Department of Electronics Engineering

B. Tech. Electronics and Communication Engineering

SEMESTER – VII/VIII

Sr. No.	Subject	Code	Credit	Teaching Scheme		
				L	T	P
1.	Microwave Engineering	EC 401	04	3	0	2
2.	Information Theory and Coding	EC 403	03	3	0	0
3.	Project	EC 405	03	0	0	6
4.	Department Elective - IV	EC 4XX	04	3	0	2
5.	Department Elective - V	EC 4XX	03	3	0	0
6.	Department Elective - VI	EC 4XX	03	3	0	0
	Total		**20**	**15**	**0**	**10**

List of Subjects for Department Elective IV (3 - 0 - 2)

Sr. No.	Subject	Code
1.	Deep Learning	EC 421
2.	MIMO Communication systems	EC 423
3.	CMOS Analog VLSI Design	EC 425
4.	Intelligent Systems and Robotics	EC 427
5.	Real-Time Systems	EC 429

List of Subjects for Department Elective V (3 - 0 - 0)

Sr. No.	Subject	Code
1.	Optical Wireless Communication	EC 431
2.	Estimation and Detection Theory	EC 433
3.	Processor Architecture	EC 435
4.	EM Interference and Compatibility	EC 437
5.	VLSI Systems	EC 439
6.	Quantum Computing	EC 441

List of Subjects for Department Elective VI (3 - 0 - 0)

Sr. No.	Subject	Code
1.	Fundamentals of Nanoelectronics	EC 451
2.	Testing and Verification of VLSI Circuits	EC 453
3.	Ad-Hoc Networks	EC 455
4.	Cognitive Radio	EC 457
5.	Biomedical Instrumentation	EC 459
6.	SWAYAM	SW 01

SEMESTER – VII/VIII

Sr. No	Subject	Code	Scheme	Credit	Examination Scheme				
					Theory Marks	Tutorial Marks	Term work Marks	Practical Marks	Total Marks
1.	Internship training in Industry / Research Organization/ Academic Institute	EC 402	0-0-20	10	-	-	120	180	300
		Total	**0-0-20=20**	**10**	**-**	**-**	**120**	**180**	**300**

MICROWAVE ENGINEERING

L	T	P	Credit
3	0	2	04

EC 401 **Scheme**

1. Course Outcomes (COs):

At the end of the course the students will be able to:

CO1	**Explain** the working principle of waveguide based and microstrip based components, sources and their applications.
CO2	**Apply** the knowledge of transmission line theory to waveguide components, microstrip components and antennas.
CO3	**Analyze** the electric and magnetic field modes in microstrip based and waveguide based components in association with the communication systems.
CO4	**Evaluate** the different parameters of microwave communication system.
CO5	**Design** the matching networks, microstrip filters of different orders, waveguide based hybrid circuits and Microwave integrated circuits.

2. Syllabus:

- **INTRODUCTION** **(02 Hours)**
  Circuit-Field Relations, RF Behavior of Passive Components, Chip Components.

- **MICROWAVE WAVEGUIDES AND COMPONENTS** **(08 Hours)**
  Introduction, Rectangular Waveguides, Rectangular Cavity Resonators, Circular Waveguides, Microwave Hybrid Circuits: Waveguides Tees, Magic Tees, Directional Couplers, radiation from rectangular and circular apertures, Radiation from sectoral and pyramidal horns.

- **MICROWAVE NETWORK ANALYSIS AND IMPEDANCE MATCHING** **(06 Hours)**
  Basic Definitions, Interconnecting Networks, Network Properties And Application, ABCD and Scattering Parameters, Impedance Matching using Discrete Components, Microstrip Line Matching Networks.

- **POWER DIVIDERS AND DIRECTIONAL COUPLERS** **(07 Hours)**
  The T Junction Power Divider, The Wilkinson Power Divider, The Quadrature (90°) Hybrid, Coupled Line Directional Couplers, Ratrace and Hybrid Ring.

