Name : .....

Roll No. : .....

Invigilator's Signature : .....

CS / B.TECH (EE-NEW)/ SEM-8 / EE-801D / 2011

2011

NONLINEAR CONTROL SYSTEMS

Time Allotted : 3 Hours *Full Marks* : 70

The figures in the margin indicate full marks.

Candidates are required to give their answers in their own words as far as practicable.

GROUP – A

(Multiple Choice Type Questions)

1. Choose the correct alternatives for any *ten* of the following : $10 \times 1 = 10$

   i) Nonlinear systems

   a) always have single equilibrium point

   b) always have multiple equilibrium point

   c) frequently have multiple equilibrium point

   d) always have infinitely many equilibrium point.

   ii) Expression for Vander-Pol equation is

   a) $m\ddot{x} + 2c\,(x^2 - 1)\,\dot{x} + kx = 0$

   b) $m\ddot{x} - 2c\,(1 - x^2)\,\dot{x} - kx = 0$

   c) $m\ddot{x} + 2c\,(1 + x^2)\,\dot{x} + kx = 0$

   d) $m\ddot{x} - 2c\,(1 + x^2)\,\dot{x} + kx = 0$.

iii) Lyapunov's first method can be used to

a) estimate performance of nonlinear control system

b) estimate robustness of nonlinear control system

c) design nonlinear controllers

d) find stability at equilibrium point of the system.

iv) Which of the following transfer function is not positive real ?

a) $\frac{1}{1-sT}(T>0)$ b) $\frac{1}{1+sT}(T>0)$

c) $\frac{1}{s}$ d) $\frac{100\,(s+1)}{(s+10)^2}$.

v) Describing function technique is mainly used to

a) analyse second order nonlinear system only

b) predict limit cycles in nonlinear systems

c) analyse stability of control system with soft nonlinearity

d) analyse stability of higher order control system.

vi) Popov's criterion is

a) only applicable to non-autonomous systems

b) restricted to a simple memoryless nonlinearity

c) applicable to both autonomous & non-autonomous systems

d) applicable to all kinds of nonlinearities.

vii) Sliding mode approach to control is appropriate for system with

a) modelling uncertainties only

b) disturbances only

c) both (a) and (b)

d) high degree of nonlinearity only.

viii) For the system $\dot{x}_1 = x_2$

$$\dot{x}_2 = -x_1 + \frac{1}{16}x_1^5 - x_2$$

The equilibrium points are

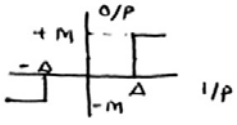
a) (0 , 0)

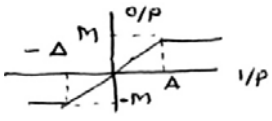
b) (2, 0) and (–2, 0)

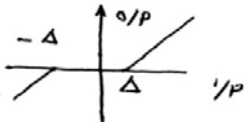
c) (0, 0), (2, 0) & (–2, 0)

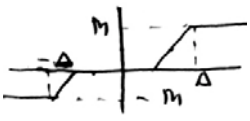
d) other than (0, 0), (2, 0) & (–2, 0).

ix) A deal band gain can be represented by

a) 

b) 

c) 

d) 

x) L_2 gains can be used to

a) determine stability of nonlinear systems

b) measure quality of system approximation

c) design nonlinear controllers

d) transform nonlinear model into linear one.

xi) Feedback linearization is conceptually

a) Jacobean linearization

b) Taylor series expansion

c) Harmonic linearization

d) Algebraically transform a nonlinear system into a linear one.

xii) A chaotic system

a) is sensitive dependence to initial conditions

b) has positive Lyapunov exponents

c) has only negative Laypunov exponents

d) both (a) and (b).

GROUP – B

(Short Answer Type Questions)

Answer any *three* of the following. $3 \times 5 = 15$

2. Obtain State-Space model of a simple unforced pendulum.

3. Show that the transfer function $G(s) = \dfrac{sW^2n}{s^2 + W\,n^2}$ is positive real, Where W_n is real.

4. Find the fixed points of the nonlinear second order system

$$\dot{x}_1 = 2x_1x_2 + x_1$$

$$\dot{x}_2 = x_2^2 = x_1^2 .$$

5. Discuss the sources of nonlinearity of Mass-Spring system.

6. Consider the system $\dot{x}_1 = x_2$

$$\dot{x}_2 = -a_1x_2 - a_2x_1 - (b_1x_2 + b_2x_1)^2 x_2$$

Using Lyapunov function $V(x) = a_2x_1^2 + x_2^2$ show that the system is globally asymptotically stable if $a_1 > 0$ and $a_2 > 0$.

GROUP – C

(Long Answer Type Questions)

Answer any *three* of the following. $3 \times 15 = 45$

7. a) Discuss Linearization Technique with suitable example.

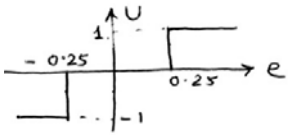
b) Explain the concept of bifurcation considering a second order system $\dot{x}_1 = x_2 - x_1^3 - ax_1$

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

with $-1. \le a \le 1$. 8 + 7

8. a) Discuss the characteristics of tunnel diode with relevant diagrams.

b) Consider the feedback system shown below whose $G(s) = \dfrac{20}{s(s+1)(s+2)}$ & the nonlinear element is a 'relay with dead zone' with input output characteristics as



Use describing function technique to predict whether any stable limit cycle exists and if so, predict its frequency & amplitude. 5 + 10

9. a) Discuss stability of nonlinear system using Lyapunov's first method.

   b) Discuss concept of Invariance Principle related to Lyapunov's stability analysis. 7 + 8

10. a) Discuss the principle of the following :

   i) Input-output feedback linearization

   ii) Full-state feedback linearization.

   b) State & explain circle criterion. 10 + 5

11. Write short notes on any *three* of the following : 3 × 5

   a) Negative resistance oscillator

   b) Sliding Mode Control

   c) Memoryless Nonlinearities

   d) Small Gain Theorems.

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