MANAKULA VINAYAGAR
INSTITUTE OF TECHNOLOGY
(An Autonomous Institution)

Curriculum and Syllabus

MASTER OF TECHNOLOGY
(M.Tech.)

Electronics and Communication Engineering

(2025-26)

M.Tech. ECE
2025-2026

SEMESTER I						
S.No	**Course Code**	**CourseTitle**	**L**	**T**	**P**	**Credits**
Theory						
1	25PECT11	Digital Communication Engineering	3	1	0	4
2	25PECT12	Information Theory and Coding Techniques	3	1	0	4
3	25PECT13	Advanced Engineering Mathematics	3	1	0	4
4	25PECLxx	Elective-I	2	1	0	3
5	25PECLxx	Elective -II	2	1	0	3
Integrated Course						
6	25PECI11	Embedded Systems and VLSI	2	0	4	4
					Total Credits	**22**

SEMESTER II						
S.No	**Course Code**	**Course Title**	**L**	**T**	**P**	**Credits**
Theory						
1	25PECT21	Advanced Digital System Design	3	1	0	4
2	25PECT22	Advanced Digital Signal Processing	3	1	0	4
3	25PECT23	Next Generation Wireless Network	4	0	0	4
4	25PECLxx	Elective-III	2	1	0	3
5	25PECLxx	Elective -IV	2	1	0	3
Integrated Course						
6	25PECI21	IoT Communication	2	0	4	4
Employability Enhancement Course						
7	25PECE21	Seminar	0	0	1	1
					Total Credits	**23**

SEMESTER III						
S.No	**Course Code**	**Course Title**	**L**	**T**	**P**	**Credits**
Theory						
1	25PECLxx	Elective -V	2	1	0	3
2	25PECLxx	Elective-VI	2	1	0	3
3	25PECN31	Non-Class Room Courses-I	0	0	4	2
4	25PECN32	Non-Class Room Courses-II	0	0	4	2
Integrated Course						
3	25PECI31	AI Application in Signal Processing	2	0	4	4
Project Work						
4	25PECW31	Project Phase-I	0	0	12	6
					Total Credits	**20**

SEMESTER IV						
S.No	**Course Code**	**Course Title**	**L**	**T**	**P**	**Credits**
Project Work						
1	25PECW41	Project Phase-II	0	0	32	16
		Total Credits				**18**

Non-Class Room Course I:

100% of marks through internal assessment only.

It is optional to undergo internship in established industry or esteemed institution / Seminar/ Workshop / Conference / FDP / Short term course / NPTEL/GIAN/MOOC Course for a period of four weeks (20 working days) either in single or multiple spans by a candidate. Further, a presentation should be given regarding the training or programme underwent during the period with the submission of a report. There shall not be any end semester evaluation. However, the internal evaluation is done by the committee comprising of internal members and one external member from other department of the same institute constituted by Head of the Department for the award of appropriate grade to the candidate based on the performance. The distribution of marks will be decided by the committee. The internship / Seminar/ Workshop / Conference / FDP / Short term course / NPTEL/GIAN/MOOC Course can be completed at any period of the duration of M.Tech. programme to fulfill the partial requirements for the award of M.Tech. degree.

Non-Class Room Course II:

It is mandatory to undergo one course related to the chosen programme for the minimum period of 30 hours either from NPTEL or GIAN or MOOC that is to be completed at any period of the duration of M.Tech. programme to fulfill the partial requirements for the award of M.Tech. degree. Absolute grade shall be awarded to a candidate based on the marks given in the certificate issued by the competent authority (NPTEL or GIAN or MOOC) for the chosen course.

Electives

Wireless Communication						
S.No	Course Code	Name of the Course	L	T	P	Credits
1.	25PECL01	Advanced Optical Communication	2	1	0	3
2.	25PECL02	Mobile Communication System	2	1	0	3
3.	25PECL03	High Performance Communication Networks	2	1	0	3
4.	25PECL04	Modeling and Simulation of Wireless Communication Systems	2	1	0	3
5.	25PECL05	Information and Network Security	2	1	0	3
6.	25PECL06	Cognitive Radio Technology	2	1	0	3
7.	25PECL07	RF System Design	2	1	0	3
8.	25PECL08	Cellular & IoT	2	1	0	3
9.	25PECL09	mmWave& MIMO	2	1	0	3
10.	25PECL10	Ultra Wideband Communication Systems	2	1	0	3

Embedded Systems						
S.No	Course Code	Name of the Course	L	T	P	Credits
1.	25PECL11	Advanced Microcontroller and its Applications	2	1	0	3
2.	25PECL12	Automated Embedded systems	2	1	0	3
3.	25PECL13	Medical device Embedded systems	2	1	0	3
4.	25PECL14	Embedded Real Time System	2	1	0	3
5.	25PECL15	Internet of Every Things (IoET)	2	1	0	3
6.	25PECL16	System on Chip(SoC)	2	1	0	3
7.	25PECL17	Application-Specific Integrated Circuit.(ASIC)	2	1	0	3
8.	25PECL18	Embedded Hardware design and PCB Layout	2	1	0	3

VLSI						
S.No	Course Code	Name of the Course	L	T	P	Credits
1.	25PECL19	FPGA Design & Architecture	2	1	0	3
2.	25PECL20	VLSI Testing &Testability	2	1	0	3
3.	25PECL21	VLSI Physical Design & Verification	2	1	0	3
4.	25PECL22	Low Power Digital VLSI Design	2	1	0	3
5.	25PECL23	Design of Analog and Mixed VLSI Circuits	2	1	0	3
6.	25PECL24	Digital IC Design	2	1	0	3
7.	25PECL25	Packaging and assembling Technologies	2	1	0	3

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Course code	Course Name	Periods			Credits	Total Hours
25PECT11	DIGITAL COMMUNICATION ENGINEERING	L	T	P	4	60
		3	1	0		

Preamble/ Course Objective

To make the students to understand the various advanced concepts of digital communication techniques

Prerequisite

Basics of analog and digital communication systems.

Course Outcome

On the successful completion of the course, students will be able to

	Course Outcome	Bloom's Taxonomy Level
CO1	Analyze various digital modulation techniques including BPSK, QPSK, MSK, GMSK and M-ary modulation schemes for communication systems.	**Analyze**
CO2	Evaluate optimum receiver performance for signals corrupted by AWGN channel and design receivers for memory-less and CPM modulations.	**Evaluate**
CO3	Apply equalization techniques including linear, decision feedback, and turbo equalization to mitigate inter symbol interference in communication channels.	**Apply**
CO4	Implement synchronization algorithms including carrier phase and symbol timing estimation using ML estimators for digital communication systems.	**Apply**
CO5	Design and simulate digital communication systems with modulation, AWGN channels, equalization and synchronization using software platforms.	**Create**

Syllabus

Module I: Digital Modulation Techniques **12 Hours**

Elements of Digital Communication system - Factors influencing digital modulation techniques; Linear Modulation Techniques: BPSK - QPSK - DPSK; Constant envelope modulation techniques: MSK- GMSK; Linear and constant envelope modulation techniques: M- ary PSK and M- ary QAM.

Module II: Additive White Gaussian Noise Channel **12 Hours**

Optimum receiver for signals corrupted by AWGN - performance of the optimum receiver for memory less modulation; optimum receiver for CPM signals - optimum receiver for signals with random phase in AWGN channel.

Module III: Equalization Techniques **12 Hours**

Optimum receiver for channels with ISI and AWGN – Nyquist criterion for zero ISI - linear equalization and its variations - Decision Feedback Equalization - Predictive Decision Feedback Equalization -Turbo equalization.

Module IV: Synchronization **12 Hours**

Signal Parameter Estimation: Carrier phase estimation - symbol timing estimation - joint estimation of carrier phase and symbol timing - performance characteristics of ML estimators.

Module V: Instructional Activities **12 Hours**

Simulation: Different digital modulation - AWGN channel - equalization techniques and synchronization using any related platforms

Textbooks:

1. Proakis, John G., and Masoud Salehi. Digital Communications. 5th ed. New York: McGraw-Hill, 2008.

2. Haykin, Simon. Digital Communication Systems. New York: John Wiley & Sons, 2014.

Reference Books:

1. Sklar, Bernard. Digital Communications: Fundamentals and Applications. 2nd ed. Upper Saddle River: Prentice Hall, 2001.

2. Ziemer, Rodger E., and William H. Tranter. Principles of Communications: Systems, Modulation, and Noise. 7th ed. New York: John Wiley & Sons, 2014.

3. Couch, Leon W. Digital and Analog Communication Systems. 8th ed. Upper Saddle River: Pearson, 2013.

Web Resources

1. Digital Communication
   http://nptel.iitm.ac.in/courses/117101051.html
2. Digital Communication Systems
   http://nptel.ac.in/courses/117106030/

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PSO1	PSO2	PSO3
CO1	3	1	2	-	-	-	2	3	2	-
CO2	3	3	2	-	1	-	2	3	3	-
CO3	3	2	2	-	1	-	2	3	3	-
CO4	3	2	2	-	1	-	2	3	3	-
CO5	3	3	3	2	2	1	2	3	3	1

Course code	Course Name	Periods			Credits	Total Hours
		L	T	P		
25PECT12	INFORMATION THEORY AND CODING TECHNIQUES	3	1	0	4	60

Preamble/ Course Objective

• To understand the concepts of various coding techniques with their applications in modern communication systems and wireless technologies

Prerequisite

Knowledge in probability and calculus.

Course Outcome

On the successful completion of the course, students will be able to

	Course Outcome	Bloom's Taxonomy Level
CO1	Analyze entropy concepts for memoryless and Markov sources and evaluate mutual information for information-theoretic applications.	**Analyze**
CO2	Apply source coding theorems, design optimal codes using Huffman algorithm and evaluate channel capacity for Gaussian channels.	**Apply**
CO3	Design linear block codes including Reed Solomon codes and implement error detection and correction techniques for digital systems.	**Create**
CO4	Implement convolutional encoding and decoding algorithms including Turbo codes and modern coding techniques like LT and Raptor codes.	**Apply**
CO5	Simulate and compare performance of various coding techniques using software tools for wireless communication applications.	**Create**

Syllabus

Module I: Entropy **12 Hours**

Entropy: Memory less sources - Markov sources - entropy of a discrete random variable - joint conditional and relative entropy - mutual information and conditional mutual information; chain relation for entropy - relative entropy and mutual Information.

Module II: Source Coding Theorems & Gaussian Approach **12 Hours**

Loss less source coding: Uniquely decodable codes - instantaneous codes - Kraft's inequality - optimal codes - Huffman code-Shannon's Source Coding Theorem :Arimoto - Blahut algorithm - Fano's inequality ;Shannon's channel coding theorem and its converse; Mutual information and capacity calculation for band limited Gaussian channels - Shannon limit - parallel Gaussian channels - capacity of channels with colored Gaussian noise.

Module III: Block Codes **12 Hours**

Linear block codes - error detecting and correcting capability – types of Block Codes – Reed Solomon codes - interleaving and concatenated codes - coding and interleaving applied to the compact disc digital audio system - LDPC codes.

Module IV: Convolutional Codes **12 Hours**

Convolutional encoding: Encoder Representation - properties of convolutional codes- convolutional decoding algorithm- Turbo codes - LT codes- Raptor codes – symmetric / asymmetric codes.

Module V: Instructional Activities **12 Hours**

Simulation of minimum of five coding techniques using related tools.

Text Book:

1. Cover, Thomas M., and Joy A. Thomas. Elements of Information Theory. 2nd ed. Hoboken, NJ: John Wiley & Sons, 2006.
2. Lin, Shu, and Daniel J. Costello Jr. Error Control Coding: Fundamentals and Applications. 2nd ed. Upper Saddle River, NJ: Pearson Education, 2004.

References:

1. MacKay, David J.C. *Information Theory, Inference, and Learning Algorithms*. Cambridge: Cambridge University Press, 2003.
2. Ryan, William E., and Shu Lin. *Channel Codes: Classical and Modern*. Cambridge: Cambridge University Press, 2009.
3. Proakis, John G., and Masoud Salehi. *Digital Communications*. 5th ed. New York: McGraw-Hill Education, 2007.

Web Resources:

1. Information Theory and Coding - Prof. Pavan S Nuggehalli, IISc Bangalore - *https://nptel.ac.in/courses/117108097*
2. Information Theory, Coding and Cryptography - Prof. Ranjan Bose, IIT Delhi - *https://nptel.ac.in/courses/108102117*

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PSO1	PSO2	PSO3
CO1	3	1	2	1	2	-	2	2	3	1
CO2	3	2	2	1	2	-	2	3	3	1
CO3	3	3	2	1	2	1	2	3	3	2
CO4	3	3	3	1	2	1	2	3	3	2
CO5	2	3	3	2	3	1	3	3	3	2

<table>
<tr><th rowspan="2">Course code</th><th rowspan="2">Course Name</th><th colspan="3">Periods</th><th rowspan="2">Credits</th><th rowspan="2">Total Hours</th></tr>
<tr></tr>
<tr><td rowspan="2">25PECT13</td><td rowspan="2">ADVANCED ENGINEERING MATHEMATICS</td><td>L</td><td>T</td><td>P</td><td rowspan="2">4</td><td rowspan="2">60</td></tr>
<tr><td>3</td><td>1</td><td>0</td></tr>
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Preamble/ Course Objective

• To make the students to understand various mathematical concepts applied to electronics and communication engineering including probability theory, stochastic processes, and computational electromagnetics

Prerequisite

Basics of Engineering Mathematics including calculus, linear algebra, and elementary probability theory.

Course Outcome

On the successful completion of the course, students will be able to

COs	Course Outcome	Bloom's Taxonomy Level
CO1	Analyze random variables, probability distributions, and statistical characteristics for modeling uncertainty in communication systems.	**Analyze**
CO2	Evaluate joint probability distributions of multiple random variables and apply correlation concepts for multi-dimensional signal analysis.	**Evaluate**
CO3	Apply stochastic process theory including stationary, ergodic, and Wiener processes for modeling noise and random signals in ECE applications.	**Apply**
CO4	Implement Finite Difference Time Domain (FDTD) methods for electromagnetic wave propagation analysis and boundary value problems.	**Apply**
CO5	Design and simulate mathematical models integrating probability theory and computational electromagnetics for advanced ECE system analysis.	**Create**

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Module I: Random Variables **12 Hours**

Random variables: Probability axioms - conditional probability - discrete and continuous random variables, Cumulative Distribution Function (CDF) - Probability Mass Function (PMF) - Probability Density Function (PDF) - Conditional PMF/PDF - Expected value - Variance; Functions of a random variable; Expected value of the derived random variable.

Module II: Multiple Random Variables **12 Hours**

Multiple random variables: Joint CDF/PMF/PDF - functions of multiple random variables - multiple functions of multiple random variables - independent/uncorrelated random variables - sums of random variables - moment generating function - random sums of random variables.

Module III: Stochastic Processes **12 Hours**

Classification of stochastic process - stationary process (SSS and WSS) - ergodic process - independent increment process - counting process - narrowband process - normal process - Wiener process - Shot noise process - autocorrelation function.

Module IV: Finite Difference Time Domain Method **12 Hours**

Wave Equation: Dispersion and Stability; The FDTD method: Staggered Grids- one space dimension- three space dimensions-integral interpretation of the FDTD method- dispersion analysis in three Dimensions; Boundary conditions for open regions: The perfectly matched Layer - near to far field transformation.

Module V: Instructional Activities **12 Hours**

Response of LTI system's - probability distribution and density function - Weiner and Shot noise process- Practical applications of wave scattering in FDTD using related platforms.

Text Books

1. Papoulis, Athanasios, and S. Unnikrishna Pillai. *Probability, Random Variables and Stochastic Processes*. 4th ed. New York: McGraw-Hill, 2002.
2. Taflove, Allen, and Susan C. Hagness. *Computational Electrodynamics: The Finite-Difference Time-Domain Method*. 3rd ed. Boston: Artech House, 2005

Reference Books

1. Ross, Sheldon M. *Introduction to Probability Models*. 11th ed. Amsterdam: Academic Press, 2014.
2. Hsu, Hwei P. *Probability, Random Variables, and Random Processes*. 2nd ed. New York: McGraw-Hill, 2011.
3. Kunz, Karl S., and Raymond J. Luebbers. *The Finite Difference Time Domain Method for Electromagnetics*. Boca Raton, FL: CRC Press, 1993.

Web Resources

1. Introduction to Probability Theory and Stochastic Processes - Prof. Prabha Sharma, IIT Kanpur - *https://nptel.ac.in/courses/111102111*
2. Electromagnetic Theory - Prof. Manoj K. Harbola, IIT Kanpur - *https://nptel.ac.in/courses/108106152*

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PSO1	PSO2	PSO3
CO1	3	1	2	1	2	-	2	2	3	1
CO2	3	2	2	1	2	-	2	2	3	1
CO3	3	2	2	1	2	-	2	3	3	2
CO4	3	3	3	1	2	-	2	2	2	3
CO5	3	3	3	2	3	1	3	3	3	3

Course code	Course Name	Periods			Credits	Total Hours
		L	T	P		
25PECI11	EMBEDDED SYSTEMS AND VLSI	2	**0**	4	4	**60**

Preamble/ Course Objective

• To provide comprehensive understanding of embedded system design integrated with VLSI concepts, covering microcontroller programming, hardware-software co-design, custom IC development, and system-on-chip implementation for modern embedded applications

Prerequisite

Knowledge of digital electronics, microprocessors, C programming, and basic VLSI design concepts.

Course Outcome

On the successful completion of the course, students will be able to

COs	Course Outcome	Bloom's Taxonomy Level
CO1	Analyze embedded system architectures and design microcontroller-based systems with optimized hardware-software interfaces for real-time applications.	**Analyze**
CO2	Apply VLSI design principles to create custom embedded processors and evaluate their performance characteristics for specific application domains.	**Apply**
CO3	Design system-on-chip solutions integrating embedded processors, memory systems, and peripheral interfaces using modern EDA tools and methodologies.	**Create**
CO4	Implement hardware accelerators and co-processors for embedded systems considering power, area, and timing constraints in VLSI design.	**Apply**
CO5	Create complete embedded VLSI systems combining software development, hardware design, and system integration for IoT and edge computing applications.	**Create**

Syllabus

Module I: Embedded System Fundamentals and VLSI Integration 12 Hours

Theory (8 Hours): Embedded system architecture and design challenges - microcontroller vs microprocessor systems - real-time operating systems - embedded software development - VLSI design flow for embedded systems - hardware-software co-design methodology - system specification and modeling.

