

Mid Semester Exam # 2

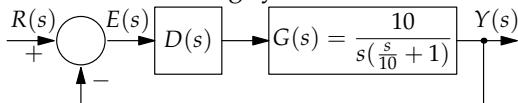
EE 250 (Control Systems Analysis) Spring 2009 *

DEPARTMENT OF ELECTRICAL ENGINEERING, IIT KANPUR.

Dear student,

1. Please number your answers in accordance with their questions.
2. Before you turn in your answer books, please verify that your answer booklet contains one semilog graph paper.
3. Use a ruler to draw the BPs.
4. You may use a pencil for trial and error, but your final drawing should be using a pen.
5. Show all your assumptions.
6. You may need a calculator. You may not borrow a calculator during the exam.

1. Consider the following system:



We wish to design a compensator $D(s)$ that satisfies the following design specifications:

- (a) $K_v = 100$.
- (b) $\Phi M = 60^\circ$.
- (c) Sinusoidal inputs of up to 1 rad/sec to be reproduced with $\leq 2\%$ error.
- (d) Sinusoidal inputs with a frequency of greater than 100 rad/sec to be attenuated at the output to $\leq 5\%$ of their input value.

- 1.1. [1 points] Determine K_1 and K_2 of Figure 1.
- 1.2. [1 points] Write the numerical values of ω_1 and ω_2 of Figure 1.
- 1.3. [1 points] What is the distance needed (in decades) between the corner frequencies ω_l and ω_h for the desired Bode plot of Figure 1?
- 1.4. [2 points] On the semilog grid provided, draw the ABMPs of the desired $D(s)G(s)$ and of $G(s)$. Your figure must contain all the necessary labels.
- 1.5. [1 points] On the semilog grid provided, show the ABMP of the resulting $D(s)$. Write the TF of $D(s)$.
- 1.6. [1 points] For the resulting CL system, given that $\omega_B \in [\omega_{\min}, \omega_{\max}]$, where ω_B is the bandwidth, what are the values of ω_{\min} and ω_{\max} ?
2. For the TF

$$KG(s) = \frac{K(s+2)}{s+10} e^{-t_d s}$$

we will use the Bode Plot (BP) method to sketch the NP of $G(s)$.

- 2.1. [1 points] Sketch the BP.
- 2.2. [1 points] Sketch the polar plot (PP) section of the NP. Show this section by a thick solid line.
- 2.3. [1 points] Work out as many points as you find necessary on the s -plane contour and the $G(s)$ -plane contour that will help complete the NP.
- 2.4. [1 points] Sketch the NP. Label the sections of the s -plane contour C_1, C_2, \dots and the corresponding sections of the NP C'_1, C'_2, \dots

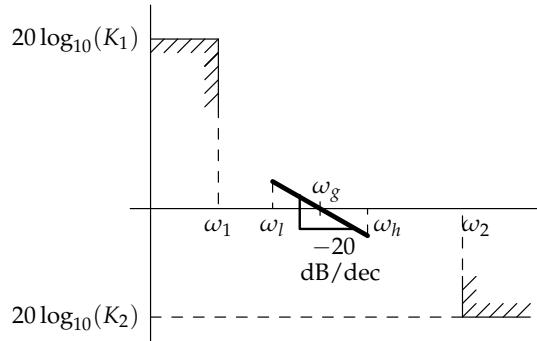
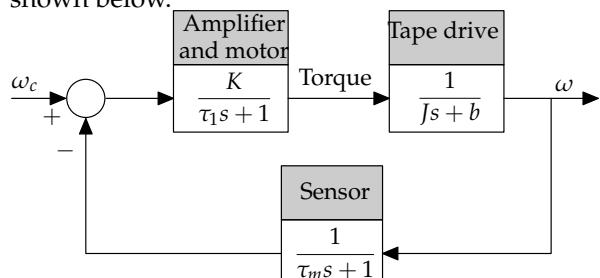


Figure 1: Parameters for loop-shaping

Label a few points on the s -plane contour $1, 2, \dots$, and the corresponding points on the NP $1', 2', \dots$.

- 2.5. [2 points] Use NST to determine the values of K and t_d for which the CL system is stable, for which it is marginally stable, and for which it is unstable.
3. [2 points] For the CL TF $\frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$, derive the expression for the bandwidth ω_{BW} in terms of ω_n and ζ .
4. A magnetic tape-drive speed-control system is shown below.



The speed sensor is slow enough that its dynamics must be included. The speed-measurement time constant is $\tau_m = 0.5$ s; the reel time constant is $\tau_r = J/b = 4$ s, where b = the output shaft damping constant = 1 N-m-sec; and the motor time constant is $\tau_1 = 1$ s.

- 4.1. [1 points] Determine the gain K required to keep the steady-state speed error to less than $x\%$ of the reference-speed setting.
- 4.2. [2+2 points] Assuming $x = 5$, determine the gain and phase margins of the system for the value of K found in item 4.1.

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