ECE 6550 Exam 1
Fall 2025

Name ______________________________

General Instructions:

- Exam is closed book / closed notes other than the one-page of handwritten notes.
- Choose the best possible answer available in all cases.
- Blank scratch paper is allowed

_____/45_ Part I: Objective Questions

_____/55_ Part II: Open Response Questions

_____/100_ Final Score

Objective Question Instructions:

- The only graded answers are those placed on the lines below, and would be the identified element (e.g. a, b, c, d, e, f).
- Each question has equal weight (3 points each)

_______________ Question 1

_______________ Question 2

_______________ Question 3

_______________ Question 4

_______________ Question 5

_______________ Question 6

_______________ Question 7

_______________ Question 8

_______________ Question 9

_______________ Question 10

_______________ Question 11

_______________ Question 12

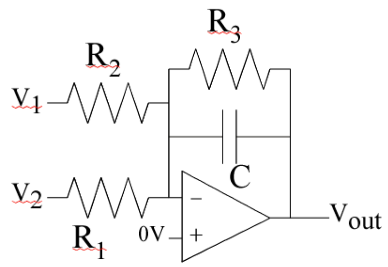
_______________ Question 13

_______________ Question 14

_______________ Question 15

Part I: Objective Questions

These questions have straight-forward answers. Make sure to put your answer in the line on the answer sheet as that is the part that will be graded for the answer given. Only the final answers, as indicated by the question, will be considered correct for each question. Each question is worth 3 points (total of 45 points)



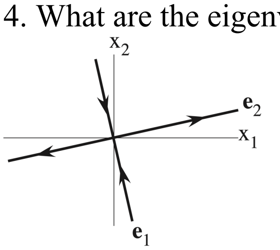
$R_1 = 2k\Omega$
$R_2 = 5k\Omega$
$R_3 = 10k\Omega$
$C = 1nF$

Question 1: What is the timeconstant of this circuit?
a. 1ns
b. 1μs
c. 2μs
d. 5μs
e. 10μs
f. 1ms

Question 2: What is the low-frequency gain magnitude from V_1 to V_{out}?
a. 0
b. 2
c. 5
d. 10
e. 20
f. 50

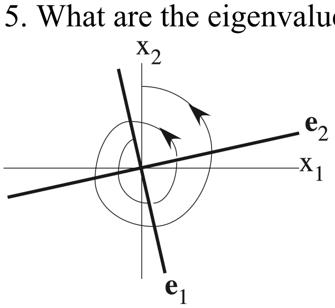
Question 3: What is the low-frequency gain magnitude from V_2 to V_{out}?
a. 0
b. 2
c. 5
d. 10
e. 20
f. 50

4. What are the eigenvalues for this phase plane plot?



a. λ_1, λ_2 Real and positive
b. λ_1, λ_2 Complex, $Re(\lambda_1, \lambda_2) > 0$
c. λ_1, λ_2 Real, $\lambda_1 > 0, \lambda_2 < 0$
d. λ_1, λ_2 Real and negative
e. λ_1, λ_2 Complex, $Re(\lambda_1, \lambda_2) < 0$

5. What are the eigenvalues for this phase plane plot?



a. λ_1, λ_2 Real and positive
b. λ_1, λ_2 Complex, $Re(\lambda_1, \lambda_2) > 0$
c. λ_1, λ_2 Real, $\lambda_1 > 0, \lambda_2 < 0$
d. λ_1, λ_2 Real and negative
e. λ_1, λ_2 Complex, $Re(\lambda_1, \lambda_2) < 0$

