16 TRIBHUVAN UNIVERSITY

INSTITUTE OF ENGINEERING

Examination Control Division

2075 Bhadra

Exam.	Regular		
Level	BE	Full Marks	80
Programme	BEL	Pass Marks	32
Year / Part	III / II	Time	3 hrs.

Subject: - Digital Control System *(EE652)*

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt **All** questions.*
- ✓ *The figures in the margin indicate **Full Marks**.*
- ✓ *Assume suitable data if necessary.*

1. a) Explain the Operation of Digital System with suitable block diagram. [4]

   b) What do you mean by sample and hold circuit? Explain how tracking and hold mode are employed in digital control system. [8]

   c) Find the region of convergence for $x(k) = -a^k u(-k-1)$, where u(k) is the unit step function. [4]

2. a) State and prove final value theorem of z-transform. [1+3]

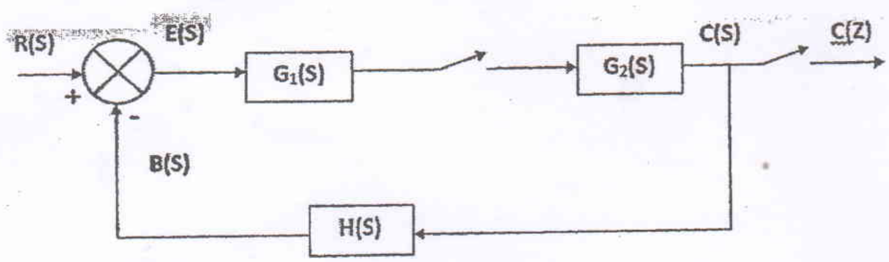
   b) Obtain z-transform of [4]

   $$x(t) = \sin wt \quad ; t >= 0$$
   $$= 0 \quad ; t < 0$$

   c) Obtain the inverse z-transform of: [8]

   $$X(z) = \frac{z^2}{(z-1)^2(z-e^{-at})}$$

3. a) Find the discrete time output C(z) of the following closed loop system. [4]



   b) Examine the stability of the following characteristics equation. [6]

   $$p(z) = z^4 - 1.2z^3 + 0.07z^2 + 0.3z - 0.08$$

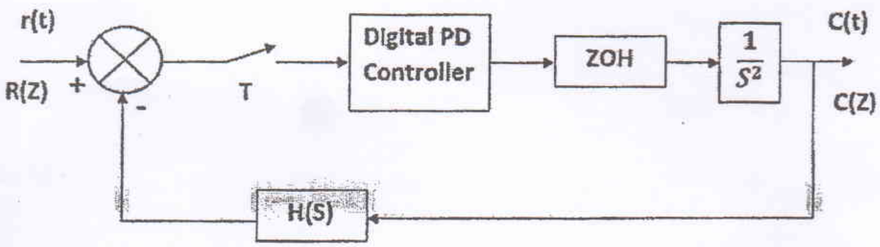
   c) Assume that a digital filter is given by the following difference equation: [6]

   $$y(k) + a_1 y(k-1) + a_2 y(k-2) = b_1 x(k) + b_2 x(k) + b_2 x(k-1)$$

   Draw block diagrams for the filters using (i) standard programming and (ii) ladder programming.

4. a) Discuss the situations where you prefer phase lag/lead controllers and PID controllers. [4]

b) Design a digital proportional-plus-derivative controller for the plant as shown in figure below. It is desired that the damping ratio ξ of the dominant closed loop poles be 0.5 and the undamped natural frequency be 4 rad/sec. the sampling period is 0.1 sec. [12]