Practical Experiments (4 Hours): - **Experiment 1:** Embedded system development environment setup - microcontroller programming and debugging - **Experiment 2:** VLSI design tool introduction - HDL coding for embedded processor components

Module II: Custom Embedded Processor Design 12 Hours

Theory (8 Hours): Processor architecture design - instruction set architecture (ISA) design - datapath and control unit implementation - pipelining in embedded processors - memory hierarchy design - cache design for embedded systems - low-power processor design techniques.

Practical Experiments (4 Hours): - **Experiment 3:** Simple processor design using Verilog/VHDL - instruction execution and control logic - **Experiment 4:** Memory system design and interface - cache implementation and optimization

Module III: System-on-Chip Design for Embedded Applications 12 Hours

Theory (8 Hours): SoC architecture for embedded systems - on-chip communication protocols (AMBA, AXI) - peripheral integration and interface design - DMA controllers and interrupt handling - clock and power management - design for testability in embedded SoCs.

Practical Experiments (4 Hours): - **Experiment 5:** SoC design project - processor and peripheral integration using system-level design tools - **Experiment 6:** Bus interface design and verification - communication protocol implementation

Module IV: Hardware Acceleration and Co-processing 12 Hours

Theory (8 Hours): Hardware acceleration concepts - co-processor design - FPGA-based acceleration - GPU computing for embedded systems - DSP and AI accelerators - parallel processing architectures - reconfigurable computing systems.

Practical Experiments (4 Hours): - **Experiment 7:** FPGA-based hardware accelerator design - algorithm implementation and optimization - **Experiment 8:** Performance analysis and comparison - hardware vs software implementation trade-offs

Module V: Integrated System Design and Applications 12 Hours

Theory (8 Hours): Embedded VLSI system integration - IoT edge devices - embedded AI and machine learning hardware - automotive embedded systems - biomedical device design - security considerations in embedded VLSI - future trends and emerging technologies.

Practical Experiments (4 Hours): - **Experiment 9:** Complete embedded VLSI system project - IoT sensor node with custom processor - **Experiment 10:** System validation and testing - performance optimization and power analysis

Textbooks :

1. Wolf's "Computers as Components" - excellent for embedded system architecture and design challenges
2. Vahid & Givargis's "Embedded System Design" - perfect for hardware-software co-design methodology

Reference Books:

1. Weste & Harris - the definitive VLSI design reference covering design flow and low-power techniques
2. Kamal's "Embedded Systems" - comprehensive coverage of embedded architectures and programming
3. Smith's "Application-Specific Integrated Circuits" - ideal for custom processor design and SoC applications

Web Resources:

1. Introductory Digital Systems Laboratory (6.111) - MIT OpenCourseWare *https://ocw.mit.edu/courses/6-111-introductory-digital-systems-laboratory-spring-2006/*
2. Introduction to VLSI Design - NPTEL *https://nptel.ac.in/courses/117106092*

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PSO1	PSO2	PSO3
CO1	3	3	3	2	2	1	2	2	2	3
CO2	3	3	3	1	2	1	3	2	2	3
CO3	3	3	3	2	2	1	3	2	2	3
CO4	3	3	3	2	2	2	2	2	3	3
CO5	3	3	3	3	3	2	3	3	3	3

Semester II

Course code	Course Name	Periods			Credits	Total Hours
25PECT21	ADVANCED DIGITAL SYSTEM DESIGN	L	T	P	4	60
		3	1	0		

Preamble/ Course Objective

• To make the students to understand the design and analysis of synchronous and asynchronous sequential circuits, programmable logic devices, and fault diagnosis techniques for advanced digital system implementation

Prerequisite

Knowledge on digital integrated circuit design, Verilog and FPGA

Course Outcome

On the successful completion of the course, students will be able to

COs	Course Outcome	Bloom's Taxonomy Level
CO1	Analyze and design clocked synchronous sequential circuits using state diagrams, state tables and ASM charts for digital system applications.	**Analyze**
CO2	Design asynchronous sequential circuits by applying flow table reduction techniques and resolving race conditions and hazard problems.	**Create**
CO3	Implement synchronous sequential circuits using programmable logic devices like PLA, PAL and realize finite state machines using FPGA.	**Apply**
CO4	Apply fault diagnosis methods including path sensitization, Boolean difference and D-algorithm for testing digital circuits and PLDs.	**Apply**
CO5	Simulate sequential circuits and perform logic synthesis using CAD tools for mapping designs to programmable logic devices.	**Create**

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Module I: Sequential Circuit Design **12 Hours**

Analysis of clocked synchronous sequential circuits and modeling- state diagram - state table - state table assignment and reduction - design of iterative circuits - ASM chart and realization using ASM.

Module II: Asynchronous Sequential Circuit Design **12 Hours**

Analysis of asynchronous sequential circuit: Design of asynchronous sequential circuit - static and dynamic methods - flow table reduction - races - state assignment transition table and problems in transition table - essential hazards - data synchronizers - mixed operating mode asynchronous circuits.

Module III: Synchronous Design Using Programmable Devices **12 Hours**

Programming logic device families: Designing a synchronous sequential circuit using PLA/PAL - realization of finite state machine using PLD/FPGA.

Module IV: Fault Diagnosis and Testability Algorithms 12 Hours

Fault diagnosis method: Path sensitization method - Boolean difference method - D – algorithm - tolerance techniques - compact algorithm - fault in PLA/PAL- test generation - built in self test.

Module V: Instructional Activities 12 Hours

Simulation of synchronous/ asynchronous sequential circuits: Logic compilation - two level and multi level logic synthesis - sequential logic synthesis -technology mapping - tools for mapping to PLDs and FPGAs.

Text Book

1. Mano, M. Morris, and Michael D. Ciletti. Digital Design: With an Introduction to the Verilog HDL. 5th ed. Boston: Pearson, 2013.
2. Kohavi, Zvi, and Niraj K. Jha. Switching and Finite Automata Theory. 3rd ed. Cambridge: Cambridge University Press, 2010.

Reference Books:

1. Unger, Stephen H. *Asynchronous Sequential Switching Circuits*. New York: Wiley-Interscience, 1969.
2. Abramovici, Miron, Melvin A. Breuer, and Arthur D. Friedman. *Digital Systems Testing and Testable Design*. New York: Computer Science Press, 1990.
3. Brown, Stephen, and Zvonko Vranesic. *Fundamentals of Digital Logic with VHDL Design*. 3rd ed. New York: McGraw-Hill, 2009.

Web Resources

1. Switching Circuits and Logic Design - Prof. Santanu Chattopadhyay, IIT Kharagpur - https://nptel.ac.in/courses/106105185
2. Digital VLSI Testing - Prof. Santanu Chattopadhyay, IIT Kharagpur - https://nptel.ac.in/courses/117103137

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PSO1	PSO2	PSO3
CO1	3	2	2	1	1	-	2	2	1	3
CO2	3	3	2	1	2	1	2	2	1	3
CO3	3	3	3	1	2	1	2	2	2	3
CO4	3	2	3	1	2	1	2	1	1	3
CO5	2	3	3	2	3	1	3	2	2	3

Course code	Course Name	Periods			Credits	Total Hours
25PECT22	ADVANCED DIGITAL SIGNAL PROCESSING	L	T	P	4	60
		3	1	0		

Preamble/ Course Objective

• To make the students to understand the concepts in advanced signal processing mechanisms, power spectrum estimation methods, adaptive filtering techniques, and wavelet transforms for modern signal processing applications

Prerequisite

Knowledge in Signal and Systems, and Digital Signal Processing

Course Outcome

On the successful completion of the course, students will be able to

COs	Course Outcome	Bloom's Taxonomy Level
CO1	Analyze fundamentals of digital signal processing systems and apply sampling techniques including decimation and interpolation for multi-channel signal processing.	**Analyze**
CO2	Evaluate power spectrum estimation using parametric and non-parametric methods including Welch, Bartlett and Yule-Walker techniques for spectral analysis applications.	**Evaluate**
CO3	Implement adaptive signal processing algorithms including LMS and RLS for noise cancellation and channel equalization applications.	**Apply**
CO4	Apply wavelet transforms including continuous and discrete wavelet transforms using Haar and Daubechies wavelets for advanced signal analysis and processing.	**Apply**
CO5	Design real-time signal processing systems for EEG/ECG analysis, echo cancellation and speech recognition using modern software platforms and tools.	**Create**

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Module I: Fundamentals of Signal Processing **12 Hours**

Introduction: Basic elements of Digital Signal Processing System- advantages of digital over analog signal processing; Classification of signals: Deterministic vs random signals - multi channel and multi-dimensional signals; Down Sampling-decimation-up sampling-interpolation.

Module II: Power Spectrum Estimation **12 Hours**

Estimation of spectra using the DFT from finite duration signals - non-parametric methods for power spectrum estimation: Welch- Bartlett methods; Parametric methods for power spectrum estimation: Yule-Walker method- Burg method for the ARM parameters- sequential estimation methods.

Module III: Adaptive Signal Processing **12 Hours**

FIR adaptive filters- steepest descent adaptive filter - LMS algorithm - convergence of LMS algorithms; Applications: Noise cancellation - channel equalization; Adaptive recursive filters - recursive least square estimation.

Module IV: Wavelet Transform **12 Hours**

Introduction: Continuous Wavelet Transform - basic properties of wavelet transforms - Discrete Wavelet Transform: Haar scaling functions and function spaces - nested spaces - Haar wavelet function - orthogonality of φ(t) and ψ(t) - normalization of Haar bases at different scales; Daubechies wavelets - support of wavelet system.

Module V: Instructional Activities **12 Hours**

EEG/ECG signal analysis for the real time environment; Echo cancellation using adaptive filters; Voice recognition and speech-to-text conversion using related tools.

Text Book

1. Proakis, John G., and Dimitris G. Manolakis. *Digital Signal Processing: Principles, Algorithms and Applications*. 4th ed. Upper Saddle River, NJ: Pearson Education, 2007.
2. Haykin, Simon. *Adaptive Filter Theory*. 5th ed. Upper Saddle River, NJ: Pearson Education, 2014.

Reference Books:

1. Oppenheim, Alan V., and Ronald W. Schafer. Discrete-Time Signal Processing. 3rd ed. Upper Saddle River, NJ: Pearson Education, 2010.
2. Mallat, Stéphane. A Wavelet Tour of Signal Processing. 3rd ed. Amsterdam: Academic Press, 2009.
3. Kay, Steven M. Modern Spectral Estimation: Theory and Application. Englewood Cliffs, NJ: Prentice Hall, 1988.

Web Resources

1. Adaptive Signal Processing - Prof. V. U. Reddy, IISc Bangalore - *https://nptel.ac.in/courses/117105075*

2. Introduction to Time-Frequency Analysis and Wavelet Transforms - Prof. Arun K. Tangirala, IIT Madras - *https://nptel.ac.in/courses/103106114*

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PSO1	PSO2	PSO3
CO1	3	2	2	1	1	-	2	2	3	2
CO2	3	2	3	1	2	-	2	2	3	1
CO3	3	3	3	1	2	1	2	3	3	2
CO4	3	2	3	1	2	-	2	2	3	2
CO5	2	3	3	2	3	1	3	3	3	3

Course code	Course Name	Periods			Credits	Total Hours
25PECT23	NEXT GENERATION WIRELESS NETWORK	L	T	P	4	60
		4	0	0		

Preamble/ Course Objective

• To impart the new concepts in advanced wireless communications including 5G technologies, massive MIMO systems, mmWave communications, and next-generation wireless network architectures

Prerequisite

Basics of analog, digital and wireless communication.

Course Outcome

On the successful completion of the course, students will be able to

COs	Course Outcome	Bloom's Taxonomy Level
CO1	Analyze 5G cellular architecture, frequency reuse concepts, and multiple access techniques including advanced schemes for next-generation wireless systems.	**Analyze**
CO2	Evaluate propagation mechanisms for wireless channels including mmWave propagation, small-scale fading, and channel modeling techniques for 5G environments.	**Evaluate**
CO3	Apply advanced modulation and detection techniques including OFDM, massive MIMO processing, and equalization methods for 5G wireless communication systems.	**Apply**
CO4	Design massive MIMO systems, beamforming algorithms, and space-time coding techniques for enhanced capacity and reliability in 5G networks.	**Create**
CO5	Simulate and analyze 5G communication systems including modulation schemes, multiple access techniques, and MIMO configurations using modern simulation tools.	**Create**

Syllabus

Module I: 5G Wireless Communication Fundamentals 12 Hours

Introduction to 5G wireless communication - technical challenges and requirements of 5G systems - applications and use cases; 5G Cellular architecture - ultra-dense networks - heterogeneous networks - network slicing; Frequency reuse in 5G - advanced channel assignment techniques - seamless handoff mechanisms; Multiple access: Enhanced FDMA/CDMA/TDMA/SDMA - OFDMA - SC-FDMA - NOMA (Non-Orthogonal Multiple Access).

Module II: 5G Propagation and Channel Modeling 12 Hours

Advanced propagation principles for 5G: mmWave propagation characteristics - channel modeling methods for sub-6GHz and mmWave bands; 5G Radio channels: indoor and outdoor channel modeling - ultra-dense network propagation - massive MIMO channel characteristics; Mobile Radio Propagation in 5G: Large scale path loss models for 5G - 3GPP channel models

- small scale fading in mmWave systems - spatial channel modeling for massive MIMO - statistical models for 5G multipath fading channels.

Module III: Advanced Modulation and Detection for 5G **12 Hours**

5G Digital modulation techniques: Structure of 5G wireless communication link - OFDM and advanced modulation schemes; Linear and constant envelope modulation for 5G - error performance in 5G fading channels - carrier aggregation; 5G Transmission Systems: Combined fast and slow fading mitigation - advanced equalization techniques - interference cancellation - detection techniques for massive MIMO and mmWave systems.

Module IV: Massive MIMO and 5G Antenna Systems **12 Hours**

Massive MIMO Systems for 5G: Large-scale antenna arrays - digital and hybrid beamforming - spatial multiplexing with massive MIMO; Advanced space-time coding: Enhanced Alamouti schemes - orthogonal and quasi-orthogonal space-time block codes for massive MIMO; mmWave beamforming: Analog and digital beamforming architectures - beam management and tracking - performance analysis for 5G massive MIMO systems - comparison of different beamforming techniques.

Module V: Instructional Activities **12 Hours**

Simulation of 5G communication systems: OFDM and massive MIMO simulation - mmWave beamforming analysis - 5G channel modeling and performance evaluation - NOMA and advanced multiple access techniques simulation using 5G-related tools and platforms.

Text Books

1. Dahlman, Erik, Stefan Parkvall, and Johan Skold. 5G NR: The Next Generation Wireless Access Technology. 2nd ed. Amsterdam: Academic Press, 2020.
2. Rappaport, Theodore S. Wireless Communications: Principles and Practice. 2nd ed. Upper Saddle River, NJ: Prentice Hall, 2002.

Reference Books

1. Larsson, Erik G., Ove Edfors, Fredrik Tufvesson, and Thomas L. Marzetta. Massive MIMO for Next Generation Wireless Systems. IEEE Communications Magazine 52, no. 2 (2014): 186-195.
2. Molisch, Andreas F. Wireless Communications. 2nd ed. Chichester: John Wiley & Sons, 2011.
3. Goldsmith, Andrea. Wireless Communications. Cambridge: Cambridge University Press, 2005.

Web Resources

1. 5G Wireless Standard Design - Prof. Abhay Karandikar, IIT Bombay - https://onlinecourses.nptel.ac.in/noc24_ee152
2. Fundamentals of MIMO Wireless Communication - Prof. Suvra Sekhar Das, IIT Kharagpur - https://onlinecourses.nptel.ac.in/noc24_ee72

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PSO1	PSO2	PSO3
CO1	3	2	2	1	1	-	3	3	2	2
CO2	3	2	3	1	2	-	2	3	3	1
CO3	3	3	3	1	2	-	2	3	3	2
CO4	3	3	3	2	2	1	3	3	3	2
CO5	2	3	3	2	3	1	3	3	3	2

Course code	Course Name	Periods			Credits	Total Hours
		L	**T**	**P**		
25PECI21	IoT COMMUNICATION	2	**0**	4	4	**60**

Preamble/ Course Objective

• To provide comprehensive understanding of Internet of Things communication technologies, protocols, network architectures, and practical implementation techniques for designing and deploying scalable IoT systems with hands-on experience

Prerequisite

Knowledge of wireless communication systems, networking protocols, and embedded system programming.

Course Outcome

On the successful completion of the course, students will be able to

COs	Course Outcome	Bloom's Taxonomy Level
CO1	Analyze IoT ecosystem architectures and evaluate various communication technologies for different IoT application requirements and constraints.	**Analyze**
CO2	Apply short-range and long-range IoT communication protocols including WiFi, Bluetooth, LoRaWAN, and cellular IoT for specific use cases.	**Apply**
CO3	Design IoT network topologies and implement routing protocols considering scalability, energy efficiency, and quality of service requirements.	**Create**
CO4	Implement IoT security mechanisms including device authentication, data encryption, and secure communication protocols for trusted IoT deployments.	**Apply**
CO5	Create complete IoT communication systems integrating sensors, gateways, cloud platforms, and mobile applications for real-world IoT solutions.	**Create**

Syllabus

Module I: IoT Communication Fundamentals and Architecture 12 Hours

Theory (8 Hours): Introduction to IoT ecosystem - IoT reference architecture - communication requirements and challenges - spectrum considerations - energy constraints - scalability issues - Quality of Service (QoS) in IoT - IoT standardization bodies and protocols overview.

Practical Experiments (4 Hours): - **Experiment 1:** IoT system setup and configuration - device connectivity and basic communication testing - **Experiment 2:** IoT architecture simulation - network topology design and analysis using simulation tools

Module II: Short-Range IoT Communication Technologies **12 Hours**

Theory (8 Hours): WiFi for IoT applications - Bluetooth and BLE protocols - ZigBee and IEEE 802.15.4 - Thread protocol - 6LoWPAN - mesh networking - personal area networks (PANs) - interference management - coexistence issues.

