Name : ....

Roll No. : ....

Invigilator's Signature : ....

CS / M.TECH (EE) / SEM-2 / CIM-203 / 2011

2011

DIGITAL 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.

Answer Question No. ***1*** *and any* ***four*** *from the rest.*

GROUP – A

(Multiple Choice Type Questions)

1. Choose the correct alternatives for the following : 7 × 2 = 14

   i) The Z-transform of $X(s) = \frac{1-e^{-Ts}}{s} . \frac{1}{s+1}$ is

      a) $\frac{(1-e^{-T})Z^{-1}}{1-e^{-T}Z^{-1}}$

      b) $\frac{(1-e^{-T})Z^{-2}}{1-e^{-2T}Z^{-1}}$

      c) $\frac{(1-e^{-T})Z^{-1}}{1-e^{-2T}Z^{-1}}$

      d) $\frac{(1-e^{-2T})Z^{-1}}{1-e^{-T}Z^{-1}}$.

   ii) The static position error constant is

      a) $K_p = \lim_{z \to 1} G_{h0}G(z)$

      b) $K_p = \lim_{z \to 1} G_{h0}(z)\,G(z)$

      c) $K_p = \lim_{z \to \infty} G_{h0}G(z)$

      d) $K_p = \lim_{z \to 0} G_{h0}(z)\,G(z)$

iii) If the S-plane poles of a 2nd order (underdamped) transfer function with damping ratio ϕ and natural frequency $\omega_n \frac{r}{s}$ result in Z-plane poles at $Z = r \angle\theta$, then ϕ can be related to the Z-plane poles as

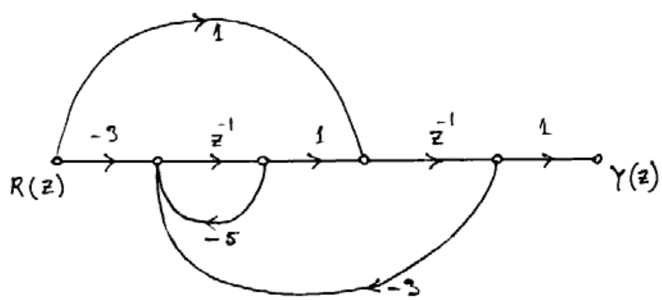
a) $\phi = \frac{1}{T}\sqrt{l^2_n\, r + \theta^2}$

b) $\phi = \frac{l_n\, r}{l^2_n\, r + \theta^2}$

c) $\phi = \frac{T}{-l_n\, r}$

d) $\phi = \frac{-l_n r}{\sqrt{l^2_n\, r + \theta^2}}$.

iv) Consider the signal processing algorithm in the following figure :



The difference equation model of the algorithm is

a) $y(k+2) + 5y(k+1) + 3y(k) = r(k+1) + 2r(k)$

b) $y(k+1) + 5y(k+2) + 3y(k) = r(k+2) + 2r(k)$

c) $y(k+2) + 5y(k+2) + 3y(k) = r(k+2) + 2r(k)$

d) $y(k+1) + 5y(k+1) + 3y(k) = r(k+1) + 2r(k)$.

v) Given $H(s) = \dfrac{1}{s+1}$, T = sampling period in sec. If trapezoidal approximation is used for integration then $H(Z)$ is

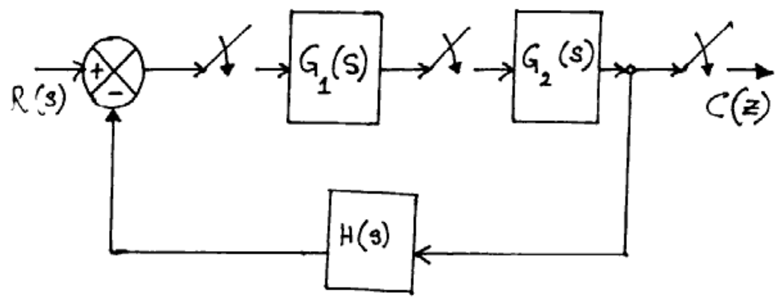
a) $\dfrac{T(1+Z^{-1})}{(1+T)-(I-T)Z^{-1}}$

b) $\dfrac{1+Z^{-1}}{(1+T)-(I-T)Z^{-1}}$

c) $\dfrac{T(1-Z)}{(1+T)-(I-T)Z}$

d) $\dfrac{T/2(1+Z^{-1})}{(1+T/2)-(I-T/2)Z^{-1}}$.

vi) Consider the figure below.



