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MANIPAL INSTITUTE OF TECHNOLOGY
MANIPAL
(A constituent unit of MAHE, Manipal)

SECOND SEMESTER M.TECH. (CONTROL SYSTEMS)

END SEMESTER DEGREE EXAMINATION, APRIL/MAY - 2019

SUBJECT: NONLINEAR CONTROL SYSTEMS [ICE 5221]

TIME: 3 HOURS MAX. MARKS: 50

Instructions to candidates :*Answer ALL questions and missing data may be suitably assumed.*

1A How do you define limit cycle in a phase plane? State Poincare and Poincare-Bendixson theorems.

1B The state-space model of a tunnel diode circuit is given below, find the equilibrium points and comment on the qualitative nature of eigenvalues of the linearized system.

$$\dot{x}_1 = \frac{1}{C}[-h(x_1) + x_2] \qquad u = 1.2\ V,\ R = 1.5\ K\Omega,\ C = 2\ pF,\ L = 5\ \mu H$$

$$\dot{x}_2 = \frac{1}{L}[-x_1 - Rx_2 + u] \qquad h(x_1) = 17.76x_1 - 103.79x_1^{\,2} + 229.62x_1^{\,3} - 226.31x_1^{\,4} + 83.72x_1^{\,5}$$

1C A unity feedback system is given in Fig. Q1C. Draw the isocline and the phase trajectory for a step input of r(t) = u(t) assuming the initial condition to be c(0)= -1 and $\dot{c}(0) = 0$ where r(t) is the input and c(t) is the output.

(2+4+4)

2A Define Invariant set theorem. Explain the geometrical meaning of the theorem with neat sketch.

2B Explain the detection of limit cycle for frequency dependent and frequency independent describing functions.

2C Determine whether the system in Fig. Q2C exhibits a self-sustained oscillation. If so, determine the stability, frequency, and amplitude of the oscillation.

(2+3+5)

3A Explain stability and asymptotic stability in the sense of Lyapunov.

3B Design a back stepping controller for the nonlinear system represented as,

$$\begin{aligned}\dot{x}_1 &= x_2 - x_1^3\\ \dot{x}_2 &= u\end{aligned}$$

3C Show that the internal dynamics of the given nonlinear system is unstable.

$$\begin{bmatrix}\dot{x}_1\\ \dot{x}_2\end{bmatrix} = \begin{bmatrix}x_2^3 + u\\ -u\end{bmatrix}$$

$$y = x_1$$

(2+4+4)

4A List and explain the conditions for input-state linearization. How do you check the involutivity condition?

4B Perform input-state linearization for single link manipulator with flexible points system represented by,

$$\dot{x} = f(x) + gu$$

$$f(x) = \begin{bmatrix} x_2 \\ -a\sin x_1 - b(x_1 - x_3) \\ x_4 \\ c(x_1 - x_3) \end{bmatrix}, \quad g = \begin{bmatrix} 0 \\ 0 \\ 0 \\ d \end{bmatrix} \qquad a, b, c, d > 0$$

(3+7)

5A Explain the algorithm to perform input-output linearization.

5B For the given functions find $[f, g]$ and $ad_f^2 g$.

$$f(x) = \begin{bmatrix} x_2 \\ -\sin x_1 - x_2 \end{bmatrix}, \qquad g(x) = \begin{bmatrix} 0 \\ x_1 \end{bmatrix}$$

5C What are the conditions to select a sliding surface? Explain the procedure of sliding mode controller design with an example.

(3+3+4)

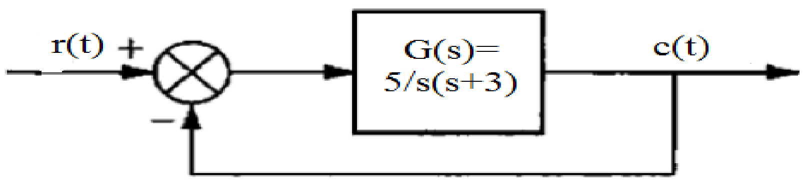

Fig. Q1C

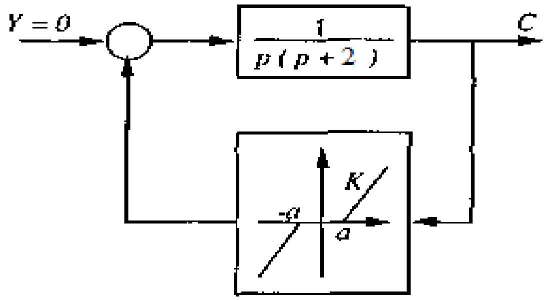

Fig. Q2C

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