Code No: RR411005 **Set No. 1**

IV B.Tech I Semester Regular Examinations, November 2005
DIGITAL CONTROL SYSTEMS
(Common to Electronics & Instrumentation Engineering and Electronics & Control Engineering)

Time: 3 hours **Max Marks: 80**

Answer any FIVE Questions
All Questions carry equal marks

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1. Convolve the two signals given by

$$f(k) = \begin{cases} 0 & k = 0,\ 5 \\ 1 & k = 1,\ 4 \\ 2 & k = 2,\ 3 \\ -1 & k = 6,\ 7,\ 8 \\ 0 & k \geq 9 \end{cases}$$

$$g(k) = \begin{cases} 1 & k = 0,\ 14 \\ 2 & k = 2,\ 3 \\ 0 & k = 5 \\ -1 & k = 6,\ 7 \\ 0 & k \geq 8 \end{cases}$$

Illustrate the steps involved in the convolution. [16]

2. Consider the following oscillatory system

$$\frac{Y(s)}{U(s)} = \frac{w^2}{s^2 + w^2}$$

Obtain the continuous time space representation of the system and hence obtain the discrete time state space representation and also the transfer function of the discretised system. [16]

3. Define controllability and observability of discrete time systems. For the following system,

$$\frac{Y(z)}{U(z)} = \frac{z^{-1}\left(1 + 0.8z^{-1}\right)}{1 + 1.3z^{-1} + 0.4z^{-2}}$$

Determine whether the system is observable and controllable. [16]

4. Determine the stability of the following characteristic equations by using suitable tests.

   (a) $5z^2 - 2z + 2 = 0$

   (b) $z^3 - 0.2z^2 - 0.25z + 0.05 = 0$

   (c) $z^4 - 1.7z^3 + 1.04z^2 - 0.268z + 0.024 = 0$. [5+5+6]

5. A sampled – data controlled system is shown figure1 below. Show that the output of the system at sampling instants is zero $T = \frac{2\pi n}{Ws}$, n positive integer [16]

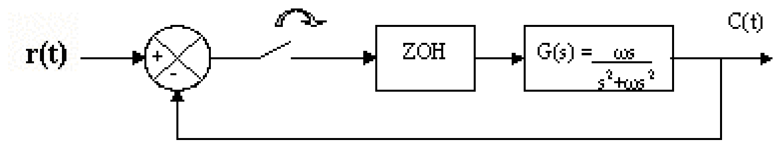

Figure 1:

6. (a) State the necessary and sufficient conditions for the arbitrary pole placement.
   (b) Explain Ackermoons formula used for the determination of the state feedback gain matrix K. [8+8]

7. (a) Give the block diagram representation of a full order observer. Hence write the state equations for the closed loop observer.
   (b) Consider the digital process with the state equations described by
   X(k + 1) = AX(k) + Bu(k)
   C(k) = DX(k)
   Where A = $\begin{bmatrix} 0 & 1 \\ -1 & 1 \end{bmatrix}$, B = $\begin{bmatrix} 0 \\ 1 \end{bmatrix}$, D = [2 0]
   Design a full order observer which will observe the states x1(k) and x2(k) from the output C(k), having dead beat response. [8+8]

8. Explain the Discretized Quadratic optimal control problem. [16]

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Code No: RR411005 **Set No. 2**

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Time: 3 hours **Max Marks: 80**

Answer any FIVE Questions
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1. Obtain the closed loop pulse transfer function of the systems shown in Fig.(a) and Fig.(b).

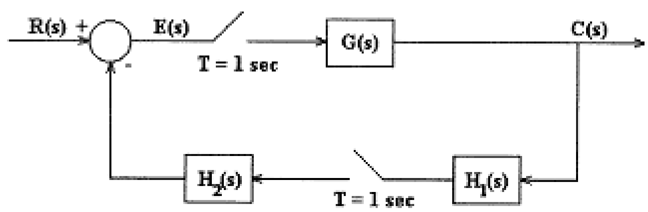

Fig (a)

