Due at 1700, Fri. Oct 12 in bcourses .

Note: up to 2 students may turn in a single writeup. Reading 9, 10-10.7.

Midterm: Thurs. Oct. 18, Location: tba, 1710-1830 pm.

1. (25 pts) Lead compensation (Nise 9.3)

Consider open loop plant

$$G(s) = \frac{1}{(s+3)(s+5)}.$$

Design goals: i) Settling time of 0.67 sec, and ii) per cent overshoot of 1.5%.

[5 pts] a) Show that the original system without compensation can not meet the transient specification for any k.

[10 pts] b) Show that a lead compensator $D(s) = k\frac{s+z}{s+p}$ with $z < p$ will meet the design specifications and find an acceptable set of values of k, p, and z. Verify with Matlab.

[8 pts] c) Hand sketch the root locus for the original system and the system with a lead compensator, and verify with Matlab.

[2 pts] d) What is the steady state error $e(t)$ for the uncompensated and compensated systems for a step input?

2. (20 pts) PID Compensation (Nise 9.4)

Consider open loop plant

$$G(s) = \frac{K}{(s+4)(s+6)(s+10)}$$

with unity feedback.

[2pts] a. Find the gain K for the uncompensated system to operate with overshoot less than 25% (Matlab ok).

[12pts] b. Design a PID controller such that overshoot is less than 25%, with $T_s < 2$ 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 of the original and compensated system, and verify with Matlab (rules1-5,9).

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

3. (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. (For the approximation, be sure to label the trends as $j\omega \to 0$ and $j\omega \to \infty$, as well as the slopes, and the frequency at which the slopes change.) Verify sketch using MATLAB plot with same axes scales, and turn in (log frequency, and magnitude in dB).

$$G_1(s) = \frac{s}{(s+1)(s+100)} \quad G_2(s) = \frac{s+1}{s(s+30)} \quad G_3(s) = \frac{1}{s^2+3s+9}$$

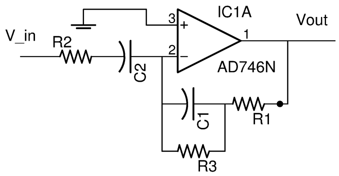
4. (15 pts) Compensation Network (Nise 9.6, 10.2)

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 for R1 = 1K Ω , R2 = 10K Ω , R3 = 100K Ω, C1 = 1000 nF , and C2 = 1000 nF.

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



5. (25 pts) Nyquist Plot (Nise 10.5)

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

$$G(s) = \frac{100}{(s+10)(s^2+2s+4)}$$

[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.