$Y(s) - R(s) = \frac{R(s)}{1+P(s)C(s)}$

ELL225: Major Examination

Electrical Engineering, IIT Delhi, Semester II 2016-2017

Total Marks: 40 Duration: 2 hours

Useful Formulas (step response of an underdamped second-order system)

Rise Time $T_r \approx \frac{1.8}{\omega_n}$, $\% M_p = e^{\frac{-\pi\zeta}{\sqrt{1-\zeta^2}}} \times 100$, Peak Time $T_p = \frac{\pi}{\omega_n\sqrt{1-\zeta^2}}$, Settling Time $T_s \approx \frac{4}{\zeta\omega_n}$.

Unity Negative Feedback System

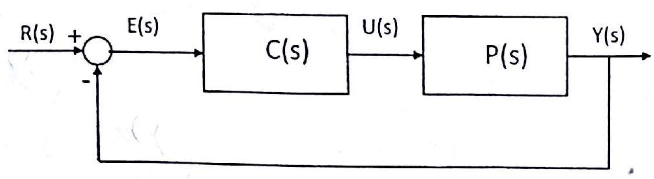


Figure 1

1. A unity feedback system (Fig. 1) with the plant

$$P(s) = \frac{1}{s(s+5)}$$

and controller $C(s) = K$ is operating with a closed-loop step response that has a rise time of 0.1 sec. Answer the following:

   (a) Evaluate the steady-state error for a unit ramp input. (2)

   (b) Design a lag compensator i.e. $C(s) = K\frac{s+z}{s+p}$ such that the steady-state error is reduced by a factor of 10 as compared to (a) without altering the transient response. (2)

2. Consider the following plant and lag compensator connected as in Fig. 1

$$P(s) = \frac{1}{(s^2+2s-3)}, \qquad C(s) = K\frac{(s+10)}{(s+5)}$$

where $K\ (>0)$. Sketch the locus of closed-loop poles as K varies from 0 to ∞. Comment on closed-loop stability for high value of gain. (4)

3. Consider the plant

$$P(s) = \frac{1}{s(s+2)}$$

Design a stabilizing feedback controller $C(s)$ (Fig.1) to meet both the specifications: (4)

   (a) zero steady-state error due to ramp reference input

   (b) zero steady-state error due to ramp disturbance input (Note: In Fig. 1, the additive disturbance enters between $C(s)$ and $P(s)$)

$z = N + P$

$Z = N$

4. Sketch the Bode plot for the following system

$$L(s) = \frac{100(s-0.1)^2}{s^2(s^2+10s+100)}$$

(4)

5. Consider the plant

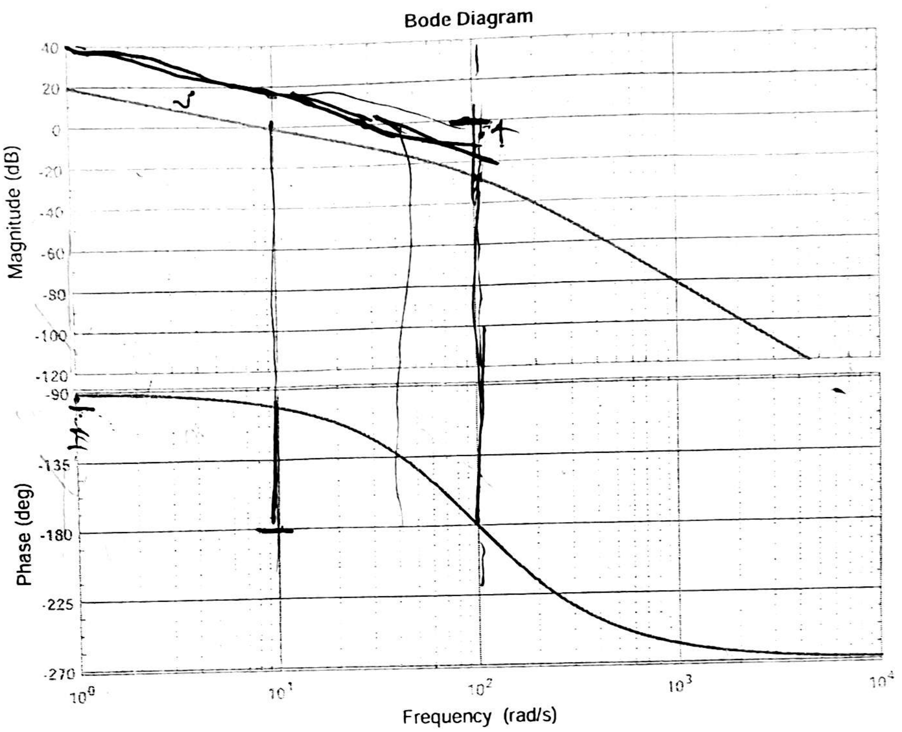
$$P(s) = \frac{1}{s(s+1)(s+3)}$$

in a negative unity feedback loop (Fig. 1), where $C(s) = K = 2$.

   (a) Using the Nyquist Stability Criterion, determine stability of the closed-loop system. (5)

   (b) Find the Gain Margin (GM). (1)

6. The experimentally determined frequency response data for a plant $P(s)$ is represented using a Bode Plot below



The plant is now connected in unity negative feedback (Fig. 1), where $C(s) = K$.

(a) For $K = 1$, estimate the Gain Margin (GM) and Phase Margin (PM). (2)

(b) For $K = 1$, estimate the steady-state error due to a unit ramp reference input. (2)

(c) By what factor should K be changed to achieve a ten-fold reduction in the steady-state error as compared to (b). (2)

(d) Estimate the GM and PM for K obtained in (c). (2)

(e) Comment on how the rise time and %OS might change (increase/decrease/no change) as K is changed from $K = 1$ to the value obtained in (c). Justify. (2)

7. For the following plant $P(s)$ connected in closed-loop (Fig. 1), it is desired to achieve a damping ratio of $\zeta = \frac{1}{\sqrt{5}}$ and natural frequency of $\omega_n = 3\sqrt{5}$.

$$P(s) = \frac{1}{(s+4)^2(s+6)}$$

(a) Find the desired closed-loop pole locations. (1)

(b) Show that it is not possible to obtain the desired closed-loop poles using $C(s) = K$. (2)

(c) Design a lead compensator $C(s) = K\frac{s+z_c}{s+p_c}$ to achieve the desired transient objective (i.e. you need to find K, z_c and p_c). (*Hint: Choose the compensator zero strategically to easily meet the dominant pole approximation*) (5)