GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Diploma Engineering
Level: Diploma
Branch: Electrical Engineering / Renewable Energy
Subject Code: DI05000211
Subject Name: Digital Signal Controller

w. e. f. Academic Year:	2026-27
Semester:	5^{th}
Category of the Course:	PEC-04

Prerequisite:	**Basic concepts of Electrical & Electronics (Analog & Digital) Engineering, Understanding of C Programming language, Basics of Microprocessors and Microcontrollers.**
Rationale:	Digital Signal Controllers (DSC) and their role in modern electrical engineering applications. As power electronics, motor drives, and renewable energy systems continue to grow, the need for efficient real-time control has become essential, with 32-bit controllers like STM32 and TI C2000 playing a key role. The course covers hardware architecture, embedded C programming, real-time control techniques, and peripheral interfacing, along with practical applications in converters, inverters, and motor control. It also introduces advanced topics such as PLL and FPGA for high-speed and synchronized systems. Overall, the course bridges the gap between theoretical knowledge and practical implementation, preparing students for careers in power electronics, embedded systems, automation, and renewable energy.

Course Outcome:

After Completion of the Course, Student will able to:

No	Course Outcomes	RBT Level
01	Differentiate the architecture and features of Digital Signal Controllers (DSC) and 32-bit controllers	U
02	Develop embedded C programs using control structures, interrupts, and peripheral interfacing techniques.	A
03	Apply Digital Signal Controllers in power electronics, motor control, and renewable energy systems and analyze their performance.	A
04	Implement STM32 and TI controller-based systems for PWM generation, ADC interfacing, and real-time control applications.	A
05	Explain advanced concepts such as PLL and FPGA and their applications in high-speed and synchronized systems.	U

**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	30	20	150

Course Content:

Unit No.	Content	No. of Hours	% of Weightage
1.	**Fundamentals of Digital Signal Controllers & Hardware Architecture** Contents: ➢ Introduction to Digital Signal Controllers (DSC): Definition and need in electrical engineering, Difference between Microcontroller, Microprocessor and DSC, Applications in power electronics, motor control and renewable energy. ➢ Overview of 32-bit Controllers: Need for 32-bit controllers, Introduction to STM32 and TI C2000. ➢ Hardware Architecture of DSC: Block diagram of DSC, CPU components (ALU, Control Unit, Registers), Harvard vs Von-Neumann architecture, Clock system and performance. ➢ On-Chip Peripherals: GPIO, Timers, ADC, DAC, Communication peripherals (UART, SPI, I2C). ➢ Memory System and Registers: Flash, SRAM, EEPROM, Special Function Registers (SFR), Register-level programming. ➢ Interrupt Processing: Concept and types (External, Timer, ADC), Interrupt priority and vector table, Basic interrupt flow.	12	27%
2.	**Embedded C Programming for 32-bit Controllers** Contents: ➢ Introduction to Embedded C: Difference between C and Embedded C, Structure of embedded program, Header files and libraries.	10	22 %

	➢ Development Environment (IDE): Introduction to STM32CubeIDE, Compilation and flashing, Project creation steps. ➢ Variables, Data Types and Registers: Embedded data types, Use of volatile keyword, Register mapping and addressing. ➢ Control Structures and Functions: Loops (for, while), Conditional statements, Functions and modular programming. ➢ Interrupt Programming in C: Writing ISR, Enabling and disabling interrupts, Practical examples. ➢ Peripheral Programming: GPIO (LED, switch), Timer (delay, PWM), ADC (sensor reading), DAC basics. ➢ Communication Protocols: UART, SPI, I2C, Basic program examples. ➢ Debugging Techniques: Software debugging (breakpoints, watch variables), Hardware debugging, Common errors and troubleshooting.		
3.	**Applications of Digital Signal Controllers** Contents: ➢ DSC in Power Electronics: DC-DC converters (Buck, Boost), Inverters (Single-phase, Three-phase). ➢ Motor Control Applications: Speed control of DC motor, Basics of induction motor control. ➢ Renewable Energy Applications: Solar MPPT control, Grid-connected inverter systems. ➢ Control Techniques: Open-loop control, Closed-loop control, Introduction to PID controller. ➢ Real-Time Implementation Challenges: Sampling time, Switching frequency, Noise and filtering issues.	08	18 %
4.	**STM32 and TI Controller Practical Concepts** Contents: ➢ Introduction to STM32 Controllers: Features and pin configuration, GPIO configuration. ➢ STM32 Programming Basics: Digital I/O, Timer-based delay, PWM generation.	10	22 %

