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APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

Seventh Semester B.Tech Degree (S, FE) Examination May 2024 (2019 Scheme)

Course Code: EET401

Course Name: ADVANCED CONTROL SYSTEMS

Max. Marks: 100 **Duration: 3 Hours**

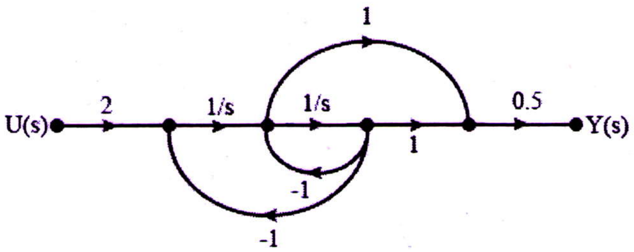
PART A

Answer all questions, each carries 3 marks. Marks

1 Obtain the system matrix of the system with the transfer function (3)

$$\frac{Y(s)}{U(s)} = \frac{1}{S^3 + 4S^2 + 5S + 3}$$

2 Derive the state model of the system described by the signal flow graph shown below (3)



3 Explain Cayley-Hamilton theorem with an example (3)

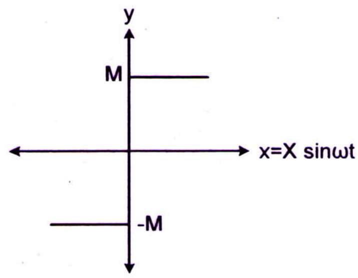
4 Derive the transfer function of an LTI system whose state model is given as $\dot{x} = Ax + Bu$ and $y = Cx + Du$. (3)

5 Discuss the conditions for controllability of the systems using the Gilberts method. (3)

6 Give the block diagram of system described by the state model, $\dot{x} = Ax + Bu$ and $y = Cx$ employing a state feedback controller with control law $u = -kx$ where k is the state feedback controller gain matrix. (3)

7 State the assumptions made in the describing function method of analysis. (3)

8 Derive the describing function for the non-linearity shown below (3)



9 List the limitations of Lyapunov method of stability analysis. (3)

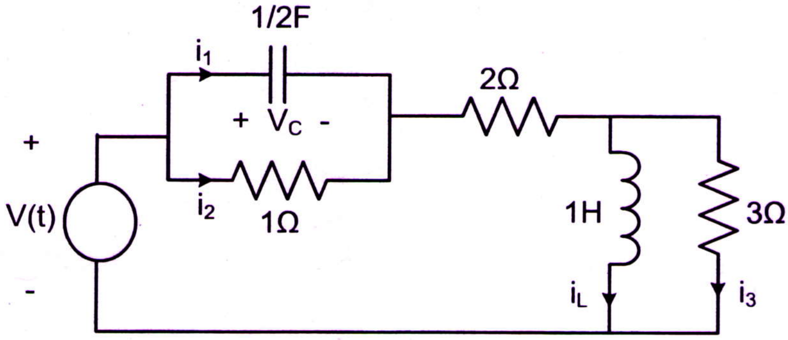
10 Explain the conditions to check the positive and negative definiteness of a quadratic function given as $(x) = X^T AX$, where A is an $n \times n$ real , symmetric matrix. (3)

PART B

Answer any one full question from each module, each carries 14 marks.

Module I

11 a) Derive the state model of the electrical circuit shown below (9)

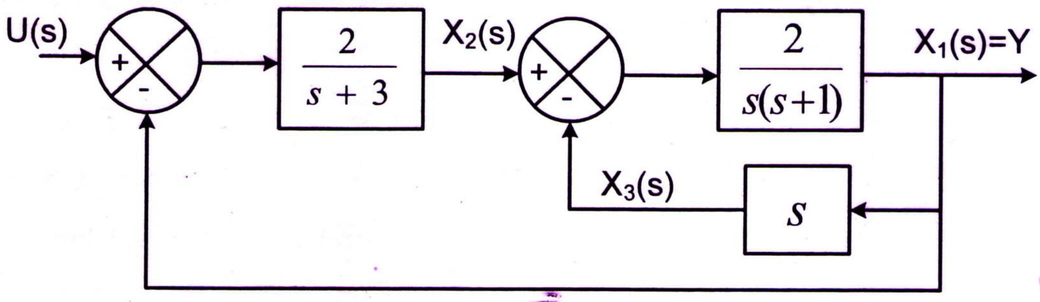


b) Determine the canonical state model of the system with the transfer function (5)

$$\frac{Y(s)}{U(s)} = \frac{10(S+4)}{S(S+1)(S+3)}$$

OR

12 a) Derive the state model of the system shown in the block diagram given below (7)



b) Using the similarity transformation, diagonalize the matrix $A = \begin{bmatrix} 1 & 2 \\ 4 & 3 \end{bmatrix}$ (7)

Module II

13 a) Obtain the unit step response of the system describe by the state model given below for the initial condition, $x(0) = \begin{bmatrix} -1 \\ 0 \end{bmatrix}$ (7)

$$\dot{x} = \begin{bmatrix} -1 & 1 \\ 0 & -2 \end{bmatrix} x + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u$$

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

b) Compute the unit step response of the discrete time system described by the state model given below with initial condition as $x(0) = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$ (7)

$$\begin{bmatrix} x_1(k) \\ x_2(k) \end{bmatrix} = \begin{bmatrix} -3 & 0 \\ 0 & -2 \end{bmatrix} x(k) + \begin{bmatrix} 1 \\ 1 \end{bmatrix} u$$

$$y = \begin{bmatrix} -1 & 1 \end{bmatrix} x(k)$$

OR

14 a) Determine the transfer function of the system describe by the state model given below (8)

$$\dot{x} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 0 & -2 & -3 \end{bmatrix} x + \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} u$$

$$y = \begin{bmatrix} 1 & 2 & 0 \end{bmatrix} x$$

b) Derive the equation for the solution of homogeneous state equation. What is state transition matrix? (6)

