Professor Fearing EECS128/MEC134 Problem Set 7 v1.01 Spring 2017

**Due at 1700, Fri. Mar. 17 in homework box under stairs, first floor Cory .**

Note: up to 2 students may turn in a single writeup. Reading 10-10.7.

Midterm: Thurs. Mar.9. Location: 277 Cory, 0800-0930 am.

1. (20 pts) Review- PID Compensation (Nise 9.4)

Consider open loop plant $G(s)$ with unity feedback:

$$G(s) = \frac{K(15)(13)}{(s+15)(s^2+6s+13)}$$

[2pts] a. Find the gain $K$ such that $G/(1+G)$ has overshoot less than 20% (Matlab ok).

[12pts] b. Design a PID controller $G_c(s)$ such that overshoot is less than 20%, with $T_s < 1$ sec, with zero steady state error for a step. Specify open and closed-loop poles, zeros and gains.

[4pts] c. Hand sketch the root locus for both $G(s)$ and $G_c(s)G(s)$, and verify with Matlab (rules1-5,8-9).

[2pts] d. Show before and after compensation step response on same plot using Matlab.

2. (15 pts) Bode Plot (Nise 10.2)

Sketch (by hand) the asymptotes of the Bode plot magnitude and phase for each of the following open-loop transfer functions. For second order poles, note peak magnitude in dB. Verify sketch using MATLAB plot with same axes scales, and turn in (log frequency, and magnitude in dB).

a) $\frac{s}{(s+1)(s+1)^2}$ b) $\frac{s^2+2s+10001}{(s+10)(s^2+2s+101)}$ c) $\frac{s+1}{s^2(s+10)}$

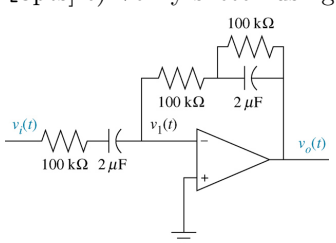
3. (15 pts) Compensation Network (Nise 9.6, 10.2)

For the ideal op amp circuit below:

[4pts] a) Determine the transfer function $T(s) = \frac{V_{out}(s)}{V_{in}(s)}$. Express the transfer function as a standard rational function (polynomial numerator, polynomial denominator).

[8pts] b) Hand sketch the Bode plot for magnitude and phase.

[3pts] c) Verify sketch using MATLAB plot and turn in plot.




4. (25 pts) Nyquist Plot (Nise 10.5)

Consider a closed loop system with unity feedback. The open loop transfer function is:

$$G(s) = \frac{k(s-1)}{(s^2+2s+5)(s^2+20s+100)}$$

[6pts] a) Hand sketch the asymptotes of the Bode plot magnitude and phase for the open-loop transfer functions.

[10pts] b) Hand sketch Nyquist diagram.

[4pts] c) From Nyquist diagram, determine range of $k$ for stability.

[5pts] d) Verify sketches with MATLAB (`bode()` and `nyquist()`) and hand in.

5. (25 pts) Gain and phase margin (Nise 10.7, 10.10)

A closed loop system with unity gain has open loop transfer function

$$G(s) = \frac{300(s-2)}{(s+10)^2(s^2+2s+17)}$$

[6pts] a) Hand sketch the asymptotes of the Bode magnitude and phase plots for the open loop system.

[6pts] b) Determine the gain and phase margin.

[6pts] c) Assuming a second order approximation for the closed loop system, estimate the transient response for a step input from the phase margin and gain margin. (That is estimate $\xi$, overshoot, peak time, and settling time.)

[4pts] d) Compare the actual closed loop step response from MATLAB with the estimates from c).

[3pts] e) Verify sketches with MATLAB (`bode()`) and hand in.