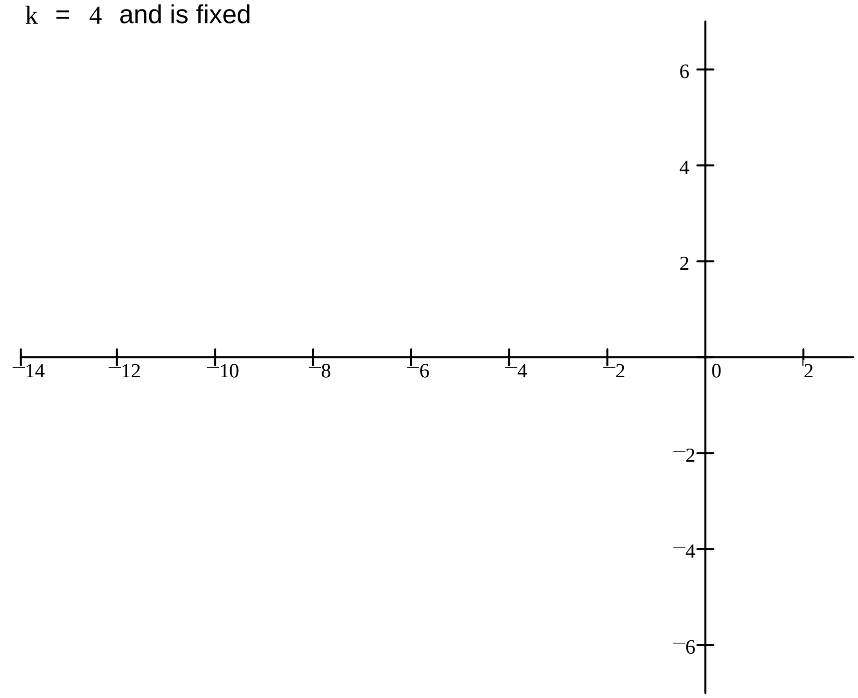
ECE 3510 Exam 3 given: Spring 20 (Some of the space between problems has been removed.)

1. (20 pts) Sketch the unconventional root-locus plot for the open-loop transfer function below.
   The root-locus should be plotted for an increasing b.

$$G(s) = \frac{k\cdot(s+21\cdot b)}{s\cdot(s+b\cdot(s+19))}$$

$k = 4$ and is fixed



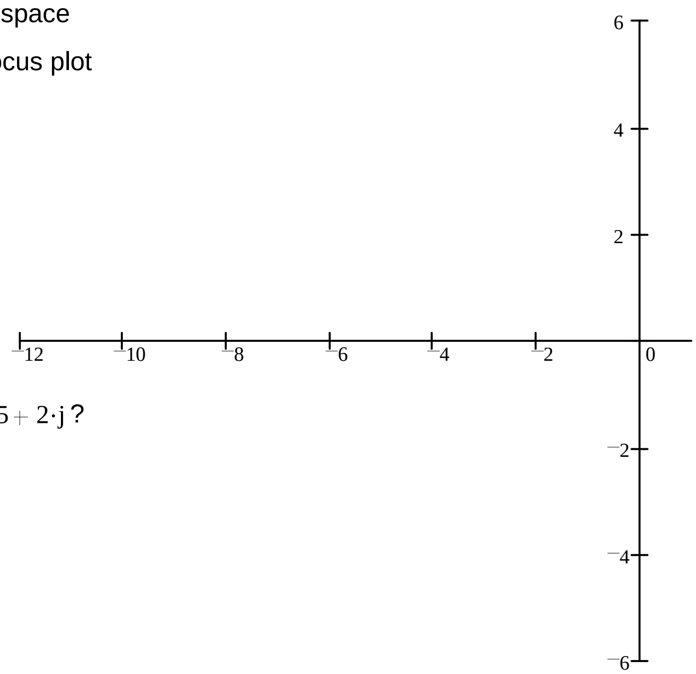
b) Draw an arrow to the place(s) on your root locus where you would like to place the closed-loop poles for minimal (or no) ringing and the shortest settling time.

c) Find the value of b needed, based on your best reading of your plot above.

