

Name :

Roll No. :

Invigilator's Signature :

CS/B.TECH(ICE)/SEM-5/IC-504/2011-12

2011

ADVANCED 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 × 1 = 10

- i) The A matrix in the state-space model of the differential equation :

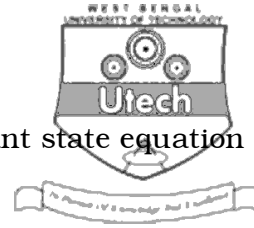
$$\frac{d^3 y(t)}{dt^3} + 2 \frac{dy(t)}{dt} + 3y(t) = u(t), \text{ is given by}$$

a) $\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ -3 & -2 & 0 \end{bmatrix}$

b) $\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 3 & 2 & 0 \end{bmatrix}$

c) $\begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -3 & -2 & 0 \end{bmatrix}$

d) $\begin{bmatrix} 0 & 0 & 3 \\ 1 & 0 & 2 \\ 0 & 1 & 0 \end{bmatrix}$



- ii) The solution to the linear time invariant state equation

$$\dot{X}(t) = AX(t) + Bu(t), X(t_0) = X_0 \text{ is}$$

a) $X(t) = e^{At} X(t_0) + \int_0^t e^{A(t-\tau)} Bu(\tau) d\tau$

b) $X(t) = e^{A(t-t_0)} X(t_0) + \int_{t_0}^t e^{A(t-\tau)} Bu(\tau) d\tau$

c) $X(t) = e^{A(t-t_0)} X(t_0) + \int_0^t e^{A(t-\tau)} Bu(\tau) d\tau$

d) $X(t) = e^{At_0} X(t_0) + \int_{t_0}^t e^{A(t_0-\tau)} Bu(\tau) d\tau$

- iii) A state space model can be converted to its diagonal canonical form if

- a) eigenvalues of A matrix are real
- b) eigenvalues of A matrix are in the left half of S-plane.
- c) eigenvalues of A matrix are positive
- d) eigenvalues of A matrix are distinct.

- iv) The state transition matrix of the discrete time state equation :

$$X(K+1) = FX(K) + Gu(K) \text{ is}$$

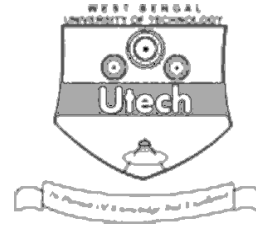
- a) e^{FK}
- b) F
- c) $G[ZI - F]^{-1}$
- d) F^K

- v) A state space realisation is stabilisable if

- a) eigenvalues of A are stable
- b) unstable eigenvalues of A are real
- c) unstable eigenvalues of A are controllable
- d) stable eigenvalues of A are controllable.



- vi) A pre-requisite for the design of LSVF controllers is that the state-space model should be
- a) controllable b) stabilizable
 - c) observable d) detectable.
- vii) The dimension of a full-order observer is
- a) twice that of the plant
 - b) same as that of the plant
 - c) does not depend on the plant order
 - d) cannot be obtained.
- viii) The phase trajectory of a linear second order system with complex conjugate poles on the R – H of S-plane is
- a) unstable focus b) stable focus
 - c) unstable node d) stable node.
- ix) A common nonlinearity occurring in a gear train is
- a) saturation b) hysteresis
 - c) backlash d) dead zone.
- x) In the describing function analysis of nonlinear elements only
- a) the state gain of the nonlinearity is taken
 - b) the fundamental component of the output is taken
 - c) the fundamental and third harmonics of the output are taken
 - d) none of these are true.



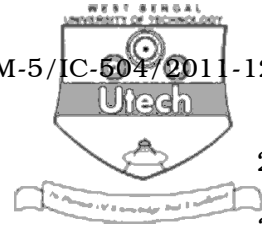
- xi) A positive semi-definite matrix has
- a) positive or zero eigenvalues
 - b) positive eigenvalues
 - c) negative or zero eigenvalues
 - d) negative eigenvalues.
- xii) Under a similarity transformation eigenvectors
- a) are multiplied by the transformation matrix
 - b) are multiplied by the inverse of the transformation matrix
 - c) cannot be evaluated
 - d) remain unchanged.
- xiii) Lyapunov stability is valid for
- a) autonomous systems
 - b) non-autonomous systems
 - c) forced systems
 - d) stable systems.

