

Y 5028

M.E. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2006.

First Semester

Control and Instrumentation

CI 131 — SYSTEM THEORY

(Common to ME–Power Systems Engineering and ME–Power Electronics and Drives)

(Regulation 2002)

Time : Three hours

Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. Identify the fixed mode of the system for state feedback

$$\dot{X} = \begin{bmatrix} 0 & -30 \\ 1 & -11 \end{bmatrix} X + \begin{bmatrix} 5 \\ 1 \end{bmatrix} U.$$

2. 'In a balanced realization, the controllability and observability indices of a state variable are equal'. Comment on this statement.

3. Show that the transfer function of the system defined by the state equations

$$\dot{X} = \begin{bmatrix} 0 & 1 \\ -6 & -7 \end{bmatrix} X + \begin{bmatrix} 0 \\ 1 \end{bmatrix} U$$
$$y = [1 \quad 6] X$$

is of order less than two. Explain the reason for the same.

4. Obtain the response of the following system for unit step input

$$\dot{X} = \begin{bmatrix} -4 & -4 \\ -4 & -4 \end{bmatrix} X + \begin{bmatrix} 1 \\ 1 \end{bmatrix} U$$
$$y = [1 \quad 1] X$$

5. Consider the system given by $G(s) = \frac{(s^3 + 8s^2 + 14s + 12)}{(s+1)(s+6)(s+3)(s+4)}$. Obtain a state model such that all the states are completely controllable, but not observable.

6. A second order system has one controllable and unobservable mode and a second uncontrollable but observable mode. Explain how many poles of this system can be assigned arbitrarily by output feedback.
7. Consider the non-linear equation $\frac{dx}{dt} = x^2 + 4x^3u^2 + 2u$. Obtain a linearised state model around the operating point say x_0 and u_0 .
8. Given $G(s) = 1/[(s+3)(s+0.5)]$. Obtain a first order equivalent using moment matching method.
9. Can we obtain alternate describing functions to include some higher harmonic terms also to represent a non-linear dynamics? Explain.
10. Explain the Liapunov's second method, for assessment of asymptotic stability of non-linear system.

PART B — (5 × 16 = 80 marks)

11. (a) A MIMO system is described by the transfer function matrix

$$G(s) = \begin{bmatrix} \frac{s+6}{(s+6s+5)} & \frac{s^2}{(s+2)(s+1)} \\ \frac{s^2}{(s+5)(s+1)} & \frac{2}{(s+1)(s+5)} \end{bmatrix}$$

- (i) Obtain a non-minimal and a minimal state model. (8)
- (ii) Identify the input and output decoupling zeros in each model. (4)
- (iii) State the relationship between controllability and the decoupling zeros. (4)

Or

- (b) (i) Discuss the Laplace transform method of determining state transition matrices. (8)
- (ii) Discuss the properties of state transition matrices for linear time variant systems. (8)

12. (a) Consider the system whose state equation is described by

$$\dot{X} = \begin{bmatrix} -1 & 0 & 0 \\ 1 & -2 & 0 \\ 0 & 0 & -3 \end{bmatrix} X + \begin{bmatrix} 1 \\ 0 \\ 1 \end{bmatrix} u$$

$$Y = \begin{bmatrix} 1 & 0 & 1 \\ 0 & 2 & 0 \end{bmatrix} X$$

- (b) (i) Consider a system whose dynamics is given by the following non-linear differential equation. Obtain the non-linear state model and determine the equilibrium points. Sketch the exact phase portraits around the singular points and the approximate phase portraits in the rest of the phase plane $\frac{d^2x}{dt^2} + \frac{dx}{dt} + x + x^2 = 0$. (10)
- (ii) Assess the stability the system described in 14 (b) (i) around each equilibrium point using Lyapunov's equation. (6)
15. (a) Consider a third order Type 1 system. It is controlled by a proportional controller under unity negative feedback. The controller introduces saturation and dead-zone non-linearity
- (i) What is a Limit-cycles? Explain. (4)
- (ii) Show that dead zone and saturation non-linearity, produce unstable and stable limit cycle of same frequency for certain initial conditions. (8)
- (iii) Can the limit-cycle be avoided by proper choice of controllers? Explain. (4)

Or

- (b) (i) Derive the describing function of a relay whose input/output characteristics is given by figure 15 (b) (i). Let the input level at which the gain of the relay changes from K1 to K2 be 'd'. (10)

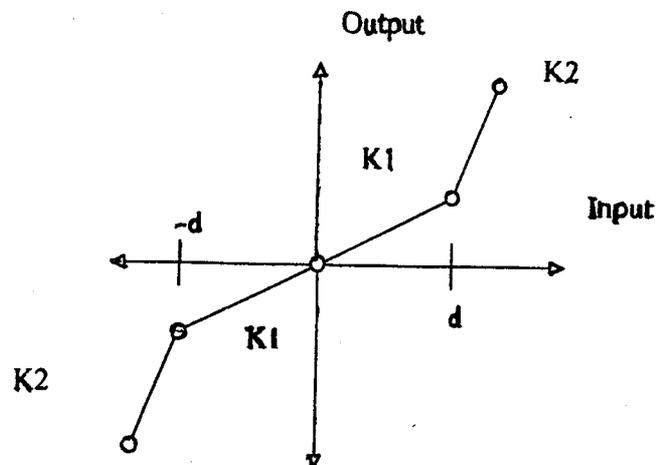


Figure 15 (b) (i) Relay Input/Output Characteristics

- (ii) Distinguish the usage of Phase plane and Describing function method in the analysis of non-linear systems. (6)