

Lab 5: Frequency Identification

References:

Franklin, Powell and Emami-Naeini. Feedback Control of Dynamic Systems 3rd ed. Addison-Wesley, Massachusetts: 1994.

Ogata, Katsuhiko. Modern Control Engineering, 5th ed. Prentice Hall, New Jersey: 2009

Department of ECE at UIUC. Control System Laboratory Experiments. Department of ECE at UIUC, Fall 1997.

Introduction

The transfer function (mathematical model) of a plant can be found in several different ways. In an earlier experiment in ME460, the open loop transfer function of the hydraulic motor was found via analyzing its open loop transient step response. The analysis involved hypothesizing that the motor was a first order system and then determining the defining parameters (time constant and DC gain) from plots of the step response. Thus, the transfer function was estimated from the transient response of the system.

One may also determine the transfer function for a system from its frequency response. To do this, one can excite the system with sinusoids of varying frequencies and then measure the gain and phase of the output signal with respect to the input sinusoid. The plots of gain versus frequency and phase versus frequency are called the frequency response of the system. The combination of these two plots is called a Bode plot, and it can be used to approximate a transfer function.

In this laboratory exercise, two different open loop plants will be identified using frequency response methods. In order to gain experience in using different kinds of hardware (among other reasons), the Parker-Hannifin Hydraulic Trainer Stand **will not** be used for this experiment.

Background

The frequency response of a system is the Bode plot of the open loop plant. Consider the open loop system in Figure 1.

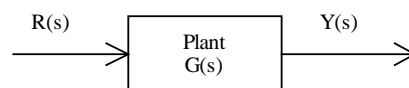


Figure 1: Simple open loop plant.

The Bode plot for this system is a plot of the gain of the system $Y(s)/R(s)$ (in decibels) and the phase lag (in degrees) versus the logarithm of the frequency of the input sinusoid $R(s)$. If one knows the transfer function $G(s)$, the Bode plot can be drawn by hand or by using the 'bode' command in Matlab.

The reverse is also possible. If one has the Bode plot for the system, then a transfer function can be approximated. This is the basis for this laboratory exercise. For more background, read Ogata 5th ed., pp. 403-422.

Experimental Objectives

Completion of the laboratory exercise will have required you to:

- Perform a frequency response ‘sweep’ of two unknown open loop systems
- Plot the collected data on a Bode plot
- Approximate the transfer function of each of two unknown open loop systems
- Understand how to conduct a frequency identification of an unknown open loop system

Experimental Apparatus

The ‘mystery’ plants will be provided by the MW2000's analog output channels 0 and 1. Real-Time Windows Target is running in the background, serving as the open loop plant $G(s)$. The sinusoidal input should be directed towards input channel 4.

Experimental Set Up

1. Copy the *freqid1.mdl* and *freqid2.mdl* files from $N:\backslash\text{HydraulicsLab}\backslash\text{ME460}$ to your folder on the path $C:\backslash\text{ME460}$. Turn on the MW2000. Start Simulink and load up the *freqid1.mdl* file.
2. Set up the physical connections. Connect *Gen Out* on the Oscilloscope’s function generator to both the Oscilloscope’s Channel 1 and the MW2000’s analog input Channel 4. Use a T-connector to do this. Connect the MW2000’s analog output Channel 1 to the oscilloscope’s Channel 2.
3. ***Function Generator setup.***
 - Press the “Wave Gen” button on the Oscilloscope
 - Use the oscilloscope function keys (below the screen) to set:
 - Waveform to Sine
 - Frequency to 1Hz
 - Amplitude to 2.00Vpp
 - Offset to 0.0V
4. ***Scope setup.*** Change the *Volts/Div* for both Channels 1 and 2 so that they are set to 500mv/Div. *Volts/Div* may need to be adjusted during the course of the lab. Adjust the vertical position on Channel 1 and 2 so that there is 0 DC offset between them. Set the *Time/Div* scale so that you see two or three periods of the sine wave. *Time/Div* will have to be modified as you sweep through the frequencies.

