Instructor's Supplement Problems

Chapter 10

1. For each function in Problem 1 in the text problems sketch the Bode asymptotic magnitude and asymptotic phase plots. Compare your results with your answers to Problem 1 in the text problems. [Section: 10.2]

2. Write a program in MATLAB that will do the following:

MATLAB **ML**

a. Plot the Nyquist diagram of a system

b. Display the real-axis crossing value and frequency

Apply your program to a unity-feedback system with

$$G(s) = \frac{K(s+5)}{(s^2+6s+100)(s^2+4s+25)}$$

3. Use MATLAB's Linear System Analyzer to find the gain margin, phase margin, zero dB frequency, and 180° frequency for a unity-feedback system with

GUI Tool **GUIT**

$$G(s) = \frac{8000}{(s+6)(s+20)(s+35)}$$

Use the following methods:

a. The Nyquist diagram

b. Bode plots

4. Write a program in MATLAB that will do the following:

MATLAB **ML**

a. Make a Nichols plot of an open-loop transfer function

b. Allow the user to read the Nichols plot display and enter the value of M_p

c. Make closed-loop magnitude and phase plots

d. Display the expected values of percent overshoot, settling time, and peak time

e. Plot the closed-loop step response

Test your program on a unity-feedback system with the forward-path transfer function

$$G(s) = \frac{5(s+6)}{s(s^2+4s+15)}$$

and explain any discrepancies.

5. The open-loop frequency response shown in Figure I-10.1 was experimentally obtained from a unity-feedback system. Estimate the percent overshoot and steady-state error of the closed-loop system. [Sections: 10.10, 10.11]

6. Given a unity-feedback system with the forward-path transfer function

$$G(s) = \frac{K}{(s+1)(s+3)(s+6)}$$

and a delay of 0.5 second, find the range of gain, K, to yield stability. Use Bode plots and frequency response techniques. [Section: 10.12]

7. An overhead crane consists of a horizontally moving trolley of mass m_T dragging a load of mass m_L, which dangles from its bottom surface at the end of a rope of fixed length, L. The position of the trolley is controlled in the feedback configuration shown in Figure 10.20. Here, $G(s) = KP(s)$, $H = 1$, and

$$P(s) = \frac{X_T(s)}{F_T(s)} = \frac{1}{m_T}\,\frac{s^2+\omega_0^2}{s^2(s^2+a\omega_0^2)}$$

The input is $f_T(t)$, the input force applied to the trolley. The output is $x_T(t)$, the trolley displacement. Also, $\omega_0 = \sqrt{\frac{g}{L}}$ and $a = (m_L + m_T)/m_T$ (*Marttinen, 1990*)

Make a qualitative Bode plot of the system assuming $a > 1$.