- **MICROWAVE FILTERS** **(06 Hours)**
  Basic Resonator and Filter Configurations, Periodic Structures, Filter Design by the Image Parameter Method, Special Filter Realizations, Stepped-Impedance Low-Pass Filters, Coupled Line Filters.

- **MICROWAVE DIODES AND TUBES** **(06 Hours)**
  GaAs FET, HEMT, Varactor diodes, PIN diodes, IMPATT, TRAPATT and BARITT, Microwave Tunnel Diodes, Gunn Diodes, Schottky Diodes and Detectors, Microwave Unipolar and Bipolar Transistor: physical structure, principle of operation, characteristics, Klystrons, Magnetrons and TWT.

- **MICROWAVE ANTENNAS** **(04 Hours)**
  Fundamentals of Antenna, Antenna Arrays, Microstrip, Helical, Yagi-Uda, Log-Periodic and Reflector Antennas.

- **MICROWAVE COMMUNICATION SYSTEMS AND OTHER APPLICATIONS** **(03 Hours)**
  Overview of Radar, Cellular Communication, Satellite Communication

(Total Contact Hours: 42)

3. List of Practicals:

1. Introduction to Microwave Bench.
2. To determine the frequency & wavelength in a rectangular wave-guide working on TE10 mode
3. To obtain characteristics of Attenuator (Fixed and Variable type)
4. To verify properties of Magic Tee
5. To verify properties of Directional Coupler.
6. To obtain characteristics of Microstrip Band Pass and Band Stop Filters.
7. To obtain characteristics of Microstrip Power Divider.
8. To plot Mode Characteristics of Reflex Klystron.
9. To plot of V-I characteristics of Gunn Diode
10. To verify properties of Resonant Cavity
11. Study and analysis of EMI and EMC standards.
12. Experiments on Microwave Measurements :
    Power measurements: Calorimeter method, Bolometer bridge method
    Measurement of Cavity Q, Measurement of S parameters of a Network.

4. Books Recommended:

1. Ludwig Reinhold and Bretchko Pavel, “RF Circuits Design: Theory and Applications”, 1st Ed., Pearson Education, Low Price ed., 2000.
2. Liao Samuel Y., “Microwave Devices and Circuits”, 3rd Ed., PHI, 2nd Reprint, 2006.
3. Pozar M. David, “Microwave Engineering”, John Wiley & Sons, Inc., 1999.
4. C. A. Balanis, “Antenna Theory and Design”, 4th Ed., John Wiley & Sons, 2016.
5. Annapurna Das, Sisir K Das, “Microwave Engineering”, 3rd Ed., Mc Graw Hill, Reprint 2017.

5. Reference Books:

1. Kumar A., “Microwave Techniques: Transmission Line”, 1st Ed., New Age International, 1998.

INFORMATION THEORY AND CODING

L	T	P	Credit
3	0	0	03

EC 403 **Scheme**

1. Course Outcomes (COs):

At the end of the course the students will be able to:

CO1	Understand the notion of information in a mathematically sound way.
CO2	Compare and analyze lossless data compression techniques with varying efficiencies as per problem requirements.
CO3	Calculate entropy, joint entropy, relative entropy, conditional entropy, and channel capacity of a system.
CO4	Design decoding strategies for block codes, linear codes, cyclic codes and BCH codes for detection and correction of errors.
CO5	Design convolutional Encoding and Decoding that meets design objectives like required protection for detection and correction of errors.

2. Syllabus:

- **INFORMATION THEORY** **(06 Hours)**
  Introduction to Information Theory, Information units, Entropy, Properties of Entropy, Measures for Continuous, Random Variable, Relative Entropy, Conditional, and Joint Entropy, Measure of Information, Average Information, Extension of Zero Memory Source.

- **SOURCE CODING** **(08 Hours)**
  Properties of Codes, Variable Length Codes, Uniquely Decodable Codes, Kraft's Inequality, Prefix Codes, Average Length of a Code, Shannon's First Theorem, Shannon's Encoding Algorithm, Shanon-Fano Codes, Huffman's Codes, Arithmetic Codes, Lempel Ziv, Run Length Code, Code Efficiency and Redundancy, Practical Application of Source Coding: JPEG Compression.