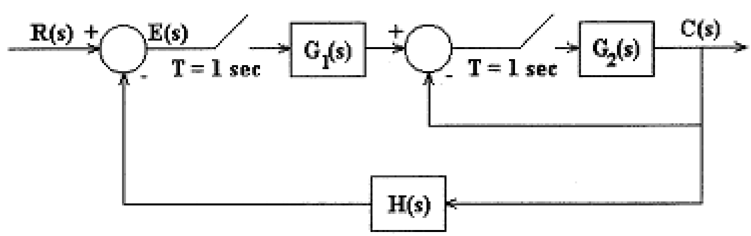

Fig. (b)

[8+8]

2. Derive the state space model of discrete control system using direct programming method and draw its block diagram. [16]

3. For the system defined by

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

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

assume that the following outputs are observed as y(0)=1 and y(1)=2 and the control signals given are u(0)=2,u(1)=-1, determine the initial state X(0) and also X(1) and X(2) . [16]

4. (a) Show that the following quadratic form is positive definite.
$V(x) = 10x_1^2+4x_2^2+x_3^2+2x_1x_2-2x_2x_3-4x_1x_3$

(b) State and explain Liapunovs main stability theorem.

(c) Consider the system described by $\dot{x}_1 = x_2 - x_1(x_1^2 + x_2^2)$; $\dot{x}_2 = -x_1 - x_2(x_1^2 + x2^2)$. Determine the stability. Also show that X = 0 is the only equilibrium state. [5+5+6]

5. Show that the transfer function U(s) / E(s) of the PID controller shown figure 1below.

$$\frac{U(s)}{E(s)} = K_o \frac{T_1 + T_2}{T_1}\left[1 + \frac{1}{(T_1 + T_2)} + \left(\frac{T_1 T_2 \cdot s}{T_1 + T_2}\right)\right]$$

Assume the gain **k** is very large compared with unity, or **k** >>**1**. [16]

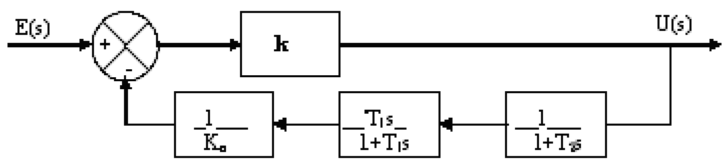

Figure 1:

6. Consider an n^{th}order, single input system X(k+1) = AX(k)+bu(k) and use a feedback of the form u(k)=-KX(k)+r(k) where r is the reference input signal. Show that the zeros of the system are invariant under state feedback. [16]

7. (a) Discuss briefly Kalman Filtering algorithm and explain the various recursive relations.

(b) With neat block diagram explain the full order observer. [8+8]

8. Evaluate the minimum performance index and also find out the optimal control law to minimize the given performance index for the discrete time control system defined by

x(k+1) = 0.3679 x(k) + 0.6321 u(k) ; x(0) = 1.

The performance index is

$$J = \frac{1}{2}[x(10)]^2 + \frac{1}{2}\sum_{k=0}^{9}[x^2(k) + u^2(k)]$$ [16]

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Set No. 3

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Time: 3 hours **Max Marks: 80**

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1. Show that the transfer function for
   (a) a zero-order hold is, $G_0(s) = \frac{1-e^{Ts}}{s}$
   (b) a first-order hold is, $G_1(s) = \frac{Ts+1}{T}\left(\frac{1-e^{Ts}}{s}\right)^2$. [8+8]

2. Consider the discrete control system represented by the following transfer function

$$G(z) = \frac{1+0.8z^{-1}}{1-z^{-1}+0.5z^{-2}}$$

   Obtain the state representation of the system in the observable canonical form. Also find its state transition matrix. [16]

3. Consider the following continuous control system
$$\begin{bmatrix} \dot{x}_1(t) \\ \dot{x}_2(t) \end{bmatrix} = \begin{bmatrix} -1 & 1 \\ 0 & -1 \end{bmatrix} \begin{bmatrix} x_1(k) \\ x_2(k) \end{bmatrix} + \begin{bmatrix} 0 \\ 1 \end{bmatrix}$$
   y(t) = x_1(t)

