EE3004: Control Engineering - Section ESB350 July - Nov 2018

Tutorial & Homework #9 Due: 25 October 2018

1. Draw polar plot for the following transfer functions:
   a) $G(s) = \frac{1}{s-1}$
   b) $G(s) = \frac{(s-2)}{(s+1)^2}$
   c) $G(s) = \frac{1}{(s+1)(s+2)(s+3)}$
   d) $G(s) = \frac{(s+2)}{(s+1)(s-1)}$
   e) $G(s) = \frac{1}{s^2(s+1)}$
   f) $G(s) = \frac{1}{(s^2+4)(s-1)}$
   g) $G(s) = \frac{1}{(s^2-4)(s-1)}$
   h) $G(s) = \frac{1}{s^2(s+2)(s-4)}$
   i) $G(s) = \frac{(s+1)(s+2)}{s^3}$
   j) $G(s) = \frac{(s+1)}{s^2(s+2)(s+4)}$

2. The open loop transfer function of a control system is given as $G(s) = \frac{1}{s+1}$. Determine the steady state response $c(t)$ for a pure sine wave input $r(t) = \sin(t)$. Also, draw the magnitude vs ω plot and phase vs ω plot for the given system.

3. For a system describes by differential equation. $\ddot{x}(t) + 2\dot{x}(t) = y(t)$. Determine the steady state response $c_{ss}(t)$ for a pure sine wave input $r(t) = 3\sin(0.5t)$. Also, draw the magnitude vs ω plot and phase vs ω plot of the system.

4. The closed loop transfer function of a control system is given as $G(s) = \frac{\omega_n^2}{s^2+2\zeta\omega_n+\omega_n^2}$. For a pure sine wave input $r(t) = \sin(\omega t)$, prove that the resonant frequency ω_r at which the magnitude of $G(j\omega)$ maximum occurs can be derived as, $\omega_r = \omega_n\sqrt{(1-2\zeta^2)}$. Show that the magnitude at the resonant frequency $M_r = \frac{1}{2\zeta\sqrt{(1-2\zeta^2)}}$. Draw the magnitude vs ω plot and phase vs ω plot for the given system for two different values of ζ, say, $0 < \zeta_1 < \zeta_2 < \frac{1}{\sqrt{2}}$.

5. Sketch the Nyquist plot for the following open loop transfer functions. Determine the range of K for which the system is stable using the Nyquist plot.

   a) $G(s)H(s) = \frac{K(s-2)}{(s+1)^2}$

   b) $G(s)H(s) = \frac{K}{(s+1)(s+2)(s+3)}$

   c) $G(s)H(s) = \frac{K(s+2)}{(s+1)(s-1)}$

   d) $G(s)H(s) = \frac{K}{s^2(s+1)}$

   e) $G(s)H(s) = \frac{K}{(s^2+4)(s-1)}$

   f) $G(s)H(s) = \frac{K}{(s^2-4)(s-1)}$

   g) $G(s)H(s) = \frac{K(s-3)}{(s^2-4)(s-1)}$

   h) $G(s)H(s) = \frac{K}{s^2(s+2)(s-4)}$

   i) $G(s)H(s) = \frac{K(s+1)(s+2)}{s^3}$

   j) $G(s)H(s) = \frac{K(s+1)}{s^2(s+2)(s+4)}$

6. Consider $G(s)H(s) = \frac{K(s+20)}{s^2}$. Determine the gain K such that the phase margin is 45^o. What is the gain margin in this case?

7. A unity feedback control system has a loop transfer function $G(s) = \frac{K}{s(s+2)(s+50)}$. Determine the phase margin, the crossover frequency, and the gain margin when $K = 1300$.

8. A unity feedback system has a loop transfer function $G(s) = \frac{1}{s(s+1)(s+2)}$. Determine the gain margin, phase margin and corresponding crossover frequencies.

9. A unity feedback system has a loop transfer function $G(s) = \frac{11.7}{s(1+0.05s)(1+0.1s)}$. Determine the phase margin and the crossover frequency.

10. Repeat problem (7) for $G(s)H(s) = \frac{Ke^{-0.1s}}{(s+10)}$ by taking phase margin 50^o.

11. A unity feedback system has a loop transfer function $G(s) = \frac{\pi e^{-0.25s}}{s}$. Determine the gain margin, phase margin and corresponding crossover frequencies.