CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
EET386	DIGITAL CONTROL	VAC	3	1	0	4

Preamble: This course aims to provide a strong foundation in digital control systems. Modelling, time domain analysis, frequency domain analysis and stability analysis of sampled data control systems based on Pulse Transfer function (conventional) approach and State variable concept are discussed. The design of digital control is also introduced.

Prerequisite: Basics of Circuits, Networks and Control Systems

Course Outcomes: After the completion of the course the student will be able to:

CO 1	Describe the role of various control blocks and components in digital control systems.
CO 2	Analyse the time domain responses of the sampled data systems using Z Transform.
CO 3	Analyse the stability of the given discrete time system.
CO 4	Apply state variable concepts to assess the performance of linear systems
CO 5	Apply Liapunov methods to assess the stability of linear systems
CO 6	Explain control system design strategies in discrete time domain.

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO 1	3		-	-	-	-	-	-	-	-	-	1
CO 2	3	2	-	-	2	-	-	-	-	-	-	1
CO 3	3	2	-	-	-	-	-	-	-	-	-	1
CO 4	3	2	-	-	2	-	-	-	-	-	-	1
CO 5	3	2	-	-	-	-	-	-	-	-	-	1
CO 6	3	2	-	-	-	-	-	-	-	-	-	1

Assessment Pattern:

Total Marks	CIE marks	ESE marks	ESE Duration
150	50	100	03 Hrs

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember (K1)	10	10	20
Understand (K2)	15	15	40
Apply (K3)	25	25	40
Analyse (K4)			
Evaluate (K5)			
Create (K6)			

End Semester Examination Pattern   **:** There will be two parts; Part A and Part B. **Part A** contains 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions.

Part B contains 2 questions from each module of which student should answer any one. Each question carries 14 marks and can have maximum 2 sub-divisions.

Course Level Assessment Questions:

Course Outcome 1 (CO1)
1. Derive the transfer function and obtain the frequency response characteristics of zero order hold circuit.
2. Explain how reconstruction of original signal is achieved from discrete time signals.
3. Explain any three factors to be considered for the choice of sampling frequency for a system.

Course Outcome 2 (CO2):
1. Derive the transfer function and obtain the frequency response characteristics of first order hold.
2. Problems related to steady state error.
3. Problems related to ZTF from difference equation form.

Course Outcome 3(CO3):
1. Problems related to the stability analysis using Jury's test
2. Problems related to the stability analysis using Bilinear Transformation
3. Problems to determine range of K or other TF parameter for stability/ oscillation.

Course Outcome 4 (CO4):
1. Problems related to canonical form representations
2. Problems based on state transition matrix
3. Problems to determine the solution of state equations.

Course Outcome 5 (CO5):
1. Check the stability of the given LTI system using Liapunov method.
2. Explain the physical relevance of Liapunov function.
3. Test the stability of the given nonlinear state model.

Course Outcome 6 (CO6):
1. Design a digital controller using root locus approach to meet the required specifications.
2. Problems on PID tuning and selection.
3. Pole placement problems for LTI systems.

Model Question Paper

QP CODE:

Reg.No:_____

Name:_____

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY
SIXTH SEMESTER B.TECH DEGREE EXAMINATION
MONTH & YEAR

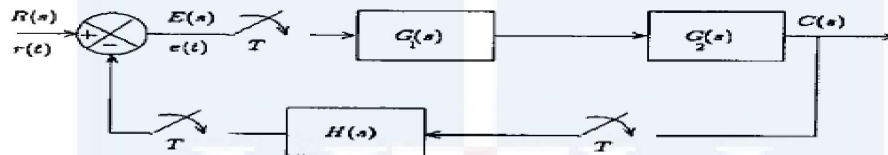Course Code: **EET386**

Course Name: **DIGITAL CONTROL**

Max. Marks: 100   **Duration: 3 Hours**

PART A

Answer all Questions. Each question carries 3 Marks

1   Explain any four advantages of sampled data control systems.

2   Determine the z-transform of $x(n)=(1/2)^n u(-n)$.

3   Obtain the pulse transfer function for the given system.

4   Obtain the poles and zeroes of the system governed by the difference equation:

$$y(n)+\frac{5}{4}y(n-1)+\frac{3}{8}y(n-2) = 2x(n)-x(n-1)$$

5   Draw and explain the mapping between s- plane to z-plane for the constant frequency loci.

6   Explain how does the P- controller affect the performance of a DT system.

7   Obtain the diagonal canonical form of the system with $G(z) = \dfrac{z+0.5}{(z^2+1.4z+0.4)}$

8   Determine the state transition matrix for the DT system with state matrix
$A = \begin{bmatrix} 0 & 1 \\ -0.15 & -1 \end{bmatrix}$