Matching

________ 6. Unstable

________ 7. Marginally Stable

________ 8. Asymptotically stable

________ 9. Exponentially stable

a. . / bounded throughout $0 < t < \infty$

b. $||y(t)|| < Ce^{\lambda t}$, positive C, negative λ

c. $||y(t)||$ unbounded somewhere $0 < t < \infty$

d. $||y(t)|| \to 0$ as $t \to \infty$

Matching

__________ 10. $\mathcal{O}$

__________ 11. LQR

__________ 12. Parameters for LQR

__________ 13. $\mathcal{C}$

__________ 14. LQE

__________ 15. Parameters for LQE

a. $\mathbf{Q}$ & $\mathbf{R}$

b. $\mathbf{PA} + \mathbf{A}^T\mathbf{P} - \mathbf{PBR}^{-1}\mathbf{B}^T\mathbf{P} + \mathbf{Q} = 0$

c. $\begin{pmatrix}\mathbf{B} & \mathbf{BA} & \mathbf{BA}^2 & ... & \mathbf{BA}^{m-1}\end{pmatrix}$

d. $\mathbf{P}_f\mathbf{C}^T\mathbf{Q}_v^{-1}$

e. $\begin{pmatrix}\mathbf{B} & \mathbf{AB} & \mathbf{A}^2\mathbf{B} & ... & \mathbf{A}^{m-1}\mathbf{B}\end{pmatrix}$

f. $\begin{pmatrix}\mathbf{C} \\ \mathbf{CA} \\ \mathbf{CA}^2 \\ \mathbf{CA}^{m-1}\end{pmatrix}$

g. $\mathbf{R}^{-1}\mathbf{B}^T\mathbf{P}$

h. $\begin{pmatrix}\mathbf{C} \\ \mathbf{AC} \\ \mathbf{A}^2\mathbf{C} \\ \mathbf{A}^{m-1}\mathbf{C}\end{pmatrix}$

i. $\mathbf{Q}_n$ & $\mathbf{Q}_d$

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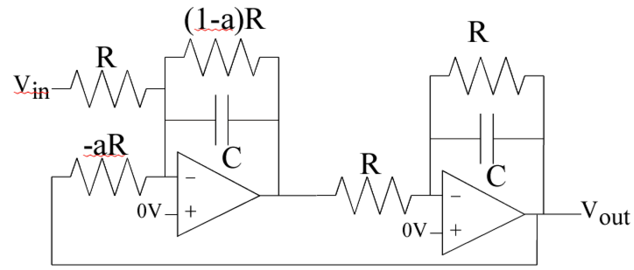
Part II: Open Response Question (55 points)

___/45_ Part II: Open Response Questions

___/28_ Question 1

___/27_ Question 2

Question 1: Consider the following linear circuit that arrives from a linearized model. Noise (amplitude) at V_{out} is 100μV. C = 1nF & R = 1kΩ. Components are known and measured. Assume the cost for measuring and applying voltages is equal and independent.

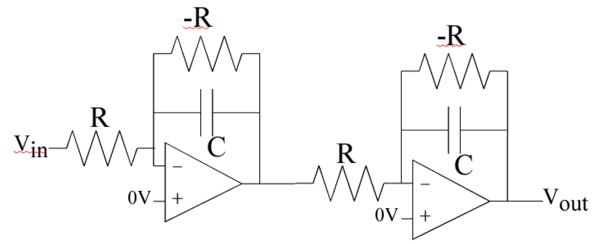


Solve for the normalized state equation (e.g. normalized by time constant). For a = 1 and a = 3, give the specific state equations, show the stability for these two state equations.

As part of this problem, we will build a controller for a = 3 to improve the stability of the system.

- Show that the system is observable and controllable.
- Set up the LQR solution assuming we have both state variables.
- Set up the LQE solution.
- Assuming you have K_R and K_F, and that the circuit above is a system with V_{in} and V_{out}, draw with relevant parameters for the entire controller.

Question 2: Consider the following linear circuit that arrives from a linearized model. C = 1nF & R = 1kΩ. Assume the cost for measuring and applying voltages is equal, and equal to the cost for measuring one state with another state.



This problem will build a controller for this well-known unstable system.

- Solve for the normalized state equation (e.g. normalized by time constant).
- Show that the system is observable and controllable.
- Assuming we know the V_{out} and the middle node (call it $-V_1$), solve for the LQR solution for this circuit.