- **CHANNEL MODELS AND CHANNEL CAPACITY** **(04 Hours)**
  Discrete Communication Channels, Continuous Channels, Entropy Functions and Equivocation, Mutual Information, Channel Capacity, redundancy and efficiency of channels, Symmetric channels, Binary Symmetric Channel, Binary Erasure Channel, Noise-Free Channel, Cascaded channels, Binary asymmetric channel, Shannon theorem

- **BLOCK CODES AND LINEAR CODES** **(08 Hours)**
  Introduction to Galois Field, Single Parity Check Codes, Product Codes, Hamming Codes, Minimum Distance of Block Codes, Linear Block Codes, Generator Matrices, Parity Check Matrices, Encoder, Standard array and Syndrome decoding, Error Correction and Error Detection Capabilities.

- **CYCLIC and BCH CODES** **(08 Hours)**
  Introduction to Cyclic Codes, Generator Polynomial, Syndrome Polynomial and Matrix Representation, Golay Code, CRC Codes and Circuit Implementation of Cyclic Codes, Introduction to BCH Codes: Generator Polynomials, Multiple Error Correcting BCH Codes, Decoding of BCH Codes, Reed Solomon (RS) Codes, Burst Error Correction.

- **CONVOLUTION CODE** **(08 Hours)**
  Introduction to Convolutional Codes, state, tree and trellis diagram, Trellis Codes: Generator Polynomial Matrix and Encoding using Trellis, Viterbi Decoding, Interleaving techniques, Introduction to Turbo Codes, Introduction to LDPC.

(Total Contact Hours: 42)

3. <u>Books Recommended:</u>

1. Ranjan Bose, “Information theory, coding and cryptography”, Tata McGraw-Hill,2nd Edition,2008
2. T. M. Cover and J. A. Thomas, “Elements of Information Theory“, 2nd Ed., John Wiley & Sons, New Jersey, USA, 2006.
3. Salvatore Gravano,“Introduction to Error Control Codes”, Oxford University Press,1st Edition,2007
4. R. J. McEliece, The Theory of Information and Coding, Cambridge Uinversity Press
5. R. Togneri, C.J.S deSilva, Fundamentals of Information Theory and Coding Design, Taylor and Francis

DEEP LEARNING

L	T	P	Credit
3	0	2	04

EC 421 **Scheme**

1. **Course Outcomes (COs):**

At the end of the course the students will be able to:

CO1	Describe basic concepts of pattern classification, Neuron and Neural Network, and to analyze ANN learning.
CO2	Demonstrate different single layer/multiple layer Perception learning algorithms.
CO3	Examine concept of deep learning algorithms for various applications.
CO4	Evaluate the concept of optimizer and Network training.
CO5	Design of another class of layered networks using deep learning principles.

2. **Syllabus:**

- **INTRODUCTION** **(12 Hours)**
  Feature Descriptor, Bayesian Learning, Decision Surfaces, Linear Classifiers, Linear Machines with Hinge Loss, Support Vector Machine, Multiclass support Vector Machine, Maximum margin hyper planes: Rationale for Maximum Margin, Linear SVM: Separable Case: Linear Decision Boundary, Margin of a Linear Classifier, learning a Linear SVM model, Linear SVM: Non-separable Case, Nonlinear SVM: Attribute Transformation, Learning a Nonlinear SVM, Kernel Trick, Characteristics of SVM.

- **NEURAL NETWORK** **(08 Hours)**
  Multilayer Perceptron, Feed forward Neural networks, Gradient descent and the back propagation algorithm, Example of Back Propagation Learning, Non-Linear Functions, Unsupervised Learning with Deep Network, Autoencoder, Autoencoder vs PCA.

- **CONVOLUTIONAL NEURAL NETWORK (CNN)** **(08 Hours)**
  Convolution, Cross correlation, building blocks of CNN, MLP vs CNN, Different CNN architectures, Popular CNN model, Transfer Learning, Vanishing and Exploding Gradient, Recurrent Neural Networks.