Module III

15 a) Obtain the restriction on a_1 and a_2 to ensure the controllability of the system described by the state equation given below (7)

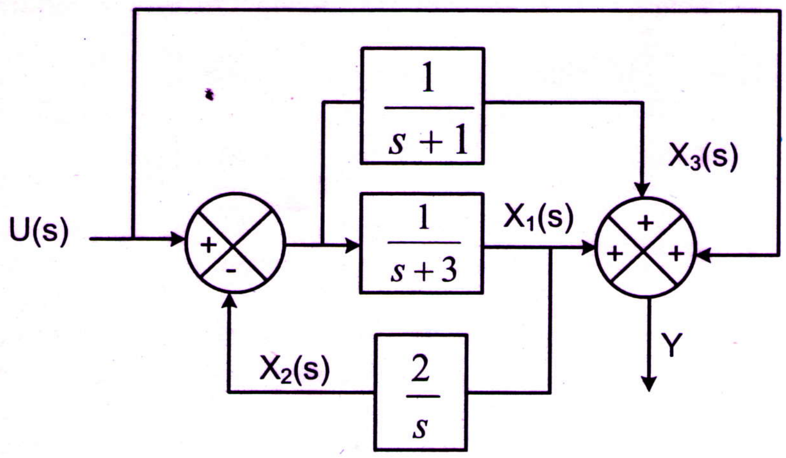
$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{bmatrix} = \begin{bmatrix} 0 & a_1 & 0 \\ 0 & 0 & a_2 \\ a_3 & 0 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} u(t)$$

$$y = \begin{bmatrix} 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$$

b) A regulator has double integrator plant $\frac{Y(s)}{U(s)} = \frac{1}{S^2}$. Compute K such that the control law $U = -KX$ gives closed loop characteristics roots with $\omega_n = 1\, rad/sec$ and $\tau = \frac{\sqrt{2}}{2}$ (7)

OR

16 a) Test the controllability and observability of the system shown in the block diagram given below (8)



b) Design a full order state observer for the system described in the state model given below (6)

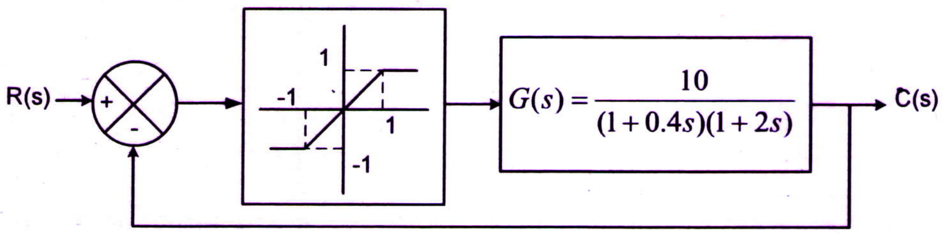
$$\dot{x} = \begin{bmatrix} 0 & 1 \\ 20.6 & 0 \end{bmatrix} x + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u$$

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

The desired eigenvalues of the observer matrix are $\mu_1 = -8$ and $\mu_2 = -8$

Module IV

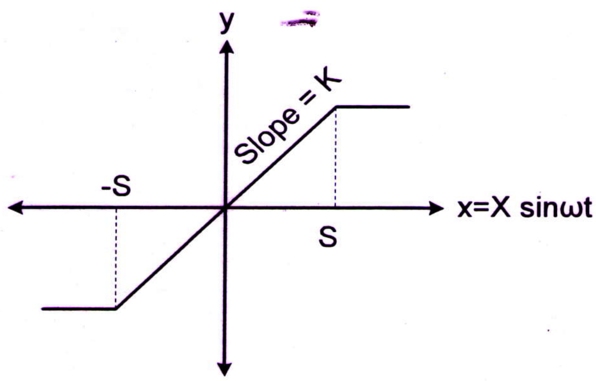
17 a) Determine the stability of the system shown below (10)



b) How the non-linearities are classified? Give examples (4)

OR

18 a) Derive the describing function of the nonlinearity shown below (9)



b) How the stability of the systems are ascertained using describing function method? What are stable and unstable limit cycles? (5)

Module V

19 a) Discuss the asymptotic stability and instability definitions based on the phase plane analysis of non linear systems. (4)

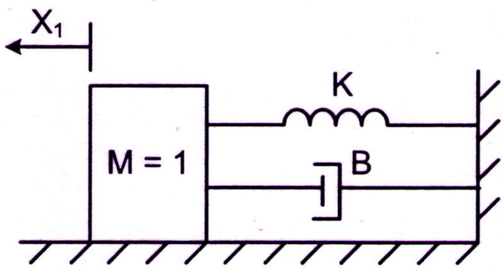
b) Determine the singular point of the system described by the state equation given below and construct a partial phase trajectory using isocline method. Choose the initial condition, $x(0) = \begin{bmatrix} 1.5 \\ 0 \end{bmatrix}$ (10)

$$\dot{x}_1 = x_2$$

$$\dot{x}_2 = -x_1 - 0.3x_2$$

OR

20 a) A spring-mass-damper-system shown below. Choose an energy function including the potential energy of the spring and the kinetic energy of the moving mass. Analyse the system stability using Lyapunov method based on concept of stored energy. (8)



b) Determine the condition for the asymptotic stability of the system described by the state equation given below using Lyapunov method (6)

$$\dot{x}_1 = -x_1 + 2x_1^2 x_2$$

$$\dot{x}_2 = -x_2$$

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