Bharatiya Vidya Bhavan's
Sardar Patel Institute of Technology
(Empowered Autonomous Institute Affiliated to University of Mumbai)
Bhavan's Campus, Munshi Nagar, Andheri (West), Mumbai-400058-India

B. Tech. (Electronics and Telecommunication Engineering)

Syllabus
(Multidisciplinary Minor)

2023 Iteration (w.e.f. 2023-24)

2023 ITERATION: ELECTRONICS AND TELECOMMUNICATION ENGG.

Nomenclature of the Courses

Abbreviation	Course Category
BSESC	Basic Science & Engineering Science Courses
BSESEC	Basic Science & Engineering Science Elective Courses
SEC	Skill Enhancement Course
AEC	Ability Enhancement Course
HSSMC	Humanities and Social Science in Management Courses
CC	Cocurricular Courses
IKS	Indian Knowledge System
UHV	Universal Human Values
PCC	Program Core Courses
PEC	Program Elective Courses
OEC	Open Elective Courses
ELC	Experiential Learning Courses
MDM	Multidisciplinary Minor
CP	Community Project
HC	Honor Courses
DMC	Double Minor Course

Abbreviations

L	Lecture Hour	O	Other Work (Self Study)
T	Tutorial Hour	E	Total Engagement in Hours
P	Laboratory Hour	C	Credit Assigned

Course Category of Multidisciplinary Minor	MDM-I (Semester IV)	MDM-II (Semester V)	MDM-III (Semester VI)	MDM-IV (Semester VII)
Industrial IoT	**M011:** Fundamental of Internet of Things	**M012:** Embedded "C" and Micro Python for IoT	**M013:** IOT Communication and Network Layer Protocols	**M014:** IoT Applications and Security
Signal Processing and Communication	**M021:** Digital Signal Processing	**M022**: Principles of Communication Systems	**M023:** Digital Image Processing	**M024:** Wireless Communication
VLSI	**M041:** Hardware Description Language Programming	**M042:** Digital CMOS VLSI Design	**M043:** VLSI Physical Design	**M044:** ASIC Verification

Bharatiya Vidya Bhavan's
Sardar Patel Institute of Technology
(Empowered Autonomous Institute Affiliated to University of Mumbai)
Bhavan's Campus, Munshi Nagar, Andheri (West), Mumbai-400058-India

Multidisciplinary Minor -Industrial IoT

Course (Category) Code	Course Name	Teaching Scheme (Hrs/week)					Credits Assigned			
		L	T	P	O	E	L	T	P	Total
MDM-I	Fundamentals of Internet of Things	3	0	0	4	8	2	0	0	3
		Examination Scheme								
MDEC11		Component	ISE (%)		MSE (%)		ESE (%)			Total
		Theory	20		20		60			100
		Laboratory	-		--		-			-

Pre-requisite Course Codes, if any.	
Course Objective: This course provides an in-depth understanding of the Internet of Things (IoT), covering its definition, impact, convergence of Information Technology (IT) and Operational Technology (OT), challenges, architecture, data management, and compute stack. It also explores the role of sensors, transducers, smart objects, and computational units in IoT.	
Course Outcomes (CO): ***At the End of the course students will be able to***	
MDEC11.1	Demonstrate basic concepts, principles, and challenges in IoT
MDEC11.2	Classify various sensing devices and actuator types used in the IoT domain
MDEC11.3	Apply Computation and Communication Technologies for various real-life applications
MDEC11.4	Illustrate IoT infrastructure for various IoT use cases

CO-PO Correlation Matrix (3-Strong, 2-Moderate, 1-Weak Correlation)

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
MDEC11.1	2	2	2									
MDEC11.2	2	2	2									
MDEC11.3	2	2	2									
MDEC11.4	2	2	2	2								

BLOOM'S Levels Targeted (Pl. Tick appropriate)

Remember	Understand	Apply	Analyze @	Evaluate	Create

Theory Component

Module No.	Unit No.	Topics	Ref.	Hrs
1	Title	**Introduction to IoT**		5
		Definition and fundamentals of IoT, Historical background and evolution, Impact of IoT on various industries, Convergence of IT and OT in IoT	1,2	
2	Title	**IoT Challenges and Opportunities**		5
		Key challenges in implementing IoT solutions, Security and privacy concerns, Scalability and interoperability issues, Opportunities and potential applications of IoT.	1,2, 3	
3	Title	**IoT Architectures**		5
		Overview of OneM2M IoT architecture, Introduction to IoT World Forum (IoTWF) architecture, Comparison of different IoT architectures Case studies of real-world implementations	1,2	
4	Title	**IoT Data Management and Compute Stack**		5
		Importance of data management in IoT, Overview of IoT data lifecycle Introduction to compute stack in IoT, Edge computing vs. cloud computing in IoT	1,2	
5	Title	**Layer-1 Things in IoT: Sensors and Transducers**		9
		Introduction to Signals and Systems. Types of sensors and transducers used in IoT, Working principles and functionalities, Examples of sensor applications in different domains, Challenges and advancements in sensor technology	1,2	
6	Title	**Things in IoT: Smart Objects**		4
		Definition and characteristics of smart objects, Role of smart objects in IoT ecosystem, Interoperability standards for smart objects, Case studies of smart object deployments	1,2, 3	
7	Title	**Things in IoT: Computation and Communication Units**		9
		Introduction to Computational Units in IoT, Microcontrollers vs. microprocessors, Embedded Systems and their Applications. Need For Communication Interfaces , Serial& Parallel, I2C/ CAN Controller Area Network) – SPI (Serial Peripheral Interface) – Serial UART, MODBUS, HART, SCADA. Introduction to Programming using Microcontrollers Sensors and Actuators.	1,2	
8	Self Study	Practical Applications: Design and implementation of IoT solutions, Solving industry-specific use cases: Manufacturing, Healthcare, Retail, Autonomous vehicles, Supply chain management, Smart Agriculture, Smart City, Tracking and monitoring livestock. Discussion on future trends and directions in IoT.	1,2, 3	4*
			Total	**42**

Text Books

Sr. No	Title	Edition	Authors	Publisher	Year
1	Internet of Things-A Hands-On Approach	First	Arshdeep Bahga, Vijay Madisetti	University Press	2015
2	Internet of Things: Architecture and Design Principles	First	Raj Kamal	McGraw Hill Education	2017
3	Introduction to Industrial Internet of Things and Industry 4.0	First	Sudip Misra,Chandana Roy,Anadarup Mukherjee	CRC Press	2021

Reference Books

Sr. No	Title	Edition	Authors	Publisher	Year
1	From Machine-to-Machine to the Internet of Things: Introduction to a New Age of Intelligence	First	Jan Holler, VlasiosTsiatsis, Catherine Mulligan, Stefan Avesand,StamatisKarnouskos, David Boyle	Academic Press	2014
2	The Internet of Things key applications and protocols	First	Olivier Hersent,DavidBoswarthick, Omar Elloumi	Willey	2012
3	Designing the Internet of Things	-	Adrian McEwen	Wiley	2013

Online references:

1. https://nptel.ac.in/courses/106/105/106105166/
2. https://nptel.ac.in/courses/108/108/108108098/
3. https://nptel.ac.in/courses/106/105/106105195/
4. https://nptel.ac.in/noc/courses/noc19/SEM1/noc19-cs31/
5. https://onlinecourses.nptel.ac.in/noc21_cs17/preview
6. https://nptel.ac.in/courses/108108147
7. https://www.mooc-list.com/tags/wearable-technology

Course (Category) Code	Course Name	Teaching Scheme (Hrs/week)					Credits Assigned			
		L	T	P	O	E	L	T	P	Total
MDM-II	Embedded "C" and Micro Python for IoT	2	--	2	5	9	2	--	1	3
MDEC12		Examination Scheme								
		Component	ISE		MSE		ESE			Total
		Theory	20		20		60			100
		Laboratory	80		--		20			100

Pre-requisite Course Codes, if any.	CS101: Problem Solving using Imperative Programming EC101: Digital Systems and Microprocessors EC201: Computer Architecture and Organization
Course Objective: To impart students the fundamentals of Embedded "C" programming and Micro Python scripting for building IoT solutions, covering device driver creation, debugging, and optimization.	
Course Outcomes (CO): After successful completion of the course, student will be able to	
MDEC12.1	Demonstrate Proficiency in Embedded "C" Programming and Micro Python
MDEC12.2	Understand Embedded Systems Concepts and Architecture
MDEC12.3	Develop Device Drivers and Hardware Abstraction Layers (HALs)
MDEC12.4	Apply Embedded "C" and Micro Python for IoT Applications
MDEC12.5	Implement Networking Protocols and Communication:

CO-PO Correlation Matrix (3-Strong, 2-Moderate, 1-Weak Correlation)

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
MDEC12.1	2	2	2	2	2							
MDEC12.2	2	2	2	2								
MDEC12.3	2	2	2	2	2							
MDEC12.4	2	2	2	2	2							
MDEC12.5	2	2	2	2	2							

Theory Component

Module No.	Unit No.	Topics	Ref.	Hrs
1	Title	**Embedded C Programming:**		06
	1.1	**C Fundamentals:** Data types, variables, operators, expressions, Conditional Compilation, Functions, function calling, parameter passing, arrays, string, pointers, Bit Operations - Packaging data, unpacking data, bit manipulations, storage classes.	1	
	1.2	**Memory Management in Embedded Systems**: Stack and heap memory, Memory allocation techniques Introduction to Integrated Development Environments (IDEs) for embedded systems, Compilers, debuggers, and simulators for embedded C	1, 2	
2	Title	**Input/Output (I/O) Operations:**		08
	2.1	Interfacing with peripherals: GPIO (General Purpose Input/Output), UART (Universal Asynchronous Receiver-Transmitter), SPI (Serial Peripheral Interface), I2C (Inter-Integrated Circuit), Analog-to-digital converters (ADC). Digital to Analog converters (DAC).	1,2	
	2.2	Using libraries for device drivers and hardware abstraction.	1,2	
	2.3	Interrupts and Timers: Interrupt handling mechanisms, Timer programming for real-time applications	1,2	
3	Title	**Introduction to Micro Python:**		06
	3.1	Overview of Micro Python and its features. Syntax, data types, variables, operators, Functions, modules, libraries Lists, tuples, dictionaries, and sets. Control flow: loops, conditionals, and exceptions in Micro Python Setting up Micro Python environment for embedded development.	4	
	3.2	Python for Data Analysis: Introduction to libraries like NumPy and pandas for data manipulation and analysis, Working with sensor data collected from IoT devices	4	
	3.3	Python for Web Development and APIs: Basics of web development using frameworks like Flask or Django (optional)	4	
4	Title	**Micro Python for IoT Applications**		06
	4.1	Interfacing with peripherals using Micro Python. Writing scripts for sensor data acquisition and control.	3,4	
	4.2	Networking protocols and communication in Micro Python. Implementing MQTT, HTTP, or other IoT protocols in Micro Python.	3,4	
	4.3	Data Processing with Python: Data preprocessing techniques for IoT data. Handling real-time and streaming data in Python.	3,4	