2. (40 pts) Consider the transfer function shown.unneeded space

$$G(s) := \frac{s+7}{(s+1)\cdot(s+3)\cdot(s+11)}$$

a) Sketch the root-locus plot



b) Does the root-locus pass through the point $s := -2.215 + 2\cdot j$?
   Show your work or state what did in your calculator.

Assuming the closed-loop pole is at $-2.215 + 2\cdot$ leads to the following values (I calculated):

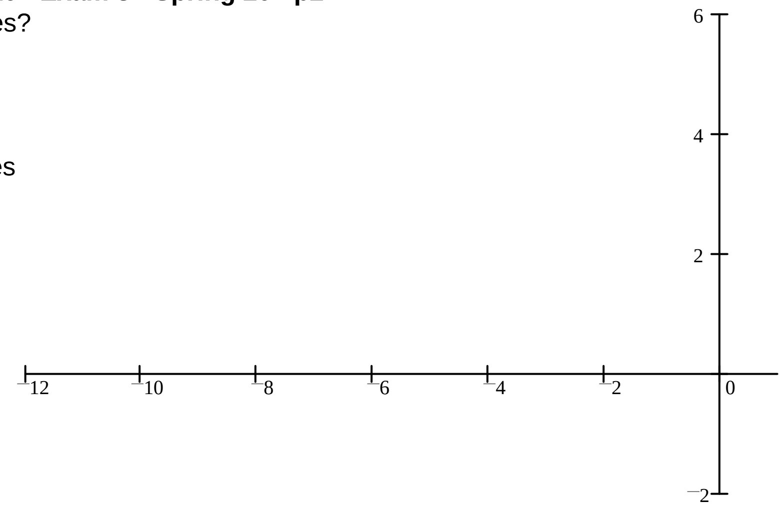
Gain: 8.735 Settling time: $1.806\cdot sec$ Steady-state error to a unit-step input: 35.1%

c) Where should the closed-loop poles be located to decrease the settling time to 1 sec and without changing the % overshoot at all? (Use the second-order approximation.)

d) What would be the damping factor of those poles?

$\zeta = ?$

e) Add a compensator so that the closed-loop poles can be placed at the location found in part c). Use the angle summing method and show your work, esp. the angles that you find.



Note: If you can't calculate the zero location or doubt your calculation, assume it is at -8 for the rest of this problem.

f) With the compensator in place and a closed-loop pole at the desired position of part c)

i) What is the gain?

ii) What is the % overshoot? Use the second-order approximation.

iii) What is the steady-state error to a unit-step input?

g) How would you improve the steady-state error to a unit-step input? If it is another compensator, give specifics (numbers). Determine if the location from part c) is still close to the RL plot

3. (22 pts) You want to use ladder logic to control a refrigerator/freezer unit. There are 6 inputs and 2 outputs Consider normally-open contacts to be closed when an associated input is "high".

<u>Inputs</u>

- M1 Manual push button to turn the refrigerator on. (Input "high" when pushed)
- M2 Manual push button to turn the refrigerator off. (Input "high" when pushed)
- T1 High whenever refrigerator temperature is above 39 degrees.
- T2 High whenever refrigerator temperature is above 41 degrees.
- T3 High whenever freezer temperature is above 25 degrees.
- C High only if it is safe to run the compressor motor.

<u>Outputs</u>

- Mot Turns or compressor motor.
- Fan Turns on fan between freezer and refrigerator.

<u>Required operation</u>

1. One press of M1 will begin operation (turn on the refrigerator/freezer unit).
2. One press of M2 will cease operation (turn off the refrigerator/freezer unit).
3. Unit will only operate if C input is high. C may go low if the compressor has overloaded. Unit will begin operation again when C goes high, no manual input required.