The output $C(Z)$ is determined by

a) $\dfrac{G_1G_2(Z)R(Z)}{1+G_1(Z)G_2(Z)H(Z)}$

b) $\dfrac{G_1(Z)G_2R(Z)}{1+G_1(Z)G_2H(Z)}$

c) $\dfrac{G_1(Z)G_2(Z)R(Z)}{1+G_1(Z)G_2H(Z)}$

d) $\dfrac{G_1G_2(Z)R(Z)}{1+G_1G_2(Z)H(Z)}$.

vii) Through the Z-transformation and W-transformation the primary strip of the left half of the S-plane is mapped

a) inside the unit circle in Z-plane

b) into the entire left half of W-plane

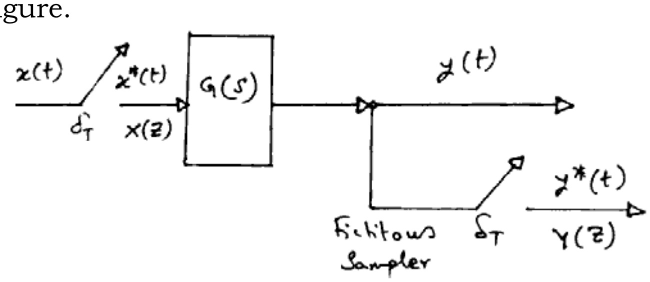
c) into the entire right half of W-plane

d) both (a) and (b).

GROUP – B

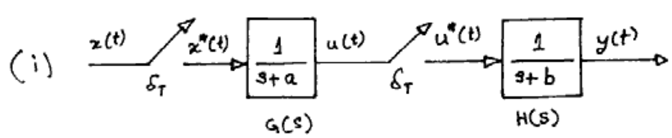
(Long Answer Type Questions)

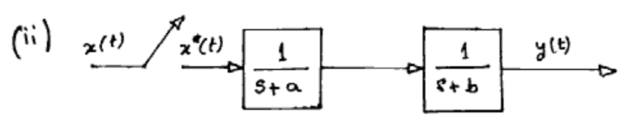
2. a) Obtain the pulse transfer function of the system in figure.



Where $G(s) = \dfrac{1 - e^{-Ts}}{s} \cdot \dfrac{1}{s(s+1)}$. 10

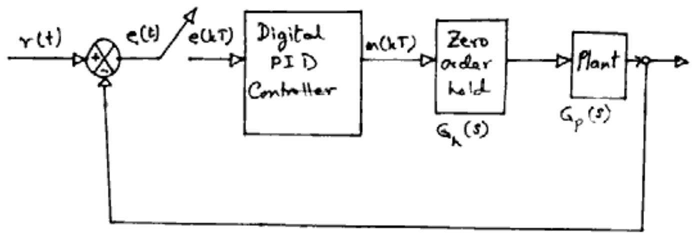
b) Consider the systems shown in figure below. Obtain the pulse transfer function $\dfrac{Y(Z)}{X(Z)}$ for each of these two systems in figure.





Comment on the difference of the two transfer functions. 4

3. a) Derive the pulse transfer function of a digital PID controller. 10

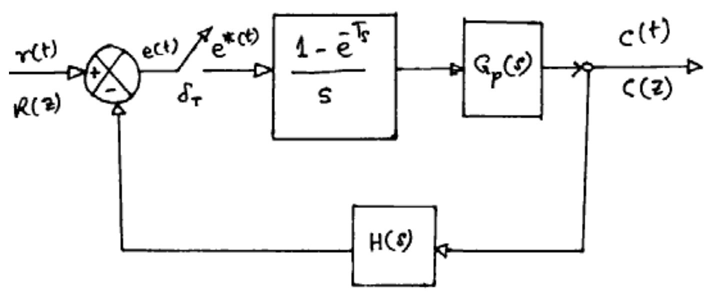
b) 

For the above system, the transfer function of the plant is assumed to be $G_p(s) = \dfrac{1}{s(s+1)}$ and the sampling period T is assumed to be 1 second. Find the closed loop transfer function, of the overall system in the figure. 4

4. a) Examine the stability of the following characteristic equation using Jury test.

$$P(Z) = Z^4 - 1 \cdot 2Z^3 + 0 \cdot 07Z^2 + 0 \cdot 3Z - 0 \cdot 08 = 0 .$$ 6

b) Consider the system shown in figure below.



