Lab 2

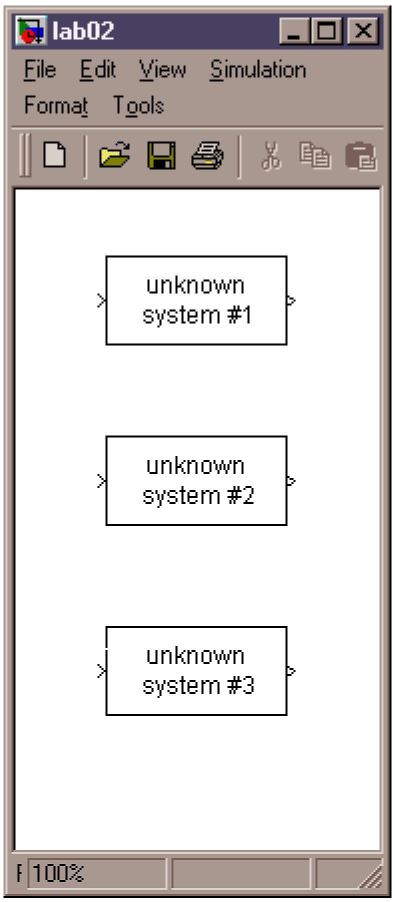
ES205 Analysis and Design of Engineering Systems
Spring Quarter 2008

Introduction

In this lab you will apply a step input to three unknown systems. From the system responses, you will develop models for the systems based on your knowledge of 1st- and 2nd-order system characteristics. In part 2 of the lab you will use Matlab to control the input and output of a Simulink simulation, including creating multiple plots on the same page.

Part 1: System Characteristics and Modeling

You can download a Simulink file from the course website called **`lab02.mdl`**. The file contains three blocks which model three different systems. The equations of motion of these systems are unknown to you.



A snapshot of the Simulink file is shown. In Simulink, complete the simulation diagram by adding a step input block and an output scope to each of the three unknown systems.

Apply a step input of magnitude 1 to system #1.

- From the steady-state response, determine the static gain. Record your answer on the *Worksheet*.
- Print and label the scope plot showing the response. You may plot the response in Matlab if you prefer.
- To save paper you can *Paste* the figure into an MSWord document.

Apply a step input of magnitude 2 to system #2.

- From the steady-state response, determine the static gain. Record your answer on the *Worksheet*.
- Print and label a plot showing the response.

Apply a step input of magnitude 3 to system #3.

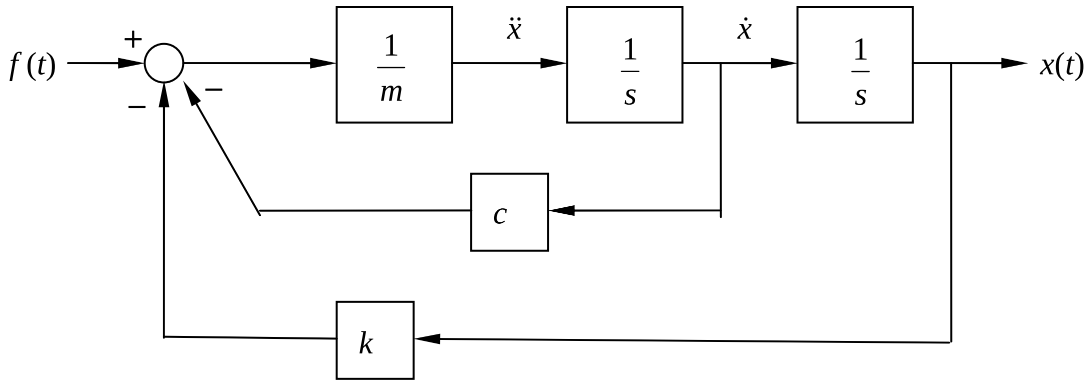
- From the steady-state response, determine the static gain. Record your answer on the *Worksheet*.
- Print and label the scope plot showing the response.

For each of the three systems, if the system appears to be first-order, estimate the system's time constant τ. If the system appears to be second-order, estimate the system's damped natural frequency ω_d. Record your estimates on the *Worksheet*. **Attach a sample calculation to the worksheet**.

(Lab continues on the next page)

Part 2: Using Matlab to Control Simulation Inputs and Outputs

In Lab 1, you created a Simulink model called **`example2.mdl`** to numerically solve the ODE $m\ddot{x} + c\dot{x} + kx = f(t)$. Your model should be similar to the simulation diagram shown below. In this part of the lab, the input *f*(*t*) and the damping coefficient *c* will be varied in different combinations using a Matlab m-file and the system responses will be plotted using Matlab.



Change your Simulink model so that a Matlab m-file controls the parameters (*m*, *c*, *k*), the initial conditions, and the input magnitude and start time, and so that the output *x*(*t*) and the time vector *t* is returned to the Matlab workspace for plotting. In your simulations, select time spans such that all responses reach steady-state. Using the subplot command, put both figures described below on the same page. **Attach a copy of your m-file and a copy of the two figures to the *Worksheet***. Be sure to comment on these figures in the space provided.

Figure 1

Step input, mag = 3, starting at *t* = 0.5 s.
Four simulations: *c* = 5, 10, 20 and 30 N-s/m.
Initial conditions (ICs) are zero, *m* = 2 kg, and *k* = 100 N/m.
Plot all four responses (each with a different symbol) for four seconds in a single figure using subplot(211). Include a legend and the title “Figure 1: Step responses as damping varies”. Be sure to clearly label your axes.

Figure 2

Step input, mag = 2.5, starts at *t* = 0 s.
Use *c* = 5 N-s/m, *m* = 2, kg and *k* = 100 N/m.
Response #1: $x(0) = 0, \dot{x}(0) = -0.4$.
Response #2: $x(0) = -0.05, \dot{x}(0) = 0$.
Response #3: $x(0) = 0.06, \dot{x}(0) = 0.5$.
Plot all three responses (each with a different symbol) for three seconds in a single figure; use subplot(212). Include a legend and the title “Figure 2: Step response with different ICs”. Be sure to clearly label your axes.

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Lab 2 Worksheet

Part 1

	System #1	System #2	System #3
Magnitude of step input			
Magnitude of steady-state response			
Static gain			
Apparent order of the system	second-order	first-order	second-order
Characteristic (with units)	ω_d =	τ =	ω_d =

From the response shown, system #2 appears to be first-order. But the response shown might also be that of a second-order system. Explain.

Suppose the natural frequencies for system #1 and #3 are as given in the table below. Determine the damping ratios. Include a sample calculation.

	System #1	System #2	System #3
Natural frequency ω_n		n/a	
Damping ratio ζ		n/a	

From the information in the tables, create a mathematical model (ODE) for each system. Show your work.

<u>ODE model of system #1:</u>

<u>Transfer function model of system #1:</u>

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ODE model of system #2:

Transfer function model of system #2:

ODE model of system #3:

Transfer function model of system #3:

Part 2

Comment on the system responses in Figure 1 and Figure 2.

Attachments

1. Attach a copy of your time response plots from the three unknown systems in Part 1.
2. Attach a sheet of sample calculations from Part 1.
3. Attach a copy of your m-file from Part 2.
4. Attach a copy of your Matlab plots from Part 2.