9   State and explain the Liapunov stability theorem for LTI discrete time systems.

10   Determine the observability of the system with: $A = \begin{bmatrix} -5 & 0 \\ -2 & -3 \end{bmatrix}; C = \begin{bmatrix} 1 & -1 \end{bmatrix}$

PART B

Answer any one full question from each module. Each question carries 14 Marks

Module 1

11   a)   Derive the transfer function of a ZoH circuit.   **(5)**

       b)   Determine the inverse z-transform of the following functions: **(9)**

$i)X(z) = \dfrac{2z^{-1}}{(1-0.25z^{-1})^2}; ROC : |z| > \dfrac{1}{4}, and, ii)F(z) = \dfrac{3z^{-1}}{(1-z^{-1})(1-2z^{-1})}; ROC : |z| > 2$

12   a)   Determine the Z transform of $H(s) = \dfrac{3}{s(s+2)^2}$ **(4)**

b) Write short notes on:
  i)   Aliasing effect
  ii) Importance of First order hold circuit
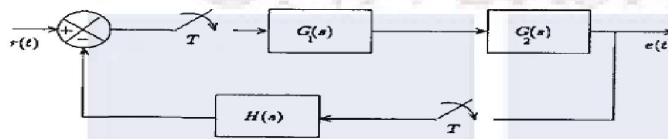 iii) Region of convergence for ZT   (10)

Module 2

13 a) i) Obtain the direct form realization for the system described by the difference
        equation: $y(n) - \dfrac{5}{6} y(n-1) + \dfrac{1}{6} y(n-2) = 2x(n)$

        ii) Also determine the impulse response h(n) for the above system.   (3+5)

    b) Obtain the pulse transfer function for the unity feedback system with $G_1(s) = \dfrac{1}{s}$,
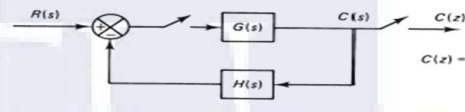 $G_2(s) = \dfrac{1}{(s+2)}$ and assume T=1 second

        (6)

14 a) Obtain the unit impulse response C(n) of the following feedback DT system with
        $G(s) = \dfrac{1}{(s+3)}$, . $H(s) = \dfrac{1}{s}$,

        Assume ideal sampling and T=1 ms.   (9)

    b) Explain the factors on which the steady state error constants depend on?   (5)

Module 3

15 a) Check stability of the system described by the following characteristic equation,
        using Bilinear transformation: $z^3 - 0.2z^2 - 0.25z + 0.05 = 0$ (7)

    b) With suitable characteristics compare between PI and PD controllers.   (7)

16 a) For a unity feedback system with $G(z) = \dfrac{K}{z\,(z^2 - 0.2z - 0.25)}$ determine the range for
        K for ensuring stability, using Jury's test.   (5)

    b) With help of suitable sketches, explain how can you use root locus technique to
        design a digital controller.   (9)

Module 4

17 a) Obtain the phase variable representation for the system with
        $G(z) = \dfrac{z+0.5}{(z^3 + 1.4z^2 + 0.5\,z + 0.2)}$ (5)

    b) Determine the solution for the homogeneous system x(k+1)= G x(k), where:
        $G = \begin{bmatrix} 0 & 1 \\ -0.16 & -1 \end{bmatrix}$ and $x(0) = \begin{bmatrix} 1 \\ -1 \end{bmatrix}$ (9)

18 a) Determine the pulse transfer function Y(z)/U(z) for the system with:
        x(k+1)= G x(k)+ Hu(k) and y(k)= Cx(k)+Du(k),
        where $G = \begin{bmatrix} 0 & 1 \\ -0.16 & -1 \end{bmatrix}$, $H = \begin{bmatrix} 1 \\ 1 \end{bmatrix}$ $C = \begin{bmatrix} 1 & 0 \end{bmatrix}$ and D=0   (9)

b) Show that for a given pulse transfer function, the states space representation is not unique. **(5)**

a) Determine the stability of the LTI system with state model using Liapunov method:

$$\dot{X} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -1 & -2 & -5 \end{bmatrix} X$$ **(9)**

b) Determine the controllability of the state model: $\dot{x} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 2 \\ 0 & -1 & -7 \end{bmatrix} x + \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} u$ **(5)**

19 a) Test stability of the nonlinear system given below, using Liapunov method.

$$\dot{X} = \begin{bmatrix} -4 & 0 \\ 3x_2{}^2 & -2 \end{bmatrix} X$$

(4)

b) Design a state feedback controller for the following system such that the closed loop poles are placed at: $-1 \pm j2$ and -10. $\dot{x} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & -1 & 2 \\ 0 & -1 & -5 \end{bmatrix} x + \begin{bmatrix} 0 \\ 0 \\ 2 \end{bmatrix} u$ **(10)**

Syllabus

Module 1

Digital control system (10 hours)

Basic block diagram of digital control system- Typical examples- Advantages of digital control systems.