5. a) Obtain the state space representation of following pulse transfer function: [8]

$$\frac{Y(z)}{U(z)} = \frac{0.368z^{-1} + 0.264z^{-2}}{1 - 1.368z^{-1} + 0.36z^{-2}}$$

i) Controllable canonical form
ii) Observable canonical form

b) Determine pulse transfer function matrix for the system which is described by state space representation as: [8]

$$\begin{bmatrix} x_1(k+1) \\ x_2(k+1) \end{bmatrix} = \begin{bmatrix} 3 & 1 \\ -2 & 1 \end{bmatrix} \begin{bmatrix} x_1(k) \\ x_2(k) \end{bmatrix} + \begin{bmatrix} 1 \\ 1 \end{bmatrix} u(k) \text{ and}$$

$$\begin{bmatrix} y_1(k) \\ y_2(k) \end{bmatrix} = \begin{bmatrix} 1 & 1 \\ 2 & 1 \end{bmatrix} \begin{bmatrix} x_1(k) \\ x_2(k) \end{bmatrix} + \begin{bmatrix} 1 \\ 0 \end{bmatrix} u(k)$$

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1. a) With the help of block diagram, explain digital control system in detail. Also mention the advantages of digital control system over analog. [8]

   b) Derive the transfer function of ZOH and also find the Pulse transfer function. [8]

2. a) Find the z-transform of the following: [4+4]

   (i) $x(t) = \frac{1}{4}t - \frac{1}{4}(t-4)1(t-4)$ (ii) $x(t) = \begin{cases} 0, & t<0 \\ \sin\omega t, & t \geq 0 \end{cases}$

   b) Solve the difference equation:

   X(k+2)+1.379X(k+1)+0.3679X(k)=0.3679u(k) where u(k) is step input and x(0)=0, x(1)=0.3679. [8]

3. a) Explain with suitable diagram how constant damping ratio line in s-plane is mapped into z-plan? [4]

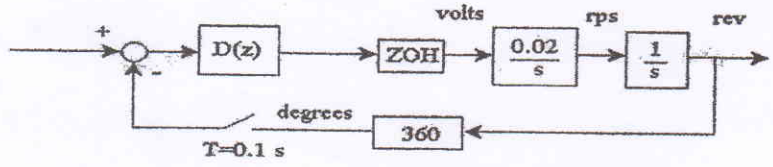
   b) Realize the digital filter by ladder programming. [8]

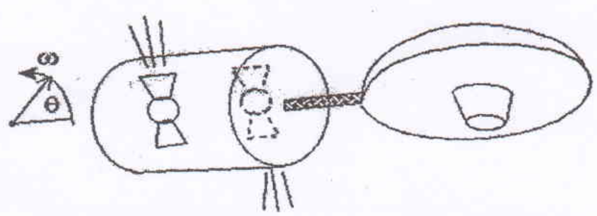
   $$G(z) = \frac{128z^{-3} + 224z^{-2} + 106z^{-1} + 11}{128z^{-3} + 160z^{-2} + 34z^{-1} + 1}$$

   c) Examine stability of characteristic equation. [4]

   $$P(z) = z^3 - 1.1z^2 - 0.1z + 0.2 = 0$$

4. A control system block diagram shown in figure below is of satellite communication system. Design a lead compensator D(z) to stabilize a satellite position. The sampling rate of digital controller is 10 samples per second. Consider design criteria: (i) damping ratio must be greater than 0.6, (ii) damped natural frequency should not exceed 1 Hz. i.e. $\omega_d < 0.1\omega_n$, and the time constant for the closed loop control system should be less than 0.5 second with 5% criterion for settling time. [16]





5. a) Obtain the state space representation of the following pulse transfer function in controllable canonical form. [6]

$$\frac{Y(z)}{X(z)} = \frac{4z^3 + 3z^2 + 5z + 4}{2z^3 + 5z^2 + 2z + 3}$$

b) Obtain Pulse transfer function matrix of the following state space representation: [10]

$$x(k+1) = Gx(k) + Hu(k)$$

$$y(k) = Cx(k) + Du(k)$$

Where $G = \begin{bmatrix} -a1 & 1 & 0 \\ -a2 & 0 & 1 \\ -a3 & 0 & 0 \end{bmatrix}$, $H = \begin{bmatrix} h1 \\ h2 \\ h3 \end{bmatrix}$, $C = \begin{bmatrix} 1 & 0 & 0 \end{bmatrix}$