GROUP – B

(Short Answer Type Questions)

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

2. a) What are “states” in a dynamic system ? 2
- b) Define the state transition matrix of a state space realization :
- $\dot{X}(t) = AX(t); X(t_0) = X_0$ 2
- c) Show that for a state transition matrix $\phi(t, t_0)$, the following property holds : $\phi(t, t) = I$ 1



3. a) Define eigenvectors of a matrix A. 2
 b) Obtain eigenvectors of $A = \begin{bmatrix} -1 & 0 \\ 1 & 2 \end{bmatrix}$ 3
4. Obtain the state variable model of the system whose transfer function is given by 5

$$G(s) = \frac{(s^2 + 3s + 1)}{(s^3 + 5s^2 + 7s + 2)}$$
5. Draw the state diagram of the following state equations :

$$\dot{X}(t) = \begin{bmatrix} -1 & 2 & 1 \\ 1 & -4 & -3 \\ -1 & 8 & 9 \end{bmatrix} X(t) + \begin{bmatrix} 1 \\ 0 \\ 1 \end{bmatrix} u(t)$$

$$Y(t) = [1 \ 1 \ 0] X(t)$$
6. What are limit cycles ? When are they stable ? Draw & explain using diagrams. 5

GROUP – C

(Long Answer Type Questions)

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

7. a) For the system given below :

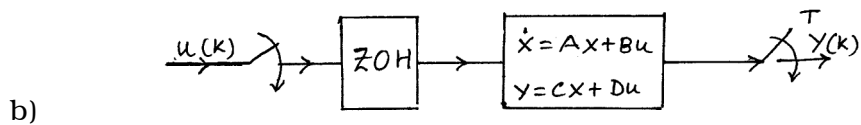
$$\dot{X}(t) = \begin{bmatrix} 0 & 1 \\ 2 & 1 \end{bmatrix} X(t) + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u(t); \quad x(0) = \begin{bmatrix} 0 \\ 0 \end{bmatrix}, \quad \text{obtain the time response for a unit step input applied at } t = 0. \quad 10$$
 b) Check whether the system is BIBO stable and / or zero input stable. 5
8. a) For the system in 7 (a) design a linear state variable feedback controller to yield a step response of the closed loop system with 16.2% overshoot and settling time 0.8 sec. 8



b) What are the pre-requisites that the system should fulfil for the design of an LSVF controller ? 3

c) Write the equations of an asymptotic full-order observer. Explain how and under what conditions does the estimation error go to zero. 4

9. a) Convert the system in 7(a) to its diagonal canonical form, if possible. What condition should the system fulfil ? 8

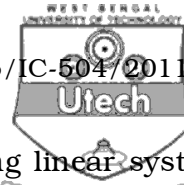


The system below is preceded by a sample and a zero-order-hold (ZOH) as in Figure given . Obtain a discrete time state space model (as given in fig. above) from $u(k)$ to $y(k)$ taking $T = 1$ sec.

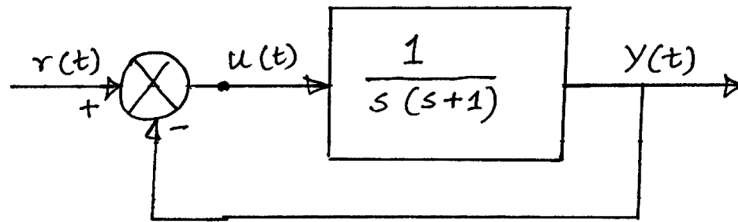
$$\dot{X}(t) = \begin{bmatrix} 1 & 0 \\ 3 & -2 \end{bmatrix} X(t) + \begin{bmatrix} 1 \\ 1 \end{bmatrix} u(t)$$

$$Y(t) = \begin{bmatrix} 1 & 0 \end{bmatrix} X(t)$$

7



10. a) Draw the phase-portrait for the following linear system in figure below assuming the initial condition : $y(0) = -1$, $\dot{y}(0) = 1$ and using isocline method. 10



- b) Comment on the nature of the phase trajectory and the equilibrium point. 5
11. a) Derive the describing function of a relay with saturation non-linearity. 8

- b) A linear system is described by :

$$\dot{X}(t) = \begin{bmatrix} 0 & 1 \\ 2 & -1 \end{bmatrix} X(t)$$

Investigate the stability of the system by using Lyapunov's method. 7

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