GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Diploma Engineering

Level: Diploma

Branch: Instrumentation & Control Engineering

Subject Code: DI04017071

Subject Name: Digital Control System

w. e. f. Academic Year:	2025-26
Semester:	4th
Category of the Course:	Professional Elective - II

Prerequisite:	Basic understanding of control theory and signals/systems, including sampling, Z-transform, and discrete-time system fundamentals.
Rationale:	The subject Digital Control System is included in the Diploma in IC Engineering syllabus to prepare students for modern automation and industrial practices where digital controllers like PLC, DCS, and microcontroller-based systems are widely used. It helps students understand sampling, Z-transform, digital stability, and controller design, which are essential for analyzing and implementing real-time control. This knowledge equips diploma engineers with skills required in process industries, automation, and embedded control applications.

Course Outcome:

After Completion of the Course, Student will able to:

No	Course Outcomes	RBT Level
CO-1	Explain the fundamentals of digital control systems, sampling process, and data conversion techniques	R,U
CO-2	Apply Z-transform methods for analysis of discrete-time control systems.	U,A
CO-3	Analyze the stability of digital control systems using different stability criteria.	U,A
CO-4	Design and simulate digital controllers and compensators (PID, Lead, Lag) for practical applications	R,U,A
CO-5	Demonstrate the application of digital control concepts in industrial automation, PLC, DCS, and embedded systems	R,U,A

**Revised Bloom's Taxonomy (RBT)*

Teaching and Examination Scheme:

Teaching Scheme (in Hours)			Total Credits L+T+ (PR/2)	Assessment Pattern and Marks				Total Marks
				Theory		Tutorial / Practical		
L	T	PR	C	ESE(E)	PA(M)	PA(I)	ESE(V)	
3	0	2	4	70	30	20	30	150

Course Content:

Unit No.	Content	No. of Hours	% of Weightage
1	**UNIT 1: Introduction to Digital Control System**	09	20
	1.1 Control System Terminology 1.1.1 Control system (definition, open loop vs closed loop) Controller (role, examples: PID, PLC, DCS) Digital Control System (discrete-time signals, microprocessor/MCU/PLC implementation) Analog Control System (continuous signals, op-amp/RC implementation) Continuous-time signals (examples: temperature, speed, voltage waveforms) Discrete-time signals (sampled signals, digital representation, aliasing note) 1.1.2 Simple block diagrams analog vs digital controllers.* 1.2 Computer-Controlled Systems 1.2.1 Basic structure: 1.2.2 Example: Liquid level control system 1.3 Computer-Based Control: History and Trends 1.3.1 Early controllers: analog electronics, pneumatic controllers. Transition to digital: minicomputers (1960s–70s). 1.3.2 Microprocessor revolution (1980s–90s). 1.3.3 Current trends: PLCs, DCS, Embedded DSPs, FPGA-		

	based control, Industry 4.0. 1.4 Control Theory: History and Trends 1.4.1 Classical era: Root locus, Bode, Nyquist. 1.4.2 Modern control (state-space, optimal, robust, adaptive). 1.4.3 Digital control: sampled-data theory, Z-transform, stability in z-plane. 1.4.4 Trends: AI/ML in control, predictive & adaptive digital control. 1.5 Overview of Classical Analog Controller Design 1.5.1 General linear feedback system (unity feedback block diagram). 1.5.2 Feedback system with disturbance input (helps explain rejection properties). 1.5.3 Feedback system without disturbance input (simplified reference model). 1.5.4 Limitations of analog controllers shift to digital control.		
2	**UNIT 2: Laplace Transform and Z-Transform**	10	25
	2.1 Laplace Transform 2.1.1 Introduction to Laplace Transform Definition and basic concept Region of convergence (ROC) Applications in engineering and control systems 2.1.2 Properties of Laplace Transform 2.2 Z-Transform 2.2.1 Introduction to Z-Transform 2.2.2 Inverse Z-Transform Long division method Partial fraction method Residue method 2.2.3 Properties of Z-Transform Linearity Time shifting Time scaling Time reversal Differentiation in Z-domain Convolution theorem		

3	**UNIT 3.Signal Processing in Digital Control**	08	15
	3.1 Advantages of Digital Control 3.2 Implementation Problems in Digital Control 3.2.1 Sampling effects 3.2.2 Quantization effects 3.3 Basic Digital Control Scheme Configuration 3.3.1 Functional block diagram Explanation of each block 3.4 Signal Conversion Principles 3.4.1 D/A (Digital-to-Analog) converter circuit 3.4.2 A/D (Analog-to-Digital) converter circuit 3.5 Basic Discrete-Time Signals(Properties) 3.5.1 Unit sample sequence 3.5.2 Unit step sequence 3.5.3 Sinusoidal sequence 3.6 Time Domain Models for Discrete-Time Systems** State variable models Difference equation models		
4	**UNIT 4: Model of Digital control Devices and Systems**	09	20
	4.1 Basic digital control scheme configuration 4.1.1 Block diagram for basic control system design 4.2 z domain description of sample continuous time plants 4.2.1 Models of A/D converter 4.2.2 Models of D/A converter 4.3 Digital PID controller 4.3.1 Non interacting PID algorithm 4.3.2 Interacting PID algorithm 4.4 Digital Temperature Control System Example 4.5 Stepping motors and their control Explain Stepping motors and their control Example		

