should be fixed in place. You need to have at least two masses on the disk, located in a symmetrical way about the torsional spring. ***Be sure you write down all of the information you need to duplicate this configuration. You need to fill out the data sheet***

indicating each configuration on the last page of the lab and turn it in! You also need to include this information in your memo.

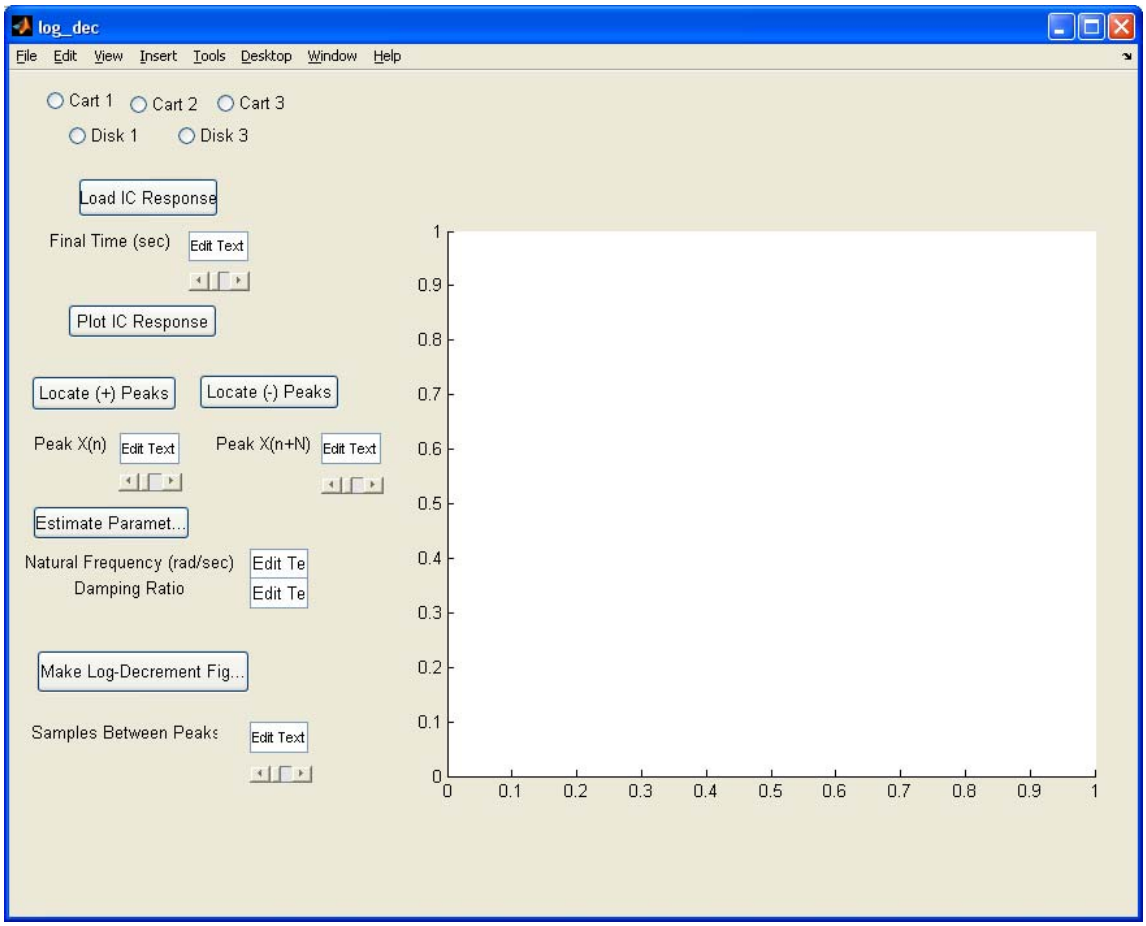
Step 2: Preparing to Use the ECP System with Simulink. Be sure the connector box (black and gray box on the top of the shelf) is off before connecting the system. *Do not force the connectors. If they don't seem to fit, ask for help!*

