

ECE 3510 hw RL7 Root Locus Design

You may sketch root locus plots and make calculations using a computer program.
 Questions and problems from Nise are the same for 3rd & 4th editions unless specified otherwise.

1. Nise Ch. 9 review questions: 3, 4, 5, 9, 10, 11, & 12.
2. Nise Ch. 9 problem 1. For an explanation of the static error constants & calculation of steady-state error, see Nise, section 7.3 or Root Locus Design Crib Sheet. If you use Bodson eq 4.6, include the gain factor (multiply $P(0)C(0)$ by K).

Use $G(s)$ and damping ratio (factor) from 3rd ed:

$$G_{uc}(s) := \frac{1}{(s+3) \cdot (s+6)} \quad uc = \text{uncompensated} \quad \zeta := 0.707$$

Design a PI controller and show that it works.

3. Nise Ch. 9 problem 3 Use $G(s)$ and 10% overshoot from 3rd ed: $G_{uc}(s) := \frac{1}{(s+1) \cdot (s+3) \cdot (s+5)}$

- a) The static error constant is K_p on our Crib Sheet.
- b) Want to improve to $K_p = 4$ using lag controller.
- c) I suggest you use the SISO tool to show the improvement.

4. Nise Ch. 9 problem 6 Use $G(s)$ from 3rd ed: $G_{uc}(s) := \frac{1}{(s+1) \cdot (s+2) \cdot (s+3) \cdot (s+6)}$ use: $\zeta := 0.707$

- a) Shorten settling time to half of what it is without PD compensation.
- b) Calculate the steady state error for a step input.

For the justification of the 2nd-order assumption, see section 8.7 in Nise. Especially, read the first numbered list and item 3 in the second list. (p. 452 in 3rd ed, p455 in 4th ed, p.416 in 6th ed.)

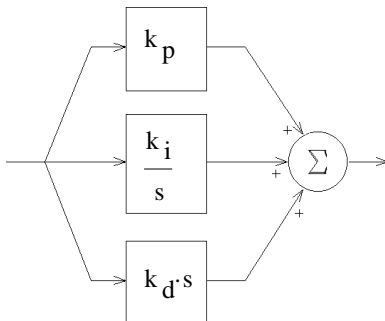
5. Nise Ch. 9 problem 8 Use $G(s)$ and 20% overshoot from 3rd ed: $G_{uc}(s) := \frac{1}{s \cdot (s+5) \cdot (s+15)}$

- a) Shorten settling time to 1/4 of what it is without PD compensation.
- b) Change design a lead compensator. Move the zero you found in part a) to -3 and finding the required pole.

6. You have designed a compensator with the following:

A pole at the origin A zero at -0.5 A zero at -10 Gain of 20

Find the k_p , k_i , & k_d of a PID controller.



Answers

1. ANSWERS TO REVIEW QUESTIONS

1. Chapter 8: Design via gain adjustment. Chapter 9: Design via cascaded or feedback filters.
2. A. Permits design for transient responses not on original root locus and unattainable through simple gain adjustments.
B. Transient response and steady-state error specifications can be met separately and independently without the need for tradeoffs
3. PI or lag compensation 4. PD or lead compensation 5. PID or lag-lead compensation
6. A pole is placed on or near the origin to increase or nearly increase the system type, and the zero is placed near the pole in order not to change the transient response.
7. The zero is placed closer to the imaginary axis than the pole. The total contribution of the pole and zero along with the previous poles and zeros must yield 180° at the design point. Placing the zero closer to the imaginary axis tends to speed up a slow response.
8. A PD controller yields a single zero, while a lead network yields a zero and a pole. The zero is closer to the imaginary axis.
9. Further out along the same radial line drawn from the origin to the uncompensated poles
10. The PI controller places a pole right at the origin, thus increasing the system type and driving the error to zero.
A lag network places the pole only close to the origin yielding improvement but not zero error.
11. The transient response is approximately the same as the uncompensated system, except after the original settling time has passed. A slow movement toward the new final value is noticed.
12. 25 times; the improvement equals the ratio of the zero location to the pole location.
13. No; the feedback compensator's zero is not a zero of the closed-loop system.
14. A. Response of inner loops can be separately designed; B. Faster responses possible;
C. Amplification may not be necessary since signal goes from high amplitude to low.

2. Uncompensated: CL pole $s_{uc} := -4.5 + 4.5 \cdot j$ $K_{uc} := 22.5$ 44.4% steady-state error

$$\%OS = 4.32\% \quad T_s = 0.889 \text{ sec}$$

For: $C(s) = \frac{s+0.1}{s}$ CL pole $s_c := -4.472 + 4.472 \cdot j$ $K_{uc} := 22.5$ no steady-state error

$$\%OS = 4.32\% \quad T_s = 0.894 \text{ sec} \quad \text{Using 2nd-order approximation}$$

3. Uncompensated: $s_{uc} := -1.4 + 1.91 \cdot j$ $K := 19.9$ steady-state error is about 43%

Compensated, want $K_p = 4$, steady-state error of 20% Try: $C(s) = \frac{s+0.3}{s+0.1}$ That should yield a 3x improvement in K_p .

Matlab output shows a good reduction in steady-state error.

4. Uncompensated: $s_{uc} := -1.05 + 1.05 \cdot j$ $K := 16.65$

Want $s_c := -2.1 + 2.1 \cdot j$ Need zero at -0.604

Possible problems with the 2nd-order assumption: Pole at -0.771 is not close enough to the zero at -0.604 to cancel it.
Pole at -7.03 is not 5 times farther from $j\omega$ axis than -2.1 .

b) 0.753 75% error! That zero close to the origin is NOT OK.

5. Uncompensated: $s_{uc} := -1.809 + 3.533 \cdot j$ $K := 258$

Want $s_c := -7.236 + 14.132 \cdot j$ Need zero at -5.422

Compare to example 9.7 (table 9.8), similar to compensated system except gain.
Gain is similar to uncompensated system.

$$b) C(s) = \frac{s+3}{s+94.43}$$

6. 210, 100, 20