- **OPTIMISER** **(03 Hours)**
  Gradient Descent, Batch Optimization, Mini-Batch Optimization, Momentum Optimizer, Momentum and Nesterov Accelerated Gradient (NAG) Optimiser, RMSProp, Adam.

- **REGULARIZATION FOR DEEP LEARNING** **(03 Hours)**
  Parameter norm penalties, Effective training in Deep Net-early stopping, Dropout, Batch Normalization, Instance Normalization, Group Normalization, Recent Trends in Deep Learning Architectures, Residual Network, Skip Connection Network, Fully Connected CNN etc.

- **APPLICATIONS AND EXAMPLES** **(08 Hours)**
  Classical Supervised Tasks with Deep Learning, Image Denoising, Semantic Segmentation, Object Detection, Image generation with Generative adversarial networks, video to text with LSTM models.

(Total Contact Hours: 42)

3. List of Practicals:

1. Introduction to Python for machine learning.
2. To learn data handling, visualization and preprocessing in Python.
3. Implement naïve Bayes classifier.
4. Implement decision tree.
5. Implement SVM for binary and multiclass classification considering linear and non-linear kernal.
6. Implement gradient descent for linear regression.
7. Implement gradient descent for logistic regression.
8. Implement and compare various optimization techniques (RMSprop, Adam, Adagrad)
9. Implement multilayer perceptron using back propagation for classification.
10. Implement principal component analysis (PCA) for dimensionality reduction of the given data.
11. Implement Autoencoder for image compression/denoising.
12. Implement CNN for binary and multiclass classification and adjust hyper parameters to improve the classification accuracy.
13. Implement CNN for classification and apply different regularization techniques to improve the classification accuracy.
14. Implement recurrent neural network for time series prediction.

4. Books Recommended:

1. Ian Goodfellow, YoshuaBenjio, Aaron Courville, “Deep Learning”, The MIT Press, 2017.
2. Eugene Charniak , “Introduction to Deep Learning”, The MIT Press, Hardcover, 2019.
3. Richard O. Duda, Peter E. Hart, David G. Stork ,Pattern Classification-, 2nd Ed., John Wiley & Sons Inc.Wiley; 2007.
4. Simon Haykins “Neural Network- A Comprehensive Foundation”, 2nd Ed., Pearson Prentice Hall.
5. Zurada and Jacek M, “Introduction to Artificial Neural Systems”, West Publishing Company.

5. Reference Book:

1. Christopher M. Bishop, “Pattern Recognition and Machine Learning”,Springer; 2nd Ed., 2011.

MIMO COMMUNICATION SYSTEMS

L	T	P	Credit
3	0	2	04

EC 423 **Scheme**

1. Course Outcomes (COs):

At the end of the course the students will be able to:

CO1	Describe basic terminologies associated with multiantenna / MIMO communication systems with perception of capacity, gain, coding and detection techniques.
CO2	Implement different MIMO channels analytically for scenarios like CSIR, CSIT etc.
CO3	Analyze BER, SER performance analysis of MIMO systems, space-time codes with baseband signal processing aspects also to analyze the capacity of various MIMO systems
CO4	Evaluate the performances of different space time codes, MIMO detection techniques like ML, ZF, MMSE etc.
CO5	Develop new capacity improving technique, Low complexity receiver design for MIMO with better link performance

2. Syllabus:

- **INTRODUCTION TO MULTI ANTENNA SYSTEM** **(10 Hours)**
  Introduction to wireless communication systems and wireless Channels, Performance in fading Wireless channels, Classical and generalized fading distributions, Error/Outage Probabilities over fading channels, Need for MIMO Systems, Multiple antennas in wireless Communication, Benefits of MIMO technology, Basic Building Block, Diversity gain, multiplexing gain, A fundamental Trade-off,MIMO in wireless networks, MIMO communication in wireless standards, Analytical MIMO channel models