		Data Visualization in Python: Introduction to data visualization libraries like Matplotlib and Seaborn. Visualizing IoT data for analysis and insights.		
5	**Title**	**Case Studies in Embedded Systems and IoT**		**02**
		Exploration of real-world case studies and applications of embedded systems and IoT like Smart Home Automation System, Industrial IoT (IIoT) Monitoring and Control System, Healthcare Monitoring Wearables, Smart Agriculture Solutions, Vehicle Tracking and Fleet Management, Energy Management Systems	3	
			Total	**28**

Laboratory Component

Sr. No.	Title of the Experiment
1	**Blinking LED (Hello World!!! Program):** Write a program to blink an LED connected to a GPIO pin of the microcontroller. Experiment with different blinking patterns (e.g., Morse code) by controlling the timing and sequence of GPIO operations.
2	**Push Button and LED Interaction:** Interface a push button and an LED to the microcontroller. Write a program to toggle the LED state when the button is pressed or released.
3	**Serial Communication:** Establish serial communication (UART) between the microcontroller and a computer. Write programs to send and receive data packets over UART, such as sending sensor readings or receiving commands.
4	**PWM Output:** Generate PWM (Pulse Width Modulation) signals using the microcontroller. Control the brightness of an LED or the speed of a motor using PWM output.
5	**Analog-to-Digital Conversion (ADC):** Interface an analog sensor (e.g., temperature sensor, light sensor) to the microcontroller. Write a program to read analog sensor values using the built-in ADC and display them.
6	**Interrupt Handling:** Configure external interrupts to detect events (e.g., button press, sensor signal). Write interrupt service routines (ISRs) to handle interrupt events and perform appropriate actions.
7	**Timers and Timed Operations:** Use timers to generate time delays and schedule periodic tasks. Implement timed operations, such as blinking LEDs at specific intervals or sampling sensors at regular intervals.
8	**Communication Protocols:**

	Implement communication protocols such as I2C or SPI to interface with external peripherals (e.g., sensors, displays). Develop projects involving multiple devices communicating over a network using standard protocols (e.g., MQTT for IoT applications).

Reference Books

Sr. No.	Title	Edition	Author	Publisher	Year
1	Embedded C Programming and the Microchip PIC	-	Richard H. Barnett, Sarah Cox, and Larry O'Cull	Delmar Cengage Learning	2003
2	Embedded System: Real time Operating Systems for the ARM Cortex^{TM}M3		Jonathan W. Valvano	Create Space Independent Publishing Platform	2012
3	Programming with MicroPython: Embedded Programming with Microcontrollers and Python		Nicholas H. Tollervey	Shroff / Oreilly Reprints	2017
4	Internet of Things, "A Hands on Approach		Vijay Madisetti, ArshdeepBahga	UniversityPress	2015.

Course (Category) Code	Course Name	Teaching Scheme (Hrs/week)					Credits Assigned			
		L	T	P	O	E	L	T	P	Total
MDM-III	IOT Communication and Network Layer Protocols	2	--	2	4	6	2	--	1	3
MDEC13		Examination Scheme								
		Component	ISE (%)		MSE (%)		ESE (%)			Total
		Theory	20		20		60			100
		Laboratory	80		--		20			100

Pre-requisite Course Codes, if any.	Computer Architecture and Organization Computer Communication and Networks Embedded Systems
Course Objective: To provide the students a comprehensive understanding of communication protocols used in the Internet of Things (IoT) ecosystem. Students will learn about various protocols, their features, advantages, and limitations, along with hands-on experience in implementing and optimizing communication for IoT devices**.**	
Course Outcomes (CO): After successful completion of the course, student will be able to	
MDEC13.1	Understand the fundamentals of IoT communication and network layer protocols.
MDEC13.2	Compare and contrast different IoT communication and network layer protocols.
MDEC13.3	Implement and configure communication layer protocols for IoT devices.
MDEC31.4	Analyze and optimize data and network layer protocols for efficiency and security.

CO-PO Correlation Matrix (3-Strong, 2-Moderate, 1-Weak Correlation)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
MDEC13.1	3											
MDEC13.2	3	2										
MDEC13.3		3				2						
MDEC31.4	3						2					

Theory Component

Module No.	Unit No.	Topics	Ref.	Hrs
1	Title	**Introduction to IoT Communication**		06
	1.1	**Overview of IoT architecture** Importance of communication protocols in IoT Types of IoT communication (Device-to-Device, Device-to-Cloud, etc.)	1,2,4	
	1.2	**Wired Communication Protocols** Ethernet: Basics, protocols, and standards Power-line Communication (PLC) Industrial Ethernet protocols (MODBUS TCP/IP, EtherNet/IP)	1,2,4	
	1.3	**Wireless Communication Protocols** Wi-Fi: Standards, security, and IoT applications Bluetooth and Bluetooth Low Energy (BLE) Zigbee and Z-Wave protocols.LoRa WAN.	1,2,4	
2	Title	**IOT Data Link Layer Protocols**		11
	2.1	**Overview**: IOT Communications Criteria,Range,Frequency Bands,Power Consumption,Topology Constrained Devices, Constrained-Node Networks, Data Rate and Throughput, Latency and Determinism.Overhead and Payload	3,4	
	2.2	**PHY/MAC Layer**: 3GPP MTC, LTE-eMTC uplink and downlink layers, Architecture of IEEE 802.11, Architecture of IEEE 802.15-BLE, BLE power class classification and protocol stack	3,4	
	2.3	**Data Link Protocols:** WirelessHART-Architecture and protocol stack, Z-Wave- Architecture and Protocol stack, DASH7-Communication models, Zigbee Smart Energy-topology and energy features, LoRaWAN Standardization and Alliances Physical Layer MAC Layer Topology Security, Competitive Technologies LoRaWAN, NB-IoT and Other LTE Variations.	3,4	
3	Title	**IOT Network Layer Protocols**		11
	3.1	**Network Layer Routing Protocols**: IPv4-Header format with functions, IPv6-Header format with functions, Dynamic IP and DHCP, ICMP, RPL, CORPL, CARP.	4	

	3.2	**Network Layer Encapsulation Protocols**: 6LoWPAN-IPv6 over Low power Wireless PAN, 6TiSCH, 6Lo, IPv6 over G.9959, IPv6 over BLE, RPL-Routing Protocol for Low Power and Lossy Networks, RPL Routing attributes.	4	
Self Study		Edge Computing and Fog Networking IoT Device Provisioning and Management IoT Interoperability and Standards		4
			Total	**28**

Laboratory Component

Sr. No.	Title of the Experiment
1	**Setting up a Basic MQTT Communication Network** Objective: To understand the basics of MQTT protocol and set up a communication network for IoT devices. Equipment: MQTT broker (e.g., Mosquitto), IoT devices (e.g., Raspberry Pi, ESP8266/ESP32), MQTT client software (e.g., MQTT.fx, Eclipse Paho). Experiment Steps: Install and configure MQTT broker on a server or local machine. Set up IoT devices as MQTT clients and connect them to the broker. Publish and subscribe to MQTT topics to exchange messages between devices.
2	**Configuring Ethernet-Based Communication for IoT Devices** Objective: To learn about Ethernet protocols and configure wired communication for IoT devices. Equipment: Ethernet switch, Ethernet cables, IoT devices with Ethernet ports (e.g., Raspberry Pi with Ethernet adapter). Experiment Steps: Connect IoT devices to an Ethernet switch using Ethernet cables. Configure IP addresses, subnet masks, and default gateways for devices. Test communication between IoT devices using TCP/IP protocols.
3	**Implementing Bluetooth Low Energy (BLE) Communication** Objective: To implement BLE communication for IoT sensors and devices. Equipment: BLE-enabled devices (e.g., Raspberry Pi with BLE module, BLE sensors), BLE development tools (e.g., BlueZ library for Linux). Experiment Steps: Set up BLE peripherals and central devices.

	Develop BLE applications for data transmission between devices. Analyze BLE communication characteristics such as range, data rate, and power consumption.
4	**Connecting IoT Devices Using Cellular Communication** Objective: To establish cellular communication for IoT devices using GSM, GPRS, or LTE-M/NB-IoT standards. Equipment: IoT devices with cellular modules (e.g., SIM800/SIM900 modules), SIM cards, cellular network access. Experiment Steps: Configure IoT devices with cellular network settings and APNs. Test data transmission over cellular networks using AT commands or APIs. Evaluate cellular communication performance and reliability for IoT applications.
5	**Comparing and Analyzing IoT Messaging Protocols** Objective: To compare and analyze the performance of different IoT messaging protocols such as MQTT, CoAP, and AMQP. Equipment: IoT devices with support for multiple messaging protocols, MQTT broker, CoAP server, AMQP server. Experiment Steps: Implement message exchange using MQTT, CoAP, and AMQP protocols. Measure message latency, throughput, and overhead for each protocol. Analyze protocol characteristics and suitability for different IoT scenarios.
6	**Optimizing IoT Communication Protocols** Objective: To optimize IoT communication protocols for resource-constrained devices. Equipment: IoT devices with limited memory and processing capabilities. Experiment Steps: Implement protocol optimization techniques such as message compression, caching, and payload reduction. Measure the impact of optimizations on device performance, power consumption, and network utilization.

	Evaluate trade-offs between optimization techniques and protocol functionality.
7	**IoT Communication Protocol Implementation** Objective: To design and implement a communication protocol for a specific IoT application. Equipment: IoT devices relevant to the chosen application, communication protocol libraries or frameworks. Project Steps: Define the communication requirements and constraints for the IoT application. Design a custom communication protocol or adapt existing protocols to meet the requirements. Implement the protocol on IoT devices and test its functionality, efficiency, and security. Present the project findings, including protocol design rationale, implementation details, and performance evaluation.