	➢ STM32 in Power Electronics: PWM for converters (Buck, Boost, Inverter), ADC for voltage/current sensing. ➢ Introduction to TI Controllers: TI C2000 series overview, Comparison with STM32, Advantages in real-time control. ➢ Basic TI Controller Concepts: High-speed PWM modules, ADC synchronization, Control loop basics.		
5.	**Introduction to PLL and FPGA** Contents: ➢ Phase Locked Loop (PLL): Basic concept, Block diagram (Phase detector, Loop filter, VCO), Applications (Frequency and grid synchronization). ➢ Introduction to FPGA: Concept of FPGA, Difference between Microcontroller and FPGA, Architecture (Logic blocks, interconnections, I/O). ➢ FPGA vs DSC: Speed comparison, Parallel vs sequential processing, Advantages and limitations. ➢ Basic FPGA Applications: PWM generation, Signal processing, High-speed control systems.	5	11 %
	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**
25 %	35 %	40 %	-	-	-

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:

1. **Embedded Systems with ARM Cortex-M Microcontrollers and Assembly Language Programming –** Muhammad Ali Mazidi, Sarmad Naimi, Sepehr Naimi, Edition: First Edition (2017), ISBN: 978-0997925944, Publisher: MicroDigitalEd

2. **Embedded Systems: Real-Time Interfacing to ARM Cortex-M Microcontrollers** – Jonathan W. Valvano, Edition: Third Edition (2014), ISBN: 978-1463590154, Publisher: CreateSpace
3. **Microprocessor Architecture, Programming and Applications with 8085** – Ramesh S. Gaonkar, Edition: Sixth Edition (2013), ISBN: 978-8131705858, Publisher: McGraw Hill Education
4. **Digital Signal Processing: Principles, Algorithms and Applications** – John G. Proakis, Dimitris G. Manolakis, Edition: Fourth Edition (2006), ISBN: 978-0131873742, Publisher: Pearson
5. **The Definitive Guide to ARM Cortex-M3 and Cortex-M4 Processors** – Joseph Yiu, Edition: Third Edition (2013), ISBN: 978-0124080829, Publisher: Elsevier
6. **Modern Power Electronics and AC Drives** – Bimal K. Bose, Edition: First Edition (2002), ISBN: 978-0130167439, Publisher: Prentice Hall
7. **Fundamentals of Analog and Digital Electronic Circuits** – Bahaa E. A. Saleh, Malvin C. Teich, Edition: Second Edition (2009), ISBN: 978-0471714484, Publisher: Wiley

(b) Open-source software and website:

1. **Texas Instruments – C2000 Series Documentation and Development Tools** – Publisher: Texas Instruments, Available at: https://www.ti.com
2. **NPTEL – Courses on Embedded Systems, Power Electronics and Control Systems** – Organization: NPTEL, Available at: https://nptel.ac.in
3. **STM32CubeIDE – Integrated Development Environment for STM32 Programming** – Software by STMicroelectronics
4. **Code Composer Studio – Development Tool for TI Controllers** – Software by Texas Instruments
5. **MATLAB / Simulink – Simulation of Control Systems and Power Electronics** – Software by MathWorks
6. **Xilinx Vivado – FPGA Design and Implementation Tool** – Software by Xilinx

Suggested Course Practical List:

Sr. No.	Practical Outcome/Title of Experiment	CO1	CO2	CO3	CO4	CO5
1	To study and understand the architecture, features, and development environment of STM32 / TI C2000 controller.	√				
2	To implement LED blinking using GPIO interfacing on STM32 / TI C2000 controller.		√			