- **MIMO CHANNEL CAPACITY** **(08 Hours)**
  Power allocation in MIMO system: Uniform power allocation, Adaptive power allocation, Near optimal power allocation,
  Channel Capacity of simplified MIMO channels: capacity of deterministic MIMO channel, capacity of random MIMO channel, Ergodic and outage capacity of i.i.d. Rayleigh fading MIMO channel, separately correlated Rayleigh fading MIMO channel and keyhole Rayleigh fading MIMO channel

- **INTRODUCTION TO SPACE-TIME CODING** **(04 Hours)**
  Sources and types of diversity, analysis under Rayleigh fading, performance of different diversity schemes, Space-Time Coded Systems, Performance Analysis of Space-Time Codes, Space-Time Code Design Criteria

- **SPACE TIME BLOCK AND TRELLIS CODES** **(08 Hours)**
  Alamouti Space-Time Code, SER analysis for Alamouti space time code over fading channels, Space time block codes, space time trellis codes, performance analysis of space time codes over separately correlated MIMO channel, Performance analysis.Space – time codes with no CSI

- **SPACE TIME CODING FOR FREQUENCY SELECTIVE FADING CHANNELS** **(04 Hours)**
  Frequency-selective channels – Capacity and Information rates of MIMO FS fading channels, Space - time coding and Channel detection for MIMO FS channels, MIMO OFDM systems.

- **INTRODUCTION TO MIMO DETECTION TECHNIQUES (04 Hours)**
  Maximum likelihood (ML) detector, Linear suboptimal detectors: Zero forcing detector, MMSE detector, Successive Interference Cancellation (SIC), Sphere decoding

- **ADVANCE TOPICS IN MIMO WIRELESS COMMUNICATION (04 Hours)**
  Space time block coded spatial modulation, MIMO based cooperative communication, Large scale MIMO systems, MIMO cognitive radios

(Total Contact Hours: 42)

3. List of Practicals:

1. To observe outage probabilities for Rayleigh and Rician fading channel models
2. To observe power delay profile (PDP) for the multi-path channel (Frequency-selective
3. fading channel)
4. To observe free space path loss model.
5. To observe the BER performance of a SISO system with coherent detection in Rayleigh Fading channels.
6. To observe the BER performance of a SIMO system with MRC, EGC, and selection combining in spatially independent Rayleigh fading channels.
7. To observe the BER performance of a STBC-MISO (Alamouti transmit diversity) system in spatially independent quasi-static Rayleigh fading channels.
8. To observe the BER performance of a STTC-MISO (Alamouti transmit diversity) system in spatially independent quasi-static Rayleigh fading channels.
9. To observe channel capacity by Spatial Multiplexing for MIMO Multipath Channel
10. To observe ergodic channel capacity for various antenna configurations
11. To observe the BER performance of ML detector for MIMO systems
12. To observe the BER performance of linear detectors for MIMO systems
13. To perform 2x2 MIMO system with Alamouti space-time block coding using NI USRP Software Defined Radio.
14. To perform 2x2 MIMO system with Maximum ratio combining using NI USRP software defined Radio.

4. Books Recommended:

15. Rakesh Singh Kshetrimayum, “Fundamentals of MIMO Wireless Communications”, 1st Ed., Cambridge University Press 2017.
16. Mohinder Jankiraman, “Space Time Codes and MIMO Systems”, Har/Cdr Ed., Artech house London, Ed. 2004
17. Branka Vucetic, Jinhong Yuan, “Space Time Coding”, 1st Ed., John Wiley & Sons Ltd, 2003
18. Paulraj, R. Nabar and D. Gore, “Introduction to Space-Time Wireless Communications”, 1st Ed., Cambridge University Press 2008
19. Tolga m. Duman, Ali Ghrayeb, “Coding for MIMO Communication Systems”, 1st Ed., John Wiley & Sons Ltd., 2007

CMOS ANALOG VLSI DESIGN

L	T	P	Credit
3	0	2	04

EC 425 **Scheme**

1. **Course Outcomes (COs):**

At the end of the course the students will be able to:

