Ex/PG/NuE/128A/2019

MASTER OF NUCLEAR ENGINEERING EXAMINATION, 2019

(2nd Semester)

Nonlinear and Adaptive Control

Time: Three hours

Full Marks: 100

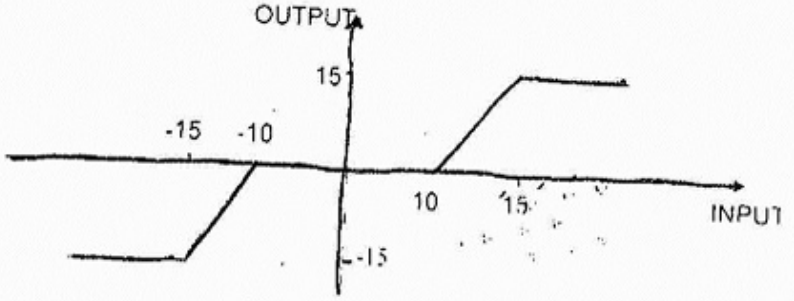
Answer any five questions

1 (a) Illustrate step-by-step procedure for developing small signal model of a nonlinear system using suitable example 8

(b). Find the equilibrium points and study their stability by linearization of the unforced van der pol equation 2+10

$$\ddot{u} + (u^2 - 1)\dot{u} + u = 0$$

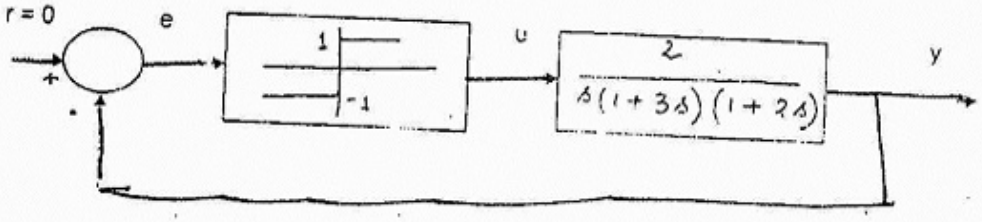
2. (a) Figure below shows the gain characteristic of a nonlinear amplifier. Derive the Describing Function for this device. 10



(b) Determine the describing function of a nonlinear device in which the input x (t) and the output y (t) are related through the following differential equation

$$y(t) = (dx/dt)^3 + x^2 (dx/dt) + 2$$ 10

3. Analyse the stability of the system shown below using Describing Function technique.



Comment on the stability information if a dead zone of amplitude of ±1 is introduced in the nonlinear relay shown above. 10 + 10

4.(a) Find the singular points of the nonlinear system below :

$$\dot{X} = X(Y-1)$$

$$\dot{Y} = 4 - X^2 - Y^2$$

Sketch the phase portrait and comment on the stability of the system at each equilibrium point. 4 + 2 + 4

(b) Consider the system represented by

$$\dot{X}_1 = X_2; \quad \dot{X}_2 = -2 \sin X_1$$

Draw the phase portrait using isocline method and comment on the stability of the system. 8 + 2

5.(a) Illustrate with example, stability analysis of nonlinear system using Lyapunov's first method. 4

(b) Investigate stability of the system represented by $\dot{X} = -X^3$ for $X \in R$ considering suitable candidate Lyapunov Function 8

(c) For a series RLC circuit with nonlinear R, determine stability of the system using direct method of Lyapunov. State the theorem used. 6 + 2

6 (a) A system is represented by

$$\dot{X}_1 = X_2$$

$$\dot{X}_2 = (1 - |X_1|) X_2 - X_1$$

Investigate stability of the system and also find the region of stability. 8 + 2

(b) Explain stable, unstable and semi-stable limit cycles with suitable sketches and deduce the nature of limit cycle, if any, for the system represented by

$$\dot{X}_1 = X_2 + X_1((X_1)^2 + ((X_2)^2 - 1)$$

$$\dot{X}_2 = X_2((X_1)^2 + ((X_2)^2 - 1) - X_1$$ 5 + 5

7 (a) Construct Lyapunov Function and investigate stability of the given nonlinear system

$$\dot{X} = [-3X_1 + X_2 \qquad X_1 - X_2 - (X_2)^3]^T$$

Can you use both first and second methods of Lyapunov stability analysis? Mention the method used. 8+2+2

(b) Explain with suitable example, the steps to construct Lyapunov Function for a nonlinear system using Variable Gradient method. 8

8. (a) For an LTI system represented by $\dot{X} = AX$, If $A = \begin{bmatrix} 5 & b \\ 2 & -1 \end{bmatrix}$

Determine the value of b for stability and find an expression for Lyapunov Function.

8

(b) What are the advantages of adaptive control system over conventional feedback control system? Illustrate basic adaptive control schemes with suitable block diagrams. Write down the steps to formulate adaptive control problems. 3 + 6 +3