Question Paper

Exam Date & Time: 22-Nov-2022 (09:00 AM - 12:00 PM)

MANIPAL ACADEMY OF HIGHER EDUCATION

FIFTH SEMESTER B.TECH END SEMESTER EXAMINATIONS, ICE DEPARTMENT, NOV 2022

MODERN CONTROL THEORY [ICE 3153]

Marks: 50 **Duration: 180 mins.**

A

Answer all the questions.

Instructions to Candidates: Missing data may be suitably assumed

1) Derive the controllable and observable canonical form for the following transfer function, (5)

A)

$$\frac{Y(s)}{U(s)} = \frac{10}{s^3 + 6s^2 + 10s + 5}$$

[CO1, PO-1,2,3 BL3]

B) Diagonalize the following matrix, (3)

$$A = \begin{bmatrix} 3 & 0 & 1 \\ 0 & -2 & 1 \\ 0 & 4 & 1 \end{bmatrix}$$

[CO2, PO-1,2,3,4 BL3]

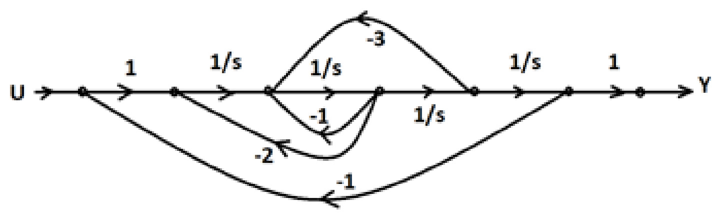
C) Comment on the stability of the given system matrix, (2)

$$A = \begin{bmatrix} 0 & 0 & -2 \\ 0 & 1 & 0 \\ 1 & 0 & 3 \end{bmatrix}$$

[CO2, PO-1,2,3,4 BL4]

2) List any two advantages and disadvantages of canonical forms of state-space representation. Also, assign the state variables and obtain the state model from the following signal-flow graph. (5)

A)



[CO1, PO-1,2,3 BL3]

B) Using the Ackerman's method, design a full-order state feedback controller which will place the closed loop poles at -6 and -1 ± 2j. (3)

$$\dot{X} = \begin{bmatrix} -1 & 0 & 0 \\ 1 & -2 & 0 \\ 2 & 1 & 3 \end{bmatrix} X + \begin{bmatrix} 10 \\ 1 \\ 0 \end{bmatrix} U$$

[CO3, PO-1,2,3,4 BL5]

C) Examine the observability of the system given below. (2)

$$\dot{X} = \begin{bmatrix} 2 & -2 & 3 \\ 1 & 1 & 1 \\ 1 & 3 & -1 \end{bmatrix} X + \begin{bmatrix} 11 \\ 1 \\ -14 \end{bmatrix} U \quad y = \begin{bmatrix} -3 & 5 & -2 \end{bmatrix} X$$

[CO3, PO-1,2,3,4 BL3]

3) A) Mathematical model of a nonlinear system is given by the equation below. Where f(t) is the input and x(t) is the output of the system. Find the equilibrium points for f=80 and linearize the system for small deviations from the equilibrium points and comment on the stability. (4)

$$2\ddot{x} + 18\dot{x} + 128000\frac{x^2}{(x+2)} = 0.03f$$

[CO4, PO-1,2,3 BL4]

B) The state-space model of a tunnel diode circuit is given below, find the type of equilibrium points and comment on the qualitative nature of eigenvalues of the linearized system. (4)

$$\dot{x}_1 = \frac{1}{C}[-h(x_1) + x_2]$$

$$\dot{x}_2 = \frac{1}{L}[-x_1 - Rx_2 + u]$$

$$u = 1.2\ V,\ R = 1.5\ K\Omega,\ C = 2\ pF,\ L = 5\ \mu H$$

$$h(x_1) = 17.76x_1 - 103.79x_1^2 + 229.62x_1^3 - 226.31x_1^4 + 83.72x_1^5$$

[CO4, PO-1,2,3 BL4]

C) List the procedure to construct phase trajectory using delta method. (2)
[CO4, PO-1,2,3 BL2]

4) A) Draw the sinusoidal response of a dead-zone nonlinearity and derive the describing function. (5)

[CO4, PO-1,2,3 BL3]

B) Consider a second order system given by the following dynamics. Generate a Lyapunov function and investigate the stability of the system. (3)

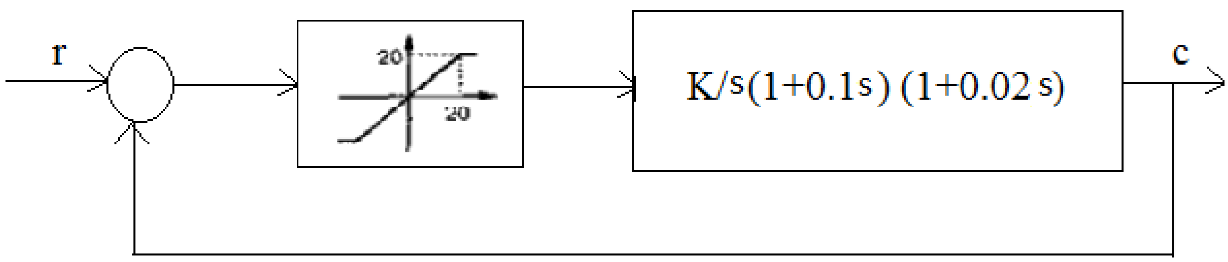
$$\dot{x}_1 = x_2$$

$$\dot{x}_2 = 5x_1 - 8x_2$$

[CO5, PO-1,2,3,4 BL4]

C) Explain the properties of a Lyapunov function. (2)
[CO5, PO-1,2,3,4 BL2]

5) A) Consider the nonlinear system shown below. Determine the largest *K* which preserves the stability of the system. If *K = 2Kmax,* find the amplitude and frequency of the self-sustained oscillation. (5)



[CO4, PO-1,2,3 BL4]

B) For the following system, find the equilibrium points and determine their stability by considering a quadratic Lyapunov function. Indicate whether the stability is asymptotic and global. (3)

$$\dot{x}_1 = -x_2 - x_1(1 - x_1^2 - x_2^2)$$

$$\dot{x_2} = x_1 - x_2(1 - x_1^2 - x_2^2)$$

[CO5, PO-1,2,3,4 BL4]

C) Define Lyapunov linearization theorem for local stability. (2)
[CO5, PO-1,2,3,4 BL2]

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