Reference Books

Sr. No.	Title	Edition	Author	Publisher	Year
1	IoT Fundamentals: Networking Technologies, Protocols, and Use Cases for the Internet of Things		David Hanes, Gonzalo Salgueiro, Patrick Grossetete Robert Barton, Jerome Henry	CISCO press	June 2017
2	Internet of Things:Architectures, Protocols and Standard		Simone Cirani, Gianluigi Ferrari, Marco Picone, Luca Veltri	WILEY Publication	2019
3	FromMachine-to-Machine to the of Things: Introduction to a New Age of Intelligence	First	Jan Holler, VlasiosTsiatsis, Catherine Mulligan, Stefan Avesand, StamatisKarnouskos, David Boyle	Elsevier AP	2014

4	The Internet of Things:Key Applications and Protocols		Hersent, Olivier, David Boswarthick, and Omar Elloumi	Wiely	2011

OnLine References:

1. https://www.nabto.com/guide-iot-protocols-standards/
2. https://azure.microsoft.com/en-in/solutions/iot/iot-technology-protocols
3. https://www.datamation.com/applications/iot-protocols-and-standards/
4. https://onlinecourses.nptel.ac.in/noc22_cs53/preview
5. https://archive.nptel.ac.in/courses/108/108/108108098/

Course (Category) Code	Course Name	Teaching Scheme (Hrs/week)					Credits Assigned			
		L	T	P	O	E	L	T	P	Total
MDM-IV	IOT Applications and Security	3	--	2	4	7	3	--	1	4
MDEC14		Examination Scheme								
		Component	ISE (%)		MSE (%)		ESE (%)			Total
		Theory	20		20		60			100
		Laboratory	80		--		20			100

Pre-requisite Course Codes, if any.	Computer Architecture and Organization Computer Communication and Networks Embedded Systems
Course Objective: To provide the students a comprehensive understanding of communication protocols used in the Internet of Things (IoT) ecosystem. Students will learn about various protocols, their features, advantages, and limitations, along with hands-on experience in implementing and optimizing communication for IoT devices**.**	
Course Outcomes (CO): After successful completion of the course, student will be able to	
MDEC14.1	Understand IoT design principles and technology fundamentals
MDEC14.2	Implement secure communication and security mechanisms in IoT systems through various protocols
MDEC14.3	Design and development of typical IoT Applications
MDEC14.4	Implement data analytics with supporting services

CO-PO Correlation Matrix (3-Strong, 2-Moderate, 1-Weak Correlation)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
MDEC14.1	3											
MDEC14.2	3	2										
MDEC14.3		3					2					
MDEC14.4	3			2								

Theory Component

Module No.	Unit No.	Topics	Ref.	Hrs
1	Title	**IoT Technology overview**		04
	1.1	**Overview of design principles:** overview of the architecture for IoT, including the overall design principles and needed capabilities, standards considerations	3	
	1.2	**IoT Technology Fundamentals:** Devices and Gateways, Local and wide area networking, Data management, Business process in IoT	3	
2	Title	**IOT Application Layer Protocols**		10
	2.1	HTTP and CoAP protocols for IoT applications,Security mechanisms for HTTP and CoAP (e.g., HTTPS, DTLS)	1,2,4	
	2.2	MQTT Protocol: Architecture, Security considerations, MQTT Deployment, MQTT based IoT Solution	1,2,4	
	2.3	CoAP Protocol: Protocol Architecture, Comparison with MQTT,Secure communication using CoAP, considerations, CoAP based IoT Solution including CoAP client-server interactions and message exchanges.	1,2,4	
3	Title	**IoT Security Fundamentals**		10
	3.1	Security threats in IoT environments, Introduction to cryptographic techniques (symmetric/asymmetric encryption, hashing, digital signatures), Authentication and access control mechanisms for IoT devices, Secure bootstrapping and provisioning of IoT devices	6	
	3.2	**IoT Communication Security Protocols:** Overview of TLS/SSL (Transport Layer Security/Secure Sockets Layer) and its relevance in IoT,Introduction to DTLS (Datagram Transport Layer Security) for secure communication over UDP,Securing MQTT communication using TLS,CoAP security considerations and usage of DTLS	5	
4	Title	**IoT Applications and Development with Data Analytics**		12
	4.1	**Design and Development:** Design Methodology, Back-end Application Designing Apache for handling HTTP Requests,	4,7	

		MongoDB Object type Database, HTML, CSS & jQuery for UI Designing, JSON lib for data processing, Security & Privacy during development		
	4.2	**Data Analytics and Supporting Services:** Introduction, Structured Versus Unstructured Data, Data in Motion versus Data at Rest, IoT Data Analytics Challenges, Data Acquiring, Organizing in IoT/M2M, Supporting Services: Computing Using a Cloud Platform for IoT/M2M Applications/Services, Everything as a service and Cloud Service Models.	4,7	
5	**Title**	**Case studies/Industrial Applications**		6
		IoT applications for industry: Future Factory Concepts, Brownfield IoT, Smart Objects, Smart Applications, Four Aspects in your Business to Master IoT, Value Creation from Big Data and Serialization, IoT for Retailing Industry, IoT for Oil and Gas Industry, Opinions on IoT Application and Value for Industry, Home Management, eHealth	7,8	
Self Study		Data analytics tools such as Python with libraries like Pandas, NumPy, and Scikit-learn for data analysis and visualization. Learn about applying machine learning algorithms to IoT data for predictive analytics and anomaly detection.		
			Total	**42**

Laboratory Component

Sr. No.	Title of the Experiment
1	**Implementing IoT Data Encryption** **Equipment/Software Needed:** ● IoT Devices ● OpenSSL library ● Python IDE **Experiment Steps:** 1. Generate public and private keys using OpenSSL.

	2. Implement encryption and decryption functions in Python using the generated keys. 3. Modify previous IoT application to encrypt sensor data before transmission. 4. Ensure that data is decrypted at the receiving end.
2	**Securing IoT Device Boot Process** **Equipment/Software Needed:** ● Raspberry Pi or similar IoT device ● Secure Boot software (e.g., U-Boot) ● Computer with Linux OS **Experiment Steps:** 1. Install U-Boot bootloader on the IoT device. 2. Configure U-Boot to verify the integrity of the boot image. 3. Implement secure boot process using cryptographic signatures. 4. Test the secure boot process by attempting to boot with a modified image.
3	**IoT Network Security Analysis** **Equipment/Software Needed:** ● Wireshark or similar network analysis tool ● IoT devices connected to a local network ● Router or network switch **Experiment Steps:** 1. Capture network traffic using Wireshark. 2. Analyze the captured packets to identify potential security threats. 3. Implement network segmentation to isolate IoT devices from other network segments. 4. Configure firewall rules to restrict unauthorized access to IoT devices.

4	**Implementing Secure Firmware Updates** **Equipment/Software Needed:** ● IoT devices with firmware update capability ● Digital signatures generation tool ● Firmware update server **Experiment Steps:** 1. Generate digital signatures for firmware updates using cryptographic algorithms. 2. Implement firmware update mechanism in IoT devices to verify the authenticity of firmware images. 3. Set up a firmware update server to distribute signed firmware updates. 4. Test the firmware update process and verify the integrity of the updated firmware.
5	**Implementing Access Control for IoT Devices** **Equipment/Software Needed:** ● IoT devices with user authentication capabilities ● Authentication server (e.g., LDAP server) ● Python IDE **Experiment Steps:** 1. Configure an authentication server (LDAP) to manage user credentials. 2. Implement user authentication mechanism in IoT devices using Python. 3. Create access control policies to restrict access based on user roles and permissions. 4. Test the access control mechanism by attempting to access IoT devices with different user credentials.
6	**IoT Device Hardening** **Equipment/Software Needed:**

	• IoT devices (e.g., Raspberry Pi, BeagleBone) • Secure shell (SSH) client • Linux OS **Experiment Steps:** 1. Disable unnecessary services and ports on the IoT device. 2. Configure firewall rules to block incoming and outgoing traffic. 3. Enable secure shell (SSH) access and disable password-based authentication. 4. Install security updates and patches to mitigate known vulnerabilities.
7	**Implementing Secure Communication with TLS/SSL** **Equipment/Software Needed:** • IoT devices with network connectivity • Web server with TLS/SSL support (e.g., Apache, Nginx) • OpenSSL library **Experiment Steps:** 1. Generate SSL/TLS certificates for the web server and IoT devices. 2. Configure the web server to enable HTTPS communication with SSL/TLS certificates. 3. Implement SSL/TLS client in IoT devices to establish secure connections with the server. 4. Test the secure communication by exchanging data between IoT devices and the server.
8	**IoT Device Monitoring and Intrusion Detection** **Equipment/Software Needed:** • IoT devices with logging capabilities • Intrusion detection system (e.g., Snort) • Monitoring software (e.g., Nagios) **Experiment Steps:**

	1. Configure logging on IoT devices to record system activities and network traffic. 2. Set up an intrusion detection system (IDS) to monitor network traffic for suspicious activities. 3. Configure alerting mechanisms to notify administrators of potential security breaches. 4. Deploy monitoring software to track the health and performance of IoT devices.
9	**Collecting and Analyzing IoT Sensor Data** **Equipment/Software Needed:** ● IoT devices with sensors (e.g., temperature, humidity) ● Raspberry Pi or similar IoT platform ● Python IDE ● Pandas and Matplotlib libraries for data analysis and visualization **Experiment Steps:** 1. Connect sensors to the IoT device and collect real-time data. 2. Write Python scripts to read sensor data and store it in a CSV file or a database. 3. Use Pandas library to perform basic data analysis such as mean, median, and standard deviation. 4. Visualize sensor data using Matplotlib library to identify trends and patterns.
10	**Anomaly Detection in IoT Sensor Data** **Equipment/Software Needed:** ● IoT devices with sensors ● Historical sensor data with known anomalies ● Python IDE ● Statistical libraries such as NumPy and SciPy **Experiment Steps:** 1. Collect historical sensor data containing both normal and anomalous behavior. 2. Calculate statistical measures such as mean, standard deviation, and z-score for the sensor data.

	3. Identify thresholds for anomaly detection based on statistical measures. 4. Implement anomaly detection algorithms using Python and NumPy/SciPy libraries. 5. Evaluate the performance of the anomaly detection system using precision, recall, and F1-score metrics.

