DIGITAL CONTROL TECHNIQUES
(AEIE 4232)

Time Allotted : 3 hrs **Full Marks : 70**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 5 (five) from Group B to E, taking at least one from each group.

Candidates are required to give answer in their own words as far as practicable.

Group – A
(Multiple Choice Type Questions)

1. Choose the correct alternative for the following: **10 × 1 = 10**

(i) A linear time invariant system is stable if
(a) the system is excited by a bounded input and the output is also bounded
(b) in the absence of input output tends zero
(c) both (a) and (b)
(d) system is excited by a bounded input and the output is not bounded.

(ii) The impulse function is a derivative of _____ function.
(a) Parabolic (b) Step (c) Ramp (d) Linear

(iii) The z-transform is a conformal mapping from the s-plane to the z-plane by the relation
(a) $Z = e^{-ST}$ (b) $Z = e^{-S/T}$ (c) $Z = e^{ST}$ (d) $S = e^{ZT}$.

(iv) Transfer function of a system is used to calculate which of the following?
(a) The order of the system (b) The time constant
(c) The output for any given input (d) The steady state gain.

(v) What is the z-transform of the signal $(a)^k$?
(a) X(z) =1/z-1 (b) X(z) = 1/1-z (c) X(z) = z/z-a (d) X(z) = 1/z-a.

(vi) A sampled system is stable if all the poles of the closed-loop transfer-function lie _____ the unit circle of the z-plane.
(a) inside (b) on the periphery of
(c) outside (d) not depends on the pole position

(vii) Which one of the following rules determines the mapping of s-plane to z-plane?
(a) Right side of the s-plane maps into outside of the unit circle in z-plane
(b) Left half of s-plane maps into inside of the unit circle
(c) Imaginary axis in s-plane maps into the circumference of the unit circle
(d) All the above.

(viii) Roots with higher multiplicity on the unit circle makes the system
(a) Absolutely stable (b) Unstable (c) Linear (d) Stable.

(ix) A system has a single pole at origin. Its impulse response will be
(a) Constant (b) Ramp (c) Decaying exponential (d) Oscillatory.

(x) If the time sequence x(z) is delayed by 5 units then its z-transform would be represented in the form
(a) $-5x(z)$ (b) $z^{-5}x(z)$ (c) $5x(z)$ (d) $-z^5\frac{dx(z)}{dz}$.

Group- B

2. (a) Explain the functions of different components of a typical closed loop digital control system using a general block diagram. [(CO1)(Remember/LOCQ)]
(b) Demonstrate the digital control scheme of a fighter aircraft in two steps. [(CO1)(Understand/LOCQ)]
(c) Prove that in discrete PI controller design, previous controller output is needed to add to get the present controller output. [(CO1)(Evaluate/HOCQ)]
3 + 5 + 4 = 12

3. (a) How natural sampling is different from flat top sampling? Explain with proper diagram. [(CO1)(Remember/LOCQ)]
(b) Explain a scheme to control insulation level to a critical diabetic patient in hospital. [(CO1)(Understand/LOCQ)]
(c) Map the left hand side of the s-plane into the z-plane and justify the mapping in terms of stability. [(CO2)(Analyze/IOCQ)]
4 + 4 + 4 = 12

Group - C

4. (a) Calculate z-domain transfer function of a four-wheeler of mass m, running at a velocity u for application of an input force F. Consider B is the viscous friction coefficient. [(CO3)(Evaluate/HOCQ)]
(b) A car tyre is pressurized by a compressor. Derive the mathematical model of the compressor-tyre model connected through a valve of resistance R. 'C' is the capacity of the tyre, P_1 and P_2 are the compressor pressure and tyre pressure respectively, and Q is the air flow rate. Find $G_{ZAS}(z)$ of the model. [(CO2)(Understand/LOCQ)]
(c) Prove that the steady state error of a system with feedback depends on the input signal R(z) and loop transfer function GH(z). [(CO2)(Remember/LOCQ)]
4 + 5 + 3 = 12

5. (a) Find $G_{ZAS}(z)$ for the series R-C circuit with the capacitor voltage as output and V_{in} as input voltage. [(CO2)(Analyze/IOCQ)]
(b) Calculate the error transfer function E(z) in terms of input, feedback gain and feed-forward gain in z-domain. [(CO2)(Understand/LOCQ)]

(c) Find position, velocity and acceleration error coefficients for the provided data of digital position control system with unity feedback and controller transfer function C(z). Also determine corresponding steady state errors.