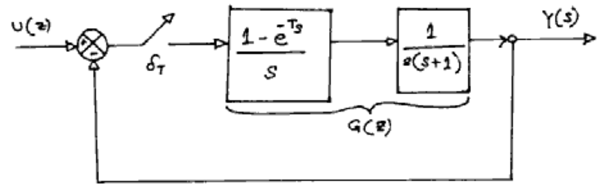
Derive the static position error constant and static velocity error constant expressions for unit step input. 8

5. a) Obtain the state equation and the output equation for the system defined by

$$\frac{Y(Z)}{U(Z)} = \frac{Z^{-1} + 5Z^{-2}}{1 + 4Z^{-1} + 3Z^{-2}}$$

Draw the block diagram for the system showing all state variables. 8

b) Obtain a state-space representation of the system shown in figure below. The sampling period is $T = 1$ second. figure shows the system.



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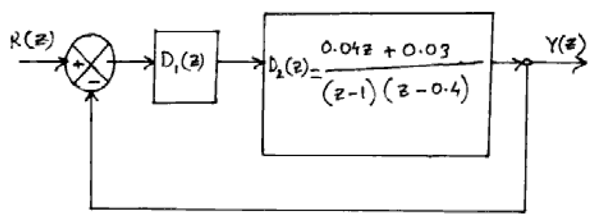
6. a) A digital process described by the transfer function $D_2(Z)$ uses a digital controller $D_1(Z)$ as shown in figure. Design the controller transmittance $D_1(Z)$ so that the closed loop system exhibits a deadbeat response and the error between the input and output is zero in the steady state when the system is operated by a unit step input.



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b) A satellite control system has the following discrete model :

$$\underline{x}(k+1) = \begin{bmatrix} 1 & 0\cdot12 \\ 0 & 1 \end{bmatrix} \underline{x}(k) + \begin{bmatrix} 0\cdot004 \\ 0\cdot11 \end{bmatrix} u(k)$$

$$y(k) = [1 \;\; 0] \;\; \underline{x}(k)$$

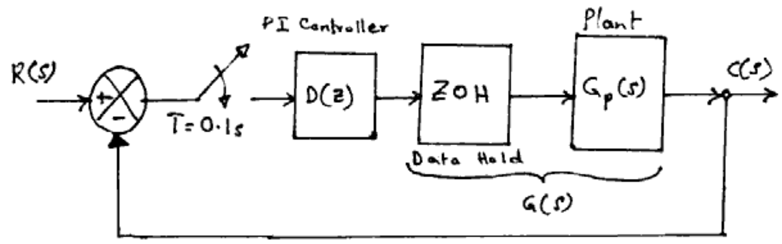
Where $x_1(k)$ and $x_2(k)$ are angular position and angular velocity respectively. A closed loop control system has to be designed using pole assignment technique with a control input $u(k) = -K\,\underline{x}(k)$, where K is the gain matrix. The desired closed-loop control pole locations are $(0\cdot8 \pm j\,0\cdot25)$. Determine the gain matrix and show how the feedback gains may be implemented. 9

7. A robot arm control system configuration is shown in figure. The open loop transfer function of the digital scheme is known to be $G(Z) = \dfrac{0 \cdot 022Z + 0 \cdot 01}{(Z-1)(Z-0 \cdot 84)}$.

   Design a PI controller to meet the following performance specifications :

   (i) $Kv \geq 12$

   (ii) Phase margin $\geq 55°$.



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8. a) Discuss the role of Integral Control by state augmentation in the state space design methodology. Draw a block diagram representation to show the Integral control structure for a digital control system employing full state feedback. State the significance of introducing a feed forward control gain in the presence of an Integrator control action. 7

   b) Write a note on full order observer in the Z-domain. Comment on the error dynamics of the full order state observer. 7

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