5	**UNIT 5: Design of Digital Control Algorithm** 5.1 Digital Design Procedures 5.1.1 Direct synthesis procedure 5.1.2 Iterative design procedure 5.2 z plane specifications of control system design Stability Steady state accuracy Transient accuracy Disturbance rejection Insensitivity and robustness 5.3 Root locus in z plane Mapping of s plane patterns on the z-plane 5.4 Digital compensator design using frequency response plots 5.4.1 Lead Compensator 5.4.2 Lag compensator 5.4.3 Lead –Lag compensator Example : 1 /s(s+5)	09	20
	Total	**45**	**100 %**

Suggested Specification Table with Marks (Theory):

Distribution of Theory Marks (in %)					
R Level	**U Level**	**A Level**	**N Level**	**E Level**	**C Level**
40	**40**	**20**	**-**	**-**	**-**

Where R: Remember; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create (as per Revised Bloom's Taxonomy)

References/Suggested Learning Resources:
(a) Books:

Sr. No.	Title of Book	Author	Publication with place, year and ISBN
1	Digital Control and State Variable Methods	M Gopal	2nd edition Tata McGraw Hill Publishing Company Limited, New Delhi

2	Digital Control Systems	Benjamin C. Kuo	ISBN 0-03-012884-6
3	Discrete time control systems	Kaushiko Ogata	PRENTICE HALL, Englewood cliffs second edition

(b) Open-source software and website:

No.	Resource Name	Web Address
1	NPTEL	http://nptel.ac.in/courses/108103008/
2	Web Supplements provided by Gopal, M	http://www.mhhe.com/gopal/dc4e
3	MATLAB Simulator	https://www.mathworks.com/products/matlab/live-editor.html

Suggested Course Practical List: If any

Sr. No.	Practical Outcomes (Pros)	Unit No.	Approx. Hrs. Required
1	Generate Discrete signal using MATLAB.	1	2
2	Convert A to D convertor using MATLAB.	1	2
3	Observe the sampling effect using signal in MATLAB.	2	2
4	Observe the quantization effect using signal in MATLAB.	2	2
5	Convert given continuous system to a discrete system using the zero order hold operation(MATLAB)	3	2
6	Analyze the transient response from pole location in the z plane. (MATLAB)	3	2
7	Generate root locus using z transform. (MATLAB)	4	2
8	Plot the step response of a discrete-time system. (MATLAB)	4	2
9	Design digital controller(Lead compensation ,Lag compensation) with given specifications(MATLAB)	5	2

List of Laboratory/Learning Resources Required:

1. MATLAB Software

Suggested Project List:

The projects serve as practical learning experiences for students in the field of Instrumentation and Control Engineering. These projects integrate theoretical knowledge with hands-on application, fostering competency development across various Course Outcomes (COs). Below are guidelines for designing and executing micro-projects:

1. Digital Temperature Control System
   Use a temperature sensor (LM35) and microcontroller to maintain set temperature using a heater or fan.
2. Stepper Motor Position Control
   Control the angle and direction of a stepper motor using a microcontroller or PLC.
3. DC Motor Speed Control using PWM
   Implement speed control through Pulse Width Modulation (PWM) and feedback.
4. Liquid Level Control System
   Measure and control the water level in a tank using ultrasonic or float sensors.
5. Simulation of Digital PID Controller
   Design and test a digital PID algorithm for a first-order system in MATLAB or Python
6. Analog vs Digital Control Comparison
   Build two small circuits (one analog, one digital) to compare response and accuracy.
7. Sampling and Aliasing Demonstration
   Show how different sampling rates affect signal reconstruction using simulation tools.
8. A/D and D/A Converter Interface Project
   Interface a sensor through ADC and display its converted digital value on LCD.
9. Root Locus Plot in z-Plane
   Simulate and analyze root locus behaviour of a discrete control system using MATLAB/Scilab.
10. Digital Lead–Lag Compensator Design
    Design and verify a digital compensator for improved transient response using a given plant model.

Suggested Activities for Students (Digital Control System)

In addition to classroom and laboratory learning, students are encouraged to participate in the following co-curricular activities to strengthen their conceptual understanding and practical skills. These activities can be done individually or in small groups and should be documented in a 5-page report.

Students are also advised to collect physical or digital evidence (photos, screenshots, data logs, etc.) to include in their portfolio for placement interviews.

Suggested Activities

1. Prepare a survey report on real-life applications of digital control systems
   Include examples like temperature control, motor speed control, robotics, and industrial automation.
2. Test sensors, actuators, and control circuits
   Use multimeters, signal generators, and microcontroller-based test setups to verify digital control operation.
3. Deliver a seminar on a course-related topic
   Examples: Digital PID Controller, Z-Transform Applications, PLC-based Control, or Stepping Motor Control.
4. Conduct a library or internet survey on data sheets and manuals
   Collect and study data sheets of microcontrollers, A/D and D/A converters, and PID controller ICs.
5. Prepare a PowerPoint presentation on digital control concepts
   Suggested topics: Sampling & Quantization, Digital Filters, and Root Locus in z-plane, or Digital Compensator Design.
6. Undertake a market survey of commonly used control hardware
   Compare specifications and prices of PLCs, sensors, actuators, and industrial controllers.
7. Search for videos or animations related to complex topics
   For example, stability in z-plane, ZOH (Zero Order Hold), or stepper motor control — and present a short summary or demo.
8. Create a simulation of a simple digital control loop
   Use MATLAB, Scilab, or Python to model a feedback system with sampling and quantization.
9. Prepare a comparative report on analog vs digital control systems
   Highlight advantages, limitations, and modern trends such as Industry 4.0 and AI-based controllers.
10. Design a small prototype of a digital control system
    Example: Temperature or level control using Arduino or microcontroller board and display results.

* * * * * * *