Reference Books

Sr. No.	Title	Edition	Author	Publisher	Year
1	IoT Fundamentals: Networking Technologies, Protocols, and Use Cases for the Internet of Things		David Hanes, Gonzalo Salgueiro, Patrick Grossetete Robert Barton, Jerome Henry	CISCO press	June 2017
2	Internet of Things:Architectures, Protocols and Standard		Simone Cirani, Gianluigi Ferrari, Marco Picone, Luca Veltri	WILEY Publication	2019
3	FromMachine-to-Machine to the of Things: Introduction to a New Age of Intelligence	First	Jan Holler, VlasiosTsiatsis, Catherine Mulligan, Stefan Avesand, StamatisKarnouskos, David Boyle	Elsevier AP	2014
4	The Internet of Things:Key Applications and Protocols		Hersent, Olivier, David Boswarthick, and Omar Elloumi	Wiley	2011
5	Implementing SSL / TLS Using Cryptography and PKI		Joshua Davies	Wiley	2010

6	Security and Privacy in Internet of Things (IoTs): Models, Algorithms, and Implementations	First	Fei Hu	CRC Press	2016
7	Internet of Things – A hands-on approach		Arshdeep Bahga, Vijay	Universities Press	2017
8	Rethinking the Internet of Things: A Scalable Approach to Connecting Everything	First	Francis daCosta	Apress Publications	2016

Online resources:-https://onlinecourses.nptel.ac.in/noc22_cs52/preview
Introduction to Industry 4.0 and Industrial Internet of Things
OnLine References:

1. https://www.nabto.com/guide-iot-protocols-standards/
2. https://azure.microsoft.com/en-in/solutions/iot/iot-technology-protocols
3. https://www.datamation.com/applications/iot-protocols-and-standards/
4. https://onlinecourses.nptel.ac.in/noc22_cs53/preview
5. https://archive.nptel.ac.in/courses/108/108/108108098/

Bharatiya Vidya Bhavan's
Sardar Patel Institute of Technology
(Empowered Autonomous Institute Affiliated to University of Mumbai)
Bhavan's Campus, Munshi Nagar, Andheri (West), Mumbai-400058-India

Multidisciplinary Minor - Signal Processing and Communication

Course (Category) Code	Course Name	Teaching Scheme (Hrs/week)					Credits Assigned			
		L	T	P	O	E	L	T	P	Total
MDM-I	Digital Signal Processing	2	0	2	5	8	2	0	1	3
		Examination Scheme								
		Component	ISE (%)		MSE (%)		ESE (%)			Total
MDEC21		Theory	20		20		60			100
		Laboratory	80		--		20			100

Pre-requisite Course Codes, if any.	
Course Objective: The primary objective of this course is to provide a thorough understanding and working knowledge of Discrete Time Signal operation and implementation of DSP Algorithms.	
Course Outcomes (CO): ***At the end of the course students will be able to***	
MDEC21.1	Sample and describe Discrete time signals
MDEC21.2	Classify and Perform signal operations
MDEC21.3	Apply DFT properties
MDEC21.4	Illustrate FFT algorithm
MDEC21.5	Design FIR filter
MDEC21.6	Implement DSP Algorithms

CO-PO Correlation Matrix (3-Strong, 2-Moderate, 1-Weak Correlation)

CO	PO 1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
MDEC21.1	3	3							2			
MDEC21.2	3	3		2	2				2			
MDEC21.3	3	3							2			
MDEC21.4	3	3							2			
MDEC21.5	3	3	2	2	2				2			
MDEC21.6	3	3	2	2	3				2			

BLOOM'S Levels Targeted (Pl. Tick appropriate)

Remember ✓	Understand ✓	Apply ✓	Analyze	Evaluate	Create

Theory Component

Module No.	Unit No.	Topics	Ref.	Hrs.
1	Title	**Discrete-Time Signal**	1, 2, 3	8
	1.1	Introduction: Signals and Systems, Continuous Time signal, Discrete - Time signal and representation, Digital signal, The Sampling theorem, Classification of Discrete - Time Signals		
	1.2	Operations on Discrete - Time Signals: Linear Convolution, Circular Convolution, Matrix Representation of Circular Convolution, Linear Convolution using Circular Convolution, Auto and Cross Correlation		
	1.3	Discrete - Time systems: Representation of system using impulse response, Finite Impulse Response (FIR) and Infinite Impulse Response (IIR) system, Response of the FIR system using convolution		
2	Title	**Discrete Fourier Transform**	1, 2	6
	2.1	Introduction to DTFT, Relation between DFT and DTFT, DFT of DT signal, Inverse DFT. Computations in DFT		
	2.2	Properties of DFT		
3	Title	**Fast Fourier Transform**	1,2	6
	3.1	Need of FFT, Radix-2 DIT-FFT algorithm, Flow graph for N=4 and N=8 using Radix-2 DIT-FFT		
	3.2	Inverse FFT algorithm, Computations in FFT		
4	Title	**Digital FIR Filter Design**	1,2, 3	04
	4.1	Linear Phase Concept		
	4.2	Linear Phase Low Pass/High Pass/Band Pass FIR filter design using Windowing Method		
5	Title	**DSP Algorithms**	1,2	04
	5.1	Fast Linear and Circular Convolution using FFT		
	5.2	Linear FIR filtering		
	5.3	Signal Matching using Carl's Correlation Algorithm		
6	Self Study	Composite FFT, FFT Flowgraph for N=6 and N=9 Linear Phase Realization of FIR Filter	1,2	06
			Total	**28**

Laboratory Component, if any. (Minimum 10 Laboratory experiments are expected)

Sr. No	Title of the Experiment
1	Sampling and Reconstruction
2	Digital Signal Operations
3	Discrete Convolution
4	Discrete Correlation
5	Discrete Fourier Transform
6	Fast Fourier Transform
7	FIR Filter Design
8	Linear Convolution using FFT
9	Circular Convolution using FFT
10	Linear Filtering using Overlap Add Method
11	Linear Filtering using Overlap Save Method
12	Audio Signal Matching using Carl's Correlation Algorithm

Text Books

Sr. No	Title	Edition	Authors	Publisher	Year
1	Digital Signal Processing	Forth Edition	John Proakis and Dimitris Monolakis	Pearson Publication	2007
2	Digital Signal Processing	Second Edition	S.Salivahanan, A Vallavaraj	Tata McGraw Hill	2010
3	Analog and Digital Signal Processing	Second Edition	Ashok Ambardar	Brooks/Cole Publishing	1999

Reference Books

Sr. No	Title	Edition	Authors	Publisher	Year
1	Digital Signal Processing	Forth Edition	P. Ramesh Babu	Scitech Publication Pvt Ltd	2011
2.	Digital Signal Processing	First Edition	M. H. Hayes	The McGraw Hill	2007
3	Digital Signal Processing	Second Edition	Nagoor Kani	Tata McGraw Hill	2012

Web References :

NPTEL Courses

1. **Digital Signal Processing and Applications by Prof. V. M. Gadre, IIT Bombay**
   https://onlinecourses.nptel.ac.in/noc21_ee20/preview

2. **Digital Signal Processing by Prof. S.C.Dutta Roy IIT Delhi**
   https://nptel.ac.in/courses/117102060

MIT OpenCouseWare

1. **Digital Signal Processing by Prof. Alan V. Oppenheim**
   https://ocw.mit.edu/courses/res-6-008-digital-signal-processing-spring-2011/

Course (Category) Code	Course Name	Teaching Scheme (Hrs/week)					Credits Assigned			
		L	T	P	O	E	L	T	P	Total
MDM-II	Principles of Communication Systems	2	0	2+2	5	10	2	0	1+1	4
MDEC22		Examination Scheme								
		Component		ISE (%)		MSE (%)		ESE (%)		Total
		Theory		20		20		60		100
		Laboratory-I		80		--		20		100
		Laboratory-II		80		--		20		100

Pre-requisite Course Codes, if any.	MDM-I: Analog Electronics and Circuits
Course Objective: The objective is to equip the students with basic knowledge for analyzing analog and digital communication systems ranging from data networks and internet to mobile data communication systems such as cellular and WiFi systems. Specifically, the students will learn how to manage communication system resources including bandwidth and power by selecting a proper signaling and/or analog/pulse/digital modulation scheme	
Course Outcomes (CO): ***At the end of the course students will be able to***	
MDEC22.1	Explain, compare, and distinguish between the components of analog, pulse, and digital communication systems.
MDEC22.2	Analyze the behavior of modulated signals in time domain, frequency domain, and signal space.
MDEC22.3	Create different source coding and error correction codes.
MDEC22.4	Examine the performance of different analog and digital modulation schemes.
MDEC22.5	Examine and calculate system performance metrics like bit rate and bandwidth for different digital modulation techniques, as well as for source and error correction codes.

CO-PO Correlation Matrix (3-Strong, 2-Moderate, 1-Weak Correlation)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
MDEC22.1	3				-				-	-		1
MDEC22.2	2	2			3				3	3		
MDEC22.3	2	2			3				3	3		1
MDEC22.4	3	3			3				3	3		1
MDEC22.5	2	2			3				3	3		

CO-PEO/PSO Correlation Matrix (3-Strong, 2-Moderate, 1-Weak Correlation)

	PEO1	PEO2	PEO3	PSO1	PSO2
MDEC22.1	2	2			
MDEC22.2	2	2		2	1
MDEC22.3	2	2		2	1
MDEC22.4	2	2		2	1
MDEC22.5	2	2			

BLOOM'S Levels Targeted (Pl. Tick appropriate)

Remember✓	Understand✓	Apply✓	Analyze✓	Evaluate	Create

Theory Component

Module No.	Unit No.	Topics	Ref.	Hrs.
1	Title	**Analog and Pulse modulation**	7	
	1.1	Introduction to Signals, fourier analysis, Classification of Frequency spectrum,Need for modulation, Block diagram of an analog and digital communication system.		
	1.2	DSB-FC : Principle of working, Waveforms and power relations and power spectrum,Single and multitone, Types of AM FM:Mathematical analysis, Armstrong method of FM generation, Block diagram of Superheterodyne receiver		
	1.3	Sampling theorem, Types of Sampling, Pulse Amplitude modulation, Pulse Width Modulation, Pulse code modulation (PCM)		
	1.4	Delta modulation, Time Division multiplexing		
2	Title	**Source coding and Channel Coding**	07	
	2.1	Uncertainty, Information, Entropy, Source coding theorem, Huffman encoding, Shannon Fano coding		
	2.2	Channel capacity Theorem, Linear block codes,Cyclic codes-Shift register method and Polynomial division method, Convolutional codes- Shift Register approach, State diagram,Trellis , Viterbi decoding		
3	Title	**Digital Modulation Techniques**	10	
	3.1	Line coding and Power spectral density (PSD) of line codes		

	3.2	BPSK,8-QAM,16-QAM,BFSK,MSK- Principle of working, PSD and Signal space analysis.WLAN specific		
	3.3	Inter symbol Interference , Eye diagram,		
	3.4	Digital Modulation tradeoffs:Probability of Error evaluations of various modulations		
5	**Title**	**Spread Spectrum and OFDM**	04	
	5.1	Direct sequence spread spectrum		
	5.2	Frequency hopping spread spectrum		
	5.3	OFDM		
6	**Self Study**	Applications and health, safety, and environment aspects of Analog and Digital communication techniques		**06**
			Total	**28**

PCS-I Laboratory Component, if any. (Minimum 10 Laboratory experiments are expected)

Sr. No	**Title of the Experiment**
1	Implementation of double sideband full carrier for various modulation index and demodulation
2	Implement the frequency modulation circuit to obtain FM waveforms and calculate modulation index
3	Implementation of natural sampling and reconstruction of waveforms
4	Implementation of pulse amplitude modulation.
5	LBC encoder and decoder
6	Implementation of Binary Phase Shift Keying
7	Implementation of Binary Frequency shift keying
8	Signal space analysis of QAM
9	PSD and ISI analysis of BPSK
10	BER analysis of BPSK without and with Convolutional codes

PCS -II Laboratory Component, if any. (Minimum 10 Laboratory experiments are expected)

Sr. No	Title of the Experiment

1	**Getting Started with ARM Microcontrollers**
	• **Objective**: Learn the basics of ARM microcontrollers and set up the development environment.
	• **Experiments**:
	  • Install ARM development tools (e.g., Keil, GCC, STM32CubeIDE, or others).
	  • Write and execute a simple "Hello, World!" program with onboard LED blinking.

