Electrical Engineering EE 4CL4

Day Class — Instructor: Dr. I. C. BRUCE

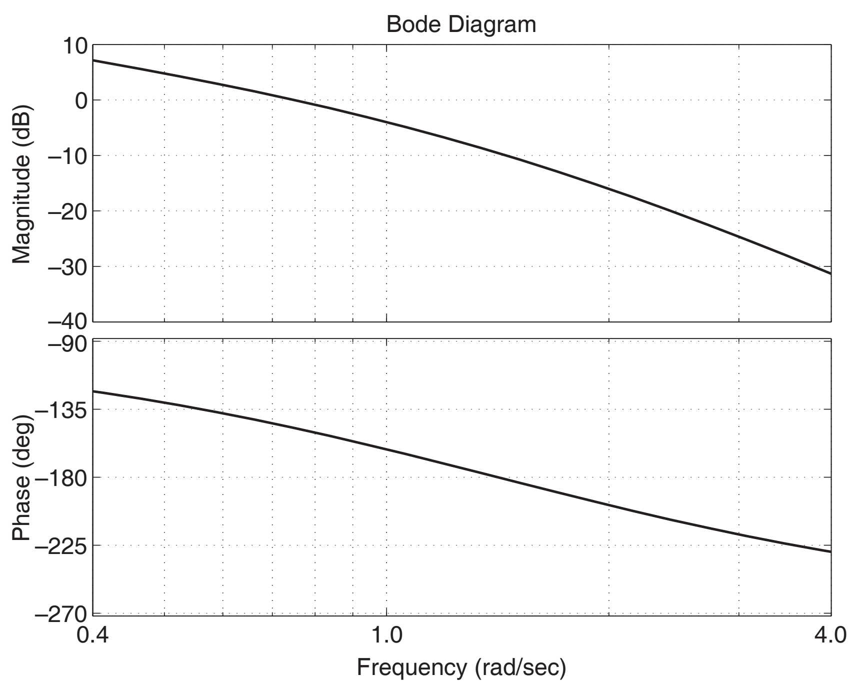
Duration of Examination: 3 Hours

McMaster University Final Examination — April, 2003

This examination paper includes nine (9) pages and eight (8) questions. You are responsible for ensuring that your copy of the paper is complete. Bring any discrepancy to the attention of your invigilator.

Special Instructions: Use of Casio *fx*-991 calculator only is allowed.
All major questions (numbered 1 to 8) are worth equal marks.
Some equations and tables that may assist you are provided on pages 3–9.

1. The figure below shows the Bode diagram for the open-loop transfer function $C(s)G_o(s)$ of a system to be placed in a one-d.o.f. unity-feedback loop.



   a. From the Bode diagram, estimate both the *gain margin* and the *phase margin* for stability.
   b. Design a lead compensator to increase the phase margin for this system.

2. Determine the PID controller parameters (K_p, T_r and T_d) for a plant with the nominal model:

$$G_o(s) = \frac{-s+4}{(s+2)^2},$$

   using the *Ziegler-Nichols oscillation method*.

3. Compare and contrast the requirements for *stability robustness* and *performance robustness*.

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4. Find suitable PID controller parameters (K_p, T_r and T_d) for a plant with the open-loop unit-step response:

$$y(t) = \frac{1}{3} - \frac{1}{2}\mathrm{e}^{-t} + \frac{1}{6}\mathrm{e}^{-3t} \qquad \text{for} \qquad t \geq 0,$$

using the *Cohen-Coon reaction curve method*.

5. There are a number of fundamental design limitations that place upper or lower bounds on the desired closed-loop bandwidth of a feedback control system. Discuss any two (2) of these limitations.

6. Consider the nominal plant model:

$$G_o(s) = \frac{16s^2 + 1}{(s+2)^3},$$

which is to be controlled by a one-d.o.f. unity-feedback loop.

a. Find a time-domain integral constraint on the controller error $e(t)$ in response to a unit step reference.

b. From the integral constraint obtained in part a, what can be said about the trade-off between the system response time and large transient responses in this feedback system?

7. Consider a feedback control loop where the open-loop transfer function is given by:

$$C(s)G_o(s) = \frac{s+5}{(s+1)(s+3)}.$$

In light of Bode's integral constraint on sensitivity:

a. calculate the frequency ω_0 at which the log-magnitude of the nominal sensitivity is equal to zero, i.e., $\ln|S_o(\mathrm{j}\omega_0)| = 0$;

b. determine the difference between the areas of $\ln|S_o(\mathrm{j}\omega)|$ above and below the line $\ln|S_o(\mathrm{j}\omega)| = 0$; and

c. based on the results from parts a and b, sketch the system's log-magnitude nominal sensitivity versus frequency, i.e., $\ln|S_o(\mathrm{j}\omega)|$ versus ω.

8. A discrete-time (shift form) approximation of a continuous-time plant model is given by:

$$G_{oq}(z) = \frac{0.0175(z+0.875)}{(z-0.819)^2}.$$

a. Design a discrete-time (shift form) minimum-time dead-beat controller $C_q(z)$ for this plant.

b. Calculate the resulting nominal complimentary sensitivity $T_{oq}(z)$.

THE END

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