- Read the file **shortguide.pdf** and change the *Base Address* of both **ESCPDSPReset.mdl** and **Model205_Openloop.mdl** if necessary.
- Be sure to save the files after changing the *Base Address.*
- *Be sure to load the correct controller personality file for the ECP system !!!*

Step 3: Log Decrement Estimate of ζ *and* ω_n

The log decrement method is a way of estimating the natural frequency ω_n and damping ratio ζ of a second order system. You will go through the following steps:

- Reset the system using **ECPDSPresetmdl.mdl.**
- Modify **Model205_Openloop.mdl** so the input has ***zero*** amplitude.
- Compile **Model205_Openloop.mdl** if necessary.
- Connect **Model205_Openloop.mdl** to the ECP system. (The mode should be **External**.)
- Displace the first disk, and hold it.
- Start **(play) Model205_Openloop.mdl** and let the disk go.
- Run the m-file **log_dec.m.** (be sure the file **log_dec.fig** is in the same folder**)**. The program **log_dec** comes up with the following GUI:



You need to

- Select **Disk 1**
- Select **Load IC (initial condition) Response** (the variables *time* and *theta1* will be loaded from the workspace). At this point some initial estimates will be made.
- Set/modify the **Final Time**
- Select **Plot IC Response** to plot the initial condition response
- Choose to identify the positive peaks (**Locate + Peaks**) or negative peaks (**Locate - Peaks**) . ***If the peaks are not numbered consecutively,*** you need to decrease the **Samples Between Peaks** and try again until all peaks have been identified.
- Choose the initial peak (**Peak x(n)**) and final peak (**Peak x(n+N)**) to use in the log-decrement analysis. These should be fairly close to the beginning of the initial condition response. Don't try and use more than a few peaks.
- Select **Estimate Parameters** to get the initial estimates of ζ and ω_n
- Select **Make Log-Decrement Figure** to get a plot and summary of the results. *You need to include this figure in your memo.*

Step 4: Estimating the Static Gain K

You will go through the following steps:

- Reset the system using **ECPDSPresetmdl.mdl.**
- Modify **Model205_Openloop.mdl** so the input is a step. You may have to set the mode to **Normal**.
- ***The input for the torsional system must be in radians, not degrees***
- Set the amplitude to something small, like 2 or 5 degrees (converted to radians).
- Compile **Model205_Openloop.mdl,** if necessary.
- Connect **Model205_Openloop.mdl** to the ECP system. (The mode should be **External**.)
- Run **Model205_Openloop.mdl.** If the disk does not seem to move much, increase the amplitude of the step. If the cart moves too much (more than 20 or 30 degrees) , decrease the amplitude of the step. You may have to recompile after the change.
- You only need to run the system until it comes to steady state, then stop it.

Estimate the static gain as $K = \frac{\theta_{1,ss}}{A}$ where $\theta_{1,ss}$ is the steady state value of the disk position, and A is the input amplitude. *Be sure you use the same using for the input and output (both degrees or both radians)!* You should determine the value $\theta_{1,ss}$ in Matlab, **don't use the X-Y Graph**. The variables *theta1* and *time* should be in your workspace. You should use **three different input amplitudes** and produce three different estimates for the static gain. Try and make your systems move so the steady state values are between 5 and 15 degrees. Average your three estimates to produce a final estimate of the static gain. Your static gain should generally be between 1.5 and 10. If yours is not, it is likely you did not use the same units for A and $\theta_{1,ss}$.

Part B: Frequency Domain Modelling of a One degree of Freedom System

Step 1: Fitting the Estimated Frequency Response to the Measured Frequency Response

We will be constructing the magnitude portion of the Bode plot and fitting this measured frequency response to the frequency response of the expected transfer function to determine K , ζ , and ω_n . For each frequency

$\omega = 2\pi f$ we have as input $u(t) = A\cos(\omega t)$ where, for our systems, A is measured in degrees (or radians). After a transition period, the steady state output will be $\theta_1(t) = B\cos(\omega t + \psi)$, where B is also measured in degrees (or radians). Since we will be looking only at the magnitude portion of the Bode plot, we will ignore the phase angle ψ.

