MASTER IN CONTROL SYSTEM ENGINEERING FIRST YEAR FIRST SEMESTER EXAM 2024

NONLINEAR CONTROL

Time: Three hours **Part-I** **Full Marks 100 (50 marks for each part)✓**

Use a separate Answer-Script for each part

Answer Any Three Questions

Two marks are reserved for neat and well-organized answers

Q1a) A nonlinear control system can have multiple equilibrium points. Justify the statement with the help of a suitable example. 4

Q1b) Explain the phenomenon of bifurcation with the help of Duffing Equation. In this respect establish the physical significance of the Duffing Equation. 4+3

Q1c) Why Van der Pol equation is considered to be a benchmark problem for understanding the phenomenon of limit cycle? Explain. 5

Q2a) Explain the notion of equilibrium point/s with the help of suitable example. Also define equilibrium point/s mathematically. 4

Q2b) Why equilibrium points are called singular points for a second order nonlinear/linear system? Explain. 4

Q2c) Consider the following nonlinear differential equation

$$\ddot{y} - (0.1 - \frac{10}{3}\dot{y}^2)\dot{y} + y + y^3 = 0$$

i) Find all the singularities of the system.
ii) Identify the nature of the singularities 2+6

Q3a) Consider the first order system $\dot{x} = f(x) = -x^2 + 2x + 24$. Plot f(x) versus x (a rough sketch would suffice). Find out the equilibrium points. Draw a few representative trajectories. 7

Q3b) Draw the vector fields and comment on the stability of the equilibrium points. Justify your answer citing suitable reasons. 5

Q3c) From the representative trajectory plots explain the notion of "Uniqueness of a solution" of the differential equation. 4

Q4) Consider a nonlinear element consisting of dead-zone and saturation kind of nonlinearity. Draw the transfer characteristic of the combined nonlinearity. Derive the Describing Function for this nonlinearity. 16

Q5) Write short notes on any two 8+8

i) Admissible Control
ii) Significance of Forward and Backward Integration
iii) Domains of Attraction and Effectiveness

Ref. No. : **Ex/PG/CTLE/T/115B/2024**

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Part-II

Answer any three questions. Two marks reserved for neatness.

Answer all parts of a question in the sequential order.

1. a) Explain the challenges that occur while analyzing the stability of nonlinear systems.

b) What is "Equilibrium State" of a nonlinear system?

c) How the Error Dynamic Model is derived for nonlinear systems and what is the significance of it in the analysis of nonlinear systems?

d) Explain (i) BIBO Stability, (ii) Local Stability, (iii) Global Stability.

[4+2+4+6=16]

2. a) "Lyapunov's method of stability analysis is a generalized approach of stability study"- Do you agree with this statement? Justify your answer with reasons.

b) Explain, with example, the Direct method of Lyapunov for the stability analysis of nonlinear systems.

[4+12=16]

3. a) Explain the basic idea of backstepping control.

b) "Backstepping based design of nonlinear control law is essentially a nonlinear state feedback control" – Is the above statement correct? Justify your answer with reasons.

c) Derive the feedback control law for the following system employing Integrator Backstepping:

$$\dot{\eta} = f(\eta) + g(\eta)\xi$$
$$\dot{\xi} = u$$

Where η and ξ are the system states and u is the control input.

[4+4+8=16]

4. a) Explain the concept of Variable Structure System.

b) Explain the significant features of Sliding Mode Controllers.

c) What is Sliding Manifold? How will you choose the Sliding Manifold for a Sliding Mode Controller?

d) Why "Chattering" is observed in Sliding Mode Controllers? What are the measures to reduce it?

[3+3+5+5=16]

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5. Write short note on **any two** from the following:

a) Nonlinear System Modeling.

b) Jacobian linearization.

c) Lyapunov Candidate Function.

d) Basic steps of Sliding Mode Controller design.

[8x2=16]