Code No: K0222 **R07** **Set No. 1**

IV B.Tech. II Semester Regular Examinations, April, 2013

ADVANCED CONTROL SYSTEMS

(Electrical and Electronics Engineering)

Time: 3 Hours **Max Marks: 80**

Answer any FIVE Questions
All Questions carry equal marks
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1. a) Explain the significance of the state transition matrix?
   b) Compute the state transition matrix for the system given by
   $$\dot{x}(t) = \begin{bmatrix} 0 & 1 \\ 0 & -2 \end{bmatrix}$$
   Comment on the state transition matrix obtained.

2. a) Derive the condition for complete state controllability.
   b) Test the controllability and observability of the system described by
   $$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} 1 & 1 \\ -3 & -2 \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u, \qquad y = \begin{bmatrix} 1 & 0 \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

3. a) Write the assumptions of describing function analysis? Explain the reasons to validate the assumptions.
   b) Derive the describing function of relay with dead zone.

4. a) Explain the concept of phase plane analysis.
   b) Draw the slope of the tangent to the trajectory at the point (X_1, X_2) in X_1-X_2 plane of the following.
   i) $\dot{X} = -X$ ii) $\dot{X} = -X + X^3$ iii) $\ddot{X} + \dot{X} + X = 0$

5. a) Explain the stability in the sense of Lyapunov.
   b) Find the Lyapunov function for the following system.
   $$\begin{bmatrix} \dot{X}_1 \\ \dot{X}_2 \end{bmatrix} = \begin{bmatrix} -1 & 1 \\ 2 & -3 \end{bmatrix}\begin{bmatrix} X_1 \\ X_2 \end{bmatrix}$$

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6. a) Discuss the reduced order observer.
   b) Consider the system defined by

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

   Show that this system cannot be stabilized by the state feedback control u=-Kx. Whatever matrix K is chosen.

7. a) Explain the terms incremental and variation of a functional.
   b) Derive the necessary conditions for an extremal of the functional

$$J(x) = \int_{t_0}^{t_1} g(x(t), \dot{x}(t), t)dt$$

   Where terminal time t_1 free, $x(t_1)$ specified.

8. a) Explain the concept of formulation of the optimal control problem.
   b) Discuss the state regulator problem.

Code No: K0222 **R07** **Set No. 2**

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ADVANCED CONTROL SYSTEMS

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1. a) Discuss any two canonical forms of the state space representation.
   b) Consider the system defined by
   $$\dot{x} = Ax + Bu$$
   $$y = Cx$$
   Where $A = \begin{bmatrix} 1 & 2 \\ -4 & -3 \end{bmatrix}, B = \begin{bmatrix} 1 \\ 2 \end{bmatrix}, C = \begin{bmatrix} 1 & 1 \end{bmatrix}$
   Transform the system equations into the controllable canonical form.

2. a) State and explain controllability and observability.
   b) Consider the following transfer function
   $$\frac{X(s)}{Y(s)} = \frac{s + 2.5}{(s + 2.5)(s - 1)}$$
   Check system is completely state controllable or not.

3. a) Define the describing function? Derive the describing function of sinusoidal input.
   b) Derive the describing function of dead zone nonlinearity.

4. a) What are the different methods for constructing trajectories? Explain any one method.
   b) Construct the phase plane trajectories for the second order nonlinear system.
   $$\ddot{X} + |\dot{X}| + X = 0$$

5. a) Define i) Asymptotic stability
   ii) Instability
   iii) Asymptotic stability in the large.
   b) Consider the second order system described by
   $$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ -1 & -1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$
   Clearly the equilibrium state is the origin. Determine the stability of this state.

Code No: K0222 **R07** **Set No. 2**

6. a) Derive the error dynamics of the full order observer.
   b) Consider the system defined by

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

   Show that the system cannot be stabilized by the state feedback control scheme u=-Kx.