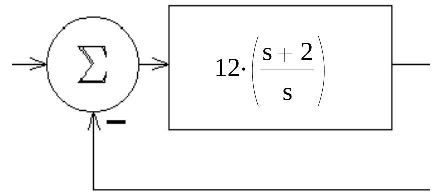
<u>Regular operation when "on"</u>

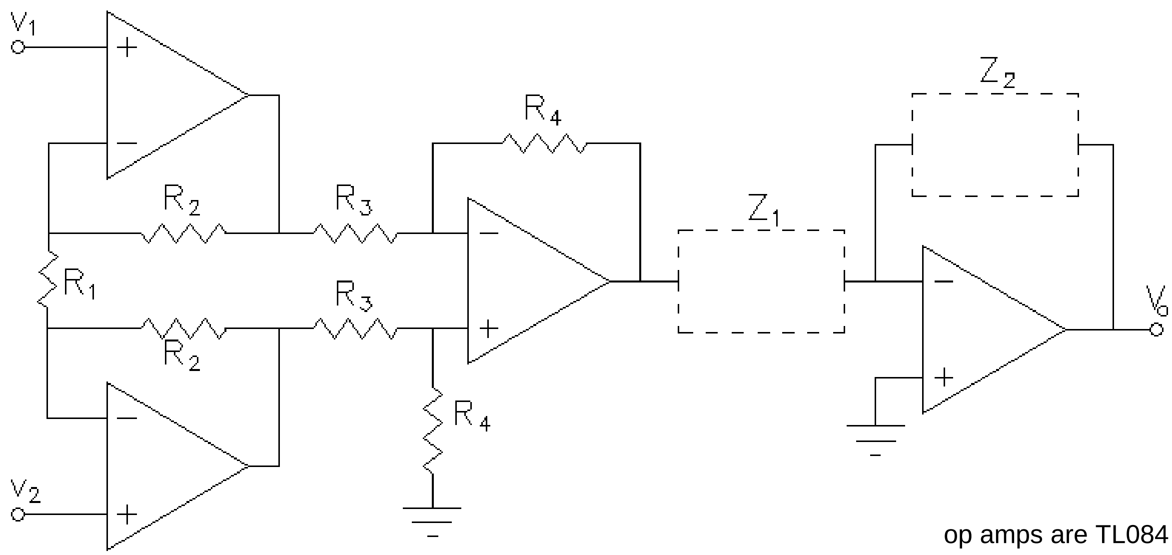
4. When refrigerator temperature goes above 41 degrees, compressor motor should turn on and should remain on until refrigerator temperature goes below 39 degrees
5. When compressor motor is on and freezer temperature is below 25 degrees, fan should turn on..

You may use as many relays as you wish. I suggest the following:

1. Implement requirements 1 and 2 using inputs M1 and M2 and a single "ON" relay.
2. To Implement requirements 3 and 4, use the "ON" relay, T1, T2, Mot, and C to operate the motor (Mot output). You may want to use another relay and possibly more than one ladder "rung" or circuit.
3. For requirement 5, use Mot and T3 to control the Fan output.

4. (18 pts) Implement the following sumation and PI controller in op-amp circuitry.





op amps are TL084

a) Specify which input to the instrumentation amplifier corresponds to which signal.

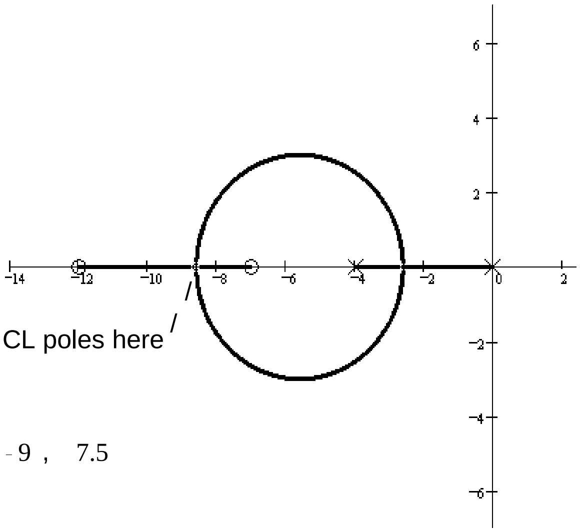
V_1 is:	i) input signal	ii) feedback signal	(circle one)
V_2 is:	i) input signal	ii) feedback signal	(circle one)

