Professor Fearing EECS128/MEC134 Problem Set 8 v1.04 Fall 2018

Due at 1700, Fri. Nov. 2 in bcourses. .

Note: up to 2 students may turn in a single writeup. Reading Nise 10, 11, 12.2

1. (20 pts) Time Delay (Nise 10.12)

Given a unity feedback system with forward path transfer function

$$G(s) = \underline{2}\,\frac{8000}{(s+20)^3}.$$

Assume an added delay in the feedforward path, for example from camera frame rate limit, of ΔT.
[2pts] a) Draw a block diagram for the system, including ΔT propagation delay for error $e(t)$ to reach the controller/plant $G(s)$.
[8pts] b) Draw Bode diagrams for the system without delay, and estimate gain and phase margin. Determine ΔT for a 20° reduction in phase margin for the system with delay.
[6pts] c) Estimate overshoot and settling time from second order approximation for both cases.
[4pts] d) Use Matlab to plot the step response for the closed loop system with and without delay and compare to the estimate from part c. (Use `Gdelay=tf(num,den,'InputDelay',deltaT)` to include time delay in the system.)

2. (25 pts) Lag Compensation (Nise 11.3)

Given unity feedback system with OLTF:

$$G(s) = \frac{K(s+4)}{(s+2)(s+6)(s+8)}$$

[7pts] a) Sketch by hand the Bode plot for $G(j\omega)$.
[15pts] b) Design a lag compensator (using methods of Ch 11) such that the phase margin is at least 45°, and the static error constant = 100 and sketch the Bode plot for the compensated OLTF.
[3pts] c) Use Matlab to plot the closed-loop step response for the compensated and uncompensated system, and compare steady state error. Also use `margin` to check design spec is met.

3. (25 pts) Lead Compensation (Nise 11.4)

Given unity feedback system with OLTF:

$$G(s) = \frac{K}{s(s+5)(s+20)}$$

[7pts] a) Sketch by hand the Bode plot for $G(j\omega)$.
[15pts] b) Design a lead compensator using frequency domain techniques (of Ch 11) , such that per cent overshoot is approximately 10% or less, with $T_p \approx 0.5 sec$ and $k_v \approx 10$, and sketch the Bode plot for the compensated OLTF.
[3pts] c) Use Matlab to plot the closed-loop ramp response for the compensated and uncompensated system, and compare steady state error and settling time. Also use `margin` to check design spec is met.

4. (30 pts) State Feedback/Pole placement (Nise 12.2)

Consider the plant, where $G(s) = Y(s)/U(s)$:

$$G(s) = \frac{100}{(s+1)^4}.$$

[8pts] a. Draw the signal graph in phase variable form and write the corresponding state equations.
[12pts] b. Find $K = [k_1\ k_2\ k_3\ k_4]$ such that feedback $u = r - K\mathbf{x}$ yields an equivalent second order step response with $\zeta = 0.5$ and $\omega_n = 10$. (Place third and fourth pole 5 times further from $j\omega$ axis as the dominant pole pair).
[10pts] c. With zero initial conditions, use Matlab to plot the step response $y(t)$ and also $u(t)$, and each individual component $k_1x_1(t)$, $k_2x_2(t)$, $k_3x_3(t)$, $k_4x_4(t)$. Which state contributes most to $u(t)$?