7. a) Derive the necessary conditions for an extremal of the functional
   $J(x) = \int_{t_0}^{t_1} g(x(t), \dot{x}(t), t)dt$, Where both terminal time t_1 and $x(t_1)$ free.
   b) Find the extremals for the functions

$$J(x) = \int_0^1 [x^2(t) + \dot{x}^2(t)]dt; \quad x(0) = 0, x(1) = 1.$$

8. Write a short note on the following
   a) Tracking problem
   b) Minimum energy control

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ADVANCED CONTROL SYSTEMS

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Time: 3 Hours **Max Marks: 80**

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1. For the system represented by $\dot{X}(t) = AX(t)$

   $X(t) = \begin{bmatrix} e^{-2t} \\ -2e^{-2t} \end{bmatrix}$ $when\ X(0) = \begin{bmatrix} 1 \\ -2 \end{bmatrix}$ $X(t) = \begin{bmatrix} e^{-t} \\ -e^{-t} \end{bmatrix}$ $when\ X(0) = \begin{bmatrix} 1 \\ -1 \end{bmatrix}$

   Compute A and e^{At}

2. a) Write the controllable, observable and Jordan canonical forms of state model?
   b) Consider the following system
   $$\dddot{y} + 6\ddot{y} + 11\dot{y} + 6y = 6u$$
   Obtain a state space representation of this system in controllable and Jordan canonical form.

3. List out the types of nonlinearities are to be found in practical control systems? Explain in detail.

4. a) Explain the singular points in phase plane analysis.
   b) Draw the phase plane portrait of the following system.
   $$\dot{x}_1 = x_1 + x_2$$
   $$\dot{x}_2 = 6x_1 + 2x_2$$

5. Explain in detail about the Lyapunov stability and instability theorem.

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6. a) Explain the effect of state feedback on observability
   b) Consider the system

$$\dot{x} = Ax + Bu$$

y=Cx

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

   The closed loop poles at $s_{1,2} = -2 + j2\sqrt{3},\ s_3 = -6$. Design minimum order observer.

7. a) State and prove the fundamental theorem of calculus of variations?
   b) Determine an extremal for the functional

$$J(x) = \int_0^{t_f} \sqrt{1 + \dot{x}^2(t)}\, dt$$

   which has x(0)=2 and terminates on the curve $\theta(t) = -4t + 5$.

8. Explain the following
   a) Minimum fuel problem
   b) Output regulator problem.

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ADVANCED CONTROL SYSTEMS

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1. a) Show that the solution to the homogeneous state equation $\dot{x}(t) = Ax(t)$ is unique.
   b) Obtain the response y(t) of the following system
   $$\begin{bmatrix}\dot{x}_1\\ \dot{x}_2\end{bmatrix} = \begin{bmatrix}-1 & -0.5\\ 1 & 0\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix} + \begin{bmatrix}0.5\\ 0\end{bmatrix}u, \quad \begin{bmatrix}x_1(t)\\ x_2(t)\end{bmatrix} = \begin{bmatrix}0\\ 0\end{bmatrix}$$
   $y = [1 \quad 0]\begin{bmatrix}x_1\\ x_2\end{bmatrix}$ $where\ u(t)$ is the unit step input occurring at t=0 or u(t)=1(t).

2. a) Define the term duality? Explain the principle of duality between controllability and observability.
   b) Explain the concept of minimum energy control.

3. a) What are the popular intentional nonlinear elements and their functions.
   b) Derive the describing function of on-off nonlinearity.

4. a) Construct the trajectories by using Isoclines method.
   b) Obtain a phase plane portrait of the following equation by using the isoclines method
   $$\ddot{x} + a|\dot{x}| + x = 0 \ \ (a > 0)$$

5. a) Explain the direct method of Lyapunov for nonlinear continuous time autonomous system.
   b) For the system $\dot{x} = \begin{bmatrix}0 & 1\\ -1 & -1\end{bmatrix}x.$ Find a suitable Lyapunov function V(x).

Code No: K0222 **R07** **Set No. 4**

6. a) Explain the effect of state feedback on controllability.
   b) Consider the system

$$\dot{x}(t) = Ax(t) + Bu(t)$$

$$A = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -1 & -5 & -6 \end{bmatrix}, B = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$$

   It is desired to place the poles at s=-2±j4 and s=-10. Determine the state feedback matrix.

7. a) Discuss the constrained minimization and minimum principle.
   b) Find the external of the functional

$$J(x) = \int_0^{\pi/2} (\dot{x}_1^2 + 2x_1x_2 + \dot{x}_2^2)dt \quad x_1(0) = 0, x_1\left(\frac{\pi}{2}\right) \ is\ free$$

$$x_2 = 0, x_2\left(\frac{\pi}{2}\right) = -1$$

8. Explain the following
   a) Minimum time problem
   b) Continuous time linear regulators.