Turn on the *cursors* option on the scope (top middle on the front panel). The press the *Cursors* button at the bottom of the oscilloscope screen. You should get two dotted horizontal lines with a number at the bottom right corner of the screen that tells you the difference between the two lines. Turn the

knob in the cursors box to move one of the lines up and down. Press the Cursors button and select X1. This is a time cursor and you can control it in the same way as the Y cursors to measure time.

Set the *trigger mode* to be normal. Set the *trigger level* to be somewhere within -1.0 to 1.0 . Set the *trigger source* to be Channel 1.

If you can't get the scope set up correctly, ask the TA.

Experimental Procedure

You will perform a frequency sweep of the open loop system and record gain and phase data at enough frequencies so that you can identify the transfer function later. There is a convenient table attached to this lab which you may use to record your data.

Experiment 1: Frequency Identification of Mystery Transfer Function 1

1. After starting `freqid1.mdl` in Simulink, do a preliminary frequency sweep without taking data. Vary the frequency from 0 Hz to 200 Hz and watch the input and output signals on the screen. What's happening?
2. Pick a start frequency. This should be a frequency that is small enough so that there is little or no phase lag. You should have observed such a frequency in the first step.
3. Determine the gain and phase lag of the transfer function at this start frequency. Create an Excel spreadsheet based on the sample provided on the next page. It is up to you to add the appropriate cell calculations (e.g. a function calculation should be used in the second column to convert your measured frequency from Hertz to radians per second). Note that in the last column (phase lag), you should simply negate the phase you measured. This is because you should see that the output of the mystery plant is *lagging* that of the input sinusoid that you are sending to the plant.
4. Increase the frequency at regular intervals and record the gain and phase lag information until you feel confident that nothing else of interest will happen at higher frequencies. Again, you should have a feel for this because you did the frequency sweep in Step 1.
5. Go back and record more data at frequencies where there is a significant change in the gain or phase lag, i.e. break frequencies, etc. You want to know in detail what is happening at these points.
6. Now you will obtain the step response of the system. Change the waveform of the FG's output to be a square wave instead of a sinusoid. Change the function generator's amplitude so that it is 1.0 Volts p-p. Slow down the frequency to about 0.1 Hz or slower so that you have the step response of the "mystery" transfer function on the oscilloscope. Hit the *Run/Stop* button on the oscilloscope to keep a particular step response on the scope's screen. Use the oscilloscope's cursors to measure relevant features such as overshoot, rise time, peak time, etc., and record these values.
7. Use a Simulink Scope to record the step response so that it can be included in your Lab Report.

Experiment 2: Frequency Identification of Mystery Transfer Function 2

Now load up the `freqid2.mdl` file. Repeat all of the steps outlined in Experiment 1 for the second 'mystery' plant.

Lab Report

1. Plot the data collected in class on a Bode plot using Matlab. Remember all the necessary conversions. You may find it useful to use the 'semilogx' command in Matlab.
2. Estimate transfer functions based on each experimentally-obtained Bode plot.
3. Obtain Bode plots of your estimated transfer functions using Matlab, and compare them to the Bode plots you generated in Question 1 (using only your experimental data).
4. Obtain step responses of your estimated transfer functions using Matlab and/or Simulink. Compare each Matlab-generated step response to the corresponding step response recorded from Real-Time Windows Target during the laboratory exercise.
5. Explain how frequency identification could have been used to identify the transfer function for the open loop hydraulic motor system. How is this different from, and similar to, transient response system identification?

Excel Spreadsheet Sample

Frequency (Hz)	Frequency (Rad/s)	Output Voltage (V)	Input Voltage (V)	Time Difference (ms)	Phase (deg)	Magnitude (--/--)	Magnitude (dB)	Phase Lag (deg)