b) Show what parts should be placed in the boxes marked Z_1 and Z_2. You may wish to consult Table 9.10 (p.555 in 3rd ed. p.504 in 6th) in the Nise textbook.

c) Specify reasonable values for all the parts shown. Make the gain of the Instrumentation amplifier 6.

Answers

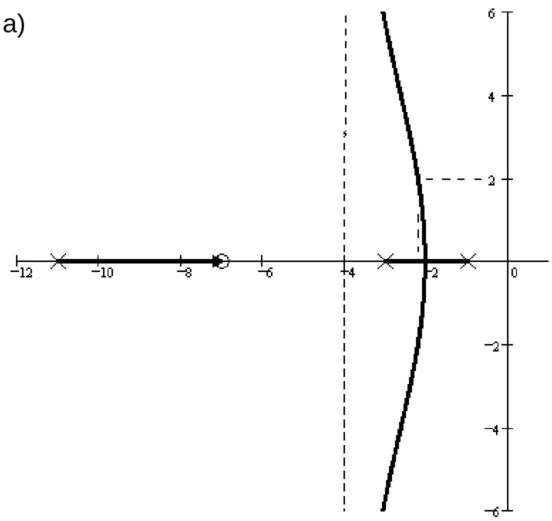
1. a)



b) Place CL poles here

c) if $s := -9$, 7.5

2. a)



b) YES

c) $s := -4 + 3.612 \cdot j$

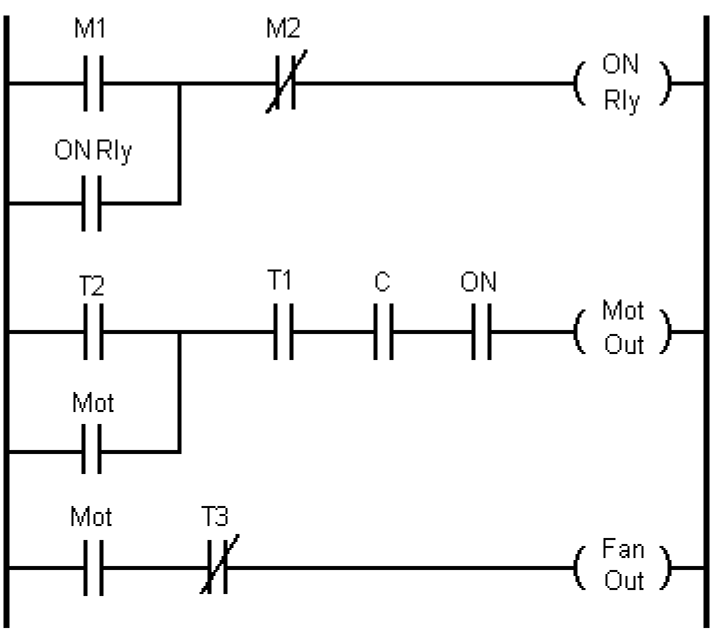
d) 0.742

e) $C(s) = s + 9.737$

f) i) 4.36 ii) $3.08 \cdot \%$ iii) $10 \cdot \%$

g) Just increase the gain

3.



4. a) i), ii) b) this part of exam was open-book

c) possible ans: $R_1 = R_2$ and $R_4 = 2 \cdot R_3$

$\mathbf{Z_1} = R_{Z1} = 250 \cdot k\Omega$

$\mathbf{Z_2} = R_{Z2} + \frac{1}{C_{Z2} \cdot s} = 500 \cdot k\Omega$ and $1 \cdot \mu F$ cap