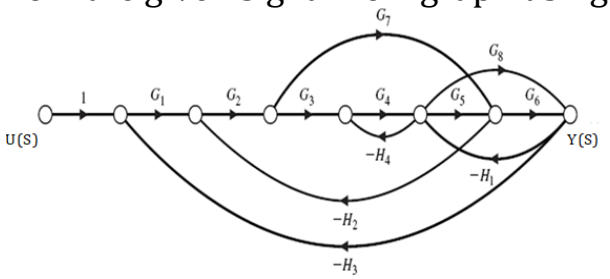
$$G_{ZAS}(z)=\frac{K(z+a)}{(z-1)(z-b)};C(z)=\frac{K_1(z-b)}{z-c};0<a,b,c<1$$ [(CO4)(Analyze/IOCQ)]

4 + 3 + (3 + 2) = 12

Group - D

6. (a) Discuss about the correlation between time response and root locations in s plane and z plane. [(CO5)(Remember/LOCQ)]

(b) Find Y(s)/U(s) from the given signal flow graph using Mason Gain formula:



[(CO4)(Analyze/IOCQ)]

(c) Analyze the stability of the system using Jury's stability criterion having characteristic polynomial: $C(z)=2z^4+7z^3+10z^2+4z+1.$

[(CO5)(Analyze/IOCQ)]

4 + 4 + 4 = 12

7. (a) (i) Draw the root loci of the given transfer function: $G(s)=\frac{k}{(z+0.1)(z+0.3)(z+0.5)}$, and

(ii) Find the value of *k* for which system will be stable.

(iii) For which value of *k*, the system gives sustained oscillation.

[(CO5)(Evaluate/HOCQ)]

(b) Discuss the effect of sampling period (T) on the steady state error.

[(CO4)(Understand/LOCQ)]

(6 + 2 + 1) + 3 = 12

Group - E

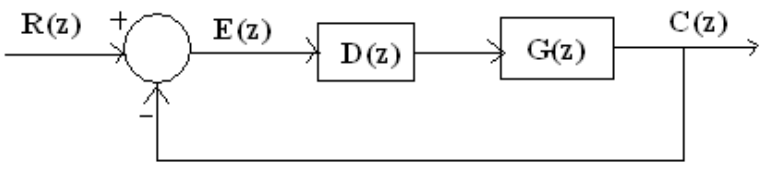
8. (a) Write deadbeat response design criteria,

(i) when the system's poles and zeros are inside the unit circle

(ii) when some of the system's poles and zeros are on or outside the unit circle.

[(CO6)(Remember/LOCQ)]

(b)

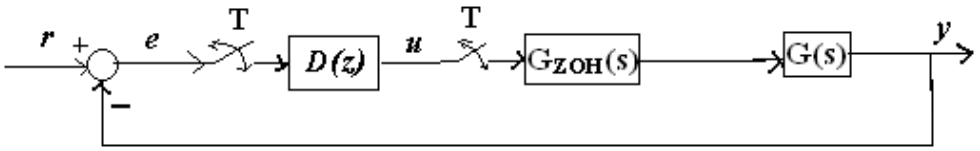


When input is a step function and overall transfer function **M(z)=z^{-2}** and $G(z)=\frac{0.05(z+0.5)}{(z-0.9)(z-0.8)(z-0.3)}$

(i) Find controller transfer function D(z)
(ii) Output sequence C(z). [(CO6)(Evaluate/HOCQ)]

(3 + 3) + (4 + 2) = 12

9.



In the above figure, D(z) is the controller transfer function and $G(s)=\frac{1}{s(s+1)}$ is the process.

Given: The dominant pole pair in continuous domain is $-\xi\omega_n \pm j\omega_n\sqrt{1-\xi^2}$. Dominant closed loop poles have a damping ratio ξ=0.5 and settling time ts=2 sec for 2% tolerance band. Consider the sampling period, T=0.2 secs.

From the above consideration:

(i) Find $G_{ZOH}(s)xG(s)$ in z-domain.
(ii) Draw the pole-zero map to compute angle contribution.
(iii) Design the digital controller D(z). [(CO6)(Evaluate/HOCQ)]

(4 + 4 + 4) = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	45.83	17.71	36.46

Course Outcome (CO):

After the completion of the course students will be able to

1. Acquire knowledge about fundamental concepts and techniques used in digital control system.
2. Understand and formulate the mathematical models of linear discrete time control systems.
3. Apply knowledge of z-transform and explain the concept of pulse transfer function.
4. Deduce signal flow graph and determine the transient and steady state behavior of process model.
5. Analyze the stability of the process model using different methods.
6. Design compensator and digital controllers by applying different design procedures.

*LOCQ: Lower Order Cognitive Question; IOCQ: Intermediate Order Cognitive Question; HOCQ: Higher Order Cognitive Question