In this part, limit the motion of the torsional system to +/- 30 degrees. If it appears to be turning more than this stop the system and put in a smaller amplitude!

You will go through the following steps

For frequencies $f = 0.5,1,1.5...7.5$ Hz

- Modify **Model205_Openloop.mdl** so the input is a sinusoid. You may have to set the mode to **Normal**.
- Set the frequency and amplitude of the sinusoid. Try a small amplitude to start, like 1 degree (the input to the ECP needs to be in *radians*). *The frequency needs to be entered in radians/sec!*
- Compile **Model205_Openloop.mdl,** if necessary. (Assume it is not necessary. The system will let you know if it is necessary!)
- Connect **Model205_Openloop.mdl** to the ECP system. (The mode should be **External**.)
- Run **Model205_Openloop.mdl.** If the disk does not seem to move much, increase the amplitude of the input sinusoid. If the disk moves too much, decrease the amplitude of the input sinusoid.

Record the input frequency (f), the amplitude of the input (A), and the amplitude of the output (B) when the system is in steady state. Not that the output may not be a sine wave symmetric about zero. Hence you need the average of the positive and negative values. The Matlab file **get_B.m** will help with this, *though you will probably have to modify this file to read in theta1!*

Enter the values of f , A, and B into the program **process_data_1dof.m** (you need to edit the file)

At the Matlab prompt, type **data = process_data_1dof**;

Step 2: Fitting Your Model to the Transfer Function

Run the program **model_1dof.m** at the Matlab prompt**.** There are four input arguments to this program:

- data, the measured data as determined by **process_data_1dof.m**
- K the estimated static gain
- ω_n the estimated natural frequency (from the log decrement analysis)
- ζ the estimated damping ratio (from the log decrement analysis)

The program **model_1dof.m** will produce the following:

- A graph indicating the fit of the identified transfer function to the measured data. *(You need to include this graph in your memo.)*
- The optimal estimates of K , ζ , and ω_n (written at the top of the graph)
- A file **state_model_1dof.mat** in your directory**.** This file contains the A, B, C, and D matrices for the state variable model of the system. If you subsequently type **load state_model_1dof** you will load these matrices into your workspace.

Step 3: Improving the Model

Add additional data points so you have ***at least*** 4 points close to the resonant peak of the transfer function. It is important that this be well defined before you go on. If your damping ratio is less than 0.01 you definitely need more points near the peak!

Step 4: Renaming your Model

You should save and rename the files **process_data_1dof.m,** and **state_model_1dof.mat** in a way that you will be able to identify them later. *Write these names on the data sheet at the end of this lab and include theses names in your memo.* These are the files that contain a state variable model of your system and will be used in nearly all future labs!

Part C: Model Matching Control of a One degree of Freedom System

We would like our final design to meet the following design requirements:

- Settling time less than 0.75 seconds.
- Absolute value of the steady state error less than 2 degrees for a 15 degree step, and less than 1 degree for a 10 degree step (*the input to the Model 205 must be in radians!*) Only one of these is required.
- Percent Overshoot less than 10%

You should start with the lower step amplitudes, and work your way up to the higher step amplitudes. Not all systems or controllers will work for a 15 degree step. Your real systems may oscillate a bit. If this happens try to reduce the input level, since this limits the allowed control effort. *It may not be possible to eliminate all of the oscillations, since these types of controllers depend on canceling the plant dynamics,* and if your model is not accurate enough the controller will not cancel the real plant well enough. *Be sure your system input in the simulation file* ***closedloop_driver.m*** *is in radians!*

Step 1: Modify **closedloop_driver.m** to read in the correct model file (from part B-4).

Step 2: Modify **closedloop_driver.m** to use the correct *saturation_level* for the system you are using.