Practical Experiments (4 Hours): - Experiment 3: WiFi and Bluetooth IoT device implementation - sensor data transmission and mobile app integration **- Experiment 4:** ZigBee mesh network setup - multi-hop communication and network formation

Module III: Long-Range IoT Communication and Cellular Technologies **12 Hours**

Theory (8 Hours): LoRaWAN architecture and protocol stack - Sigfox technology - NB-IoT and LTE-M cellular technologies - satellite IoT communication - coverage and capacity planning - network deployment strategies - cost considerations.

Practical Experiments (4 Hours): - **Experiment 5:** LoRaWAN network deployment - end device programming and gateway configuration - **Experiment 6:** Cellular IoT implementation - NB-IoT module programming and network registration

Module IV: IoT Network Protocols and Security **12 Hours**

Theory (8 Hours): Internet protocols for IoT - IPv6 and 6LoWPAN - CoAP and MQTT protocols - HTTP/2 for IoT - routing protocols (RPL, AODV) - IoT security threats and vulnerabilities - authentication and authorization - encryption techniques - PKI for IoT.

Practical Experiments (4 Hours): - **Experiment 7:** IoT protocol implementation - MQTT broker setup and secure communication - **Experiment 8:** IoT security implementation - device authentication and encrypted data transmission

Module V: IoT System Integration and Applications **12 Hours**

Theory (8 Hours): IoT cloud platforms (AWS IoT, Azure IoT, Google Cloud IoT) - edge computing and fog networking - data analytics and machine learning - IoT applications (smart cities, industrial IoT, healthcare IoT) - interoperability and standards - future trends and 5G integration.

Practical Experiments (4 Hours): - Experiment 9: Complete IoT system integration - sensor to cloud data pipeline with dashboard creation - **Experiment 10:** IoT application development - smart home/industrial monitoring system with mobile and web interfaces

Textbooks:

1. Buyya, Rajkumar, and Amir Vahid Dastjerdi, eds. *Internet of Things: Principles and Paradigms*. Cambridge, MA: Morgan Kaufmann, 2016.
2. Madakam, Somayya, R. Ramaswamy, and Siddharth Tripathi. *Internet of Things (IoT): A Literature Review*. Amsterdam: Elsevier, 2015.

Reference Books:

1. Hersent, Olivier, David Boswarthick, and Omar Elloumi. *The Internet of Things: Key Applications and Protocols*. 2nd ed. New York: John Wiley & Sons, 2012.
2. Minerva, Roberto, Abyi Biru, and Domenico Rotondi. *Towards a Definition of the Internet of Things (IoT)*. Geneva: IEEE Internet Initiative, 2015.
3. Greengard, Samuel. *The Internet of Things*. Cambridge, MA: MIT Press, 2015.

Web Sources:

1. Introduction to Internet of Things *http://nptel.ac.in/courses/106105166/*
2. IoT and Wireless Communication *http://nptel.ac.in/courses/108105054/*

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PSO1	PSO2	PSO3
CO1	3	2	2	2	2	1	3	3	2	2
CO2	3	2	3	2	2	1	3	3	2	3
CO3	3	3	3	2	2	2	3	3	2	2
CO4	2	2	3	2	2	3	2	3	2	2
CO5	3	3	3	3	3	2	3	3	3	3

SEMESTER III

Course code	Course Name	Periods			Credits	Total Hours
		L	T	P		
25PECI31	AI APPLICATION IN SIGNAL PROCESSING	2	0	4	4	**60**

Preamble/ Course Objective

• To provide comprehensive understanding of artificial intelligence techniques applied to signal processing problems, covering machine learning algorithms, deep learning architectures, and practical implementation for audio, image, biomedical, and communication signal processing applications

Prerequisite

Knowledge of digital signal processing, linear algebra, probability theory, and basic programming skills in Python/MATLAB.

Course Outcome

On the successful completion of the course, students will be able to

COs	Course Outcome	Bloom's Taxonomy Level
CO1	Analyze the integration of AI techniques with traditional signal processing methods and evaluate their advantages for various signal processing applications.	**Analyze**
CO2	Apply machine learning algorithms including supervised and unsupervised learning for signal classification, feature extraction, and pattern recognition tasks.	**Apply**
CO3	Design deep learning architectures including CNNs, RNNs, and transformer networks for complex signal processing problems in multiple domains.	**Create**
CO4	Implement AI-based signal processing solutions for real-world applications including audio processing, image analysis, and biomedical signal interpretation.	**Apply**
CO5	Create optimized AI signal processing systems considering computational constraints, real-time requirements, and deployment strategies for edge devices.	**Create**

Syllabus

Module I: AI and Signal Processing Integration Fundamentals **12 Hours**

Theory (8 Hours): Introduction to AI in signal processing - traditional vs AI-based approaches - machine learning fundamentals for signal processing - feature engineering and selection - dimensionality reduction techniques - signal representation learning - time-frequency analysis with AI - signal preprocessing for ML algorithms.

Practical Experiments (4 Hours): - **Experiment 1:** Python environment setup for AI signal processing - NumPy, SciPy, scikit-learn introduction - **Experiment 2:** Traditional vs ML-based signal filtering - performance comparison and analysis

Module II: Machine Learning for Signal Processing **12 Hours**

Theory (8 Hours): Supervised learning for signal classification - support vector machines for signal data - decision trees and ensemble methods - unsupervised learning for signal clustering - principal component analysis and independent component analysis - Gaussian mixture models - time series analysis with ML - hidden Markov models.

Practical Experiments (4 Hours): - **Experiment 3:** Audio signal classification using SVM and random forests - music genre recognition - **Experiment 4:** Unsupervised signal analysis - clustering of EEG signals and anomaly detection

Module III: Deep Learning Architectures for Signal Processing **12 Hours**

Theory (8 Hours): Deep neural networks for signal processing - convolutional neural networks for 1D and 2D signals - recurrent neural networks for temporal signals - LSTM and GRU architectures - attention mechanisms and transformer networks - autoencoders for signal compression and denoising - generative adversarial networks for signal synthesis.

Practical Experiments (4 Hours): - **Experiment 5:** CNN implementation for ECG signal classification - arrhythmia detection using TensorFlow/PyTorch - **Experiment 6:** RNN-based speech recognition - sequence-to-sequence learning for audio processing

Module IV: Domain-Specific AI Signal Processing Applications **12 Hours**

Theory (8 Hours): AI in audio signal processing - speech recognition and synthesis - music information retrieval - AI in image processing - computer vision applications - AI in biomedical signal processing - EEG, ECG, EMG analysis - AI in communication signals - modulation recognition and channel equalization - radar and sonar signal processing with AI.

Practical Experiments (4 Hours): - **Experiment 7:** Real-time speech processing system - voice activity detection and speaker identification - **Experiment 8:** Medical signal analysis - automated diagnosis from ECG and EEG signals using deep learning

Module V: Advanced Topics and System Implementation **12 Hours**

Theory (8 Hours): Edge AI for signal processing - model compression and quantization - hardware acceleration (GPUs, TPUs, FPGAs) - real-time AI signal processing - federated learning for distributed signal processing - reinforcement learning applications - explainable AI in signal processing - future trends and emerging applications.

Practical Experiments (4 Hours): - **Experiment 9:** Edge deployment of AI signal processing models - optimization for mobile and embedded devices - **Experiment 10:** Complete AI signal processing system - end-to-end application development with performance optimization

Textbooks:

1. Oppenheim, Alan V., and Ronald W. Schafer. *Discrete-Time Signal Processing*. 3rd ed. Upper Saddle River: Pearson, 2010.

2. Goodfellow, Ian, Yoshua Bengio, and Aaron Courville. *Deep Learning*. Cambridge, MA: MIT Press, 2016.

Reference Books:

1. Haykin, Simon. *Neural Networks and Learning Machines*. 3rd ed. Upper Saddle River:

Pearson, 2009.

2. Bishop, Christopher M. *Pattern Recognition and Machine Learning*. New York: Springer, 2006.

3. Duda, Richard O., Peter E. Hart, and David G. Stork. *Pattern Classification*. 2nd ed. New York: John Wiley & Sons, 2001.

Web Sources:

1. Machine Learning for Signal Processing *http://nptel.ac.in/courses/117104135/*

2. Digital Signal Processing *http://nptel.ac.in/courses/117101053/*

Mapping with Programme Outcomes

COs	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PSO1**	**PSO2**	**PSO3**
CO1	3	2	3	1	2	-	3	2	3	2
CO2	3	2	3	2	2	1	3	2	3	2
CO3	3	3	3	2	2	1	3	2	3	2
CO4	3	3	3	2	2	2	3	3	3	2
CO5	3	3	3	3	3	2	3	3	3	3

Electives

Course code	Course Name	Periods			Credits	Total Hours
		L	T	P		
25PECL01	ADVANCED OPTICAL COMMUNICATION	2	1	0	3	45

Preamble/ Course Objective

• Impart the concepts of multilevel modulation schemes, OFDM and MIMO for optical communication systems
• Develop understanding of nonlinear optics in optical communication
• Master advanced modulation and detection schemes in optical systems
• Learn optical channel estimation and capacity calculation techniques
• Gain hands-on experience with optical communication simulation tools

Prerequisite

Sound knowledge on basic optics, optical communication, various modulation and detection schemes in optical communication

Course Outcome

On the successful completion of the course, students will be able to

COs	Course Outcomes	Bloom's Level
CO1	Analyze nonlinear optical phenomena including SHG, FWM, and self-focusing in optical communication systems.	**Analyze**
CO2	Apply advanced modulation schemes including multilevel modulation, OFDM, and MIMO for optical communications.	**Apply**
CO3	Evaluate coherent detection techniques including heterodyne, homodyne, and intradyne detection methods.	**Evaluate**
CO4	Calculate optical channel capacity for various optical communication systems including OFDM and MIMO configurations.	**Analyze**
CO5	Implement simulation tools for optical communication systems using FDTD methods and analyze photonic structures.	**Apply**

Syllabus

Module I: Electromagnetic Waves **9 Hours**

Maxwell Equations: Integral and differential form - constitutive relations - time dependent wave equations - boundary conditions - polarization - time harmonic fields - pointing theorem - mode concepts - guided waves - TE & TM waves in a rectangular waveguide and circular waveguide - the coaxial transmission line - Smith chart and its applications.

Module II: Theorems and Concepts **9 Hours**

Source concept: Duality - uniqueness ; Image Theory: Equivalence principle - fields in half space - the induction theorem - reciprocity - Green's function - tensor Green's function - integral equation; Construction of solutions; Radiation fields.

Module III: Time Varying Harmonic Electromagnetic Fields **9 Hours**

Introduction: Maxwell equations - differential and integral form - constitutive parameters and relations - circuit field relations - boundary conditions - sources along boundary - time harmonic electromagnetic fields - Maxwell equations in differential and integral form - power and energy.

Module IV: Integral Equation in Momentum Method **9 Hours**

Introduction: Integral equation method - electro charge distribution - integral equation - radiation pattern - point matching method - basis function - moment method electric and magnetic field integral equations; Finite diameter wires - Pocklington's integral equation-Hallen's integral equation.

Module V: Instructional Activities **9 Hours**

Simulation study of Green's function - Green's function for Sturm - Green's function in two dimensions - double series method - single series expansion method - Green's function in spectral domain - Green's function for unbounded region

Text Book

1. Balanis, Constantine A. *Advanced Engineering Electromagnetics*. 2nd ed. Hoboken, NJ: John Wiley & Sons, 2012.
2. Harrington, Roger F. *Time-Harmonic Electromagnetic Fields*. 2nd ed. New York: IEEE Press, 2001.

Reference Book

1. Cheng, David K. Field and Wave Electromagnetics. 2nd ed. Reading, MA: Addison-Wesley, 1989.
2. Peterson, Andrew F., Scott L. Ray, and Raj Mittra. Computational Methods for Electromagnetics. New York: IEEE Press, 1998.
3. Tai, Chen-To. Dyadic Green Functions in Electromagnetic Theory. 2nd ed. New York: IEEE Press, 1994.

Web Resources

1. Electromagnetic Theory - Prof. Manoj K. Harbola, IIT Kanpur - *https://nptel.ac.in/courses/108106152*
2. Advanced 3D Electromagnetics - Prof. Y. S. Mayya, IISc Bangalore - *https://nptel.ac.in/courses/117108078*

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PSO1	PSO2	PSO3
CO1	3	2	3	2	1	2	1	1	2	1
CO2	3	3	2	3	2	2	2	2	2	2
CO3	2	3	3	2	3	2	2	3	2	2
CO4	3	2	3	3	2	3	2	2	3	2
CO5	2	3	2	2	3	2	3	3	2	3

Course Code	Course Name	Periods			Credits	Total Hours
25PECL02	MOBILE COMMUNICATION SYSTEM	**L**	**T**	**P**	**3**	**45**
		2	**1**	**0**		

Preamble/ Course Objective

- To learn the architecture and working principles of mobile communication systems
- Understand the evolution and trends in cellular radio and personal communication
- Master various mobile communication standards including GSM, CDMA, 3G, 4G, and 5G
- Develop knowledge of diversity schemes and MIMO systems
- Gain understanding of Mobile IP networks and transport layer protocols
- Acquire hands-on experience with mobile communication simulation tools

Prerequisite

Fundamentals of analog and digital communication systems

Course Outcome

On the successful completion of the course, students will be able to

COs	Course Outcomes	Bloom's Level
CO1	Analyze cellular concepts including handoff mechanisms and radio channel characterization in mobile systems.	**Analyze**
CO2	Evaluate various mobile communication standards from GSM to 5G and their system architectures.	**Evaluate**
CO3	Apply diversity schemes including receiver and transmitter diversity for MIMO systems.	**Apply**
CO4	Analyze Mobile IP network protocols including agent discovery, registration, and tunneling mechanisms.	**Analyze**
CO5	Implement simulation tools for mobile communication standards and analyze system performance.	**Apply**

Syllabus

Module I: Introduction to Cellular Concepts 9 Hours

Evolution of mobile radio communication - trends in cellular radio and personal communication; Basics of cellular concepts - types and components of mobile communication - operation of cellular system - handoff - radio channel characterization - multiple access schemes.

Module II: Mobile Standards 9 Hours

System architecture and working principle: GSM - SCSD - GPRS - EDGE - CDMA digital cellular standard - 3G CDMA 2000 - 3G W-CDMA - IMT-2000 - 4G LTE - 5G.

Module III: Diversity Schemes 9 Hours

Realization of independent fading paths - Receiver diversity - selection combing - Threshold combing - maximal - ratio combing - equal - gain combing; Transmitter Diversity - channel known at transmitter - channel unknown at transmitter - transmit and receive diversity for MIMO systems.

Module IV: Mobile IP Network and Transport Layer **9 Hours**

Introduction to Mobile IP: Requirements - IP packet delivery - agent discovery - registration, tunneling and encapsulation - optimization - reverse tunneling; Mobile adhoc networks - routing - destination sequence distance vector - dynamic source routing and alternative metrics; Traditional TCP - congestion control - slow start - fast retransmit - fast recovery - implications of mobility; Classical TCP improvements - methods of mobile TCP: Indirect TCP - snooping TCP - mobile TCP - fast retransmit.

Module V: Instructional Activities **9 Hours**

Simulation study of any (five) mobile communication standards using related tools.

Text Books

1. Rappaport, Theodore S. Wireless Communications: Principles and Practice. 2nd ed. Upper Saddle River, NJ: Pearson Education, 2010.
2. Goldsmith, Andrea. Wireless Communications. Cambridge: Cambridge University Press, 2005.

Reference Books

1. Lee, William C. Y. Mobile Communications Engineering: Theory and Applications. 2nd ed. New York: McGraw-Hill, 1998.
2. Molisch, Andreas F. Wireless Communications. 2nd ed. Chichester: John Wiley & Sons, 2011.
3. Stallings, William. Data and Computer Communications. 10th ed. Boston: Pearson Education, 2013.

Web Resources

1. Introduction to Wireless and Cellular Communications - Prof. David Koilpillai, IIT Madras - https://onlinecourses.nptel.ac.in/noc21_ee66
2. Computer Networks and Internet Protocol - Prof. Indranil Sengupta, IIT Kharagpur - https://onlinecourses.nptel.ac.in/noc22_cs19

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PSO1	PSO2	PSO3
CO1	3	2	3	2	1	2	1	2	3	2
CO2	3	3	2	3	2	2	2	3	2	2
CO3	2	3	3	2	3	2	2	2	2	3
CO4	3	2	3	3	2	3	2	3	3	2
CO5	2	3	2	2	3	2	3	2	2	3

Course code	Course Name	Periods			Credits	Total hours
		L	T	P		
25PECL03	HIGH PERFORMANCE COMMUNICATION NETWORKS	2	1	0	3	45

Preamble/ Course Objective

- To learn the architecture and uniqueness of high performance networks.

Prerequisite

Fundamentals of computer networks and wireless networks.

Course Outcome

On the successful completion of the course, students will be able to

COs	Course Outcomes	Bloom's Level
CO1	Analyze communication network architectures including telephone, computer, cable television and wireless networks with their layered structures and QoS requirements.	**Analyze**
CO2	Evaluate MANET architectures, routing protocols, packet scheduling algorithms and power control mechanisms for multihop wireless broadband networks.	**Evaluate**
CO3	Apply Internet and TCP/IP networking concepts including SONET, DWDM, DSL technologies and intelligent network schemes for circuit-switched networks.	**Apply**
CO4	Design enabling network solutions using WiFi, WiMAX, UWB and LTE technologies with their PHY/MAC layer specifications and system architectures.	**Design**
CO5	Simulate and integrate high performance networks including WiFi, WiMAX mesh networks and LTE-A integration using network simulation tools.	**Create**

Syllabus

Module I: Introduction **9 Hours**

Communication Networks: Telephone and computer networks - cable television networks - wireless networks - networking principles - digitalization - network externalities - service integration; Layered architecture - network bottlenecks - network elements - network mechanisms - traffic characterization and QoS.

Module II: MANET **9 Hours**

Multihop wireless broadband networks - mesh networks; MANET architecture - classification of routing protocols in MANET - routing metrics; packet scheduling algorithms - power control mechanism.

