Registration no: | | | | | | | | | | |

Total Number of Pages: 03 **M.TECH**
P2PRCC07

2nd Semester Regular Examination 2016-17
ADVANCED CONTROL SYSTEMS

BRANCH: ELECTRI & ELECTRONIC ENGG (POWER SYSTEM ENGG), ELECTRICAL AND ELECTRO ENGG, ELECTRICAL ENGG., ELECTRICAL POWER SYSTEM, INDUS. POWER CONTROL AND DRIVES (PT), POWER AND ENERGY ENGG

Time: 3 Hours
Max Marks: 100
Q.CODE:Z795

Answer Question No.1 which is compulsory and any four from the rest.
The figures in the right hand margin indicate marks.

Q1 **Answer the following questions:** (2 x 10)

a) Consider the discrete-time system given below.

$$\begin{bmatrix} x_1(k+1) \\ x_2(k+1) \\ x_3(k+1) \end{bmatrix} = \begin{bmatrix} 0.55 & 0 & 0 \\ 0 & -0.12 & 0 \\ 0 & 0 & 2 \end{bmatrix} \begin{bmatrix} x_1(k) \\ x_2(k) \\ x_3(k) \end{bmatrix} + \begin{bmatrix} 0 \\ 1 \\ 2 \end{bmatrix} u(k)$$

Comment on the controllability and stabilizability of the system, giving reasons for your answer.

b) If a linear time-invariant digital system is described by the difference equation $X(k+1) = AX(k)$ and $V(X) = X^T(k)PX(k)$ is a Lyapunov function for the system, write down the condition for the equilibrium state $X_e = 0$ to be asymptotically stable.

c) According to Gilbert's test, enumerate the conditions for complete observability of a SISO system and a MIMO system.

d) What do you understand by the term 'Similarity Transformation'? Show that the characteristic equation remains invariant under similarity transformation.

e) Write down the expression for performance index for a finite time tracking problem and a finite time output regulator problem.

f) Find the variation of the functional

$$v = \int_0^2 (2x^2(t) + x(t))dt$$

Using the lemma $\delta v = \frac{d}{d\alpha} v(x+\alpha\,\delta x)\,|_{\alpha=0}$

g) Write down the four basic problems in variational calculus giving appropriate figures for each.

h) Describe the 'Kalman Conjecture'.

i) What do you mean by 'Defuzzification'? Name different defuzzification techniques.

j) Two fuzzy sets are defined as follows:

A = $\left\{\frac{0.1}{30} + \frac{0.2}{60} + \frac{0.3}{90} + \frac{0.4}{120}\right\}$

B = $\left\{\frac{1}{1} + \frac{0.2}{2} + \frac{0.5}{3} + \frac{0.7}{4} + \frac{0.3}{5} + \frac{0}{6}\right\}$

Determine $R = A \times B$

Q2 a) For a digital control system described by $X(k+1) = GX(k) + HU(k)$, the system matrix A is given by (8)

$$A = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -6 & -11 & -6 \end{bmatrix}$$

Determine the state transition matrix.

b) Obtain the discrete-time state and output equations and the pulse transfer function (When the sampling period T=1 sec) of the following continuous-time system (12)

$$G(s) = \frac{Y(s)}{U(s)} = \frac{1}{s(s+2)}$$

Which may be represented in state space by the equations

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ 0 & -2 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u$$

$$y = \begin{bmatrix} 1 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

Compare the pulse transfer function with that obtained by taking the z-transform of G(s)when it is preceded by a sampler and a zero-order hold.

Q3 a) Consider the system given by (10)

$$\begin{bmatrix} x_1(k+1) \\ x_2(k+1) \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ -0.16 & -1 \end{bmatrix} \begin{bmatrix} x_1(k) \\ x_2(k) \end{bmatrix} + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u(k)$$

Determine the state feedback gain matrix K when the control signal is given by $u(k) = -Kx(k)$, the closed loop system exhibits deadbeat response to an initial state $X(0)$. Assume that the control signal u(k) is unbounded.

Verify that the response of the system to an arbitrary initial state $X(0)$ is indeed the deadbeat response.

b) Draw the block diagram of an observed state feedback control system with full order observer. (10)

Check the controllability and observability of the discrete-time system defined by the equations

$$X(k+1) = GX(k) + Gu(k)$$
$$y(K) = CX(k)$$

Where the sampling period T is assumed to be 0.2 sec and

$$G = \begin{bmatrix} 1 & T \\ 0 & 1 \end{bmatrix}, \qquad H = \begin{bmatrix} T^2/2 \\ T \end{bmatrix} \qquad C = \begin{bmatrix} 1 & 0 \end{bmatrix}$$

Q4 a) A second order plant is described by (10)

$$\dot{x}_1(t) = x_2(t)$$
$$\dot{x}_2(t) = -2x_1(t) - 3x_2(t) + 5u(t)$$

and the cost function is

$$J = \int_0^\infty [x_1^2(t) + u^2(t)]dt$$

Find the optimal control, when $x_1(0) = 3$ and $x_2(0) = 2$.

b) Obtain the control law which minimises the performance index (10)

$$J = \int_0^\infty [x_1^2(t) + u^2(t)]dt$$

For the system

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

Q5 a) Differentiate between LQR and LQG systems. Derive its transfer function and write the same in packed matrix notation. (8)

b) Find the optimal control u^* for the system (12)

$$\dot{X} = \begin{bmatrix} 0 & 1 \\ -10 & 0 \end{bmatrix} X + \begin{bmatrix} 0 \\ 10 \end{bmatrix} u$$

Which minimises the performance index

$J = \frac{1}{2}\int_0^2 u^2 dt$ Given $X(0) = \begin{bmatrix} 1 \\ 1 \end{bmatrix}$, $X(2) = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$

Q6 a) What do you understand by 'Sliding Mode'? (10)
Show that the system behaviour is governed by a reduced set of differential equations while in sliding.

b) Two fuzzy relations are given by (10)

$$R = \begin{matrix} & y_1 & y_2 \\ x_1 & 0.6 & 0.3 \\ x_2 & 0.2 & 0.9 \end{matrix} \quad \text{and } S = \begin{matrix} & z_1 & z_2 & z_3 \\ y_1 & 1.0 & 0.5 & 0.3 \\ y_2 & 0.8 & 0.4 & 0.7 \end{matrix}$$

Obtain the fuzzy relation T as a (i) max-min and (ii) max-product composition of R and S.

Q7 a) Explain in detail the procedure for inference for a Mamdani Inference system in case of multiple rules and multiple antecedents. (10)

b) Differentiate between Model Reference Adaptive Controller and Self-Tuning Regulator, drawing block diagram in each case. (10)