UNIVERSITY OF CALIFORNIA, SANTA CRUZ
BOARD OF STUDIES IN COMPUTER ENGINEERING

CMPE-242:
APPLIED FEEDBACK CONTROL

PRACTICE MIDTERM
MIDTERM TENTATIVELY SCHEDULED FOR 09-NOV-2010

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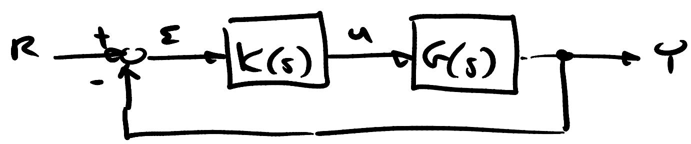
1. *Digital and Continuous Equivalents (25 points)*: Consider the following simple system:

$$G(s) = \frac{25}{(s+5)^2}$$



a. Design a continuous compensation system K(s) to achieve a closed loop bandwidth of 10 rad/s and a phase margin of 50 degrees.

b. Convert that compensator to K(z) using a Tustin transformation and a sample time rate of 100Hz., and write down the difference equation you would implement.

c. Use the exact linear phase loss from the ZOH and redesign the controller to account for it.

d. Convert the plant to G(z) using a ZOH approximation, again using a sample rate of 100Hz.

e. Design directly in the digital domain to achieve closed loop poles at s_{des} = -7±7j

f. Compare the compensator roots for all three compensators (in the continuous domain).

Problem 2 (20 points). The bode plot for the transfer function

$$G(s) = \frac{20}{s(s+1)(s+4)}$$

is shown in Figure 2. The plot shows that the system has a gain margin of 1, or $0\,\text{dB}$, measured at $\omega = 2\,\text{rad/s}$; and a phase margin of 0 at $\omega = 2\,\text{rad/s}$.

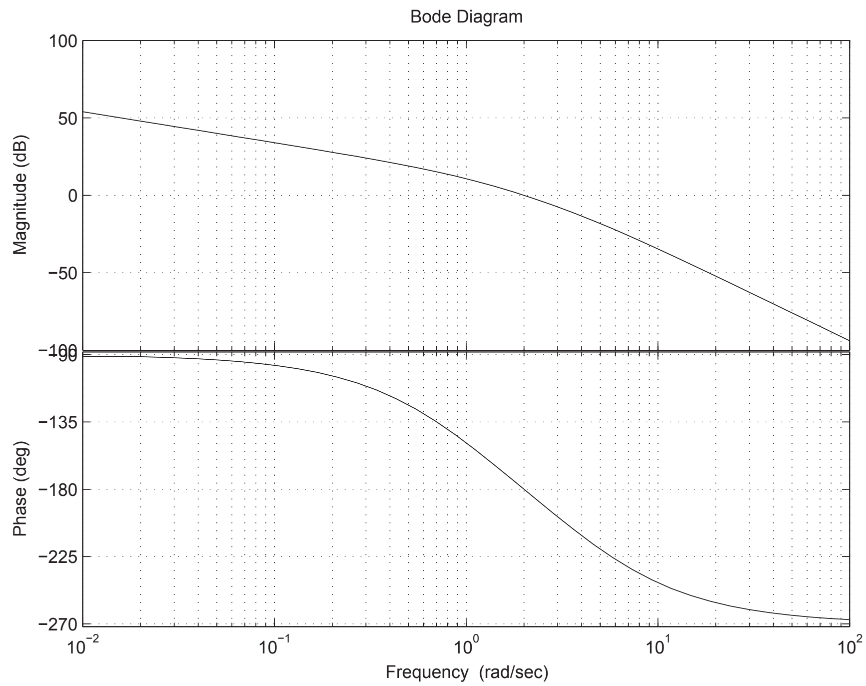


Figure 2: Bode plot for Problem 1.

(a) (5 points). Given this Bode plot, what can you say about the locations of two of the closed loop poles of the system resulting from putting $G(s)$ into a unity feedback loop (Figure 1) with $K(s) = K = 1$?

(b) (15 points). Design a compensator $K(s)$ such that, with $G(s)$ defined as above, the closed loop system shown in Figure 1 has a bandwidth of approximately 2 rad/s, steady state error to unit ramp inputs of no more than 0.1, and so that open loop transfer function $K(s)G(s)$ has phase margin of 30.

Problem 3 (20 points).

Consider the plant $G(s)$, whose transfer function is given by:

$$G(s) = \frac{(s-1)}{(s-2)}$$

(a) (4 points). Sketch the locus of poles of the closed loop system shown in Figure 1, for a controller $K(s)$ which is simply a positive gain K.

(b) (6 points). Sketch the locus of poles of the closed loop system shown in Figure 1, for the proper (at least as many poles as zeros), unstable controller $K(s) = \frac{1}{s-3}$. Hence, could this controller in series with a proportional gain K be used to stabilize the system?

(c) (4 points). Could the controller $K(s) = \frac{1}{(s-3)(s-4)}$ in series with a proportional gain K be used to stabilize the system?

(d) (4 points). Using the same unity feedback form (Figure 1), could you stabilize $G(s)$ with a proper, stable compensator $K(s)$? Explain why or why not.

(e) (2 points). Suppose that you are given an unstable plant $G(s)$, which has one real zero in the right half plane. Hypothesize a condition on the possible locations of the real unstable poles of $G(s)$ with respect to its right half plane zero, so that a proper, stable compensator $K(s)$, used in unity feedback (Figure 1), will stabilize the system.

Problem 4 (15 points).

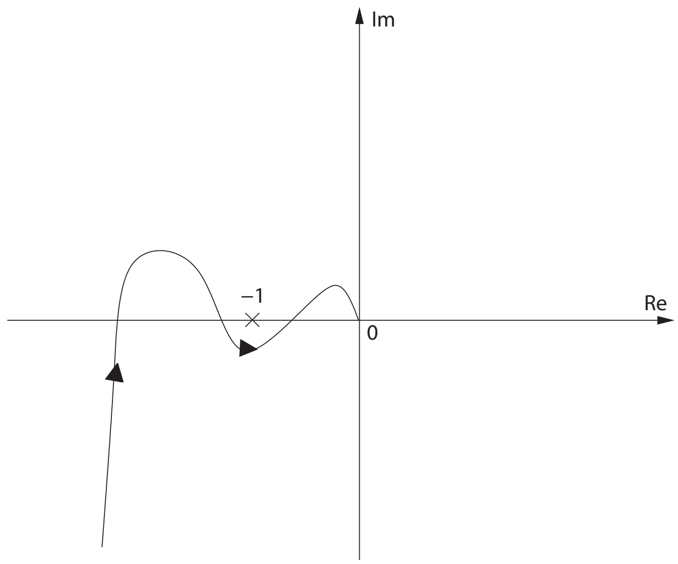


Figure 3: Nyquist plot for Problem 3.

A Nyquist plot of a unity feedback system with the feedforward transfer function $G(s)$ is shown in Figure 3. The plot shows the curve $G(j\omega)$, and the arrows indicate the direction along $G(j\omega)$ as ω ranges from very small (positive) values to very large (positive) values. For small ω, the curve starts in the third quadrant, though it is not specified exactly where.

(a) (8 points) Suppose that $G(s)$ has only one pole in the closed right half s-plane (ie. the pole could be on the $j\omega$-axis). Complete the Nyquist plot above. Is the closed loop system (of Figure 1 with $K = 1$) stable?

(b) (7 points) Now, suppose that $G(s)$ has no pole in the closed right half s-plane, and has only one zero in the right half s-plane. Complete the Nyquist plot above. Is the closed loop system stable?