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M.E. DEGREE EXAMINATION, MAY/JUNE 2006.

First Semester

Control and Instrumentation

CI 131 — SYSTEMS THEORY

(Common to M.E. — Power Electronics and Drives and M.E. — Power Systems Engineering)

Time : Three hours

Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. List any two effects of adding to a linear second order system
   (a) a zero
   (b) a pole.

2. Enumerate any four properties of transfer function approach.

3. Obtain a state model for a system whose transfer function is given by $G(s) = \dfrac{s+1}{(s+3)(s+4)}$.

4. Determine the impulse response of a system under zero initial conditions given the system

$$\dot{X} = \begin{bmatrix} 0 & 1 \\ -30 & -11 \end{bmatrix} X + \begin{bmatrix} 0 \\ 1 \end{bmatrix} U \quad Y = [6 \;\; 1] X.$$

5. Define a deadbeat observer. What is its necessity?

6. State Kalman's test for controllability and observability of an nth order multiple input LTI system.

7. List any four types of non-linearities present in a system.

8. State any two assumptions made in
   (a) the describing function method
   (b) phase plane method of analysis of non-linear systems.

9. Define limit cycle. What is its significance?

10. State Popov's method of stability of a system.

PART B — (5 × 16 = 80 marks)

11. (i) Find the values of K and a of a unity feedback system with open loop transfer function $G(s) = \dfrac{K}{s(s+a)}$ so as to satisfy the frequency domain specifications of $M_r = 1.04$ and $W_r = 11.55$ rad/sec. Derive any formula used. (8)

(ii) For the values of K and a determined in (i), calculate the settling time and bandwidth. Derive any formula used. (8)

12. (a) (i) Explain in detail, the controllability and observability of a system. (6)

(ii) Determine the controllability and observability of a system having $\dot{X} = AX + BU$ and $Y = CX$, where $A = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 0 & -2 & -3 \end{bmatrix}$; $B = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$; $C = [1 0 0 0]$. (10)

Or

(b) (i) Define state transition matrix. How is it evaluated? (6)

(ii) A system has :

$$A = \begin{bmatrix} 0 & 0 & -2 \\ 0 & 1 & 0 \\ 1 & 0 & 3 \end{bmatrix} \text{ and } X(0) = \begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix}.$$

Determine the state transition matrix and also the free response of the system. (10)

13. (a) (i) Describe in detail the design of a full-order state observer for a system. (6)

(ii) A system has the following states model components :

$$A = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -6 & -11 & -6 \end{bmatrix};\ B = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix};\ C = [1\ 0\ 0].$$

Design a full order state observer assuming that the desired eigen values of the observer matrix are $-2 + j\,3.464$, $-2 - j\,3.464$ and -5. (10)

Or

(b) (i) Explain in detail the necessity and design of a state feedback control in a system. (6)

(ii) A system is described by

$\dot{X} = AX + BU$ and $Y = CX$, where

$$A = \begin{bmatrix} 0 & 1 \\ -2 & -3 \end{bmatrix}; B = \begin{bmatrix} 0 \\ 2 \end{bmatrix}; C = \begin{bmatrix} 1 & 0 \end{bmatrix}.$$

It is desired to have eigen values at -3 and -5 by using a state feedback control $\mu = -KX$. Determine the necessary feedback gain matrix K and the control signal. (10)

14. (a) (i) Discuss any two describing function representations of non-linear elements. (8)

(ii) Describe the analysis of non-linear systems using describing function approach. (8)

Or

(b) A non-linear system consisting of a relay with dead-zone whose characteristics is shown in Figure 1. Analyse the system by phase plane method in different regions. Also compare the behaviour of the system with no dead-zone. Assume $r = 3$. (16)

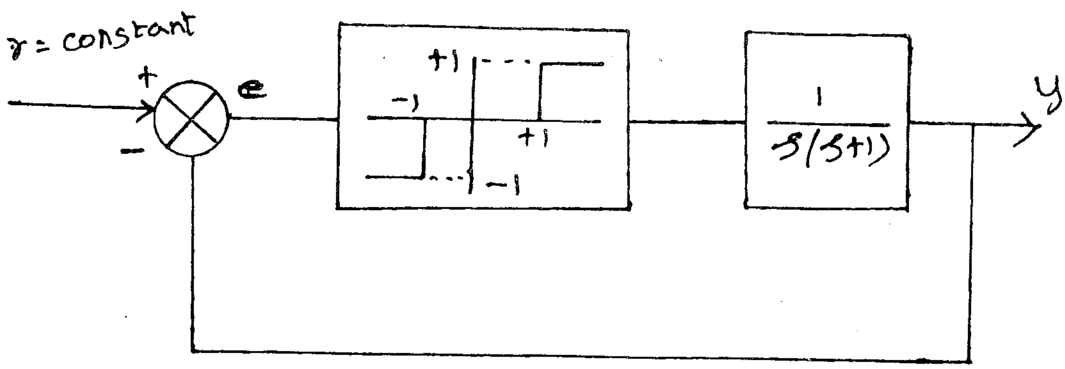

Figure 1.

15. (a) (i) Define the terms : Equilibrium point, BIBO stability and asymptotic stability. (4)

(ii) Explain the different methods of constructing Lyapunov functions for non-linear systems. (12)

Or

(b) (i) State and explain Lyapunov stability criterion. (6)

(ii) Discuss the stability of the system and plot the stability regions of a non-linear system, described by $\dot{x}_1 = x_2$; $\dot{x}_2 = -x_2 - x_1^3$. (10)