2	**GPIO and Basic Peripherals**
	• **Objective**: Understand General Purpose Input/Output (GPIO) and basic peripherals.
	• **Experiments**:
	  • Control an LED using a GPIO pin.
	  • Read input from a push-button or switch.
	  • Implement Pulse Width Modulation (PWM) to control an LED's brightness.

3	**Analog-to-Digital Conversion (ADC)**
	• **Objective**: Learn to read analog signals with ADC.
	• **Experiments**:
	  • Read a value from a potentiometer.
	  • Connect a temperature sensor (e.g., LM35, TMP36) and read temperature data.

4	**UART/Serial Communication**

	• **Objective**: Establish communication between the microcontroller and other devices via UART.
	• **Experiments**:
	  • Set up a UART connection and send/receive data to/from a computer.
	  • Connect a serial-based sensor (e.g., GPS module) and extract information.

5	**Interfacing with Digital Sensors**
	• **Objective**: Learn to connect and read data from digital sensors.
	• **Experiments**:
	  • Connect a digital temperature/humidity sensor (e.g., DHT11/DHT22).
	  • Connect a motion sensor (e.g., PIR sensor).
	  • Connect a distance sensor (e.g., ultrasonic HC-SR04).

6	**Interfacing with Analog Sensors**
	• **Objective**: Connect and read data from analog sensors.
	• **Experiments**:
	  • Connect an analog temperature sensor (e.g., LM35, TMP36).
	  • Use a photoresistor (LDR) to measure light intensity.
	  • Connect an analog accelerometer to measure acceleration.

7	**Communication Protocols: I2C and SPI**
	• **Objective**: Learn to use I2C and SPI for sensor communication.
	• **Experiments**:
	  • Connect and read data from an accelerometer (e.g., MPU6050) using I2C.
	  • Connect and control an OLED display via SPI.

8	**Wi-Fi Communication** ● **Objective**: Establish Wi-Fi connectivity for IoT applications. ● **Experiments**: ● Connect an ESP8266 or ESP32 module to the ARM microcontroller for basic Wi-Fi communication. ● Implement a simple HTTP server on the microcontroller to serve data. ● Send data to a cloud platform (e.g., ThingSpeak, AWS IoT, Google Cloud IoT).
9	**Bluetooth/BLE Communication** ● **Objective**: Explore Bluetooth connectivity for short-range communication. ● **Experiments**: ● Connect a Bluetooth module (e.g., HC-05/HC-06) and send/receive data to/from a smartphone. ● Implement BLE communication with a smartphone or another BLE-capable device.
10	**Integration with IoT Platforms** ● **Objective**: Connect the microcontroller to an IoT platform for data monitoring and control. ● **Experiments**: ● Send sensor data to an IoT platform and visualize it. ● Set up IoT triggers to control microcontroller outputs (e.g., control an LED from a remote platform).

Text Books

Sr. No	Title	Edition	Authors	Publisher	Year
1	Principles of Communication Systems	2nd	Taub H. and Schilling D.L	Tata McGraw Hill	2001

2	Communications Systems	4th	Haykin S	John Wiley and Sons	2001

Reference Books

Sr. No	Title	Edition	Authors	Publisher	Year
1	Digital and Analog Communication	4th	B.P.Lathi	Oxford	2017
2.	Communication Systems Engineering	4th	Proakis J. G. and Salehi M.	Pearson Education	2002.
3.	Digital Communication	3rd	Haykin S	John Wiley and Sons	2001

Course (Category) Code	Course Name	Teaching Scheme (Hrs/week)					Credits Assigned			
		L	T	P	O	E	L	T	P	Total
MDM-III	Digital Image and Video Processing	2	1	2	5	10	3	0	1	4
MDEC23		Examination Scheme								
		Component	ISE (%)		MSE (%)		ESE (%)			Total
		Theory	20		20		60			100
		Laboratory	80		--		20			100

Pre-requisite Course Codes, if any.	
Course Objective: The primary objective of Image Processing Course is to understand and apply image processing tools to process the Digital image	
Course Outcomes (CO): ***At the end of the course students will be able to***	
MDEC23.1	apply image enhancement technique
MDEC23.2	apply image segmentation technique
MDEC23.3	perform binary image processing Operation
MDEC23.4	develop fast image transform flowgraph
MDEC23.5	solve image compression and decompression
MDEC23.6	develop image processing application

CO-PO Correlation Matrix (3-Strong, 2-Moderate, 1-Weak Correlation)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
MDEC23.1	3	3	2	3	3				2			
MDEC23.2	3	3	2	3	3				2			
MDEC23.3	3	3	2	3	3				2			
MDEC23.4	3	3	2	3	3				2			
MDEC23.5	3	3	2	3	3				2			
MDEC23.6	3	3	2	3	3				2			

BLOOM'S Levels Targeted (Pl. Tick appropriate)

Remember ✓	Understand ✓	Apply ✓	Analyze ✓	Evaluate	Create

Theory Component

Module No.	Unit No.	Topics	Ref.	Hrs.
1	Title	**Fundamentals of Digital Image and Video**	1,2	2
	1.1	Sampling and Quantization, Digital Image Representation		
	1.2	Introduction of Coordinate representation and Pixel, Neighbors of pixel adjacency connectivity		
2	Title	**Image Enhancement**	1,2	6
	2.1	Gray Level Transformations, Zero Memory Point Operations		
	2.2	Histogram Processing		
	2.3	Spatial Filtering: Smoothing and Sharpening Filters		
	2.4	Spatial Filtering: Smoothing and Sharpening Filters		
3	Title	**Image Segmentation**	1,2, 4	6
	3.1	Detection of Discontinuities, Point Detection, Line Detection and Edge Detection		
	3.2	Edge Linking using Local processing and Global Processing Hough Transform, Graph Theoretic Method		
	3.3	Region based Segmentation, Image growing by pixel aggregation, Split and Merge Technique		
4	Title	**Binary Image Processing**	1,2	6
	4.1	Representation and Description, Chain Code, Shape Number, Moments.		
	4.2	Binary Morphological Operators : Dilation, Erosion, Opening and Closing, Boundary Extraction, Region Filling, Hit or Miss Transform, Corner Detection, Thinning and Thickening algorithm		
5	Title	**Image Transform and Compression**	1,3	4
	5.1	Introduction to Unitary Transform, Discrete Fourier Transform(DFT) and Fast Fourier Transform (FFT),Discrete Hadamard Transform(DHT), Fast Hadamard Transform, Discrete Cosine Transform (DCT)		
	5.2	Introduction, Redundancy, Fidelity Criteria,Lossless Compression Techniques : Run Length Coding, Arithmetic Coding, Huffman Coding, Differential PCM, Lossy Compression Techniques: Improved Gray Scale Quantization, Vector Quantization, JPEG		
	5.3	**2-D Motion Estimation**: Pixel based motion estimation, Block Matching Algorithm, Region based Motion		

		Estimation, Multi resolution Motion Estimation. Block based transform coding, MPEG		
6	**Self Study**	Connected Component Labeling, Gray Scale Morphology and Colour Image Enhancement, Image restoration		
			Total	**28**

Laboratory Component, if any. (Minimum 10 Laboratory experiments are expected)

Sr. No	**Title of the Experiment**
1	Image Enhancement using zero memory point processing
2	Image Enhancement using Histogram Processing
3	Image Enhancement using Spatial Filtering
4	Image Segmentation based on discontinuity property
5	Image Segmentation based on similarity property
6	Morphological Image Processing
7	Thinning and Thickening Algorithm
8	Image representation using Chain code, Shape Number and Moments
9	Fast Image Transform
10	Image Compression using Lossless Compression techniques
11	Image Compression using Lossy Compression techniques
12	Application of Image Processing

Text Books

Sr. No	**Title**	**Edition**	**Authors**	**Publisher**	**Year**
1	Digital Image Processing	Third Edition	Rafel C. Gonzalez and Richard E.	Pearson Educatio Asia	2009

			Woods		
2	Digital Image Processing	First Edition	S.Jayaraman, E.Esakkirajan and T. Veerkumar	TataMcGraw Hill Education Private Ltd	2009
3	Digital Image Processing	First Edition	S. Sridhar	Oxford	2011
4	Digital Image Processing	First Edition	B. Chanda D. Dutta Majumdar	PHI	2003

Reference Books

Sr. No	Title	Edition	Authors	Publisher	Year
1	Fundamentals and Digital Image Processing	Third Edition	Anil K. Jain	Prentice Hall of India Private Ltd	
2.	Digital Image Processing and computer Vision	First Edition	Milan Sonka, Vaclav Hlavac and Roger Boyle	Cengage Learning	2008
3	Multidimensional Signal, Image and Video Processing and Coding	Second Edition	John W Woods	Elsevier	2012
4	Digital Image Processing	Third Edition	William Pratt	John Wiley & Sons	2003

Web References :

NPTEL Courses

1. **Digital Image Processing by Prof. Prabir Kumar Biswas, IIT Kharagpur**
   https://onlinecourses.nptel.ac.in/noc22_ee116/preview

Online Video Course :

1. **Digital Image Processing by Prof. Rich Radke ,Rensselaer Polytechnic Institute**
   https://sites.ecse.rpi.edu/~rjradke/improccourse.html

Course (Category) Code	Course Name	Teaching Scheme (Hrs/week)					Credits Assigned			
		L	T	P	O	E	L	T	P	Total
MDM	Wireless Communication	2	0	4	5	7	2	0	2	4
		Examination Scheme								
		Component		ISE (%)		MSE (%)	ESE (%)			Total %
IV		Theory		-		-	40			40
		Lab-I		25		--	5			30
M024		Project		25		--	5			30