Module III: Internet and TCP/IP Networks **9 Hours**

Internet Protocol (IP): Technology trends in IP networks - IP packet communications in mobile communication networks; TCP and UDP - performance of TCP/IP networks; Circuit switched networks: SONET - DWDM - fiber to the home - DSL; Intelligent Network (IN) scheme -

comparison with conventional systems - merits of the IN scheme; CATV and layered network - services over CATV.

Module IV: Enabling Networks **9 Hours**

WiFi: overview - architecture - PHY and MAC layer; WiMAX overview - system architecture - frame structure - PMP mode - mesh mode - multihop relay mode; UWB overview - time hopping UWB - direct sequence UWB - multiband UWB; LTE and LTE-A overview - system model - frame structure - comparison with broadband technologies.

Module V: Instructional Activities **9 Hours**

Simulation study: WiFi network - WiMAX network in mesh mode and multihop relay mode - integration of LTE-A and WiMAX network with single IP network.

Textbooks

1. Kurose, James F., and Keith W. Ross. *Computer Networking: A Top-Down Approach*. 8th ed. Boston: Pearson, 2021.
2. Stallings, William. *Data and Computer Communications*. 10th ed. Boston: Pearson, 2013.

Reference Books

1. Tanenbaum, Andrew S., and David J. Wetherall. *Computer Networks*. 5th ed. Boston: Pearson, 2011.
2. Peterson, Larry L., and Bruce S. Davie. *Computer Networks: A Systems Approach*. 5th ed. San Francisco: Morgan Kaufmann, 2011.
3. Forouzan, Behrouz A. *Data Communications and Networking*. 5th ed. New York: McGraw-Hill, 2012.

Web Resources

1. **Computer Networks** by University of Washington (Coursera) Link: *https://www.coursera.org/learn/computer-networks*
2. **Introduction to Computer Networking** by Stanford University (Stanford Online) Link: *https://online.stanford.edu/courses/cs144-introduction-computer-networking*

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PSO1	PSO2	PSO3
CO1	3	2	3	2	1	2	1	2	2	1
CO2	3	3	2	3	2	2	2	3	2	2
CO3	2	3	3	2	3	2	2	3	3	2
CO4	3	2	3	3	2	3	2	2	3	3
CO5	2	3	2	2	3	2	3	3	2	3

<table>
<tr><th rowspan="2">Course Code</th><th rowspan="2">Course Name</th><th colspan="3">Periods</th><th rowspan="2">Credits</th><th rowspan="2">Total Hours</th></tr>
<tr></tr>
<tr><td rowspan="2">25PECL04</td><td rowspan="2">Modeling and Simulation of Wireless Communication Systems</td><td>L</td><td>T</td><td>P</td><td rowspan="2">3</td><td rowspan="2">45</td></tr>
<tr><td>2</td><td>1</td><td>0</td></tr>
</table>

Preamble/Course Objective

• To understand the modeling of wireless communication systems through simulation • Develop knowledge of Monte Carlo simulation techniques for wireless systems • Master the concepts of deterministic and stochastic simulation methods • Learn advanced techniques for generating and processing random signals • Gain hands-on experience with simulation tools for wireless communication analysis

Prerequisite

Knowledge of MATLAB programming, digital signal processing and digital communication

Course Outcome

On the successful completion of the course, students will be able to

COs	Course Outcomes	Bloom's Level
CO1	Analyze the role of simulation in wireless communication systems and understand deterministic and stochastic simulation methodologies.	Analyze
CO2	Generate and process random signals for wireless communication modeling using uniform and Gaussian random number generators.	Apply
CO3	Implement Monte Carlo simulation techniques and semi-analytic methods for wireless system analysis.	Apply
CO4	Model and simulate time-varying wireless communication systems including multipath fading channels and discrete channel models.	Create
CO5	Evaluate wireless communication system performance through simulation studies using appropriate tools and techniques.	Evaluate

Syllabus

Module I: Introduction **9 Hours**

Role of Simulation: Examples of complexity - multidisciplinary aspects of simulation - models - deterministic and stochastic simulations; Simulation methodology - aspects of methodology - performance estimation; Fundamental Concepts: Sampling - quantizing - reconstruction and interpolation - simulation sampling frequency - complex envelope techniques.

Module II: Generating and Processing Random Signals **9 Hours**

Stationary and Ergodic Processes: Uniform random number generators - mapping uniform random variables to an arbitrary PDF - generating uncorrelated and correlated Gaussian random numbers - PN sequence generators; Establishing a PDF and PSD Post Processing: Basic graphical techniques - estimation - coding.

Module III: Methodology for Simulating a Wireless System **9 Hours**

Fundamental Concepts of Monte Carlo Simulation - applications and integration - two Monte Carlo examples; Semi Analytic Techniques System: Level simplifications and sampling rate considerations - overall methodology; Modeling and simulation of nonlinearities: Modeling and simulation of memoryless nonlinearities - modeling and simulation of nonlinearities with memory - techniques for solving nonlinear differential equations.

Module IV: Modeling and Simulation of Time-Varying Systems **9 Hours**

Introduction: Models for LTV systems - random process models - simulation models for LTV systems; Wired and guided wave - radio channels - multipath fading channels - random process models - simulation methodology; Discrete channel models: Discrete memoryless channel models - Markov models for discrete channels with memory- HMMs - Gilbert and Fritchman models - estimation of Markov model parameters.

Module V: Instructional Activities **9 Hours**

Simulation study of generating PDF for the Gaussian and non-Gaussian distributions - linear and non-linear systems using different techniques with the help of simulation tools.

Textbooks

1. Jeruchim, Michel C., Philip Balaban, and K. Sam Shanmugan. *Simulation of Communication Systems: Modeling, Methodology and Techniques*. 2nd ed. New York: Kluwer Academic Publishers, 2000.
2. Banks, Jerry, John S. Carson, Barry L. Nelson, and David M. Nicol. *Discrete-Event System Simulation*. 5th ed. Boston: Pearson, 2010.

Reference Books

1. Law, Averill M., and W. David Kelton. *Simulation Modeling and Analysis*. 4th ed. New York: McGraw-Hill, 2007.
2. Ross, Sheldon M. *Simulation*. 5th ed. Amsterdam: Academic Press, 2013.
3. Fishman, George S. *Monte Carlo: Concepts, Algorithms, and Applications*. New York: Springer-Verlag, 1996.

Web Resources

1. **Introduction to Mathematical Modeling** by University of Pennsylvania (Coursera) Link: *https://www.coursera.org/learn/mathematical-modeling*
2. **Simulation and Modeling of Natural Processes** by University of Geneva (Coursera) Link: *https://www.coursera.org/learn/modeling-simulation-natural-processes*

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PSO1	PSO2	PSO3
CO1	3	2	3	2	1	2	1	2	2	1
CO2	3	3	2	3	2	2	2	3	2	2
CO3	2	3	3	2	3	2	2	3	3	2
CO4	3	2	3	3	2	3	2	2	3	3
CO5	2	3	2	2	3	2	3	3	2	3

Course Code	Course Name	Periods			Credits	Total Hours
		L	T	P		
25PECL05	Information and Network Security	2	1	0	3	45

Preamble/Course Objective

• To study the various security attacks, data security and network security algorithms • Develop understanding of symmetric and asymmetric cryptographic techniques • Master authentication mechanisms and digital signature standards • Learn network security protocols including IPSec, SSL/TLS, and wireless security • Gain hands-on experience with cryptographic algorithm implementation and security tools

Prerequisite

Analog and digital communication

Course Outcome

On the successful completion of the course, students will be able to

COs	Course Outcomes	Bloom's Level
CO1	Analyze security problems in computing systems and understand fundamental cryptographic techniques including substitution and transposition ciphers.	**Analyze**
CO2	Apply data security algorithms including DES, AES, RSA, and elliptical curve cryptography for secure data transmission.	**Apply**
CO3	Evaluate network security protocols including IPSec, SSL/TLS, and implement security mechanisms for web and mobile communications.	**Evaluate**
CO4	Design intrusion detection systems and implement security measures against malicious software and distributed denial of service attacks.	**Create**
CO5	Implement and analyze public key and private key cryptographic algorithms using simulation tools and security frameworks.	**Apply**

Syllabus

Module I: Introduction to Cryptography **9 Hours**

Security issues: Security problems in computing - attacks - security services - security mechanism - OSI security architecture - standard setting organizations; Need for cryptographic techniques- substitution - transposition - block ciphers - stream ciphers - cryptanalysis techniques.

Module II: Data Security and Authentication **9 Hours**

Symmetric Key Cryptography: Data Encryption Standard (DES) - Triple DES with two keys - Advanced Encryption Standard (AES); Asymmetric Key Cryptography: RSA algorithm - elliptical curve cryptography algorithm; Hash Functions: MD5 - HASH algorithm - SHA 512 logic - Digital Signatures standards - message authentication codes.

Module III: Network Security **(9 Hours)**

Network Security Protocols: IP security overview - IP security architecture - authentication header - encapsulating security payload - combining security association - key management; Web Security: secure socket layer and transport layer security - secure electronic transaction - HTTPS protocol; Wireless Security: security in GSM - security in 3G and 4G - WPA/WPA2 protocols.

Module IV: System Security **(9 Hours)**

Intrusion Detection and Prevention: Intruders and intrusion detection systems - anomaly detection - signature-based detection; Malicious Software: viruses and related threats - trojans - worms - rootkits - virus counter measures - antivirus strategies; Network Protection: distributed denial of service attacks - firewalls design principles - trusted systems - access control mechanisms.

Module V: Instructional Activities **(9 Hours)**

Simulation and implementation of cryptographic algorithms: Implementation of symmetric key algorithms (DES, AES) - implementation of asymmetric key algorithms (RSA, ECC) - digital signature verification - hash function analysis - network security protocol simulation using appropriate tools and frameworks.

Textbooks

1. Stallings, William. *Cryptography and Network Security: Principles and Practice*. 8th ed. Boston: Pearson, 2020.
2. Forouzan, Behrouz A., and Debdeep Mukhopadhyay. *Cryptography and Network Security*. 3rd ed. New York: McGraw-Hill Education, 2015.

Reference Books

1. Menezes, Alfred J., Paul C. van Oorschot, and Scott A. Vanstone. *Handbook of Applied Cryptography*. Boca Raton: CRC Press, 1997.
2. Schneier, Bruce. *Applied Cryptography: Protocols, Algorithms, and Source Code in C*. 2nd ed. New York: John Wiley & Sons, 1996.
3. Katz, Jonathan, and Yehuda Lindell. *Introduction to Modern Cryptography*. 3rd ed. Boca Raton: CRC Press, 2020.

Web Resources

1. **Cryptography I** by Stanford University (Coursera) Link: *https://www.coursera.org/learn/crypto*
2. **Applied Cryptography** by University of Colorado System (Coursera) Link: *https://www.coursera.org/specializations/applied-crypto*

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PSO1	PSO2	PSO3
CO1	3	2	3	2	1	3	2	2	2	1
CO2	3	3	2	3	2	2	2	3	2	2
CO3	2	3	3	2	3	3	3	3	3	3
CO4	3	2	3	3	2	3	2	2	3	2
CO5	2	3	2	2	3	2	3	3	2	3

Course code	Course Name	Periods			Credits	Total Hours
		L	T	P		
25PECL06	COGNITIVE RADIO TECHNOLOGY	2	1	0	3	45

Preamble/ Course Objective

• To introduce students to cognitive radio technology concepts, software defined radio architectures, spectrum sharing techniques, and security issues in cognitive radio networks for next-generation wireless communications

Prerequisite

Knowledge of wireless communication systems, digital signal processing, and networking fundamentals.

Course Outcome

On the successful completion of the course, students will be able to

COs	Course Outcome	Bloom's Taxonomy Level
CO1	Analyze fundamentals of communication networks and evaluate multiple access schemes with cross-layer design approaches for cognitive radio applications.	**Analyze**
CO2	Design and evaluate Software Defined Radio architectures including functional components, interface topologies, and programmability aspects.	**Evaluate**
CO3	Apply cognitive radio network architectures for spectrum sharing and implement topology-aware network optimization techniques.	**Apply**
CO4	Assess security vulnerabilities in cognitive radio networks and develop countermeasures against primary user emulation attacks.	**Evaluate**
CO5	Simulate and analyze cognitive radio and SDR network performance using modern simulation tools and platforms.	**Create**

Syllabus

Module I: Introduction **9 Hours**

Fundamentals of communication networks: New challenges - multiple access schemes - cross layer design and optimization; Multicarrier modulation and equalization - ISI; RF spectrum and regulation: Regulatory issues of cognitive access.

Module II: SDR Architecture **9 Hours**

Software Defined Radio: Evolution - essential functions of the Software Defined Radio - architecture goals - quantifying degrees of programmability - top level component topology - computational properties of functional components - interface topologies among plug and play modules - architecture partitions - merits and demerits of SDR - problems faced by SDR.

Module III: CR Architecture **9 Hours**

Cognitive radio network architectures: Architectures for spectrum sharing - network optimization - topology aware CRN architectures - Haykin dynamic spectrum architecture.

Module IV: CR Network Security **9 Hours**

Primary user emulation attacks - security vulnerabilities in IEEE 802.22 - security threats to the radio software.

Module V: Instructional Activities **9 Hours**

Simulation of CR & SDR network using related tools.

Textbooks

1. Mitola, Joseph III. *Cognitive Radio Architecture: The Engineering Foundations of Radio XML*. New York: Wiley-Interscience, 2006.
2. Reed, Jeffrey H., ed. *Software Radio: A Modern Approach to Radio Engineering*. Upper Saddle River: Prentice Hall PTR, 2002.

Reference Books

1. Fette, Bruce A., ed. *Cognitive Radio Technology*. 2nd ed. Amsterdam: Academic Press, 2009.
2. Arslan, Hüseyin, ed. *Cognitive Radio, Software Defined Radio, and Adaptive Wireless Systems*. Dordrecht: Springer, 2007.
3. Haykin, Simon. *Cognitive Radio: Brain-Empowered Wireless Communications*. IEEE Journal on Selected Areas in Communications, 2005.

Web Resources

1. Software Defined Radio with HackRF by Great Scott Gadgets Link: *https://greatscottgadgets.com/sdr/*
2. Introduction to GNU Radio by GNU Radio Project Link: *https://wiki.gnuradio.org/index.php/Tutorials*

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PSO1	PSO2	PSO3
CO1	3	2	2	1	2	-	3	3	2	2
CO2	3	3	3	1	2	-	3	3	2	2
CO3	3	3	3	2	2	1	3	3	3	2
CO4	3	2	2	2	2	3	2	3	2	2
CO5	2	3	3	2	3	1	3	3	3	2

Course code	Course Name	Periods			Credits	Total Hours
		L	T	P		
25PECL07	RF SYSTEM DESIGN	2	1	0	**3**	**45**

Preamble/ Course Objective

• To provide comprehensive knowledge of RF system design including passive components analysis, RF circuits design, power amplifiers, and frequency synthesis techniques for modern wireless communication applications

Prerequisite

Knowledge of electronic circuits, electromagnetic theory, and high-frequency circuit analysis.

Course Outcome

On the successful completion of the course, students will be able to

COs	Course Outcome	Bloom's Taxonomy Level
CO1	Analyze RF passive components and apply transmission line theory including Smith chart applications for impedance matching and SWR calculations.	**Analyze**
CO2	Design RF amplifiers, oscillators, and mixers with appropriate stability considerations and performance optimization techniques.	**Create**
CO3	Evaluate RF feedback systems and design various classes of power amplifiers with linearization and efficiency enhancement techniques.	**Evaluate**
CO4	Design phase-locked loops and frequency synthesizers for RF applications including noise analysis and performance optimization.	**Create**
CO5	Simulate and analyze RF circuits including amplifiers, oscillators, and mixers using modern CAD tools for practical applications.	**Create**

Syllabus

Module I: RF Passive Components and Transmission Line Analysis 9 Hours

High Frequency Components: Resistors- capacitors and inductors; Transmission line analysis - line equation - microstrip line - SWR - voltage reflection co-efficient - propagation constant - phase constant - phase velocity - Smith chart - parallel RL and RC circuits - ABCD parameters and S parameters.

Module II: RF Devices and Circuits 9 Hours

RF amplifier design- power gain equations - maximum gain design, low noise amplifier design, high power amplifier design- stability considerations; RF oscillator design - one - port and two - port negative resistance oscillators - oscillator design using large - signal measurements; RF Mixer Design: Single ended mixer - double ended mixer.

Module III: RF Feedback Systems and Power Amplifiers **9 Hours**

Stability of feedback systems: Gain and phase margin - root - locus techniques - time and frequency domain considerations - compensation; General model - Class A, AB, B, C, D, E and F amplifiers - power amplifier linearization techniques - efficiency boosting techniques - ACPR metric- design considerations.

Module IV: PLL and Frequency Synthesizers **9 Hours**

Linearised model - noise properties - phase detectors - loop filters and charge pumps – integer - N frequency synthesizers - direct digital frequency synthesizers.

Module V: Instructional Activities **9 Hours**

Simulation of the frequency response of amplifier, oscillator and mixer for different applications using related tools.

Textbooks

1. Pozar, David M. *Microwave Engineering*. 4th ed. New York: John Wiley & Sons, 2012.
2. Lee, Thomas H. *The Design of CMOS Radio-Frequency Integrated Circuits*. 2nd ed. Cambridge: Cambridge University Press, 2004.

Reference Books

1. Gonzalez, Guillermo. *Microwave Transistor Amplifiers: Analysis and Design*. 2nd ed. Upper Saddle River: Prentice Hall, 1997.
2. Razavi, Behzad. *RF Microelectronics*. 2nd ed. Boston: Prentice Hall, 2012.
3. Bowick, Chris, John Blyler, and Cheryl Ajluni. *RF Circuit Design*. 2nd ed. Burlington: Newnes, 2008.

Web Resources

1. RF and Microwave Circuit Design by University of Colorado Boulder (Coursera) Link: *https://www.coursera.org/learn/rf-microwave-circuit-design*
2. Introduction to RF and Microwave Design by MIT OpenCourseWare Link: *https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-013-electromagnetics-and-applications-spring-2009/*

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PSO1	PSO2	PSO3
CO1	3	2	3	1	1	-	2	3	2	3
CO2	3	3	3	1	2	1	2	3	2	3
CO3	3	3	3	1	2	1	2	3	2	3
CO4	3	3	3	1	2	1	3	3	2	3
CO5	2	3	3	2	3	1	3	3	2	3

Course code	Course Name	Periods			Credits	Total Hours
25PECL08	CELLULAR & IoT	**L**	**T**	**P**	**3**	**45**
		2	**1**	**0**		

Preamble/ Course Objective

• To provide comprehensive understanding of cellular network evolution, Internet of Things architectures, integration of cellular technologies with IoT systems, and emerging applications in smart cities and Industry 4.0

Prerequisite

Knowledge of wireless communication systems, networking protocols, and basic understanding of mobile communication principles.