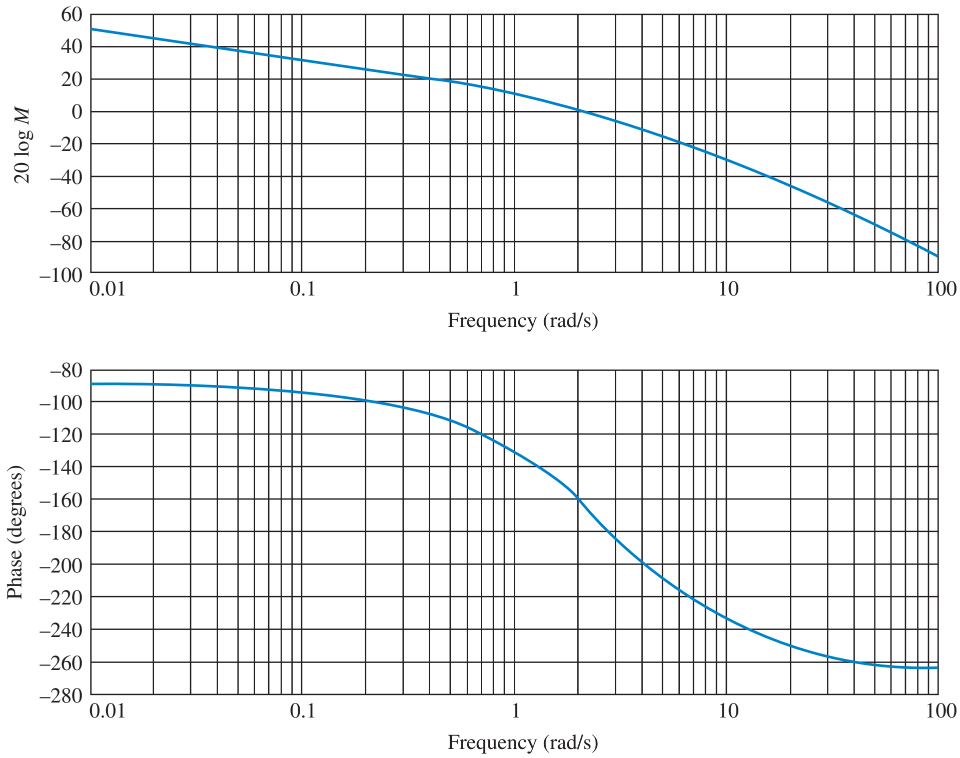

FIGURE I-10.1

8. The open-loop dynamics from dc voltage armature to angular position of a robotic manipulator joint is given by $P(s) = \dfrac{48500}{s^2 + 2.89s}$ (*Low, 2005*).

a. Draw by hand a Bode plot using asymptotic approximations for magnitude and phase.

b. `Use MATLAB to plot the exact Bode plot and compare with your sketch from Part` **`a`**`.` MATLAB **ML**

9. The control of the radial pickup position of a digital versatile disk (DVD) was discussed in Problem 38, Chapter 9 in the text problems. There, the open-loop transfer function from coil input voltage to radial pickup position was given as (*Bittanti, 2002*)

$$P(s) = \frac{0.63}{\left(1 + \dfrac{0.36}{305.4}s + \dfrac{s^2}{305.4^2}\right)\left(1 + \dfrac{0.04}{248.2}s + \dfrac{s^2}{248.2^2}\right)}$$

Assume the plant is in cascade with a controller,

$$M(s) = \frac{0.5(s + 1.63)}{s(s + 0.27)}$$

and in the closed-loop configuration shown in Figure 10.20, where $G(s) = M(s)P(s)$ and $H = 1$. Do the following:

a. Draw the open-loop frequency response in a Nichols chart.

b. Predict the system's response to a unit-step input. Calculate the $\%OS$, c_{final}, and T_s.

c. `Verify the results of Part` **`b`** `using MATLAB simulations.` MATLAB **ML**

10. The design of cruise control systems in heavy vehicles, such as big rigs, is especially challenging due to the extreme variations in payload. Assume that the frequency response for the transfer function from fuel mass flow to vehicle speed is shown in Figure I-10.2.

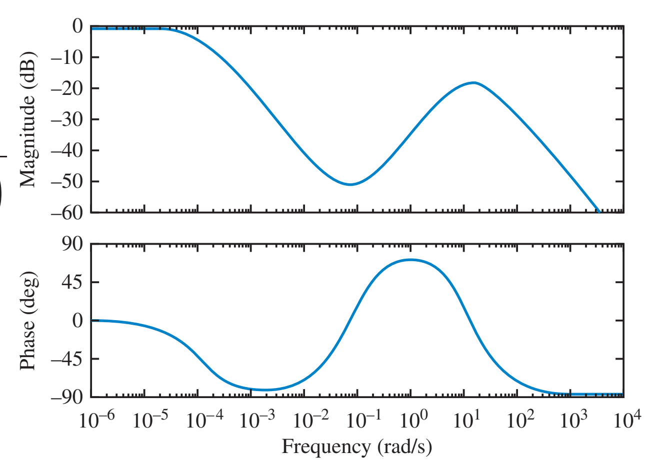

FIGURE I-10.2

This response includes the dynamics of the engine, the gear box, the propulsion shaft, the differential, the drive shafts, the chassis, the payload, and tire dynamics. Assume that the system is controlled in a closed-loop, unity-feedback loop using a proportional compensator (*van der Zalm, 2008*).

a. Make a plot of the Nyquist diagram that corresponds to the Bode plot of Figure I-10.2.

b. Assuming there are no open-loop poles in the right half-plane, find out if the system is closed-loop stable when the proportional gain $K = 1$.

c. Find the range of positive K for which the system is closed-loop stable.

11. Fruit flies' flight dynamics are interesting to study because they provide a proof-of-concept framework and inspiration for the invention of man-made machines. In an experiment (*Roth, 2012*), flies are stimulated to follow, in flight, an oscillating vertical bar. Through frequency response measurements, the obtained open-loop transfer function from stimulus stripe position to a voltage proportional to wingbeat amplitudes is

$$G(s) = e^{-0.032s}\frac{0.181s^2 + 1.23s + 8.68}{s^3 + 20.6s^2 + 277s + 1098}$$

Assume a unit feedback system.

a. Make a Bode plot of the open-loop transfer function.

b. Find the gain and phase margins.

c. Use a computer program to make a plot of the corresponding Nyquist diagram.

d. Use the result in Part **b** to find the range of K for closed-loop stability if the open-loop transfer function becomes $KG(s)$.

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