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M.Sc.TE, 1st Semester

December 09, 2023
1:30 pm – 4:30 pm

ISLAMIC UNIVERSITY OF TECHNOLOGY (IUT)
ORGANISATION OF ISLAMIC COOPERATION (OIC)
DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

Semester Final Examination
Course No.: EEE 6195
Course Title: Modern Control Theory

Winter Semester, A. Y. 2022-2023
Time: 3 Hours
Full Marks: 150

There are **8 (eight)** questions. Answer any **6 (six)** questions. The symbols have their usual meanings. Programmable calculators are not allowed. Marks of each question are written in the brackets.

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1. a) With suitable diagram, derive the pole placement equations for controller design for the plants in phase-variable form. **10**

   b) Given the plant, **15**

$$G(s) = \frac{20(s+5)}{s(s+1)(s+4)}$$

   Design the phase-variable feedback gains to yield 9.5% overshoot and a settling time of 0.74 second.

2. a) Derive necessary formula to Systems represented in other forms to convert into phase variable form and applying pole placement topology and revert back to original system. **13**

   b) Determine whether the system is controllable. **12**

$$x = Ax + Bu = \begin{bmatrix} -1 & 1 & 2 \\ 0 & -1 & 5 \\ 0 & 3 & -4 \end{bmatrix} x + \begin{bmatrix} 2 \\ 1 \\ 1 \end{bmatrix} u$$

3. a) What is the challenge in designing controller for the system not represented in phase variable form? **12**

   b) Design a linear state-feedback controller to yield 20% overshoot and a settling time of 2 seconds for a plant **13**

$$G(s) = \frac{(s+6)}{(s+7)(s+8)(s+9)}$$

   that is represented in state space in cascade form by

$$z = Az + Bu = \begin{bmatrix} -7 & 1 & 0 \\ 0 & -8 & 1 \\ 0 & 0 & -9 \end{bmatrix} z + \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} u$$

$$y = Cz = \begin{bmatrix} -1 & 1 & 0 \end{bmatrix} z$$

4. a) Explain with necessary diagram and formula different configuration of observer design. **13**

   b) Design an observer for the plant **12**

$$G(s) = \frac{(s+6)}{(s+7)(s+8)(s+9)}$$

   whose estimated plant is represented in state space in observer canonical form as

$$\hat{x} = A\hat{x} + Bu = \begin{bmatrix} -24 & 1 & 0 \\ -191 & 0 & 1 \\ -504 & 0 & 0 \end{bmatrix} \hat{x} + \begin{bmatrix} 0 \\ 1 \\ 6 \end{bmatrix} u$$

$$\hat{y} = C\hat{x} = \begin{bmatrix} 1 & 0 & 0 \end{bmatrix} \hat{x}$$

   The observer will respond 10 times faster than the controlled loop design.

5. a) What is the downside of the determining controllability and observability by inspection? 12

b) Determine whether the system 13

$$x = Ax + Bu = \begin{bmatrix} -2 & -1 & -3 \\ 0 & -2 & 1 \\ -7 & -8 & -9 \end{bmatrix} x + \begin{bmatrix} 2 \\ 1 \\ 2 \end{bmatrix} u$$
$$y = Cx = [4 \quad 6 \quad 8]x$$

is observable.

6. a) Derive necessary formulas related to alternative approaches to Observer Design. 12

b) Design an observer for the plant 13

$$G(s) = \frac{(s+6)}{(s+7)(s+8)(s+9)}$$

whose estimated plant is represented in state space in cascade form as

$$\hat{z} = A\hat{z} + Bu = \begin{bmatrix} -7 & 1 & 0 \\ 0 & -8 & 1 \\ 0 & 0 & -9 \end{bmatrix} \hat{z} + \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} u$$
$$\hat{y} = C\hat{z} = [1 \quad 0 \quad 0]\hat{z}$$

The closed-loop step response of the observer is to have 10% overshoot with a 0.1 second settling time.

7. a) Steady-State Error Design via Integral Control. 12

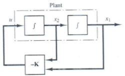
b) Design an integral controller for the plant 13

$$x = \begin{bmatrix} 0 & 1 \\ -7 & -9 \end{bmatrix} x + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u$$
$$y = [4 \quad 1]x$$

to yield a step response with 10% overshoot, a peak time of 2 seconds, and zero steady-state error.

8. Derive the Reduced-Matrix Riccati equation for optimal quadratic regulator systems. 12

Consider the system shown in the following figure. 13



Assuming the control signal to be

$$u(t) = -kx(t)$$

determine the optimal feedback gain matrix K such that the following performance index is minimized:

$$J = \int_0^\infty (x^T Qx + u^2)dt$$

$$Q = \begin{bmatrix} 1 & 0 \\ 0 & \mu \end{bmatrix} \qquad (\mu \geq 0)$$