And $D = b_0$

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1. a) Explain the data acquisition system in digital control system? Define tracking mode and hold mode in Sample-and-hold circuits. [8]

   b) Compare different types of sampling operations used for sampling of continuous time signal. [4]

   c) Write the advantages of digital control system over analog control system. [4]

2. a) Obtain the inverse z-transform of [4]

$$x(z) = \frac{z(1-e^{-aT})}{(z-1)(z-e^{-aT})}$$

   using Inversion integral method.

   b) Obtain X(z) by the use of convolution Integral in the Left Half of s-plane of the transfer function. [4]

$$X(S) = \frac{1}{S^2(S+1)}$$

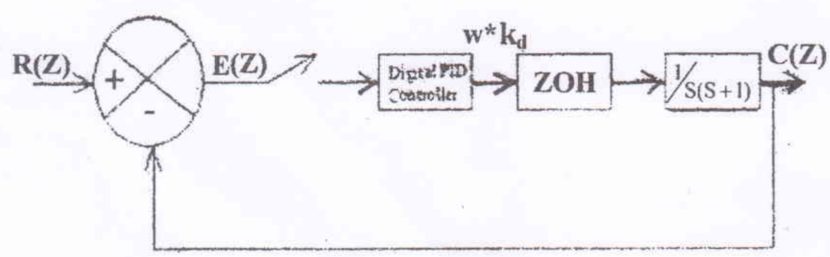
   c) Solve the following difference equation using z transform method. Also determine the value of $x(k + 2) / x(k + 1)$ as k approaches to infinity. [8]

$$x(k + 3) - 2.2x(k + 2) + 1.57x(k + 1) - 0.36x(k) = u(k)$$

   where, $u(k) = 1$ for all $k \geq 0$, and $x(0) = x(1) = x(2) = 0$.

3. a) Obtain the closed loop transfer function of the system shown in figure below. Assume proportional gain (k_p) = 1, Integral gain (k_i) = 0.2. [8]

   Derivative gain (k_d) = 0.2. [Take T = 1 sec]

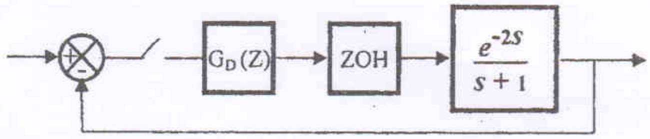


   b) Realize the given digital controller by Ladder Programming. [8]

$$G(z) = \frac{2z^2 + 2.2z + 0.2}{z^2 + 0.4z - 0.12}$$

4. a) Examine the stability of the characteristic equation given by $P(z) = z^3 - 1.1z^2 - 0.1z + 0.2 = 0$. [4]

b) Design a digital PI controller such that the dominant closed loop poles have damping ratio $\xi = 0.5$, sampling period T = 1, and $\frac{wd}{ws} = \frac{1}{10}$ and dead time of 2 sec. Also find KV and ess in response to unit ramp input. [12]



5. a) Obtain the state space representation of the system shown below in Jordan canonical form: [4]

$$\frac{Y(z)}{U(z)} = \frac{5}{(z+1)^2(z+2)}$$

b) Obtain the state space representation of the following pulse transfer function by observable canonical form: [6]

$$\frac{Y(z)}{X(z)} = \frac{(0.368z^{-1} + 0.264z^{-2})}{(1 - 1.368z^{-1} + 0.368z^{-2})}$$

c) Derive the pulse transfer function of the given state space representation form

$x(k+1) = G\,x(k) + H\,x(k)$ and $y(k) = C\,x(k) + D\,u(k)$ [6]

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