Step 3: Second Order ITAE Model Matching Control. (Be sure to record the value of ω_o *you use.)*

- Using a second order ITAE system, vary ω_o until you meet the design specs with the *simulation* ***(closedloop_driver.m)***. The larger the value of ω_o, the faster your system will respond and the closer your model will predict the response of the real system. Be sure you do not reach the limiter on the control effort, unless you really like restarting your computer. At this point all of the variables you should need are in your current Matlab workspace. Y*ou should run the simulation until the system is clearly at a steady state value, but at least one second.*

- Open **Model205_Closedloop.mdl** and be sure the *Base Address* is correct for your system.

- Compile **Model205_Closedloop.mdl**. The parameters this file needs are in the workspace. The yellow block is what makes the ECP system work, and replaces your model of the system with the real system.

- Reset the system by running **ECPDSPReset.mdl**.

- Connect **Model205_Closedloop.mdl** to the system and then run it.

- Use the **compare1.m** file (or a modification of it) to plot the results of both the simulation and the real system on one nice, neatly labeled graph. ***The results must be displayed in degrees***. You may need to modify this file to get the plot you want. *You need to include this graph in your memo.*

Step 4: Third Order ITAE Model Matching Control. (Be sure to record the value of ω_o you use.)

- Using a third order ITAE system, vary ω_o until you meet the design specs with the *simulation* ***(closedloop_driver.m)***. Y*ou should run the simulation until the system is clearly at a steady state value, but at least one second.*

- Open **Model205_Closedloop.mdl** and be sure the *Base Address* is correct for your system.

- Compile **Model205_Closedloop.mdl**. The parameters this file needs are in the workspace. The yellow block is what makes the ECP system work, and replaces your model of the system with the real system.

- Reset the system by running **ECPDSPReset.mdl**.

- Connect **Model205_Closedloop.mdl** to the system and then run it.

- Use the **compare1.m** file (or a modification of it) to plot the results of both the simulation and the real system on one nice, neatly labeled graph. ***The results must be displayed in degrees***. *You need to include this graph in your memo.*

Step 5: Second Order Deadbeat Model MatchingControl. (Be sure to record the value of ω_o you use.)

- Using a second order deadbeat system, vary ω_o until you meet the design specs with the *simulation* ***(closedloop_driver.m)***. Y*ou should run the simulation until the system is clearly at a steady state value, but at least one second.*

- Compile the correct closed loop ECP Simulink driver, connect to the system, and run the simulation.

- Use the **compare1.m** file (or a modification of it) to plot the results of both the simulation and the real system on one nice, neatly labeled graph. ***The results must be displayed in degrees***. *You need to include this graph in your memo.*

Step 6: Third Order Deadbeat Model MatchingControl. (Be sure to record the value of ω_o you use.)

- Using a third order deadbeat system, vary ω_o until you meet the design specs with the *simulation* ***(closedloop_driver.m)***. Y*ou should run the simulation until the system is clearly at a steady state value, but at least one second.*

- Compile the correct closed loop ECP Simulink driver, connect to the system, and run the simulation.

- Use the **compare1.m** file (or a modification of it) to plot the results of both the simulation and the real system on one nice, neatly labeled graph. ***The results must be displayed in degrees***. *You need to include this graph in your memo.*

Your memo should compare the difference between the predicted response (from the model) and the real response (from the real system) for each of the systems. There should be two figures per page, and they should be large enough I can read them.

Be sure in include the number of the ECP system you are using. These sometimes get moved around and you need to be able to find the exact same one again. They are not interchangeable.

Name(s) _____

1 dof torsional systems (model 205)

Number of Masses: 2 4
Each mass
a) is as far in (towards the center) as it can go
b) is as far out (away from the center) as it can go
c) is aligned so the outer edge is on the _____ ring from the outside

state_model_1dof.mat *is now named :*

process_data_1dof.m *is now named:*

ECP System Number:

Instructor Verification and Time _____