CO1	Understand Impact of MOS Device Parameters on Analog Circuit Design and the Analog Design Requirements.
CO2	Apply circuit theory to CMOS analog circuits.
CO3	Analyze various Analog Circuits in the Presence of Noise.
CO4	Evaluate suitability of a specific topology of Analog Circuits like Amplifiers / Biasing Circuits / Data Converters etc. for a particular application.
CO5	Design and Analyze Various CMOS Amplifiers, Differential Amplifiers, Current Source/Sink Circuitry, Operational Amplifiers (OP-AMPs) Topologies, OP-AMP Compensation.

2. **Syllabus:**

- **ANALOG SUB-CIRCUITS** **(18 Hours)**
Small Signal Model for MOS, MOS Switch, MOS Resistor, Current Sink/Source, High Input Impedance Current Mirrors, Supply Independent and Temperature Independent Current and Voltage References, Design of Single Stage Amplifiers, Differential Amplifiers and Output Amplifiers, Frequency Response of Amplifiers, High Gain Amplifier Architectures.

- **OPAMPS** **(10 Hours)**
Single ended and fully differential CMOS Operational Amplifiers, Telescopic and Folded Cascode OP-AMPs, Compensation, Design Of Two Stage OP-AMPs, High Speed OP-AMPs.

- **COMPARATORS** **(06 Hours)**
Characterization of Comparators, Single Stage Comparators, Two Stage Open loop Comparators, Comparators with Hysteresis, Auto Zero Techniques

- **DATA CONVERTERS** **(08 Hours)**
Sample and Hold Circuits. Specification Parameters for D/A and A/D Converters Nyquist Rate DAC – Resistor String Based Converter, R-2R Ladder Network, Current Scaling DAC, Nyquist Rate ADC - Successive-Approximation Converters, Integrating ADCs (Single and Dual Slope)

(Total Contact Hours: 42)

3. **List of Practicals:**

1. Obtrain various V-I characteristics of PMOS and NMOS transistor and compute
2. Design and simulate single stage CS amplifier using NMOS driver with (i) resistive load (ii)NMOS diode.
   (a) Obtain transfer curve and compute vo,max, vo,min, transition slop and maximum allowable output swing.
   (b) Draw frequency response plot and measure DC (low frequency) voltage gain, 3-dB bandwidth and unity gain frequency.

(c) Observe input and output signals with respect to time and compute peak to peak output swing and gain.
(d) Measure output resistance Zo.

3. Repeat practical 2 with (i) PMOS Diode load (ii) PMOS current source load
4. Design and Simulate Cascode amplifier for given specifications
5. Design & Simulate following current mirrors that supply 100µA current: (i) Basic (ii)Cascode (iii) Low Voltage Cascode. Obtain ro, vo,min and Io. Assume IREF =20 µA.
6. Design a 3 bit ADC using resistor string ladder with (i) passive switches (b) active switches.
7. Design 4-bit R-2R ladder DAC having worse case power dissipation of 1.8mW and VREF=1.8V using (i) using passive switches (ii) active switches
8. Design basic Differential amplifier with resistive load with ISS=68µA, RD=20kΩ, Av=12. Obtain various characteristics in Differential and Common mode.
9. Design 3-bit Charge Scaling DAC and find output voltage for all input combinations.
10. Design Differential amplifier with current mirror load for following specifications: Av ≥55, SR(slew rate) ≥5V/µs, Pmax=0.4mW, CL=10pF and ICMR=0.85 to 1.5V. Obtain transfer characteristics, common mode characteristics and frequency response.
11. Implement and simulate telescopic and folded cascade op-amps

4. Books Recommended:

1. Razavi Behzad,“Design of Analog CMOS Integrated Circuit”,Tata McGraw-Hill,2002.
2. Allen Philip and Holberg Douglas,“CMOS Analog Circuit Design”,Oxford University Press,2002.
3. Baker Jacob R., Harry W. Li and Boyce David E.,“CMOS: Circuit Design, Layout and Simulation”,Wiley Interscience, 2003.
4. Paul R. Gray, Paul J. Hurst, Stephen H. Lewis & Robert G. Meyer, “Analysis and Design of Analog Integrated Circuits” 5th Edition, Wiley 2009.
5. John D.A. and Martin K.,“Analog Integrated Circuit Design”, 2nd Edition, Wiley, 2003.