3	To interface a push button, switch with LED and control its operation using GPIO on STM32 / TI C2000 controller.		√			
4	To generate accurate time delay using timer module of STM32 / TI controller		√			
5	To implement external interrupt using push button input and observe interrupt handlingusingSTM32 / TI C2000 controller.		√			
6	To implement timer-based interrupt for periodic event control		√			
7	To generate PWM signal using timer and vary duty cycle for control applicationsSTM32 / TI C2000 controller.			√	√	
8	To interface Analog to Digital Converter (ADC) for reading analog input signalusingSTM32 / TI C2000 controller.			√		
9	To generate analog output using Digital to Analog Converter (DAC)usingSTM32 / TI C2000 controller.			√		
10	To interface sensors (temperature/voltage/current) using ADC and analyze readingsusingSTM32 / TI C2000 controller.			√		
11	To implement UART communication for serial data transmission and reception.			√		
12	To implement SPI communication protocol for high-speed data transfer.			√		
13	To implement I2C communication protocol for multi-device interfacing.			√		
14	To control speed of DC motor using PWM technique any micro controller.				√	
15	To implement PWM control for DC-DC Buck converter and observe output voltage variationusingSTM32 / TI C2000 controller.				√	
16	To implement PWM control for DC-DC Boost converter and analyze voltage gain characteristicsusingSTM32 / TI C2000 controller.				√	
17	To implement single-phase inverter using PWM technique and observe output waveformusingSTM32 / TI C2000 controller.				√	

18	To implement closed-loop control system using basic PID controller and analyze performanceusingSTM32 / TI C2000 controller.					√
19	To study and simulate Phase Locked Loop (PLL) operation and its applications					√
20	To implement PWM generation using FPGA through simulation or hardware demonstration.					√

List of Laboratory/Learning Resources Required:

Sr. No.	Equipment Name with Broad Specifications
1	**STM32 Development Board** – 32-bit ARM Cortex-M (STM32F4), up to 168 MHz, Flash: 512 KB–1 MB, SRAM: 128–256 KB, Peripherals: GPIO, ADC, DAC, UART, SPI, I2C, USB and debugging support.
2	**TI C2000 Development Board** – 32-bit DSP controller (TMS320F28379D), High-speed PWM, fast ADC, real-time control capability, communication interfaces: SPI, I2C, UART.
3	**FPGA Development Board (Intel Cyclone V)** – Up to ~110K logic elements with DSP blocks, DDR3 support, high-speed processing, interfaces: GPIO, UART, SPI, I2C, USB (JTAG), supports VHDL/Verilog.
4	**Digital Storage Oscilloscope (DSO)** – Bandwidth: 50–100 MHz, ≥2 channels, ≥1 GS/s sampling rate, used for waveform and PWM signal analysis.
5	**Communication Interface Modules** – UART-to-USB, SPI and I2C modules, external sensors and EEPROM.
6	**Power Electronics Trainer Kit** – Buck, Boost and H-bridge inverter modules, PWM control with protection circuits.
7	**Regulated DC Power Supply** – Output: 0–30V adjustable, current: 2–5 A, overload and short-circuit protection.
8	**Function Generator –** Frequency range: 1 Hz – 1 MHz, outputs: sine, square and triangle waves, adjustable amplitude and duty cycle.

Suggested Project List:

1. Implement closed-loop control (basic PID simulation or hardware).
2. Demonstrate ADC-based voltage/current sensing system.
3. Study and simulate PLL operation (software or MATLAB/Simulink).
4. Study basic FPGA implementation for PWM generation (simulation/demo).
5. Mini Project: Develop a real-time embedded system (e.g., motor control / converter control).

Suggested Activities for Students:

Other than the classroom and laboratory learning, following are the suggested student-related ***co-curricular*** activities which can be undertaken to accelerate the attainment of the various outcomes in this course. Students should perform following activities in group (or individual) and prepare reports of about 5 pages for each activity. They should also collect/record physical evidence for their (student's) portfolio which may be useful for their placement interviews:

1. Perform **hands-on programming** using STM32 / TI controllers for real-time applications.
2. Develop **mini projects** related to power electronics (converter/inverter control) and motor control.
3. Conduct **simulation studies** of DC-DC converters, inverters, and control techniques using tools like MATLAB/Simulink.
4. Practice **embedded C programming** for peripheral interfacing (GPIO, ADC, PWM, UART, SPI, I2C).
5. Participate in **technical workshops / webinars** on embedded systems, FPGA, and real-time control.
6. Analyze **case studies** on renewable energy systems such as solar MPPT and grid-connected inverters.
7. Implement **closed-loop control systems** (basic PID controller) in simulation or hardware.
8. Explore **debugging techniques** using IDE tools (breakpoints, watch variables, debugging hardware).
9. Work on **team-based projects** to develop problem-solving and collaborative skills.
10. Prepare and present **technical seminars** on advanced topics like PLL, FPGA, and DSC applications.
11. Engage in **self-learning** through online platforms, datasheets, and reference manuals of STM32 and TI controllers.

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