Pre-requisite Course Codes, if any.	
Course Objective:	
Course Outcomes (CO): ***At the end of the course students will be able to***	
M024.1	Comprehend wireless communication concepts, system capacity and service provided.
M024.2	Evaluate various path loss and fading effects and propagation path loss models
M024.3	Analyze losses, multipath effects and doppler spread .
M024.4	Describe working and analyze emerging wireless communication technologies understanding their key features, potential applications

CO-PO Correlation Matrix (3-Strong, 2-Moderate, 1-Weak Correlation)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
M024.1	3	2			2				2	2		
M024.2	3	2			2				2	2		
M024.3	3	2			2				2	2		
M024.4	3	2			2				2	2		

CO-PEO/PSO Correlation Matrix (3-Strong, 2-Moderate, 1-Weak Correlation)

BLOOM'S Levels Targeted (Pl. Tick appropriate)

Remember✓	Understand✓	Apply✓	Analyze✓	Evaluate	Create

Theory Component

Module No.	Unit No.	Topics	Ref.	Hrs.
1 2	Title	**The Cellular Concept-System Design Fundamentals**		8
	1.1	Introduction, Frequency Reuse, Channel Assignment Strategies, Handoff Strategies- Prioritizing Handoffs, Practical Handoff Considerations, ,		
	1.2	Interference and system capacity — Co channel Interference and system capacity, Channel planning for Wireless Systems, Adjacent Channel interference		
	1.3	Power Control for Reducing interference, Trunking and Grade of Service, Improving Coverage & Capacity in Cellular Systems- Cell Splitting, Sectoring.		
2	Title	**Radio Propagation Models**		8
	2.1	Large-Scale Path Losses due to reflection ,diffraction, Scattering		
	2.2	Outdoor Propagation Models- Longley-Ryce Model, Okumura Model, Hata Model, PCS Extension to Hata Model, Walfisch and Bertoni Model, Wideband PCS Microcell Model		
	2.2	Indoor Propagation Models-Partition losses (Same Floor), Partition losses between Floors, Log-distance path loss model, Ericsson Multiple Breakpoint Model, Attenuation Factor Model, Signal penetration into buildings, Ray Tracing and Site Specific Modeling		
3	Title	**Mobile Radio Propagation**		6
	3.1	Small Scale Multipath propagation Factors influencing small scale fading, Doppler shift, Relationship between Bandwidth and Received power, Parameters of Mobile Multipath Channels-Time Dispersion Parameters, Coherence Bandwidth, Doppler Spread and Coherence Time,		
	3.2	Types of Small-Scale Fading-Fading effects Due to Multipath Time Delay Spread, Flat fading, Frequency selective fading, Fading effects Due to Doppler Spread-Fast fading, slow fading, Statistical Models for multipath Fading Channels-Clarke's model for flat fading, Simulation of Clarke and Gans Fading Model, Level crossing and fading statistics, Two-ray Rayleigh Fading Model		
4	Title	**Wireless Technologies and Standards**		6
	4.1	Introduction to CDMA , GSM and LTE, Wireless Local Area Networks, WLAN Topologies, WLAN Standard IEEE 802.11 Comparison of IEEE 802.11 a,b,g and n standards, IEEE 802.16		

		and its enhancements, Wireless PANs: bluetooth, zigbee, Hiper LAN		
			Total	**28**

Text Books

Sr. No	Title	Edition	Authors	Publisher	Year
1	Wireless Communications, Principles,Practice	Second	Theodore, S.Rappaport	PHI	2002
2	Fundamentals of Wireless Communication		David Tse and Pramod Viswanath	Cambridge University Press	2005
3	Wireless Communication	Fifth	Upen Dalal	Oxford Univ. Press	2013

Additional Resources:

- National Telecommunications and Information Administration (NTIA): https://www.ntia.gov/
- IEEE 802.11 standard: https://standards.ieee.org/beyond-standards/the-evolution-of-wi-fi-technology-and-standards/
- Bluetooth website: https://www.bluetooth.com/
- WiMAX Forum website: https://wimaxforum.org/
- 3GPP website: https://www.3gpp.org/
- LTE white paper: http://lightspeedt.com/wp-content/uploads/2015/10/LTE-Brochure.pdf

Lab-I

https://ns3simulation.com/how-to-implement-wireless-communication-in-ns3/

1. Virtual lab:To study the effect of handover threshold and margin on SINR and call drop probability and handover probability

2. Virtual lab :Frequency re-use

3. GSM modem interfacing and sending text messages.

4.Basic client server paradigm. Reading pcap traces.

5. TCP internals and the difference between each of the variants. NS-3 tracing mechanism.

6. To analyze how Radio channel models (indoor, outdoor, LoS, NLoS etc) affect transmission and an insight to correctly model the channel.

7. Configure settings of a simple LTE network, and to explore the performance evaluation of a long-running TCP flow from an Internet server to the UE.
8. Case studies on real-world deployments of wireless communication technologies

Lab-II Project (1 credit)

Group projects on designing and simulating wireless applications using software tools and hardware boards such as ESP -32, STM-32, etc

Presentation of project findings and discussions on current trends and future directions in wireless communication and networks

- **Group Project Evaluation:**
  - Assessment Criteria:
  1. Design and simulation of wireless networks using software tools.
  2. Application of theoretical concepts to practical scenarios
  3. Collaboration and teamwork within the group
  - Evaluation Method:
  1. Group project report detailing the design, implementation, and simulation results.
  2. Evaluation rubric assessing technical accuracy, creativity, teamwork, and presentation quality.
  3. Peer evaluation component to assess individual contributions within the group.
- **Presentation and Discussion Evaluation:**
  - Assessment Criteria:
  1. Presentation of project findings and analysis
  2. Engagement and participation in discussions
  - Evaluation Method:
  1. Individual or group presentations of project findings
  2. Evaluation rubric assessing clarity, depth of analysis, engagement, and contributions to discussions
  3. Instructor-led or peer-led discussions assessing understanding of current trends and ability to articulate insights

Multidisciplinary Minor -VLSI

Course (Category) Code	Course Name	Teaching Scheme (Hrs/week)					Credits Assigned			
		L	T	P	O	E	L	T	P	Total
MDM-I	Hardware Description Language (HDL) Programming	2	0	2	5	9	2	0	1	3
		Examination Scheme								
		Component	ISE (%)		MSE (%)		ESE (%)			Total
MDEC31		Theory	20		20		60			100
		Laboratory	80		--		20			100

Pre-requisite Course Codes, if any.	Problem Solving using Imperative, Programming, Digital Systems and Microprocessors, Problem Solving using OOPs.

Course Objective: The course aims to familiarize students with the syntax, semantics, and constructs of Verilog HDL to design, simulate, and verify of digital logic design, including combinational and sequential logic, finite state machines, and synchronous circuits. This includes understanding synthesis process, where HDL descriptions are translated into actual hardware implementations. Students learn about synthesis tools, timing constraints, and optimizing designs for area, power, and performance. The course also aims to provide students with insights into industry practices, standards, and emerging trends in digital hardware and emerging technologies (e.g., hardware accelerators for AI/ML).

Course Outcomes (CO): ***At the end of the course students will be able to***

MDEC31.1	Demonstrate understanding of basic FPGA design flow and FPGA architecture
MDEC31.2	Write Verilog code for a given digital design using fundamental concepts of Verilog language
MDEC31.3	Construct combinational and sequential circuits in different modelling styles using Verilog HDL.
MDEC31.4	Implement a given digital design problem using Verilog on FPGA platform

CO-PO Correlation Matrix (3-Strong, 2-Moderate, 1-Weak Correlation)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
MDEC31.1	3		3		3			1	3	1		1
MDEC31.2	3		3		3			1	3	1		1
MDEC31.3	3		3		3			1	3	1		1
MDEC31.4	3		3		3			1	3	1		1

BLOOM'S Levels Targeted (Pl. Tick appropriate)

Remember √	Understand √	Apply √	Analyze	Evaluate	Create

Theory Component

Module No.	Unit No.	Topics	Ref.	Hrs.
1	Title	**FPGA Design Flow**	1,2	8
	1.1	India Semiconductor Industry and GoI policies.		
	1.2	Need of HDL, FPGA Design Flow and EDA tools		
	1.3	FPGA Architecture Fundamentals, Different FPGAs available in the market and their applications		
2	Title	**Fundamentals of Verilog**	1,2	4
	2.1	Verilog Program Structure and concept of testbench		
	2.2	Language constructs, Verilog datatypes, Operators etc.		
3	Title	**Design abstractions and Modeling Styles**	1,2	8
	3.1	Design Abstractions, Behavioral, Data flow, Gate level and Switch level modelling		
	3.2	Procedural Assignment and Continuous Assignment		
4	Title	**Finite State Machines**	1,2	8
	4.1	Verilog code for both Mealy & Moore FSM		
5	Self Study	**Verilog Models for Memories and Buses:** Static RAM Memory, a simplified 486 Bus Model, UART Design, Datapath and Controller Design	Online Resource 2	*5
			Total (*Not included)	**28**

Laboratory Component, if any. (Minimum 10 Laboratory experiments are expected)

Sr. No	Title of the Experiment
1	Design, simulate and synthesize any combinational digital design using structural modelling and carry out physical verification on a given FPGA. a. Logic Gates b. 4-bit Ripple Carry Full Adder by instantiating one-bit full adder c.2:1 Mux: Using case Statement
2	Design, simulate and synthesis any sequential digital design with behavioral modelling and carry out physical verification on a given FPGA. a. D Flip Flop using gates b. S-R Flip Flop c. 8-Bit Up Counter with Load
3	Create an ALU module capable of performing basic arithmetic and logical operations like addition, subtraction, AND, OR, XOR, etc.
4	Implement a floating-point arithmetic unit capable of performing operations on floating-point numbers following IEEE 754 standards.

5	Design of greatest common divisor using both data-path and control path implementation in Verilog HDL.
6	Design and simulate Round Robin arbiter using behavioral modelling.
7	Design, simulate and synthesis Verilog code using FSM for any one of the following: i. Elevator operation with 4x4 hex key pad input and display the output in LCD. ii. Traffic Light controller using Finite State machine.
8	Develop a Verilog code for any of the concepts of computer organizations like: Implement an I2C controller module for communication with I2C-compatible devices like sensors, EEPROMs, and RTCs. ii. Develop a controller module for interfacing with SPI flash memory chips commonly used for program storage in embedded systems. iii. Design a module to convert UART serial data to Ethernet frames for network communication.
9	Develop a Verilog code for algorithms in the areas like machine learning or cryptography using specialized hardware, such as SoC for faster processing.
10	Mini projects as an application of Verilog programming.