Course Outcome

On the successful completion of the course, students will be able to

COs	Course Outcome	Bloom's Taxonomy Level
CO1	Analyze the evolution of cellular networks from 2G to 5G and evaluate their capabilities for supporting diverse IoT applications.	**Analyze**
CO2	Design IoT system architectures using various communication protocols and assess their integration with cellular infrastructure.	**Create**
CO3	Apply cellular IoT technologies including NB-IoT, LTE-M, and 5G IoT for massive machine-type communications and critical applications.	**Apply**
CO4	Evaluate security challenges in cellular IoT networks and implement appropriate security mechanisms for IoT deployments.	**Evaluate**
CO5	Simulate cellular IoT networks and analyze their performance for smart city and industrial IoT applications using modern tools.	**Create**

Syllabus

Module I: Cellular Network Evolution and IoT Fundamentals 9 Hours

Cellular network evolution: 2G, 3G, 4G LTE, and 5G technologies - comparison of cellular generations - spectrum allocation and reuse; Introduction to Internet of Things: IoT definition, characteristics, and applications - IoT ecosystem and value chain - IoT device categories and requirements; Convergence of cellular and IoT: Mobile IoT market drivers - cellular IoT use cases - smart cities, industrial IoT, and connected vehicles.

Module II: IoT Communication Technologies and Protocols 9 Hours

IoT communication protocols: Short-range protocols (WiFi, Bluetooth, Zigbee) - long-range protocols (LoRaWAN, Sigfox) - cellular IoT protocols; Network layer protocols: IPv6, 6LoWPAN, RPL routing - application layer protocols (CoAP, MQTT, HTTP/2); IoT network architectures: Three-tier architecture - fog computing and edge computing - cloud integration and data analytics.

Module III: Cellular IoT Technologies **9 Hours**

LTE-Advanced for IoT: LTE-M (eMTC) architecture and features - coverage enhancement techniques - power saving mechanisms; NB-IoT (Narrowband IoT): System architecture - physical layer design - MAC and RRC protocols - deployment scenarios; 5G IoT and mMTC: Ultra-reliable low-latency communications (URLLC) - massive machine-type communications - network slicing for IoT applications.

Module IV: Cellular IoT Security and Management **9 Hours**

IoT security challenges: Device authentication and authorization - data encryption and integrity - key management systems; Cellular IoT security mechanisms: SIM-based security - bootstrapping and provisioning - end-to-end security architectures; IoT device management: Over-the-air updates - remote configuration - device lifecycle management - energy management and battery optimization.

Module V: Instructional Activities **9 Hours**

Simulation and analysis: Cellular IoT network performance evaluation - NB-IoT vs LTE-M comparison - smart city IoT deployment scenarios - industrial IoT use case simulations - energy consumption analysis for cellular IoT devices using related tools.

Textbooks

1. Dahlman, Erik, Stefan Parkvall, and Johan Skold. 5G NR: The Next Generation Wireless Access Technology. 2nd ed. Amsterdam: Academic Press, 2021.

2. McEwen, Adrian, and Hakim Cassimally. Designing the Internet of Things. Chichester: John Wiley & Sons, 2014.

Reference Books

1. Ratasuk, Rapeepat, Benny Vejlgaard, Niels Mangalvedhe, and Amitava Ghosh. NB-IoT System for M2M Communication. In 2016 IEEE Wireless Communications and Networking Conference. Piscataway: IEEE, 2016.

2. Palattella, Maria Rita, Mischa Dohler, Alfredo Grieco, Gianluca Rizzo, Johan Torsner, Thomas Engel, and Latif Ladid. Internet of Things in the 5G Era: Enablers, Architecture, and Business Models. IEEE Journal on Selected Areas in Communications, 2016.

3. Cisco Systems. Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2017–2022. San Jose: Cisco Public Information, 2019.

Web Resources

1. Introduction to the Internet of Things and Embedded Systems by University of California, Irvine (Coursera) Link: *https://www.coursera.org/learn/iot*

2. 5G for Everyone by University of California San Diego (edX) Link: *https://www.edx.org/course/5g-for-everyone*

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PSO1	PSO2	PSO3
CO1	3	2	2	1	2	-	3	3	2	2
CO2	3	3	3	2	2	2	3	3	2	3
CO3	3	2	3	2	2	1	3	3	2	2
CO4	2	2	2	2	2	3	2	3	2	2
CO5	2	3	3	2	3	1	3	3	2	3

Course code	Course Name	Periods			Credits	Total Hours
		L	**T**	**P**		
25PECL09	mmWAVE & MIMO	**2**	**1**	**0**	**3**	**45**

Preamble/ Course Objective

• To provide comprehensive understanding of millimeter wave communication systems, MIMO technology principles, massive MIMO systems, and their integration for 5G/6G wireless communications

Prerequisite

Knowledge of wireless communication systems, antenna theory, and signal processing fundamentals.

Course Outcome

On the successful completion of the course, students will be able to

	Course Outcome	Bloom's Taxonomy Level
CO1	Analyze mmWave propagation characteristics, atmospheric effects, and evaluate channel models for millimeter wave communication systems.	**Analyze**
CO2	Design MIMO systems including spatial diversity, spatial multiplexing, and assess capacity enhancement techniques for wireless communications.	**Create**
CO3	Implement beamforming algorithms for mmWave systems and analyze massive MIMO architectures for 5G applications.	**Apply**
CO4	Evaluate hybrid analog-digital beamforming techniques and design mmWave MIMO transceivers for high data rate applications.	**Evaluate**
CO5	Simulate mmWave MIMO systems including channel modeling, beamforming algorithms, and performance analysis using advanced simulation tools.	**Create**

Syllabus

Module I: mmWave Communication Fundamentals **9 Hours**

Introduction to mmWave communications: Spectrum allocation and characteristics - frequency bands (28 GHz, 39 GHz, 60 GHz, 73 GHz) - advantages and challenges; mmWave propagation: Path loss models - atmospheric absorption - rain attenuation - oxygen absorption - diffraction and scattering effects; Channel characteristics: Line-of-sight and non-line-of-sight propagation - multipath fading - Doppler effects - channel coherence time and bandwidth.

Module II: MIMO System Fundamentals **9 Hours**

MIMO system principles: Spatial diversity and spatial multiplexing - MIMO channel capacity - water-filling algorithm - singular value decomposition; MIMO detection algorithms: Maximum likelihood detection - zero-forcing - MMSE detection - sphere decoding; Space-time coding: Alamouti scheme - space-time block codes - space-time trellis codes - performance analysis in fading channels.

Module III: Massive MIMO and Beamforming **9 Hours**

Massive MIMO systems: Large-scale antenna arrays - channel hardening - pilot contamination

- asymptotic analysis; Beamforming techniques: Analog beamforming - digital beamforming - hybrid beamforming architectures; Precoding and combining: Linear precoding techniques - nonlinear precoding - interference alignment - coordinated multipoint transmission.

Module IV: mmWave MIMO Systems 9 Hours

mmWave MIMO architectures: Antenna array design for mmWave - RF front-end considerations - power consumption issues; Hybrid analog-digital beamforming: Architecture design - codebook-based beamforming - adaptive beamforming algorithms; mmWave MIMO challenges: Hardware impairments - phase noise effects - beam alignment and tracking - mobility management.

Module V: Instructional Activities 9 Hours

Simulation and analysis: mmWave channel modeling and simulation - MIMO capacity analysis - beamforming algorithm implementation - massive MIMO performance evaluation - hybrid beamforming system design using MATLAB, Python, and specialized tools.

Textbooks

1. Tse, David, and Pramod Viswanath. Fundamentals of Wireless Communication. Cambridge: Cambridge University Press, 2005.

2. Larsson, Erik G., and Pei-Jung Chung. MIMO Detection Methods: How They Work. Cambridge: Cambridge University Press, 2015.

Reference Books

1. Heath, Robert W., Nuria González-Prelcic, Sundeep Rangan, Wonil Roh, and Akbar M. Sayeed. An Overview of Signal Processing Techniques for Millimeter Wave MIMO Systems. IEEE Journal of Selected Topics in Signal Processing, 2016.

2. Björnson, Emil, Jakob Hoydis, and Luca Sanguinetti. Massive MIMO Networks: Spectral, Energy, and Hardware Efficiency. Foundations and Trends in Signal Processing, 2017.

3. Rappaport, Theodore S., Shu Sun, Rimma Mayzus, Hang Zhao, Yaniv Azar, Kevin Wang, George N. Wong, Jocelyn K. Schulz, Mathew Samimi, and Felix Gutierrez.

Millimeter Wave Mobile Communications for 5G Cellular: It Will Work! IEEE Access, 2013.

Web Resources

1. 5G Technology Fundamentals by Qualcomm (edX)
2. Link: https://www.edx.org/course/5g-technology-fundamentals

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PSO1	PSO2	PSO3
CO1	**3**	2	2	1	2	-	2	**3**	**3**	2
CO2	**3**	**3**	**3**	1	2	1	2	**3**	**3**	2
CO3	**3**	**3**	**3**	2	2	1	**3**	**3**	**3**	2
CO4	**3**	**3**	**3**	2	2	1	**3**	**3**	**3**	**3**
CO5	2	**3**	**3**	2	**3**	1	**3**	**3**	**3**	2

Course code	Course Name	Periods			Credits	Total Hours
		L	T	P		
25PECL10	ULTRA WIDEBAND COMMUNICATION SYSTEMS	2	1	0	3	45

Preamble/ Course Objective

• To provide comprehensive understanding of ultra wideband communication systems, UWB signal generation and processing, channel modeling techniques, and UWB antenna design for high data rate wireless applications

Prerequisite

Knowledge of wireless communication systems, electromagnetic wave propagation, and antenna theory.

Course Outcome

On the successful completion of the course, students will be able to

	Course Outcome	Bloom's Taxonomy Level
CO1	Analyze UWB signal characteristics, spectral properties, and evaluate multipath propagation effects for UWB communication system design.	**Analyze**
CO2	Design UWB pulse generation circuits and apply various modulation schemes for UWB transmitter and receiver systems.	**Create**
CO3	Implement UWB channel models including path loss analysis and evaluate MIMO techniques for UWB system performance enhancement.	**Apply**
CO4	Design UWB antennas and filters considering radiation characteristics, beamforming techniques, and positioning applications.	**Create**
CO5	Simulate UWB communication systems including pulse generation, channel modeling, and antenna performance using electromagnetic simulation tools.	**Create**

Syllabus

Module I: UWB Signals and Systems **9 Hours**

Introduction: Comparison of UWB with other wideband communication system - power spectral density - pulse shape - pulse trains - UWB spectrum and spectral masks - multipath and penetration characteristics - spatial and spectral capacities - speed of data transmission - Gaussian waveforms - designing waveforms for specific spectral masks - practical constraints and effects of imperfections - applications of UWB systems.

Module II: UWB Pulse Generation and Processing **9 Hours**

UWB signal generation: UWB modulation schemes - transmitter and receiver - multiple access techniques - capacity - interference and coexistence of UWB with other systems - Hermite pulses - Orthogonal prolate spheroidal wave functions - wavelet packets in UWB PSM - signal processing: effects of a lossy medium on a UWB transmitted signal - time domain analysis - frequency domain techniques.

Module III: UWB Channel Modeling **9 Hours**

IEEE proposals for UWB channel models - simplified UWB multipath channel model - path loss model - two-ray UWB propagation model - frequency domain autoregressive model - MIMO for UWB systems - self interference in high data-rate UWB communications - coexistence of UWB with WIMAX and other short range wireless radios.

Module IV: UWB Antennas and Filters **9 Hours**

Antenna fundamentals - antenna radiation for UWB signals - conventional antennas and impulse antennas for UWB systems - beam forming for UWB signals - UWB filters - prototype - characteristics - filtering techniques - wireless positioning and location - GPS techniques - positioning techniques - time resolution issues - UWB positioning and communications.

Module V: Instructional Activities **9 Hours**

Simulation of UWB: Pulse generation and processing - channel modeling - antennas using EM - MIMO for UWB systems using related tools.

Textbooks:

1. Ghavami, Mohammad, Lain B. Michael, and Ryuji Kohno. *Ultra Wideband Signals and Systems in Communication Engineering*. 2nd ed. New York: John Wiley & Sons, 2007.
2. Arslan, Huseyin, Zhi Ning Chen, and Maria-Gabriella Di Benedetto, eds. *Ultra Wideband Wireless Communication*. New York: John Wiley & Sons, 2006.

Reference Books:

1. Benedetto, Maria-Gabriella Di, and Guerino Giancola. *Understanding Ultra Wide Band Radio Fundamentals*. Upper Saddle River: Prentice Hall, 2004.
2. Aiello, G. Roberto, and Anuj Batra. *Ultra Wideband Systems: Technologies and Applications*. Amsterdam: Newnes, 2006.
3. Fontana, Robert J., and Edward A. Richley. *Observations on Low Data Rate, Short Pulse UWB Systems*. IEEE Press, 2003.

Web Resources:

1. Ultra Wide Band Communication *http://nptel.ac.in/courses/117106078/*
2. Wireless Communication *http://nptel.ac.in/courses/117104117/*

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PSO1	PSO2	PSO3
CO1	3	2	2	1	2	-	2	3	2	2
CO2	3	3	3	1	2	1	2	3	2	3
CO3	3	2	3	1	2	-	2	3	3	2
CO4	3	3	3	1	2	1	3	3	2	3
CO5	2	3	3	2	3	1	3	3	2	3

Course code	Course Name	Periods			Credits	Total Hours
		L	T	P		
25PECL11	ADVANCED MICROCONTROLLER AND ITS APPLICATIONS	2	1	0	3	45

Preamble/ Course Objective

• To provide comprehensive understanding of advanced microcontroller architectures including 8051, PIC, and ARM processors with embedded C programming and interfacing techniques for real-world applications

Prerequisite

Knowledge of digital electronics, basic microprocessor concepts, and fundamental programming skills in C language.

Course Outcome

On the successful completion of the course, students will be able to

	Course Outcome	Bloom's Taxonomy Level
CO1	Analyze 8051 microcontroller architecture and implement assembly language programming for various interfacing applications including sensors and communication systems.	**Analyze**
CO2	Apply embedded C programming concepts including data types, control structures, and functions for microcontroller-based system development.	**Apply**
CO3	Design programs for PIC 18F family microcontrollers using instruction set architecture and implement timer, counter, and subroutine applications.	**Create**
CO4	Evaluate ARM processor fundamentals and implement ARM assembly programming with exception handling and interrupt processing techniques.	**Evaluate**
CO5	Create integrated embedded systems by interfacing various peripheral devices with microcontrollers using embedded C programming for practical applications.	**Create**

Syllabus

Module I: Introduction to 8051 Microcontroller and its Architecture 9 Hours

Introduction to 8051 microcontroller: pin diagram - block diagram - on-chip internal memory (RAM, ROM) - counters - watch dog timer and its applications - instruction set - UART - assembly language programming from simple to interfacing of ADC / DAC - stepper motors - keyboard - sensors - serial data communication.

Module II: Programming of 8051 in Embedded C 9 Hours

Date types in embedded C - arithmetic and logical operators - control statements and loops in embedded C - functions and arrays in embedded C.

Module III: PIC 18F Family **9 Hours**

Introduction to PIC 18F: Architecture - programming model - instruction set - simple programming using data transfer - arithmetic and logical instructions - programming on stack - loop instructions and subroutines - programming on timers and counters.

Module IV: ARM Architectures **9 Hours**

Introduction to ARM: ARM processor fundamentals - ARM instruction set - thumb instruction set - writing and optimizing ARM assembly code - exception and interrupt handling.

Module V: Instructional Activities **9 Hours**

Interfacing of memory and I/O devices with ARM/ PIC using embedded C programming: Keyboard - servo motor - stepper motor - sensors - ADC/DAC - display devices.

Textbooks

1. Ghavami, Mohammad, Lachlan B. Michael, and Ryuji Kohno. *Ultra Wideband Signals and Systems in Communication Engineering*. 2nd ed. Chichester: John Wiley & Sons, 2007.
2. Arslan, Hüseyin, Zhi Ning Chen, and Maria-Gabriella Di Benedetto, eds. *Ultra Wideband Wireless Communication*. Hoboken: John Wiley & Sons, 2006.

Reference Books

1. Reed, Jeffrey H., ed. *An Introduction to Ultra Wideband Communication Systems*. Upper Saddle River: Prentice Hall PTR, 2005.
2. Oppermann, Ian, Matti Hämäläinen, and Jari Iinatti, eds. *UWB: Theory and Applications*. Chichester: John Wiley & Sons, 2004.
3. Fontana, Robert J., Edward Richley, and John Barney. *Commercialization of an Ultra Wideband Precision Asset Location System*. In *IEEE Conference on Ultra Wideband Systems and Technologies*. Piscataway: IEEE, 2003.

Web Resources:

1. Ultra-Wideband Communications by IEEE Education Society Link: *https://www.ieee.org/education/continuing-education/course-catalog.html*
2. Advanced Wireless Communications by MIT OpenCourseWare Link: *https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-452-principles-of-wireless-communications-spring-2006/*

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PSO1	PSO2	PSO3
CO1	2	3	3	1	1	1	2	2	1	3
CO2	2	3	3	2	1	1	2	2	2	3
CO3	3	3	3	1	2	1	2	2	1	3
CO4	3	2	3	1	2	1	3	2	1	3
CO5	2	3	3	2	3	2	2	2	2	3

Course code	Course Name	Periods			Credits	Total Hours
		L	T	P		
25PECL12	AUTOMATED EMBEDDED SYSTEMS	2	1	0	3	45

Preamble/ Course Objective

• To provide comprehensive understanding of automated embedded systems design, control algorithms, sensor integration, and artificial intelligence techniques for developing autonomous and self-adaptive embedded systems for industrial and consumer applications

Prerequisite

Knowledge of embedded systems, control theory, sensors and actuators, and programming skills in C/C++.

