Assignment 7: Bode Plots

ENGR 105: Feedback Control Design
Winter Quarter 2013
Due no later than 4:00 pm on Wednesday, Mar. 6, 2013
Submit in class or in the box outside the door to area of Room 107, Building 550

Note: For hand sketches of the Bode plots, please download and use the `BodePaper` function in MATLAB (See http://lpsa.swarthmore.edu/Bode/BodePaper.html) to generate some nice log-log and log-linear scales for you to draw on – this will make it easier for you to plot and for us to grade.

Problem 1. (25 pts.)

Draw the asymptotes of the Bode plot magnitude and phase for each of the following open-loop transfer functions, using the rules described in lecture and in Section 6.1 of the textbook. Then sketch the Bode plot, using the asymptotes as a guide. After completing the hand sketches, verify your result using MATLAB with the bode function. Submit your hand sketches, MATLAB plots, and MATLAB code. It is okay if MATLAB puts the Bode plot on a different scale than your hand sketch.

a. $L(s) = \frac{2000}{s(s+200)}$ (no zeros, real poles)

b. $L(s) = \frac{10(s+4)}{s(s+1)(s^2+2s+5)}$ (real zero, real and complex poles)

c. $L(s) = \frac{(s^2+2s+8)}{s(s^2+2s+10)}$ (complex poles and real/complex zeros)

d. $L(s) = \frac{1}{s^3(s+8)}$ (multiple poles at the origin)

e. $L(s) = \frac{s-1}{s^2}$ (right half plane zero)

Problem 2. (10 pts.)

A normalized second-order system with $\zeta = 0.5$ and an additional pole is given by:

$$G(s) = \frac{1}{[(s/p)+1](s^2+s+1)}.$$

Draw Bode plots (try sketching by hand and then verify with MATLAB) for $p = 0.01, 0.1, 1, 10$, and 100. In addition, draw the Bode plots for the case where this is no extra pole.

What conclusions can you draw about the effect of an extra pole on the bandwidth compared with the bandwidth for the second-order system with no extra pole?

Problem 3. (15 pts.)

A DC voltmeter is shown in the schematic below. Specifications for the inertia of the point, the torsional stiffness of the spring, and the torque/motor constant are given. The pointer is damped so that its maximum overshoot to a step input is 10%.

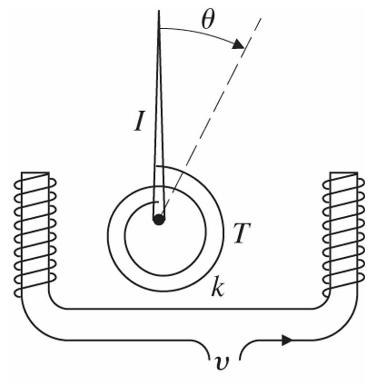
$I = 40\times10^{-6}$ kg-m^2

$k = 4\times10^{-6}$ kg-m^2/sec^2

$T = K_m v$ (input torque)

$v =$ input voltage

$K_m = 4\times10^{-6}$ N-m/V



a. What is the undamped natural frequency, ω_n, of the system?

b. What is the damped natural frequency, $\omega_d = \omega_n\sqrt{1-\zeta^2}$, of the system?

c. Plot the frequency response (Bode plots) using MATLAB. Submit your plot and code. What input frequency will produce the largest magnitude output?

d. Suppose this meter is now used to measure a 1-V AC input with a frequency of 2 rad/sec. Use a Bode plot analysis (try sketching by hand and then verify with MATLAB) to answer the following questions:

(i) What amplitude will the meter indicate after initial transients have died out? Explain how the Bode plots provide the answer.

(ii) What is the phase lag of the output with respect to the input? Explain how the Bode plots provide the answer.

e. Use the `lsim` function in MATLAB to verify your answer in part d(i). Submit your code and plot with evidence