Text Books

Sr. No	Title	Edition	Authors	Publisher	Year
1	Digital Design and Computer Architecture	1st	David Money Harris, Sarah L. Harris	Elsevier Science	2013
2	Verilog HDL: A Guide to Digital Design and Synthesis	2nd	Samir Palnitkar	Pearson Education	2009
3	Advanced Digital Design with Verilog HDL	2nd	Michel D. Ciletti	PHI	2009

Reference Books

Sr. No	Title	Edition	Authors	Publisher	Year
1	Digital System Design with FPGA: Implementation Using Verilog and VHDL	1st	By Cem Unsalan, Bora Tar	Mc Graw Hill Publication	2017
2	Verilog HDL Primer	3rd	Bhasker J	BSP	2001
3	Digital Design: With an Introduction to the Verilog HDL, VHDL, and System Verilog	6th	Michel D. Ciletti	Pearson Education	2018

4	Design through Verilog HDL	2nd	Padmanabhan, Tripura Sundari	Wiley	2016

Online Resources:

1. Digital System design with PLDs and FPGAs
Prof. Kuruvilla Varghese, IISc Bangalore
Link: https://nptel.ac.in/courses/117108040

2. Hardware modeling using Verilog,
Prof. Indranil Sengupta, IIT Kharagpur
Link: https://nptel.ac.in/courses/106/105/106105165/

Course (Category) Code	Course Name	Teaching Scheme (Hrs/week)					Credits Assigned			
		L	T	P	O	E	L	T	P	Total

MDM-II	**Digital CMOS VLSI Design**	**3**	**0**	**2**	**5**	**10**	**3**	**0**	**1**	**4**
		Examination Scheme								
		Component	**ISE (%)**		**MSE (%)**		**ESE (%)**			**Total**
MDEC32		**Theory**	**20**		**20**		**60**			**100**
		Laboratory	**80**		**--**		**20**			**100**

Pre-requisite Course Codes, if any.	Basic Electrical Engineering, Electronic Devices and Circuits (EDC), Analog Signal Integrated Circuits, Hardware Description Language (HDL) Programming
Course Objective: Today's growth in electronic sector is due to improvements in semiconductor chip design. VLSI course is the foundation course introduced to teach fundamentals of MOSFET based logic circuit design. The primary objective of this course is to impart basic knowledge required to study advanced courses in VLSI domain.	
Course Outcomes (CO): ***At the end of the course students will be able to***	
MDEC32.1	Discuss structure, operation, scaling theory for MOSFET
MDEC32.2	Design MOSFET based inverter circuits with given constraints
MDEC32.3	Analyze MOSFET based combinational and sequential logic circuits
MDEC32.4	Realize MOSFET based logic circuits with different design styles

CO-PO Correlation Matrix (3-Strong, 2-Moderate, 1-Weak Correlation)

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
MDEC32.1	3			3	3			1	3	1		
MDEC32.2	3	3		3	3			1	3	1		
MDEC32.3	3		3	3	3			1	3	1		
MDEC32.4	3		3	3	3			1	3	1		

BLOOM'S Levels Targeted (Pl. Tick appropriate)

Remember √	**Understand√**	**Apply√**	**Analyze√**	**Evaluate**	**Create**

Theory Component

Module No.	Unit No.	Topics	Ref.	Hrs.
1	Title	**Review of MOSFET Physics**	1	8
	1.1	Threshold Voltage Equation, MOSFET Structure and Operation		
	1.2	MOSFET Scaling, Types of scaling and small geometry effects		
2	Title	**MOSFET Inverters**	1	10
	2.1	Static Characteristics of resistive load and CMOS Inverter, comparison of all types of MOS inverters		
	2.2	Dynamic Characteristics of inverters, design of CMOS inverters with constraints		
3	Title	**Combinational MOS Logic Circuits**	1,2	10
	3.1	MOS Logic Circuits with Depletion NMOS Loads and CMOS Logic Circuits		
	3.2	Complex Logic Circuits and Concept of equivalent CMOS inverter		
4	Title	**Dynamic Logic Circuits**	1	10
	4.1	Static CMOS, pass transistor logic, transmission gate		
	4.2	Pseudo NMOS, Domino, NORA, Zipper, C^2MOS		
5	Title	**Sequential MOS Logic Circuits**	1,2	4
	5.1	Behavior of Bi-stable Elements		
	5.2	**Circuit Realization:** SR Latch, JK FF, D FF		
	Title	**Semiconductor Memories**		
6	Self Study	ROM Array, SRAM (operation, design strategy, leakage currents, read/write circuits), DRAM (Operation 3T, 1T, operation modes, leakage currents, refresh operation, Input-Output circuits), Flash (mechanism, NOR flash, NAND flash), Peripheral Circuits: Sense amplifier, decoder	Online Resource 1	5*
		Total (*Not included)		42

Laboratory Component, if any. (Minimum 10 Laboratory experiments are expected)

Sr. No.	Title of the Experiment
1	To develop a program using any programming language to plot the NMOS and PMOS Transistor VI characteristics.
2	To analyze NMOS and PMOS Transistor VI characteristics.
3	To simulate Resistive Load Inverter and CMOS Inverter, verify the VTC. Compare both the topologies. Comment on the Noise Margins.
4	Implement CMOS NAND, NOR, AND, OR using Static CMOS Logic.
5	Design and implement 2:1 Mux using different CMOS Logic styles.
6	Design and implement given Boolean equation using different CMOS Logic styles.
7	Simulate Pseudo NMOS Inverter and comment on the result.

8	Design and implement given equation using Pseudo NMOS, Domino Logic and C^2MOS Logic
9	To design, analyze and simulate the ring oscillator.
10	Simulate Clocked JK and D Flip Flop using Static CMOS Logic.

Text Books

Sr. No	Title	Edition	Authors	Publisher	Year
1	Electronic circuits: analysis and design	3rd	Donald Neaman	Tata McGraw Hill	2006
2	CMOS Digital Integrated Circuits Analysis and Design	4th	Sung-Mo Kang, Yusuf Leblebici	Tata McGraw Hill	2003

Reference Books

Sr. No	Title	Edition	Authors	Publisher	Year
1	Digital Integrated Circuits: A Design Perspective	2nd	Jan M. Rabaey, Anantha Chandrakasan, Borivoje Nikolic	Pearson Education	2019
2	Introduction to VLSI Circuits and Systems	Student Edition	John P. Uyemura	Wiley	2013

Online Resource: 1. https://onlinecourses.nptel.ac.in/noc21_ee09

Course (Category) Code	Course Name	Teaching Scheme (Hrs/week)					Credits Assigned			
		L	T	P	O	E	L	T	P	Total

MDM-III	VLSI Physical Design	2	0	2	5	9	2	0	1	3
		Examination Scheme								
MDEC33		Component	ISE (%)		MSE (%)		ESE (%)			Total
		Theory	20		20		60			100
		Laboratory	80		--		20			100

Pre-requisite Course Codes, if any.	Basic Electrical Engineering, Electronic Devices and Circuits (EDC), Analog Signal Integrated Circuits, Basic CMOS VLSI Design, Hardware Description Language (HDL) Programming
Course Objective: The objectives of the course to entail a basic understanding of CMOS technology, transistor-level design, and circuit implementation enough to navigate through the physical design flow. It focuses on understanding algorithms used for floorplanning, placement, routing, clock tree synthesis, and final verification using DRC and LVS checks while optimizing performance, power, and area metrics alongside introduction to industry-standard CAD tools for VLSI physical design.	
Course Outcomes (CO): ***At the end of the course students will be able to***	
MDEC33.1	Sketch the layout of CMOS VLSI circuits.
MDEC33.2	Understand physical design techniques, including partitioning, chip planning, placement, and routing to optimize performance, power, and area in VLSI circuits.
MDEC33.3	Understand the principles and techniques of Static Timing Analysis (STA), analyze and ensure that synchronous circuits meet timing requirements, including setup, hold, and clock-to-q delays.
MDEC33.4	Apply optimization algorithms to efficiently partition chips, plan layouts, and place and route VLSI circuits, as well as clock routing algorithms for analyzing performance and area utilization of VLSI design.
MDEC33.5	Effectively utilize Electronic Design Automation (EDA) tool for physical design tasks, static timing analysis, and verification.

CO-PO Correlation Matrix (3-Strong, 2-Moderate, 1-Weak Correlation)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
MDEC33.1	2		3		3			1	1	1		1
MDEC33.2	2		3		3			1	1	1		1
MDEC33.3	2		3		3			1	1	1		1
MDEC33.4	2		3		3			1	1	1		1
MDEC33.5	2		3		3			1	1	1		1

BLOOM'S Levels Targeted (Pl. Tick appropriate)

Remember √	Understand √	Apply√	Analyze√	Evaluate	Create

Theory Component

Module No.	Unit No.	Topics	Ref.	Hrs.
1	Title	**Introduction to VLSI Physical Design & Static Timing Analysis**	1	8
	1.1	Introduction, Physical Design flow, Physical Verification, EDA Tools for Physical Design, Data Structures and Algorithms for Physical Design		
	1.2	Necessity of Design rules and Lambda based design rules, Layout of inverters and basic gates.		
	1.3	Introduction (STA, DTA, Behavior of synchronous circuit, Timing Arcs and Unateness, Definitions – Setup, Hold, Latch, Flipflop, STA for Flipflop and Latch		
2	Title	**Partitioning, Chip Planning and Placement**	1	8
	2.1	Introduction and Optimization goals, KL-Algorithm, Extensions of KL-Algorithm, FM-Algorithm, Multilevel Partitioning		
	2.2	Introduction and Optimization goals, Floor planning Representations, Floor planning Algorithms		
	2.3	Introduction and Optimization goals, Min-cut placement, Analytic Placement, Simulated Annealing, Modern Placement Algorithms		
3	Title	**Routing: Global and Detailed**	1,2	6
	3.1	Introduction and optimization goals, Single net routing (Rectilinear routing), Global routing in the connectivity graph, finding shortest paths with Dijkstra's Algorithm, Horizontal and vertical constraint graphs, Channel Routing Algorithms, Switch box routing algorithms, Over the cell routing algorithms, Power and Ground routing, Unified Power Format and Special cells used for Power Planning		
4	Title	**Routing: Clock Routing**	1	6
	4.1	Clocking Schemes and Design Considerations, Clock Routing algorithms – 1 (H-tree based and MMM algorithms), Clock Routing algorithms – 2 (Geometric matching and Weighted center algorithms), Clock Routing algorithms – 3 (Exact zero skew and DME algorithm), Skew, Latency, Uncertainty, and Jitter		
	Self Study	**Machine Learning for Physical Design:** Machine Learning Models, Predict Path-Based Slack from Graph-Based Timing Analysis, Data collection, Model creation and predicting data	Online Resource 1	5*
			Total (*Not included)	**28**

Laboratory Component, if any. (Minimum 10 Laboratory experiments are expected)

Sr. No	Title of the Experiment
1	Sketch the circuit and Layout for CMOS inverter using CAD tool.
2	Sketch the circuit and Layout for CMOS AND/OR gate using CAD tool.
3	Sketch the circuit and Layout for Flip Flop using CAD tool.
4	Use Electronic Design Automation (EDA) tool for physical design tasks including partitioning, chip planning, placement, and routing to optimize performance, power, and area in any VLSI circuit.
5	Use Electronic Design Automation (EDA) tool to perform Static Timing Analysis for latch and flip-flop using CAD tool.
6	Develop a program for chip partitioning algorithm and simulate VLSI chip partitioning
7	Develop a program for chip planning algorithm and simulate VLSI chip planning
8	Develop a program for placement algorithm and simulate placement of circuit modules
9	Simulate algorithm for global and detailed routing to simulate exact pathways for interconnecting standard cells, macros, and I/O pins.
10	Develop a program for clock routing algorithm to simulate interconnection of multiple clocked cells to a single clock generator.