   The control signal u(k) is now generated by processing the signal u(t) through a sampler and zero order hold. Study the controllability and observability properties of the system under this condition. Determine the values of the sampling period for which the discretised system may exhibit hidden oscillation. [16]

4. (a) Show that the following quadratic form is positive definite.
   $V(x) = 10x_1^2+4x_2^2+x_3^2+2x_1x_2-2x_2x_3-4x_1x_3$
   (b) State and explain Liapunovs main stability theorem.
   (c) Consider the system described by $\dot{x}_1 = x_2-x_1(x_1^2+x_2^2)$; $\dot{x}_2 = -x_1-x_2(x_1^2+x2^2)$. Determine the stability. Also show that X = 0 is the only equilibrium state. [5+5+6]

5. Write notes on the following:
   (a) Digital controller design using Bilinear transformation
   (b) Difference equation solution using Z-transform method.
   (c) Dead beat response. [5+5+6]

6. For the state equation

$$\overset{\bullet}{X} = AX \;\; A = \begin{bmatrix} 0 & 1 & 0 \\ 3 & 0 & 2 \\ -12 & -7 & -6 \end{bmatrix}$$

Find the initial condition vector X(0) which will excite only the mode corresponding to the eigen value with the most negative real part. [16]

7. (a) Discuss briefly Kalman Filtering algorithm and explain the various recursive relations.

   (b) With neat block diagram explain the full order observer. [8+8]

8. Write notes on linear regulator with a prescribed degree of stability that can be solved by using state regulator results. [16]

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Answer any FIVE Questions
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1. Convolve the two signals given by

$$f(k) = \begin{cases} 0 & k = 0 \ \ and \ \ k \geq 4 \\ 1 & k = 1, \ 3 \\ 2 & k = 2 \end{cases}$$

$$g(k) = \begin{cases} 2 & k = 2 \\ 1 & k = 9 \\ 0 & otherwise \end{cases}$$

Illustrate the steps involved in the convolution. [16]

2. A regulator system has a plant, described by

$$\frac{Y(s)}{U(s)} = \frac{10}{(s+1)\,(s+2)\,(s+3)}$$

Obtain the discrete-time state variable model. [16]

3. Consider the following continuous control system

$$\begin{bmatrix} \dot{x}_1(t) \\ \dot{x}_2(t) \end{bmatrix} = \begin{bmatrix} -1 & 1 \\ 0 & -1 \end{bmatrix} \begin{bmatrix} x_1(k) \\ x_2(k) \end{bmatrix} + \begin{bmatrix} 0 \\ 1 \end{bmatrix}$$

y(t) = x_1(t)

The control signal u(k) is now generated by processing the signal u(t) through a sampler and zero order hold. Study the controllability and observability properties of the system under this condition. Determine the values of the sampling period for which the discretised system may exhibit hidden oscillation. [16]

4. Determine the stability of the following characteristic equations by using suitable tests.

   (a) $5z^2 - 2z + 2 = 0$

   (b) $z^3 - 0.2z^2 - 0.25z + 0.05 = 0$

   (c) $z^4 - 1.7z^3 + 1.04z^2 - 0.268z + 0.024 = 0.$ [5+5+6]

5. What are the different techniques used to design digital controllers. Explain the merits and demerits of the techniques. Explain any two techniques in detail. [16]

6. Consider an n^{th}order, single input system X(k+1) = AX(k)+bu(k) and use a feedback of the form u(k)=-KX(k)+r(k) where r is the reference input signal. Show that the zeros of the system are invariant under state feedback. [16]

7. (a) Consider the system
   X(k+1) = GX(k) + Hu(k)
   Y(k) = CX(k)
   where G = $\begin{bmatrix} 0 & -0.16 \\ 1 & -1 \end{bmatrix}$; H = $\begin{bmatrix} 0 \\ 1 \end{bmatrix}$; C = [0 1] Design a full-order observer.
   The desired eigenvalues of the observer matrix are $\lambda_1 \lambda_2 = 0.5 \pm j0.5$.

   (b) Describe the reduced-order observed with suitable diagram. [8+8]

8. Explain the Discretized Quadratic optimal control problem. [16]

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