Course Outcome

On the successful completion of the course, students will be able to

COs	Course Outcome	Bloom's Taxonomy Level
CO1	Analyze automation requirements and design embedded system architectures for autonomous operation in various application domains.	**Analyze**

CO2	Apply control algorithms and feedback systems in embedded platforms for precise automation and process control applications.	**Apply**
CO3	Integrate multiple sensors and actuators with embedded systems to create intelligent automation solutions with decision-making capabilities.	**Apply**
CO4	Implement machine learning and AI algorithms on embedded platforms for adaptive and self-learning automated systems.	**Apply**
CO5	Create complete automated embedded systems for industrial automation, robotics, and smart home applications with performance optimization.	**Create**

Syllabus

Module I: Fundamentals of Automated Embedded Systems 9 Hours

Introduction to automation and embedded systems - automation levels and classifications - distributed control systems - SCADA and HMI systems - embedded automation architecture - real-time requirements - fault tolerance and reliability - system specification and modeling for automation.

Module II: Control Algorithms and Implementation 9 Hours

Digital control theory for embedded systems - PID controller implementation - adaptive control algorithms - fuzzy logic control - model predictive control - state-space control methods - control loop tuning and optimization - embedded control software architecture.

Module III: Sensor Integration and Data Fusion 9 Hours

Multi-sensor systems for automation - sensor calibration and characterization - data acquisition and preprocessing - sensor fusion algorithms - Kalman filtering - machine vision integration - wireless sensor networks - IoT integration for automated systems.

Module IV: Intelligent and Adaptive Systems 9 Hours

Embedded artificial intelligence - machine learning on microcontrollers - neural networks for embedded systems - decision trees and expert systems - pattern recognition in automation - self-adaptive systems - edge computing for automation - predictive maintenance algorithms.

Module V: Instructional Activities 9 Hours

Design and implementation of automated systems: Industrial process control - autonomous robotics - smart building automation - agricultural automation - automotive embedded systems - performance analysis and optimization using simulation and development tools.

Textbooks

1. Boukas, El-Kébir, and Qing Zhang. *Embedded Control Systems: Theory and Design with Applications*. 2nd ed. New York: Springer, 2019.

2. **2.** Saha, Anjan Kumar, and Sudip Kumar Sahana. *Machine Learning Algorithms for Industrial Applications*. Switzerland: Springer, 2021.

Reference Books

1. Astrom, Karl Johan, and Björn Wittenmark. *Computer-Controlled Systems: Theory and Design*. 3rd ed. Upper Saddle River, NJ: Prentice Hall, 1997.

2. Hall, David L., and James Llinas. *Handbook of Multisensor Data Fusion: Theory and Practice*. 2nd ed. Boca Raton, FL: CRC Press, 2009.

3. Zurawski, Richard. *Industrial Communication Systems*. In *The Industrial Electronics*

Handbook. 2nd ed. Boca Raton, FL: CRC Press, 2011.

Web Resources

1. Control System Design - MIT OpenCourseWare https://ocw.mit.edu/courses/2-14-analysis-and-design-of-feedback-control-systems-spring-2014/

2. Introduction to Embedded Systems - UC Berkeley *https://ptolemy.berkeley.edu/books/leeseshia/*

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PSO1	PSO2	PSO3
CO1	3	3	2	2	2	2	2	2	2	3
CO2	3	3	3	1	2	1	2	2	3	3
CO3	3	3	3	2	2	1	2	2	3	3
CO4	3	3	3	2	2	1	3	2	3	3
CO5	3	3	3	3	3	2	3	3	3	3

Course code	Course Name	Periods			Credits	Total Hours
		L	**T**	**P**		
25PECL13	MEDICAL DEVICE EMBEDDED SYSTEMS	**2**	**1**	**0**	**3**	**45**

Preamble/ Course Objective

• To provide comprehensive understanding of embedded systems design for medical devices, including regulatory compliance, safety standards, signal processing for biomedical applications, and implementation of reliable and secure medical embedded systems

Prerequisite

Knowledge of embedded systems, biomedical engineering basics, signal processing, and understanding of electronic circuits.

Course Outcome

On the successful completion of the course, students will be able to

COs	Course Outcome	Bloom's Taxonomy Level
CO1	Analyze medical device requirements and evaluate regulatory standards for designing compliant embedded medical systems.	**Analyze**
CO2	Apply biomedical signal processing techniques on embedded platforms for patient monitoring and diagnostic applications.	**Apply**
CO3	Design safety-critical embedded systems for medical devices considering fault tolerance, redundancy, and fail-safe mechanisms.	**Create**
CO4	Implement wireless communication and data security protocols for connected medical devices and telemedicine applications.	**Apply**
CO5	Create complete medical device prototypes including hardware design, software development, and regulatory compliance documentation.	**Create**

Syllabus

Module I: Medical Device Regulations and Standards 9 Hours

Introduction to medical device classification - FDA regulations and CE marking - IEC 60601 safety standards - ISO 13485 quality management - IEC 62304 medical device software lifecycle - risk management (ISO 14971) - cybersecurity for medical devices - clinical evaluation and validation.

Module II: Biomedical Signal Processing on Embedded Systems 9 Hours

Biomedical signals (ECG, EEG, EMG, SpO2) - signal conditioning and amplification - analog-to-digital conversion - digital filtering techniques - artifact removal - feature extraction algorithms - real-time signal processing on microcontrollers - low-power signal processing techniques.

Module III: Safety-Critical Design and Reliability 9 Hours

Safety-critical system design principles - hazard analysis and risk assessment - fault detection and diagnostic systems - redundancy and fail-safe mechanisms - medical device software architecture - verification and validation methods - electromagnetic compatibility (EMC) considerations.

Module IV: Connected Medical Devices and Security 9 Hours

Wireless communication in medical devices - Bluetooth Medical Device Profile - security threats and vulnerabilities - encryption and authentication - HIPAA compliance - remote monitoring systems - cloud integration - interoperability standards (HL7, FHIR).

Module V: Instructional Activities 9 Hours

Medical device development projects: Patient monitoring system design - portable diagnostic devices - implantable device programming - telemedicine platform development - regulatory compliance case studies - performance testing and validation using development tools and medical simulators.

Textbooks

1. Fries, Richard C. Reliable Design of Medical Devices. 3rd ed. Boca Raton, FL: CRC Press, 2012.

2. Bronzino, Joseph D., and Donald R. Peterson. Biomedical Engineering Fundamentals. 4th ed. Boca Raton, FL: CRC Press, 2015.

Reference Books

1. Khandpur, R. S. Handbook of Biomedical Instrumentation. 3rd ed. New Delhi: McGraw-Hill Education, 2014.

2. Spaan, Jos A. E., Nico Westerhof, Hans Stergiopulos, and Nikos Stergiopulos. Medical Device Regulations: Global Overview and Guiding Principles. Amsterdam: Academic Press, 2019.

3. Webster, John G., and Amit J. Nimunkar. Medical Instrumentation: Application and Design. 5th ed. Hoboken, NJ: John Wiley & Sons, 2020.

Web Resources

1. Introduction to Biomedical Engineering - MIT OpenCourseWare

https://ocw.mit.edu/courses/hst-190-introduction-to-bioinformatics-and-computational-biology-fall-2021/

2. Medical Device Development - FDA Training Courses

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PSO1	PSO2	PSO3
CO1	3	2	2	2	2	3	2	2	2	3
CO2	3	3	3	1	2	2	2	2	3	3
CO3	3	3	3	2	2	3	2	2	2	3
CO4	3	3	3	2	2	3	3	3	2	3
CO5	3	3	3	3	3	3	2	2	3	3

Course code	Course Name	Periods			Credits	Total Hours
		L	T	P		
25PECL14	EMBEDDED REAL TIME SYSTEM	2	1	0	3	45

Preamble/ Course Objective

• To provide comprehensive understanding of embedded real-time systems, system-on-chip platforms, communication interfaces, and RTOS programming for modern embedded applications

Prerequisite

Knowledge of microcontrollers, embedded programming, and real-time system concepts.

Course Outcome

COs	Course Outcome	Bloom's Taxonomy Level
CO1	Analyze embedded automatic systems architecture and evaluate processor, memory, and interconnect components for system-on-chip designs.	**Analyze**
CO2	Apply various embedded platforms including Arduino, BeagleBone, and Raspberry Pi for different application requirements.	**Apply**
CO3	Implement communication interfaces and utilize Python programming for embedded system development and control applications.	**Apply**
CO4	Design RTOS-based applications using tasks, semaphores, message queues, and interrupt handling for real-time embedded systems.	**Create**
CO5	Create integrated embedded systems for practical applications including RFID systems, video processing, and home automation.	**Create**

Syllabus

Module I: Introduction to Embedded Automatic Systems (9 Hours) Embedded Automatic Systems (EAC): Overview - architecture; Components of the system: Processors-memories and interconnects - processor architectures - memory and addressing: SOC memory examples - addressing.

Module II: SOC (9 Hours) Introduction to Arduino: Types of Arduino devices - common Arduino shields - Beagle Bone; Introduction to Raspberry Pi

Module III: Communication Interfaces and Python Basics (9 Hours) Communication interfaces: I2C- SPI Bus- UART- RS-232- RS-485- USB- IEEE 139.4 (Firewire) - Infrared

(IRDA) - Bluetooth - Wi-Fi - ZigBee – GPRS; Python basics: Introduction - variables - displaying output - reading user input - arithmetic - operations on strings - running commands conditionally - comparing values - logical operators- loops.

Module IV: RTOS Programming (9 Hours) Tasks and Task states - semaphores - shared data - message queues - mail boxes and pipes - memory management - interrupt routines - encapsulating semaphore and queues - task management - inter task communication - process input/ output.

Module V: Instructional Activities (9 Hours) RFID based attendance management system - embedded video processing - home automation systems using Raspberry Pi/ Arduino /any other SOC.

Textbooks

1. Wolf, Wayne H. Computers as Components: Principles of Embedded Computing System Design. 4th ed. Burlington: Morgan Kaufmann, 2017.
2. Barr, Michael, and Anthony Massa. Programming Embedded Systems: With C and GNU Development Tools. 2nd ed. Sebastopol: O'Reilly Media, 2006.

Reference Books

1. Labrosse, Jean J. MicroC/OS-II: The Real-Time Kernel. 2nd ed. Gilroy: CMP Books, 2002.
2. Upton, Eben, and Gareth Halfacree. Raspberry Pi User Guide. 4th ed. Indianapolis: John Wiley & Sons, 2016.
3. Margolis, Michael. Arduino Cookbook: Recipes to Begin, Expand, and Enhance Your Projects. 3rd ed. Sebastopol: O'Reilly Media, 2020.

Web Resources:

1. Introduction to Embedded Systems Software and Development Environments by University of Colorado Boulder (Coursera)
2. Link: https://www.coursera.org/learn/introduction-embedded-systems

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PSO1	PSO2	PSO3
CO1	3	2	2	1	2	1	2	2	3	2
CO2	3	3	3	2	3	2	3	2	3	3
CO3	3	3	3	2	3	2	3	3	3	3
CO4	3	3	3	3	3	3	3	3	3	3
CO5	2	3	3	3	3	2	3	3	3	3

Course code	Course Name	Periods			Credits	Total Hours
		L	T	P		
25PECL15	INTERNET OF EVERY THINGS (IoET)	2	1	0	3	45

Preamble/ Course Objective

• To provide comprehensive understanding of Internet of Everything (IoE) architectures, sensor technologies, security mechanisms, and practical implementation for next-generation connected systems

Prerequisite

Knowledge of networking protocols, embedded systems, and wireless communication technologies.

Course Outcome

COs	Course Outcome	Bloom's Taxonomy Level
CO1	Analyze IoT and M2M architectural principles and evaluate design standards for scalable connected systems.	**Analyze**
CO2	Design IoE sensor systems with appropriate wireless structures, energy management, and RF communication modules.	**Create**
CO3	Assess security requirements and implement authentication, authorization, and access control mechanisms for IoE applications.	**Evaluate**
CO4	Apply IoE testbed technologies including various sensor platforms and wearable electronics for practical implementations.	**Apply**
CO5	Create comprehensive IoE applications integrating sensors, embedded systems, and communication technologies for real-world scenarios.	**Create**

Syllabus

Module I: Introduction (9 Hours) IoT: Architectural overview - main design principles - standards considerations; M2M and IoT technology fundamentals: devices and gateways - data management - business processes in IoT - everything as a service - M2M and IoT analytics - knowledge management.

Module II: IoE Sensors (9 Hours) Sensors for IoE: Wireless sensor structure - energy storage module - power management module - RF Module - sensing module.

Module III: IoE Security (9 Hours) Security requirements in IoE architecture - security in enabling technologies - security concerns in IoE applications: Architecture - insufficient authentication/authorization - insecure access control - threats to access control, privacy, and availability - attacks specific to IoE.

Module IV: IoE Testbed (9 Hours) ACOEM Eagle - EnOcean Push Button - NEST sensor - Ninja blocks focus on wearable electronics.

Module V: Instructional Activities (9 Hours) Simulation of (minimum of any five) IoE applications - home and office infrastructures - security - home appliances and other IoE electronic equipment- interfacing of sensor with sensor node using any embedded target boards (Raspberry Pi / Intel Galileo/ARM Cortex/ Arduino).

Textbooks:

1. Buyya, Rajkumar, and Amir Vahid Dastjerdi, eds. Internet of Things: Principles and Paradigms. Cambridge: Morgan Kaufmann, 2016.
2. Patel, Kiran, and Sunil Patel. Internet of Things-IOT: Definition, Characteristics, Architecture, Enabling Technologies, Application & Future Challenges. International Journal of Engineering Science and Computing, 2016.

Reference Books:

1. Greengard, Samuel. The Internet of Things. Cambridge: MIT Press, 2015.
2. Miller, Michael. The Internet of Things: How Smart TVs, Smart Cars, Smart Homes, and Smart Cities Are Changing the World. Indianapolis: Que Publishing, 2015.
3. Cisco Systems. Internet of Everything: A $4.6 Trillion Public-Sector Opportunity. San Jose: Cisco Public Information, 2013.

Web Resources

1. Introduction to the Internet of Things and Embedded Systems by University of California, Irvine (Coursera) Link: *https://www.coursera.org/learn/iot*
2. IoT Sensors and Devices by University of California San Diego (Coursera) Link: *https://www.coursera.org/learn/iot-sensors-devices*

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PSO1	PSO2	PSO3
CO1	3	2	2	1	2	1	2	2	3	2
CO2	3	3	3	2	3	2	3	2	3	3
CO3	3	3	3	2	3	2	3	3	3	3
CO4	3	3	3	3	3	3	3	3	3	3
CO5	2	3	3	3	3	2	3	3	3	3

Course code	Course Name	Periods			Credits	Total Hours
		L	T	P		
25PECL16	SYSTEM ON CHIP (SOC)	2	1	0	3	45

Preamble/ Course Objective

• To provide comprehensive understanding of System-on-Chip design methodologies, integration techniques, verification approaches, and implementation strategies for complex integrated systems

Prerequisite

Knowledge of digital VLSI design, computer architecture, and HDL programming.

Course Outcome

COs	Course Outcome	Bloom's Taxonomy Level
CO1	Analyze SoC architecture and design challenges including integration of heterogeneous components and system-level optimization.	**Analyze**
CO2	Design on-chip communication architectures including buses, networks-on-chip, and memory hierarchies for SoC applications.	**Create**
CO3	Apply hardware-software co-design techniques and evaluate partitioning strategies for optimal SoC implementation.	**Apply**
CO4	Implement SoC verification and testing methodologies including functional verification and design-for-test techniques.	**Apply**
CO5	Create complete SoC designs integrating processors, memories, and IP blocks using modern EDA tools and design flows.	**Create**

Syllabus

Module I: SoC Design Fundamentals (9 Hours) SoC overview and evolution - design challenges and constraints - system specification and modeling - performance analysis - power and area optimization - design methodology and flow.

Module II: SoC Architecture and Communication (9 Hours) SoC architecture design - processor selection and integration - on-chip buses (AMBA, Avalon) - network-on-chip design - memory hierarchy and cache design - DMA and interrupt controllers.

Module III: Hardware-Software Co-design (9 Hours) Co-design methodology - hardware-software partitioning - interface design - software development for SoCs - real-time operating systems - middleware and device drivers.

Module IV: SoC Verification and Testing (9 Hours) Verification planning and methodologies - functional verification - assertion-based verification - coverage analysis - system-level testing - design-for-test and built-in self-test.

Module V: Instructional Activities (9 Hours) SoC design projects using EDA tools -

processor integration and customization - on-chip communication implementation - verification and testing case studies - performance optimization techniques.

Textbooks:

1. Wolf, Wayne. *Modern VLSI Design: System-on-Chip Design*. 4th ed. Upper Saddle River: Pearson, 2009.
2. Chang, Kun-Cheng, and Youn-Long Steve Lin. *System-on-Chip Design and Test*. Boston: Artech House, 2005.

Reference Books:

1. Jerraya, Ahmed A., and Wayne Wolf, eds. *Multiprocessor Systems-on-Chips*. Amsterdam: Morgan Kaufmann, 2005.
2. Benini, Luca, and Giovanni De Micheli. *Networks on Chips: Technology and Tools*. Amsterdam: Morgan Kaufmann, 2006.
3. Pasricha, Sudeep, and Nikil Dutt. *On-Chip Communication Architectures: System on Chip Interconnect*. Amsterdam: Morgan Kaufmann, 2008.

Web Sources:

1. System on Chip Design *http://nptel.ac.in/courses/117106030/*
2. VLSI Design *http://nptel.ac.in/courses/117104120/*

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PSO1	PSO2	PSO3
CO1	3	2	3	2	1	2	1	2	3	2
CO2	3	3	2	3	2	2	2	2	3	3
CO3	2	3	3	2	3	2	2	3	3	3
CO4	3	2	3	3	2	3	2	3	3	3
CO5	2	3	2	3	3	2	3	3	3	3

Course code	Course Name	Periods			Credits	Total Hours
25PECL17	APPLICATION-SPECIFIC INTEGRATED CIRCUIT (ASIC)	L	T	P	3	45
		2	1	0		

Preamble/ Course Objective

• To provide comprehensive understanding of ASIC design methodologies, programmable logic devices, synthesis techniques, and physical design implementation for application-specific integrated circuits

Prerequisite

Knowledge of digital logic design, VLSI concepts, and hardware description languages.

