

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.

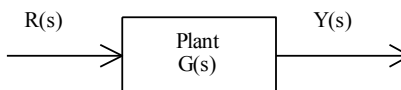


Figure 1: Simple open loop plant.

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:\HydraulicsLab\ME460` to your folder in the path `C:\ME460_SPxx\ABx`. 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 Ch. 4. Use a T-connector to do this. Connect the MW2000’s analog output Ch. 0 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. ***Oscilloscope display 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.

Select *Cursors* under the *Measure* menu on the front panel. Two horizontal and two vertical lines should appear on your display. On the display use the *select cursor* tab to choose between $X1$, $X2$, $Y1$, and $Y2$ and then use the cursor knob in the *Measure* menu to adjust position of the respective cursor. The values for each cursor appear in the bottom right corner of the display, and values for ΔX , $1/\Delta X$,

and ΔY appear under the cursor panel on the right. Use these values when determining your measurements.

Select the *Horz* button to set the *time mode* to be normal. Set the *trigger level* using the level knob to be somewhere within -1.0 to 1.0 . Select the *Trigger* button to 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. For convenience, you may change the function generator's voltage offset to 500 mV so that the step response starts at 0 V. 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 log the step response data to workspace so that it can be plotted and included in your Lab Report.