Text Books

Sr. No	Title	Edition	Authors	Publisher	Year
1	VLSI Physical Design: From Graph Partitioning to Timing Closure	1st	Kahng, A.B., Lienig, J., Markov, I.L., Hu, J.	Springer	2014
2	Algorithm for VLSI Physical Design Automation	2nd	Sherwani, N.A.	Kluwer	2012

Reference Books

Sr. No	Title	Edition	Authors	Publisher	Year
1	Static Timing Analysis for Nanometer Designs: A Practical Approach	1st	J. Bhasker and Rakesh Chadha	Springer	2009
2	Advanced ASIC Chip Synthesis: Using Synopsys Design Compiler Physical Compiler and Prime Time	2nd	Bhatnagar, H.	Kluwer Academic Publishers : New York	2013

Online Resource: 1. https://onlinecourses.nptel.ac.in/noc21_cs12/preview

Bharatiya Vidya Bhavan's
Sardar Patel Institute of Technology
(Empowered Autonomous Institute Affiliated to University of Mumbai)
Bhavan's Campus, Munshi Nagar, Andheri (West), Mumbai-400058-India

Course (Category) Code	Course Name	Teaching Scheme (Hrs/week)					Credits Assigned			
		L	T	P	O	E	L	T	P	Total
MDM-IV	ASIC Verification	3	--	2	5	10	3	--	1	4
		Examination Scheme								
MDEC34		Component	ISE (%)		MSE (%)		ESE (%)			Total
		Theory	20		20		60			100
		Laboratory	80		--		20			100

Pre-requisite Course Codes, if any.	Basic Electrical Engineering, Problem Solving using Imperative, Programming, Problem Solving using OOPs, Hardware Description Language (HDL) Programming, Basic CMOS VLSI Design, VLSI Physical Design

Course Objective: The course aims to familiarize students and select the verification methodology like simulation-based verification, formal verification, and hardware emulation based on their strengths, weaknesses, and when to use each approach. It would lead to build proficiency in hardware description System Verilog, as well as verification languages like System Verilog Assertions (SVA) and Universal Verification Methodology (UVM). Learners will be able to develop comprehensive testbenches that thoroughly exercise the ASIC design under various conditions to identify bugs and ensure functional correctness. Proficiency in using industry-standard verification tool, formal verification tools and debugging tools.

Course Outcomes (CO): ***At the end of the course students will be able to***

MDEC34.1	Recognise trends in ASIC verification
MDEC34.2	Apply System Verilog constructs for verification
MDEC34.3	Create testbenches, threads and show interprocess communication
MDEC34.4	Create test cases under constrained environment
MDEC34.5	Validate design with System Verilog assertions and functional coverage

CO-PO Correlation Matrix (3-Strong, 2-Moderate, 1-Weak Correlation)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
MDEC34.1	1							1	1	1		2
MDEC34.2	3		3	3	3			1	1	1		1
MDEC34.3	3		3	3	3			1	1	1		1
MDEC34.4	3		3	3	3			1	1	1		1
MDEC34.5	3		3	3	3			1	1	1		1

BLOOM'S Levels Targeted (Pl. Tick appropriate)

Remember	Understand√	Apply√	Analyze√	Evaluate√	Create√

Theory Component

Module No.	Unit No.	Topics	Ref.	Hrs.
1	Title	**Basics of System Verilog**	1 (T), 5 (R)	4
	1.1	**Verification Basics:** Technology challenges, Verification methodology, Testbench creation, Verification languages, Verification IP reuse, Verification approaches, Verification plans		
2	Title	**Data types, procedural statements and testbench**	1 (T), 1 (R), 3 (R)	8
	2.1	**Data Types:** Built in, Fixed size array, dynamic array, queues, associative array, linked list, array methods, choosing a storage type, creating new types with typedef, creating user-defined structures, type conversion, enumerated types, constants, strings, expression width		
	2.2	**Procedural Statements and Routines:** Procedural statements, tasks, functions and void functions, task and function overview, routine arguments, returning from a routine, local data storage, time values		
	2.3	**Connecting the Testbench and Design:** Separating the testbench and design, the interface construct, stimulus timing, interface driving and sampling, top-level scope, program-module, interactions	1 (T), 1 (R), 3 (R)	
3	Title	**OOP and Randomization**	1 (T), 1 (R), 3 (R)	10
	3.1	**Basic OOP:** Class, creating new objects, Object deallocation, using objects, variables, class methods, defining methods outside class, scoping rules, using one class inside another, understanding dynamic objects, copying objects, public Vs local, building a testbench		
	3.2	**Randomization:** Randomization in system Verilog, constraint details, solution probabilities, controlling multiple constraint blocks, valid constraints, In-line constraints, pre-randomize and post-randomize functions, Random number functions, Constraints tips and techniques, common randomization problems, Iterative and array constraints, Atomic stimulus generation Vs scenario generation, random control, random number generators, random device configuration		
4	Title	**IPC and advanced OOP**	1 (T),	12

	4.1	**Threads and Interprocess Communication:** working with threads, disabling threads, interprocess communication, events, semaphores, mailboxes, building a testbench with threads and IPC	1 (R), 3 (R)	
	4.2	**Advanced OOP and Testbench Guidelines:** Inheritance, Blueprint pattern, downcasting and virtual methods, composition, inheritance and alternatives, copying an object, abstract classes and pure virtual methods, callbacks, parameterized classes		
5	**Title**	**Assertions and Functional Coverage**	1 (T), 1 (R), 2 (R), 4 (R)	**8**
	5.1	**System Verilog Assertions:** Assertions in verification methodology, understanding sequences and properties, System Verilog Assertions in the Design Process, Formal Verification Using Assertions and System Verilog Assertions Guidelines		
	5.2	**Functional Coverage:** Coverage types, strategies, examples, anatomy of a cover group, triggering a cover group, data sampling, cross coverage, generic cover groups, coverage options, analyzing coverage data, measuring coverage statistics during simulation.		
	Self Study	**Advanced Interfaces:** Virtual interfaces with the ATM router, connecting to multiple design configurations, procedural code in an interface, **A complete System Verilog Testbench:** Design blocks, testbench blocks, alternate tests, **Interfacing with C:** Passing simple values, connecting to a simple C routine, connecting to C++, simple array sharing, open arrays, sharing composite types, pure and context imported methods, communicating from C to system Verilog, connecting other languages	1 (T), 1 (R), 2 (R), 4 (R)	**5***
			Total (*Not included)	**42**

Laboratory Component, if any. (Minimum 10 Laboratory experiments are expected)

Sr. No	Title of the Experiment
1	Design MUX and D-FF modules with parameters to enable students to understand how different parameters influence module behavior and functionality.
2	Familiarization of simulation tool for verification of design using System Verilog. Simulate MUX and D-FF.
3	Complete the given task on literals and data types in System Verilog. Also write the simulation output for the given Procedural Statements
4	Write the simulation output for the given Interprocess Communication
5	Write the simulation output for the given randomization code
6	Write the simulation output for the given Interfaces, Program and Clocking Blocks

7	Write the simulation output for the given Processes
8	Write the simulation output for the given Functional Coverage
9	Write the simulation output for the given Assertions
10	Open-ended problem: Apply System Verilog concepts to any real-life application and its execution/implementation. i. **Designing and Verifying Peripheral Interfaces:** Design, verify, and simulate interfaces like UART, SPI, I2C, or PCIe using SystemVerilog to ensure compatibility and reliability in ASIC designs. ii. **Developing Verification IP (VIP):** Create Verification IP (VIP) for popular protocols or interfaces, such as USB, Ethernet, or HDMI, to be used in larger ASIC verification environments. iii. **Verifying ASIC Components for IoT Devices:** Verify ASIC components like sensors, communication modules, or processing units for Internet of Things (IoT) devices, ensuring low power consumption, reliability, and interoperability. iv. **ASIC Verification for Automotive Electronics:** Verify ASIC components used in automotive electronics, such as engine control units, safety systems, or infotainment systems, to ensure compliance with industry standards and safety requirements. v. **ASIC Verification for Consumer Electronics:** Verify ASIC components for consumer electronics devices like smartphones, tablets, or gaming consoles, ensuring functionality, performance, and compatibility with diverse hardware and software environments.

Text Books

Sr. No	Title	Edition	Authors	Publisher	Year
1	System Verilog for Verification: A guide to learning the testbench language features	2nd	Chris Spear	Springer	2010

Reference Books

Sr. No	Title	Edition	Authors	Publisher	Year
1	System Verilog for Design: A guide to using system Verilog for hardware design and modeling	2nd	Stuart Sutherland, Simon Davidmann, and Peter Flake	Springer	2006
2	System Verilog Assertions Handbook	4th	Ben Cohen, Srinivasan Venkataramanan, Ajeetha Kumari and Lisa Piper	VhdlCohen Publishing	2015

3	System Verilog Language Reference manual	--	--	--	--
4	System on Chip Verification Methodologies and Techniques	1st	S Prakash Rashinkar, Peter Paterson and Leena Singh	Kluwer Academic	2003

Online Resource:

https://elearn.nptel.ac.in/shop/iit-workshops/completed/workshop-on-soc-verification/?v=c86ee0d9d7ed