Course Outcome

COs	Course Outcome	Bloom's Taxonomy Level
CO1	Analyze programmable logic devices and evaluate their features for implementing complex digital systems and ASIC prototyping.	**Analyze**
CO2	Apply ASIC design flow methodologies and compare different ASIC types including full-custom, semi-custom, and structured approaches.	**Apply**
CO3	Implement synthesis and simulation techniques for ASIC designs using HDL and evaluate logic synthesis optimization methods.	**Apply**
CO4	Design physical layouts using floor planning, placement, and routing techniques while considering timing and power constraints.	**Create**
CO5	Create complete ASIC implementations using FPGA platforms and analyze their performance characteristics using development tools.	**Create**

Syllabus

Module I: Introduction to Programmable Devices (9 Hours) Programmable logic devices: ROM - PLA - PAL - PLD - FPGA - features, programming and applications using complex programmable logic devices; Speed performance and system programmability.

Module II: Introduction to ASIC (9 Hours) Design flow - types of ASICs - full custom with ASIC - semi custom ASICs - standard cell based ASIC - gate array based ASIC - channeled – channel less - structured - data path elements - adders - multiplier - cell compilers; Logical effort: Area and efficiency - paths - multi stage cells - optimum delay.

Module III: Low Level Design Language (9 Hours) EDIF: PLA tools - introduction to CFI designs representation; Half gate ASIC: Introduction to synthesis and simulation - two level logic synthesis - high level logic synthesis - VHDL and logic synthesis - types of simulation -

boundary scan test - fault simulation - automatic test pattern generation.

Module IV: Floor Planning and Placement, and Routing (9 Hours) Physical design: CAD tools - system partitioning - estimating ASIC size - partitioning methods; Floor planning tools - I/O and power planning - clock planning - placement algorithms - iterative placement improvement; Time driven placement methods - physical design flow global routing - local routing - detail routing - special routing - circuit extraction and DRC.

Module V: Instructional Activities (9 Hours) Spartan 3E and Vertex Board Analysis - inputs and outputs - clock and power inputs - Xilinx I/O blocks - PLAs and PALs design using ASIC board.

Textbooks

1. Smith, Michael John Sebastian. Application-Specific Integrated Circuits. Boston: Addison-Wesley, 1997.
2. Brown, Stephen, and Zvonko Vranesic. Fundamentals of Digital Logic with VHDL Design. 3rd ed. New York: McGraw-Hill, 2009.

Reference Books

1. Weste, Neil H. E., and David Money Harris. CMOS VLSI Design: A Circuits and Systems Perspective. 4th ed. Boston: Addison-Wesley, 2011.
2. Maxfield, Clive. The Design Warrior's Guide to FPGAs: Devices, Tools and Flows. Burlington: Newnes, 2004.
3. Trimberger, Stephen M., ed. Field-Programmable Gate Array Technology. Boston: Kluwer Academic Publishers, 1994.

Web Resources:

1. FPGA Design for Embedded Systems by University of Colorado Boulder (Coursera)
2. Link: https://www.coursera.org/specializations/fpga-design

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PSO1	PSO2	PSO3
CO1	3	2	2	1	2	1	2	2	3	2
CO2	3	3	3	2	3	2	3	2	3	3
CO3	3	3	3	2	3	2	3	3	3	3
CO4	3	3	3	3	3	3	3	3	3	3
CO5	2	3	3	3	3	2	3	3	3	3

Course code	Course Name	Periods			Credits	Total Hours
		L	**T**	**P**		
25PECL18	EMBEDDED HARDWARE DESIGN AND PCB LAYOUT	**2**	**1**	**0**	**3**	**45**

Preamble/ Course Objective

• To provide comprehensive understanding of embedded hardware design principles, PCB layout techniques, signal integrity analysis, and manufacturing considerations for developing professional-grade embedded systems

Prerequisite

Knowledge of electronic circuits, embedded systems, and basic understanding of electromagnetic theory and manufacturing processes.

Course Outcome

On the successful completion of the course, students will be able to

COs	Course Outcome	Bloom's Taxonomy Level
CO1	Analyze embedded hardware requirements and design circuit schematics considering component selection, power management, and system specifications.	**Analyze**
CO2	Apply PCB layout principles including layer stack-up, routing strategies, and design rules for multi-layer embedded system boards.	**Apply**
CO3	Evaluate signal integrity, power integrity, and EMC considerations in high-speed embedded hardware design and implement mitigation techniques.	**Evaluate**
CO4	Design thermal management solutions and apply mechanical considerations for robust embedded hardware in various environmental conditions.	**Create**
CO5	Create production-ready PCB designs with complete manufacturing documentation, assembly drawings, and test procedures for embedded systems.	**Create**

Syllabus

Module I: Embedded Hardware Design Fundamentals 9 Hours

System architecture and hardware requirements analysis - microcontroller and processor selection - power supply design and management - voltage regulation and power sequencing - component selection criteria - passive component characteristics - connector and interface design - schematic capture best practices.

Module II: PCB Layout Design Principles 9 Hours

PCB layer stack-up design - trace width and impedance calculations - routing strategies for analog and digital signals - via design and placement - ground plane design - power distribution networks - component placement optimization - design rule checking (DRC) and electrical rule checking (ERC).

Module III: Signal Integrity and Power Integrity 9 Hours

High-speed signal propagation - transmission line effects - crosstalk analysis and mitigation - differential signaling - clock distribution and jitter - power delivery network design - decoupling strategies - power plane design - return path optimization - simulation and analysis tools.

Module IV: EMC, Thermal, and Mechanical Design 9 Hours

Electromagnetic compatibility principles - EMI/EMC design guidelines - shielding techniques - filtering and suppression - thermal analysis and management - heat sink design - mechanical constraints and enclosure design - vibration and shock considerations - environmental specifications.

Module V: Instructional Activities 9 Hours

Complete PCB design projects: Embedded system board design - multi-layer PCB layout using professional CAD tools - signal integrity simulation - thermal analysis - manufacturing file generation - assembly and testing procedures - design verification and validation using industry-standard tools.

Textbooks

1. Johnson, Howard, and Martin Graham. *High-Speed Digital Design: A Handbook of Black Magic*. Upper Saddle River, NJ: Prentice Hall PTR, 1993.
2. Montrose, Mark I., and Edward M. Nakauchi. *Testing for EMC Compliance: Approaches and Techniques*. Hoboken, NJ: IEEE Press, 2004.

Reference Books

1. Coombs, Clyde F. *Printed Circuits Handbook*. 7th ed. New York: McGraw-Hill Education, 2016.
2. Ott, Henry W. *Electromagnetic Compatibility Engineering*. Hoboken, NJ: John Wiley & Sons, 2009.
3. Brooks, Douglas, and Johannes Adam. *PCB Trace and Via Currents and Temperatures: The Complete Analysis*. 2nd ed. Prentice Hall, 2018.

Web Resources

1. PCB Design Guidelines - Altium Designer Academy https://www.altium.com/altium-designer/
2. Signal Integrity Engineering - Stanford University https://web.stanford.edu/class/ee254/

Mapping with Programme Outcomes

COs	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PSO1**	**PSO2**	**PSO3**
CO1	**3**	**3**	**3**	1	2	1	2	2	2	**3**
CO2	**3**	**3**	**3**	2	2	1	2	2	2	**3**
CO3	**3**	**3**	**3**	2	2	1	**3**	2	**3**	**3**
CO4	**3**	**3**	**3**	2	2	2	2	2	2	**3**
CO5	**3**	**3**	**3**	**3**	**3**	2	**3**	2	2	**3**

Course code	Course Name	Periods			Credits	Total Hours
		L	**T**	**P**		
25PECL19	FPGA DESIGN & ARCHITECTURE	**2**	**1**	**0**	**3**	**45**

Preamble/ Course Objective

• To provide comprehensive understanding of FPGA architecture, design methodologies, implementation techniques, and optimization strategies for reconfigurable computing applications

Prerequisite

Knowledge of digital logic design, Verilog/VHDL, and basic computer architecture concepts.

Course Outcome

COs	Course Outcome	Bloom's Taxonomy Level
CO1	Analyze FPGA architecture components including logic blocks, routing resources, and I/O structures for different device families.	**Analyze**
CO2	Apply FPGA design flow including synthesis, mapping, placement, and routing using modern CAD tools and optimization techniques.	**Apply**
CO3	Design digital systems using HDL for FPGA implementation including timing analysis and constraint specification.	**Create**
CO4	Implement advanced FPGA applications including DSP systems, soft processors, and high-performance computing accelerators.	**Apply**
CO5	Evaluate FPGA performance characteristics and optimize designs for speed, area, and power consumption using development tools.	**Evaluate**

Syllabus

Module I: FPGA Architecture (9 Hours) FPGA fundamentals and evolution - configurable logic blocks (CLBs) - lookup tables and multiplexers - routing architecture and switch matrices - I/O blocks and clock resources - memory blocks and DSP slices.

Module II: FPGA Design Flow (9 Hours) FPGA design methodology - synthesis and technology mapping - placement and routing algorithms - timing analysis and constraints - bitstream generation - configuration methods and partial reconfiguration.

Module III: HDL Design for FPGAs (9 Hours) Verilog/VHDL coding styles for FPGAs - synthesizable constructs - finite state machines - pipelining and parallelism - resource utilization and optimization - timing closure techniques.

Module IV: Advanced FPGA Applications (9 Hours) Digital signal processing on FPGAs -

soft processor cores - high-level synthesis - system-level design - FPGA-based acceleration - co-processing and hardware-software co-design.

Module V: Instructional Activities (9 Hours) FPGA development board projects - implementation of digital systems - DSP applications - processor design - performance optimization and analysis using Xilinx/Intel development tools.

Textbooks

1. Chu, Pong P. *FPGA Prototyping by Verilog Examples: Xilinx Spartan-3 Version*. Hoboken: John Wiley & Sons, 2008.
2. Kilts, Steve. *Advanced FPGA Design: Architecture, Implementation, and Optimization*. Hoboken: John Wiley & Sons, 2007.

Reference Books

1. Maxfield, Clive. *The Design Warrior's Guide to FPGAs: Devices, Tools and Flows*. Burlington: Newnes, 2004.
2. Meyer-Baese, Uwe. *Digital Signal Processing with Field Programmable Gate Arrays*. 4th ed. Berlin: Springer, 2014.
3. Tessier, Russell, and Wayne Burleson. *Reconfigurable Computing for Digital Signal Processing: A Survey*. Journal of VLSI Signal Processing Systems, 2001.

Web Resources

1. FPGA Design for Embedded Systems Specialization by University of Colorado Boulder (Coursera) Link: *https://www.coursera.org/specializations/fpga-design*
2. Hardware Description Languages for FPGA Design by University of Colorado Boulder (Coursera) Link: *https://www.coursera.org/learn/hardware-description-languages*

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PSO1	PSO2	PSO3
CO1	3	2	3	2	1	2	1	2	3	2
CO2	3	3	2	3	2	2	2	2	3	3
CO3	2	3	3	2	3	2	2	3	3	3
CO4	3	2	3	3	2	3	2	3	3	3
CO5	2	3	2	3	3	2	3	3	3	3

Course code	Course Name	Periods			Credits	Total Hours
		L	**T**	**P**		
25PECL20	VLSI TESTING & TESTABILITY	**2**	**1**	**0**	**3**	**45**

Preamble/ Course Objective

• To provide comprehensive understanding of VLSI testing methodologies, fault modeling, test generation techniques, and design-for-testability approaches for integrated circuit manufacturing and quality assurance

Prerequisite

Knowledge of digital VLSI design, logic circuits, and basic semiconductor physics.

Course Outcome

COs	Course Outcome	Bloom's Taxonomy Level
CO1	Analyze fault models and defect mechanisms in VLSI circuits and evaluate their impact on circuit functionality and reliability.	**Analyze**
CO2	Apply automatic test pattern generation (ATPG) algorithms and assess test coverage metrics for digital VLSI circuits.	**Apply**
CO3	Design circuits with built-in self-test (BIST) capabilities and implement design-for-testability techniques.	**Create**
CO4	Implement boundary scan testing and system-level test methodologies for complex integrated circuits and PCBs.	**Apply**
CO5	Evaluate test economics and create comprehensive test strategies for VLSI manufacturing and quality control.	**Evaluate**

Syllabus

Module I: Fault Modeling and Analysis (9 Hours) Introduction to VLSI testing - defect types and fault models - stuck-at faults - bridging and delay faults - IDDQ testing - fault simulation techniques - fault coverage and test quality metrics.

Module II: Test Pattern Generation (9 Hours) Combinational test generation - Boolean difference method - path sensitization - D-algorithm - PODEM algorithm - sequential circuit testing - scan design techniques.

Module III: Design for Testability (9 Hours) DFT principles and methodologies - scan chain design - full-scan and partial-scan techniques - built-in self-test (BIST) - linear feedback shift registers - signature analysis - memory testing.

Module IV: System-Level Testing (9 Hours) Boundary scan testing (IEEE 1149.1) - system-in-package testing - mixed-signal testing - analog and RF testing techniques - at-speed testing - production testing considerations.

Module V: Instructional Activities (9 Hours) Fault simulation and ATPG tool usage - scan chain insertion and verification - BIST implementation - test pattern analysis - manufacturing test case studies using EDA tools.

Textbooks

1. Bushnell, Michael L., and Vishwani D. Agrawal. Essentials of Electronic Testing for Digital, Memory and Mixed-Signal VLSI Circuits. Boston: Kluwer Academic Publishers, 2000.
2. Jha, Niraj K., and Sandeep Gupta. Testing of Digital Systems. Cambridge: Cambridge University Press, 2003.

Reference Books

1. Abramovici, Miron, Melvin A. Breuer, and Arthur D. Friedman. Digital Systems Testing and Testable Design. New York: Computer Science Press, 1990.
2. Wang, Laung-Terng, Cheng-Wen Wu, and Xiaoqing Wen, eds. VLSI Test Principles and Architectures: Design for Testability. San Francisco: Morgan Kaufmann, 2006.
3. Stroud, Charles E. A Designer's Guide to Built-In Self-Test. Boston: Kluwer Academic Publishers, 2002.

Web Resources

1. VLSI CAD Part II: Layout by University of Illinois at Urbana-Champaign (Coursera)
   Link: https://www.coursera.org/learn/vlsi-cad-layout
2. Digital Systems: From Logic Gates to Processors by Universitat Autònoma de Barcelona (Coursera)
   Link: *https://www.coursera.org/learn/digital-systems*

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PSO1	PSO2	PSO3
CO1	3	2	3	2	1	2	1	2	3	2
CO2	3	3	2	3	2	2	2	2	3	3
CO3	2	3	3	2	3	2	2	3	3	3
CO4	3	2	3	3	2	3	2	3	3	3
CO5	2	3	2	3	3	2	3	3	3	3

Course code	Course Name	Periods			Credits	Total Hours
25PECL21	VLSI PHYSICAL DESIGN & VERIFICATION	L	T	P	3	45
		2	1	0		

Preamble/ Course Objective

• To provide comprehensive understanding of VLSI physical design methodologies, layout techniques, timing analysis, and verification processes for integrated circuit implementation

Prerequisite

Knowledge of VLSI design principles, CMOS technology, and layout design basics.

Course Outcome

COs	Course Outcome	Bloom's Taxonomy Level
CO1	Analyze physical design challenges and apply floor planning techniques for optimal chip layout and performance.	**Analyze**
CO2	Implement placement and routing algorithms and evaluate their impact on timing, power, and area optimization.	**Apply**
CO3	Apply clock tree synthesis and power distribution network design for reliable circuit operation.	**Apply**
CO4	Perform static timing analysis and design rule checking to ensure circuit functionality and manufacturability.	**Apply**
CO5	Create complete physical verification flows including LVS, DRC, and parasitic extraction for tapeout-ready designs.	**Create**

Syllabus

Module I: Physical Design Flow and Floor Planning (9 Hours) Physical design overview - design flow and milestones - floor planning objectives - aspect ratio and utilization - I/O placement - power planning - macro placement and pin assignment.

Module II: Placement and Routing (9 Hours) Standard cell placement - global and detailed placement - congestion analysis - global routing and track assignment - detailed routing - via minimization - routing optimization techniques.

Module III: Clock and Power Distribution (9 Hours) Clock tree synthesis - clock skew and jitter - H-tree and mesh structures - power distribution network design - IR drop analysis - electromigration and current density considerations.

Module IV: Timing Analysis and Optimization (9 Hours) Static timing analysis fundamentals - setup and hold time analysis - timing paths and constraints - crosstalk analysis - timing optimization techniques - multi-corner multi-mode analysis.

Module V: Instructional Activities (9 Hours) Physical design projects using EDA tools - layout vs schematic (LVS) verification - design rule check (DRC) - parasitic extraction and back-annotation - timing closure techniques.

Textbooks

1. Kahng, Andrew B., Jens Lienig, Igor L. Markov, and Jin Hu. *VLSI Physical Design: From Graph Partitioning to Timing Closure*. Dordrecht: Springer, 2011.
2. Sherwani, Naveed A. *Algorithms for VLSI Physical Design Automation*. 3rd ed. Boston: Kluwer Academic Publishers, 1999.

Reference Books

1. Weste, Neil H. E., and David Money Harris. *CMOS VLSI Design: A Circuits and Systems Perspective*. 4th ed. Boston: Addison-Wesley, 2011.
2. Cong, Jason, and Yuzheng Ding. *FlowMap: An Optimal Technology Mapping Algorithm for Delay Optimization in Lookup-Table Based FPGA Designs*. IEEE Transactions on Computer-Aided Design of Integrated Circuits and Systems, 1994.
3. Bakoglu, H. B. *Circuits, Interconnections, and Packaging for VLSI*. Boston: Addison-Wesley, 1990.