Mathematical modelling of sampling process- sampling theorem- Aliasing effect- Impulse train sampling- Zero order and First order hold circuits- Signal reconstruction.

Discrete form of special functions- Discrete convolution and its properties.

Z Transform: Region of convergence- Properties of Z transform — Inverse ZT- methods.

Module 2

Analysis of LTI Discrete time systems   (8 hours)

Difference equation representations of LTI systems- Block diagram representation in Direct form

Z-Transfer function- Analysis of difference equation of LTI systems using Z transfer function.

Pulse transfer function: Pulse transfer function of closed loop systems.

Time responses of discrete data systems-Steady state performance-

Static error constants

Module 3

Stability analysis and Digital controllers (9 hours)

Stability analysis: Stability analysis of closed loop systems in the z-plane, Jury's stability test- Use of bilinear transformation for stability analysis.

Digital Controllers: Introduction to Digital Controllers- Root locus based design of digital Controllers.

PID controllers: Digital PID controller and design of PID controllers.

Module 4

State space analysis (8 hours)

State variable model of discrete data systems -Various canonical form representations-controllable, observable forms, Diagonal canonical and Jordan canonical forms

State transition matrix: Properties- Computation of state transition matrix using z-transform method -Solution of homogeneous systems

Determination of transfer function from state space model.

Module 5

Pole placement design and Liapunov stability analysis (10 hours)

Controllability and observability for continuous time systems

Pole placement design using state feedback for continuous time systems

Controllability and observability for discrete time systems- Digital control design using state feedback discrete time systems

Liapunov stability Analysis: Liapunov function- Liapunov methods to stability of linear and nonlinear systems- Liapunov methods to LTI continuous time systems

Liapunov methods to LTI Discrete time systems (Theorem only).

Text Books:
1. Ogata K., Discrete Time Control Systems, 2/e, Pearson Education.
2. Kuo B. C, Digital Control Systems, 2/e, Saunders College Publishing, Philadelphia, 1992.
3. Gopal M, Digital Control and State Variable Methods, 2/e, Tata McGraw Hill
4. Philips C. L., Nagle H. T. and Chakraborthy A., Digital Control Systems, 4/e, Pearson

References:
1. Constantine H. Houpis and Lamont G. B., Digital Control Systems Theory, Hardware Software, 2/e, McGraw Hill.
2. Isermann R., Digital Control Systems, Fundamentals, Deterministic Control, 2/e, Springer Verlag, 1989.
3. Liegh J. R, Applied Digital Control, 2/e, Dover Publishers.
4. Gopal M, Modern Control System Theory, 2/e, New Age Publishers

Course Contents and Lecture Schedule:

Module	Topic coverage	No. of Lectures
1	**Digital control system (10 hours)**	
1.1	Basic block diagram of digital control system- Typical examples- Advantages of digital control systems.	1
1.2	Mathematical modelling of sampling process -sampling theorem- Aliasing effect- Impulse train sampling	2
1.3	Zero order and First order hold circuits- Signal reconstruction	2
1.4	Discrete form of special functions- Discrete convolution and its properties	1
1.5	Z Transform: Region of convergence- Properties of the Z transform –	2

1.6	Inverse ZT- methods	2
2	**Analysis of LTI Discrete time systems (8 hours)**	
2.1	Difference equation representations of LTI systems- Delay operator and block diagram representation in Direct form	1
2.2	Z-Transfer function- Analysis of difference equation of LTI systems using ZTF	2
2.3	Pulse transfer function: Pulse transfer function of closed loop systems	2
2.4	Time responses of discrete data systems-Steady state performance-static error constants	3
3	**Stability analysis and Digital controllers (9 hours)**	
3.1	Stability analysis: Stability analysis of closed loop systems in the z-plane, Jury's stability test.	2
3.2	Use of bilinear transformation and extension of Routh-Hurwitz criterion for stability.	2
3.3	Digital Controllers: Introduction to Digital controllers- Root locus based design of Digital controllers.	3
3.4	PID controllers: Digital PID controller and design of PID controllers.	2
4	**State space analysis (8 hours)**	
4.1	State variable model of discrete data systems -Various canonical form representations-controllable and observable forms	2
4.2	Diagonal canonical and Jordan forms	2
4.3	State transition matrix- properties- Computation of state transition matrix using z-transform method	2
4.4	Solution of homogeneous systems	1
4.5	Determination of pulse transfer function from state space model	1
5	**Pole placement design and Liapunov Stability Analysis (10 hours)**	
5.1	Controllability and observability for continuous time systems	2
5.2	Pole placement design using state feedback for continuous time systems	2
5.3	Controllability and observability for discrete time systems- Digital control design using state feedback discrete time systems	3
5.4	Liapunov stability Analysis: Liapunov function- Liapunov methods to stability of linear and nonlinear systems- Liapunov methods to LTI continuous time systems	2
5.5	Liapunov methods to LTI Discrete Time systems (Theorem only).	1