Lab 6: FREQUENCY RESPONSE

Section 1 -- Background Information

The frequency response of a system is another tool used in the analysis and design of feedback control systems. The frequency response, aslo referred to as a Bode plot, shows the magnitude and phase response for a siusoidal input of varying frequency. From such a plot, one can determine the -3dB system bandwidth, as well as the input frequency resulting in a peak output response.

Section 2 – Procedure

In this procedure we will observe the frequency response for both an underdamped system and an overdamped system.

2.1 Step Response of the Underdamped System
In this section, you will configure the system to produce an *underdamped* response then observe its frequency response. To observe the frequency response, set the Trajectory (or input) to be a swept sine wave—a sine wave whose frequency increases linearly with time. The system's output will essentially be the frequency response of the control plant.

2.1.1 Setup the Control Plant. The torsional system will be set up with two (2 each) weights loaded on the bottom disk only. The weights are secured 180 degrees apart from each other such that the outside edge of each weight is tangent to the 9-cm radius line (last line on the disk).

2.1.2 Start the ECP Executive software program.

2.1.3 Energize the control system by pushing the "ON" button on the ECP controller.

WARNING

The system is now energized and will rotate at potentially high speeds when a control voltage is applied to the motor of the torsional system. At any point the motion of the system can be stopped by pressing the OFF (red) button on the ECP controller box.

2.1.4 Setup the ECP Program as before with the following variations:

a. Setup→Control Algorithm with
   - Kp = 0.1 *(or use the values you used in Lab 3 for underdamped response)*
   - Kd = 0.002 *(same comment as above)*
   - Ki = 0
   - Feedback – Encoder 1

b. Select Command→Trajectory
   - Select Impulse and Unidirectional moves. Click Setup.
   - Select Closed Loop Impulse, then set
     - Amplitude (degrees)= 45
     - Pulse Width (msec) = 5000
     - Number of Reps = 1
     - Dwell Time (msec)= 0

2.1.5 Run the setup.

2.1.6 Plot the data. Note the values for Kp and Kd on the plot.

2.2 Frequency Response of the Underdamped System
Now set up the ECP program for the frequency response of the same underdamped system.
2.2.1 Change the input to a sine sweep. Select Command→Trajectory

- Select Sine Sweep. Click Setup.
- Select Closed Loop Sweep and Linear Sweep, then set
  - Amplitude (degrees)=45
  - Start Frequency (Hz) = 0.1
  - End Frequency (Hz) = 75
  - Sweep Time (sec)= 360;

NOTE

The input will sweep from the Start frequency to the End frequency at a constant rate for the duration set by the Sweep time.

2.2.2 Run the setup. Notice that the disk oscillates gently at the start of the sweep, then increases up to a point before it settles down again.

2.2.3 Plot the data: Select Plotting → Setup Plot. For the left axis choose Commanded Position and Encoder 1 Position. Select Logrithmic Frequency for the horizontal axis and Db for the vertical axis.

2.2.4 From the plot, determine the frequency where the peak magnitude is observed, as well as the 3-dB system bandwidth. What is the slope of the roll-off?

2.3 Step Response of the Overdamped System
Using values of Kp and Kd that will produce an *overdamped* system response, you will first verify that the system response is overdamped, then proceed to observe its frequency response.

2.3.1 Set the values for Kp and Kd in the torsion control plant to produce the overdamped response. In the ECP program.

a. Setup→Control Algorithm.
- Verify Continuous Time and PI with Velocity Feedback
- Click on Setup Algorithm. In the new window, enter the following:
  - Kp = 0.1 *(or as required to produce <u>overdamped</u> response)*
  - Kd = 0.02 *(same comment as above)*
- Implement Algorithm, then click OK

b. Select Command→Trajectory
- Select Impulse and Unidirectional moves. Click Setup.
- Select Closed Loop Impluse, then set
  - Amplitude (degrees)= 180
  - Pulse Width (msec) = 3000
  - Number of Reps = 1
  - Dwell Time (msec)= 0

c. Utility → Zero Position
d. Command →Execute. Click Run.
e. Plot the data.

2.4 Frequency Response of the Overdamped System
Now set up the ECP program for the frequency response of the overdamped system.
2.4.1 Set up the sine sweep input. Select Command→Trajectory

- Select Sine Sweep. Click Setup.
- Select Closed Loop Sweep and Linear Sweep, then set
  - Amplitude (degrees)= 45
  - Start Frequency (Hz) = 0.1
  - End Frequency (Hz) = 75
  - Sweep Time (sec)= 360

b. Utility → Zero Position
c. Command → Execute. Click Run.

2.4.2 Plot Data: Select Plotting → Plot Data. For the left axis choose Commanded Position and Encoder 1 Position. Select Logrithmic Frequency for the horizontal axis and Db for the vertical axis. Include a copy of the plot in your report.

2.4.3 What is the 3-dB bandwidth? What is the slope of the roll-off?

Section 3 -- Report

Submit a report in the standard format for this class. In the Introduction discuss the relevant theory that was presented and explored during the lab. In the Results and Analysis discuss the frequency roll-off behavior observed from the underdamped system and the overdamped system. Be sure to include all of your plots.

What do you think the freuency response plot would look like for a system whose step response is undamped?

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