Web Resources

1. **VLSI CAD Part II: Layout** by University of Illinois at Urbana-Champaign (Coursera) Link: *https://www.coursera.org/learn/vlsi-cad-layout*
2. **Physical Design and Verification using Cadence Tools** by NPTEL (India) Link: *https://nptel.ac.in/courses/117106030*

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PSO1	PSO2	PSO3
CO1	3	2	3	2	1	2	1	2	3	2
CO2	3	3	2	3	2	2	2	2	3	3
CO3	2	3	3	2	3	2	2	3	3	3
CO4	3	2	3	3	2	3	2	3	3	3
CO5	2	3	2	3	3	2	3	3	3	3

Course code	Course Name	Periods			Credits	Total Hours
		L	T	P		
25PECL22	LOW POWER DIGITAL VLSI DESIGN	2	1	0	3	45

Preamble/ Course Objective

• To provide comprehensive understanding of low power design methodologies, power analysis techniques, circuit optimization strategies, and energy recovery methods for modern VLSI systems

Prerequisite

Knowledge of digital VLSI design, CMOS technology, and basic understanding of electronic circuits and semiconductor physics.

Course Outcome

On the successful completion of the course, students will be able to

COs	Course Outcome	Bloom's Taxonomy Level
CO1	Analyze sources of power consumption in digital VLSI circuits and evaluate design methodologies for power-efficient integrated circuits.	**Analyze**
CO2	Apply power analysis techniques including SPICE simulation, gate-level analysis, and probabilistic methods for power estimation in VLSI designs.	**Apply**
CO3	Implement circuit and logic level power optimization techniques including transistor sizing, gate reorganization, and signal gating methods.	**Apply**
CO4	Design energy recovery circuits and evaluate power reduction techniques for clock networks and bus architectures in VLSI systems.	**Create**
CO5	Simulate and analyze power dissipation in memory circuits including SRAM and DRAM using modern CAD tools and optimization techniques.	**Evaluate**

Syllabus

Module I: Power Dissipation 9 Hours

Introduction: Need for low power circuit design - sources of power consumption - design methodology - low power figure of merits - limits and applications of low power VLSI Design.

Module II: Power Analysis 9 Hours

Power Analysis: SPICE circuit simulation - discrete transistor modeling and analysis - gate level logic simulation - architecture level analysis - data correlation analysis; Probabilistic Power Analysis: Random logic signals - probabilistic power analysis techniques - signal entropy.

Module III: Circuit and Logic Level 9 Hours

Circuit Level: Transistor and gate sizing - equivalent pin ordering - network restructuring and reorganization - special latches and flip flops; Logic level: Gate reorganization - signal gating - logic encoding - precomputation logic.

Module IV: Energy Recovery Techniques 9 Hours

Energy recovery techniques: Energy dissipation using the RC model - energy recovery circuit design - power reduction in clock networks - low power bus - delay balancing.

Module V: Instructional Activities 9 Hours

Simulation study: Sources of power dissipation in SRAMs - low power SRAM circuit techniques; Sources of power dissipation in DRAMs - low power DRAM circuit techniques using related tools.

Textbooks

1. Rabaey, Jan M., Anantha P. Chandrakasan, and Borivoje Nikolic. *Digital Integrated Circuits: A Design Perspective*. 2nd ed. Upper Saddle River: Prentice Hall, 2003.
2. Pedram, Massoud, and Jan M. Rabaey, eds. *Power Aware Design Methodologies*. Boston: Kluwer Academic Publishers, 2002.

Reference Books

1. Chandrakasan, Anantha P., William J. Bowhill, and Frank Fox, eds. *Design of High-Performance Microprocessor Circuits*. Piscataway: IEEE Press, 2001.
2. Kang, Sung-Mo, and Yusuf Leblebici. *CMOS Digital Integrated Circuits: Analysis and Design*. 4th ed. New York: McGraw-Hill, 2014.
3. Athas, William C., Lars J. Svensson, Jeffrey G. Koller, Nestoras Tzartzanis, and Eric Ying-Chin Chou. *Low-Power Digital Systems Based on Adiabatic-Switching Principles*. IEEE Transactions on Very Large Scale Integration Systems, 1994.

Web Resources

1. **Low Power Design of Electronic Circuits** by NPTEL (India) Link: *https://nptel.ac.in/courses/117106086*
2. **VLSI Design Verification and Test** by University of Colorado Boulder (Coursera) Link: *https://www.coursera.org/learn/vlsi-design-verification-test*

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PSO1	PSO2	PSO3
CO1	3	2	2	1	2	2	2	1	1	3
CO2	3	2	3	1	2	1	2	1	2	3
CO3	3	3	3	1	2	1	2	1	2	3
CO4	3	3	3	1	2	2	3	1	1	3
CO5	2	2	3	2	3	1	3	1	2	3

Course code	Course Name	Periods			Credits	Total Hours
25PECL23	DESIGN OF ANALOG AND MIXED VLSI CIRCUITS	L	T	P	3	45
		2	1	0		

Preamble/ Course Objective

• To provide comprehensive understanding of analog and mixed-signal VLSI circuit design including operational amplifiers, data converters, PLLs, and layout techniques for integrated circuit applications

Prerequisite

Knowledge of analog electronics, CMOS technology, and basic VLSI design concepts.

Course Outcome

COs	Course Outcome	Bloom's Taxonomy Level
CO1	Analyze CMOS analog building blocks and design operational amplifiers with specified performance parameters.	**Analyze**
CO2	Design data conversion circuits including ADCs and DACs with appropriate resolution and speed characteristics.	**Create**
CO3	Implement phase-locked loops and voltage-controlled oscillators for clock generation and frequency synthesis applications.	**Apply**
CO4	Create mixed-signal circuit layouts considering analog-digital interference and matching requirements.	**Create**
CO5	Simulate and optimize analog and mixed-signal circuits using SPICE and other CAD tools for performance verification.	**Evaluate**

Syllabus

Module I: CMOS Analog Building Blocks **9 Hours**

CMOS technology for analog design - device modeling - current mirrors and current sources - differential amplifiers - cascode amplifiers - active loads - noise analysis in analog circuits - mismatch and offset considerations.

Module II: Operational Amplifier Design **9 Hours**

Two-stage and folded-cascode op-amp architectures - gain-bandwidth considerations - stability analysis - slew rate and settling time - low-power and high-speed design techniques - fully differential amplifiers.

Module III: Data Conversion Circuits **9 Hours**

ADC architectures: flash, successive approximation, sigma-delta, pipeline ADCs - DAC architectures: R-2R ladder, current steering, sigma-delta DACs - sampling and hold circuits - anti-aliasing filters.

Module IV: Phase-Locked Loops and Oscillators **9 Hours**

PLL fundamentals - charge pump PLLs - VCO design techniques - frequency dividers - loop filter design - jitter and phase noise analysis - delay-locked loops.

Module V: Instructional Activities **9 Hours**

Layout design and simulation of analog circuits - mixed-signal layout considerations - parasitic extraction - post-layout simulation - design optimization using SPICE and layout tools.

Textbooks

1. Razavi, Behzad. Design of Analog CMOS Integrated Circuits. 2nd ed. New York: McGraw-Hill, 2017.
2. Baker, R. Jacob. CMOS: Circuit Design, Layout, and Simulation. 4th ed. Hoboken: John Wiley & Sons, 2019.

Reference Books

1. Gray, Paul R., Paul J. Hurst, Stephen H. Lewis, and Robert G. Meyer. Analysis and Design of Analog Integrated Circuits. 5th ed. Hoboken: John Wiley & Sons, 2009.
2. Johns, David A., and Ken Martin. Analog Integrated Circuit Design. 2nd ed. Hoboken: John Wiley & Sons, 2012.
3. Sansen, Willy M. C. Analog Design Essentials. New York: Springer, 2006.

Web Resources

1. Analog Circuits by Georgia Institute of Technology (Coursera) Link: *https://www.coursera.org/specializations/analog-circuits*
2. Analog IC Design by NPTEL (India) Link: *https://nptel.ac.in/courses/117106030*

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PSO1	PSO2	PSO3
CO1	3	2	2	1	2	1	2	2	3	3
CO2	3	3	3	2	2	1	2	2	3	3
CO3	3	3	3	2	3	2	3	3	3	3
CO4	3	3	3	2	3	2	3	3	2	3
CO5	2	3	3	3	3	2	3	3	3	3

Course code	Course Name	Periods			Credits	Total Hours
25PECL24	DIGITAL IC DESIGN	**L**	**T**	**P**	**3**	**45**
		2	**1**	**0**		

Preamble/ Course Objective

• To provide comprehensive understanding of digital integrated circuit design methodologies, CMOS logic design, timing analysis, and physical implementation techniques for modern semiconductor technologies

Prerequisite

Knowledge of digital logic design, CMOS technology, Verilog/VHDL, and basic semiconductor physics.

Course Outcome

On the successful completion of the course, students will be able to

COs	Course Outcome	Bloom's Taxonomy Level
CO1	Analyze CMOS logic design principles and evaluate different logic families for performance, power, and area optimization in digital ICs.	**Analyze**
CO2	Apply digital IC design methodologies including synthesis, optimization, and technology mapping for implementing complex digital systems.	**Apply**
CO3	Design sequential circuits, memory elements, and clock distribution networks with proper timing analysis and constraint specification.	**Create**
CO4	Implement physical design techniques including floor planning, placement, routing, and design rule checking for digital IC layouts.	**Apply**
CO5	Create complete digital IC designs from RTL to GDSII including verification, timing closure, and design for testability considerations.	**Create**

Syllabus

Module I: CMOS Logic Design and Characterization 9 Hours

CMOS technology overview - NMOS and PMOS transistor characteristics - static and dynamic CMOS logic - pass transistor logic - transmission gates - logic families comparison - power consumption analysis - noise margins - logic design optimization techniques - process, voltage, and temperature (PVT) variations.

Module II: Digital IC Design Flow and Synthesis **9 Hours**

Digital IC design methodology - RTL design and coding guidelines - logic synthesis process - technology libraries - synthesis constraints and optimization - area, timing, and power trade-offs - design for testability - scan chain insertion - formal verification techniques.

Module III: Sequential Design and Timing Analysis **9 Hours**

Flip-flop and latch design - clock distribution networks - clock skew and jitter - setup and hold time analysis - static timing analysis - timing constraints and exceptions - multi-corner multi-mode analysis - clock domain crossing - metastability and synchronization.

Module IV: Physical Design and Layout **9 Hours**

Physical design flow overview - floor planning and power planning - standard cell placement - clock tree synthesis - routing algorithms - design rule checking (DRC) - layout versus schematic (LVS) - parasitic extraction - timing closure techniques.

Module V: Instructional Activities **9 Hours**

Complete digital IC design projects: Processor datapath design - memory controller implementation - digital signal processing blocks - design synthesis and optimization - physical implementation and verification using industry-standard EDA tools and process design kits.

Textbooks

1. Weste, Neil H. E., and David Money Harris. CMOS VLSI Design: A Circuits and Systems Perspective. 4th ed. Boston: Addison-Wesley, 2011.
2. Rabaey, Jan M., Anantha P. Chandrakasan, and Borivoje Nikolic. Digital Integrated Circuits: A Design Perspective. 2nd ed. Upper Saddle River, NJ: Prentice Hall, 2003.

Reference Books

1. Kang, Sung-Mo, and Yusuf Leblebici. CMOS Digital Integrated Circuits: Analysis and Design. 4th ed. New York: McGraw-Hill Education, 2014.
2. Wolf, Wayne. Modern VLSI Design: System-on-Chip Design. 4th ed. Upper Saddle River, NJ: Prentice Hall, 2009.
3. Kahng, Andrew B., Jens Lienig, Igor L. Markov, and Jin Hu. VLSI Physical Design: From Graph Partitioning to Timing Closure. Dordrecht: Springer, 2011.

Web Resources

1. Digital VLSI Design - IIT Kharagpur NPTEL
https://nptel.ac.in/courses/117/105/117105080/
2. VLSI CAD: Logic to Layout - University of California San Diego

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PSO1	PSO2	PSO3
CO1	3	2	2	1	2	1	2	1	2	3
CO2	3	3	3	1	2	1	2	1	2	3
CO3	3	3	3	1	2	1	2	2	2	3
CO4	3	3	3	2	2	1	2	1	2	3
CO5	3	3	3	2	3	2	3	2	2	3

Course code	Course Name	Periods			Credits	Total Hours
		L	T	P		
25PECL25	PACKAGING AND ASSEMBLING TECHNOLOGIES	2	1	0	3	45

Preamble/ Course Objective

• To provide comprehensive understanding of semiconductor packaging technologies, assembly processes, reliability considerations, and advanced packaging techniques for modern electronic systems and integrated circuits

Prerequisite

Knowledge of semiconductor devices, materials science basics, and manufacturing processes.

Course Outcome

On the successful completion of the course, students will be able to

COs	Course Outcome	Bloom's Taxonomy Level
CO1	Analyze semiconductor packaging requirements and evaluate different package types for various IC applications and performance specifications.	**Analyze**
CO2	Apply assembly processes including die attach, wire bonding, and flip-chip technologies for semiconductor device manufacturing.	**Apply**
CO3	Design packaging solutions considering thermal management, electrical performance, and mechanical reliability for electronic systems.	**Create**
CO4	Evaluate advanced packaging technologies including 3D packaging, system-in-package, and wafer-level packaging for modern applications.	**Evaluate**
CO5	Assess reliability testing methods and failure analysis techniques to ensure long-term performance of packaged semiconductor devices.	**Evaluate**

Syllabus

Module I: Semiconductor Packaging Fundamentals 9 Hours

Introduction to semiconductor packaging - package functions and requirements - package classification and types - leadframe and substrate technologies - package materials and properties - cost considerations - package selection criteria - environmental and regulatory considerations.

Module II: Assembly Processes and Technologies 9 Hours

Die preparation and handling - die attach processes and materials - wire bonding techniques (ball bonding, wedge bonding) - tape automated bonding (TAB) - flip-chip technology - underfill and encapsulation processes - quality control and inspection methods.

Module III: Package Design and Thermal Management **9 Hours**

Package design considerations - electrical design and signal integrity - thermal analysis and heat dissipation - thermal interface materials - heat sinks and thermal solutions - power delivery and ground planes - electromagnetic interference (EMI) shielding - mechanical design and stress analysis.

Module IV: Advanced Packaging Technologies **9 Hours**

System-in-package (SiP) technology - multi-chip modules (MCM) - 3D packaging and through-silicon vias (TSV) - wafer-level packaging (WLP) - chip-scale packaging (CSP) - fan-out wafer-level packaging - embedded die packaging - heterogeneous integration technologies.

Module V: Instructional Activities **9 Hours**

Reliability testing and failure analysis: Accelerated life testing - thermal cycling - humidity testing - mechanical stress testing - failure mode analysis - solder joint reliability - package-level simulation and modeling - case studies of packaging failures and solutions using industry tools.

Textbooks:

1. Tummala, Rao R., ed. Fundamentals of Microsystems Packaging. 2nd ed. New York: McGraw-Hill Professional, 2001.
2. Lau, John H. Electronic Packaging: Design, Materials, Process, and Reliability. New York: McGraw-Hill, 1998.

Reference Books:

1. Harper, Charles A., ed. Electronic Packaging and Interconnection Handbook. 4th ed. New York: McGraw-Hill, 2004.
2. Pecht, Michael, ed. Electronic Packaging Materials and Their Properties. Boca Raton: CRC Press, 1999.
3. Gilleo, Ken. Area Array Packaging Handbook: Manufacturing and Assembly. New York: McGraw-Hill, 2002.

Web Sources:

1. Semiconductor Packaging Fundamentals and Applications
   https://www.edx.org/course/semiconductor-packaging-fundamentals
2. Advanced Semiconductor Packaging Technologies
   https://www.coursera.org/learn/semiconductor-packaging

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PSO1	PSO2	PSO3
CO1	3	2	2	1	2	2	2	1	1	3
CO2	3	3	3	1	2	1	2	1	1	3
CO3	3	3	3	2	2	2	2	1	2	3
CO4	3	2	2	2	2	1	3	2	2	3
CO5	2	2	3	2	3	2	2	1	2	3

PROGRAM OUTCOMES (POs)
M.Tech ELECTRONICS AND COMMUNICATION ENGINEERING

PO1: Advanced Engineering Knowledge and Specialization

Apply knowledge of advanced mathematics, science, and specialized engineering principles in Electronics and Communication Engineering domains including digital communication systems, signal processing, VLSI design, wireless technologies, and emerging quantum communication systems to solve complex engineering problems.

PO2: Advanced System Design and Development

Design, develop, and optimize complex communication systems, VLSI circuits, embedded systems, and intelligent signal processing solutions that meet specified technical requirements while considering constraints such as power consumption, area, speed, and cost-effectiveness.

PO3: Modern Tool Proficiency and Computational Skills

Use advanced engineering tools, simulation software, programming languages, and computational platforms including CAD tools for VLSI design, communication system simulators, signal processing tools, and AI/ML frameworks to model, analyze, and validate complex engineering solutions.

PO4: Professional Communication and Collaborative Research

Communicate complex technical concepts effectively through technical writing, research presentations, and collaborative projects. Demonstrate ability to work in multidisciplinary teams, lead research initiatives, and disseminate knowledge through publications, seminars, and professional forums.

PO5: Research Methodology and Problem Investigation

Conduct independent research by identifying, formulating, and systematically investigating complex engineering problems using appropriate research methodologies, experimental techniques, and analytical tools to contribute new knowledge in Electronics and Communication Engineering.

PO6: Ethical Research Practices and Professional Responsibility

Demonstrate integrity in research practices, adhere to professional ethics and understand the social impact of engineering solutions while maintaining responsibility towards public safety, security, and environmental sustainability.
PO7: Lifelong Learning and Technology Leadership

Recognize the rapid evolution of technology in Electronics and Communication Engineering, demonstrate self-directed learning capabilities, adapt to emerging technologies and provide technical leadership in innovation and technology development.

PROGRAM SPECIFIC OUTCOMES (PSOs)

PSO1: Advanced Communication and Networking Systems

Design and implement next-generation communication systems including 5G/6G networks, optical communication, satellite systems, and cognitive radio technologies with emphasis on performance optimization and security.

PSO2: Intelligent Signal Processing and AI Integration

Develop advanced signal processing algorithms integrated with artificial intelligence and machine learning techniques for applications in wireless communication, image processing, and pattern recognition.

PSO3: VLSI Design and Embedded System Innovation

Create innovative VLSI circuits, system-on-chip designs, and intelligent embedded systems for applications in communication, IoT, and emerging quantum technologies.