INTELLIGENT SYSTEMS AND ROBOTICS

L	T	P	Credit
3	0	2	04

EC 427 **Scheme**

1. **Course Outcomes (COs):**

At the end of the course the students will be able to:

CO1	Identify the functional architecture of computing systems.
CO2	Estimate the performance of various classes of machines, memories, pipelined architectures etc.
CO3	Compare CPU implementations, I/O methods etc.
CO4	Analyze fast methods of ALU and FP unit implementations.
CO5	Design an instruction encoding scheme for an ISA and Build large memories using small memories for better performance.

2. **Syllabus:**

- **MOBILE ROBOTS** **(08 Hours)**
  Mobile Robot hardware, Non visual/Visual sensors and related algorithms, System Control, Robot collectives, Mobile robots in practise (Flying Robots, Underwater robots, Micro/nano robots, modular robots).

- **PLANNING AND NAVIGATION** **(10 Hours)**
  Introduction, Path planning overview, Representation of Search and Global path planning (Sequential motion planning), Real time Global Motion Planning (Depth limited approaches, Anytime approaches, Plan repair approaches-D* Algorithm, Hierarchical planning)

- **ALGORITHMIC ROBOTICS** **(10 Hours)**
  State based planning and control, Dynamics, kinodynamics, PID, Linear Quadratic Regulator, Kalman Filter and its application in robotics, State estimate, SLAM 1: Extended Kalman Filter (EKF-SLAM), SLAM 2: Particle Filter (Fast SLAM)

- **APPLIED COMPUTATIONAL INTELLIGENCE FOR ROBOTS** **(14 Hours)**
  Markov Decision Processes: Bellman backup, value/policy iterations, Reinforcement Learning, TD and Q learning, Deep learning: Concept of neural network, CNN, RNN and their applications in robotics, Deep Reinforcement Learning: Deep Q Network, Policy gradient, Gaussian Process: Informative planning and learning, Multi-Robot Coordination: Collective Intelligence, Distributed AI, Task allocation, information routing, Hungarian method, convex optimization in distributed AI. Cooperative control: Multi-agent exploration, localization, and coverage

(Total Contact Hours: 42)

3. **List of Practicals:**

1. Introduction to ROS/ROS2
2. Introduction to Gazebbo
3. Write a Code for Vehicle dynamics modeling
4. Write a Code PID control
5. Write a Code point planning
6. Write a code for PRM planning

7. Write a code reinforcement learning
8. Simulate the Robotics navigation using Gazebbo
9. Interfacing Hardware and Virtual run using Gazebbo
10. Deploying ROS2 and control robots on Hardware

4. <u>Books Recommended:</u>

1. Robert F. Stengel, “Robotics and Intelligent Systems: A Virtual Reference Book”, Princeton University, Princeton, NJ, September 12, 2017
2. Alonzo Kelly, Mobile Robotics: Mathematics, Models, and Methods, Cambridge University Press, 2013.
3. Kevin M. Lynch and Frank C. Park, Modern Robotics: Mechanics, Planning, and Control, Cambridge University Press, 2017
4. Sebastian Thrun, Wolfram Burgard, Dieter Fox, Probabilistic Robotics, MIT Press, 2005.
5. Steven M. LaValle: Planning Algorithms. Cambridge University Press, 2006

REAL TIME SYSTEMS

L	T	P	Credit
3	0	2	04

EC 429 **Scheme**

1. Course Outcomes (COs):

At the end of the course the students will be able to:

CO1	Explain fundamental principles for programming of real time systems with time and resource limitations.
CO2	Describe the foundation for programming languages developed for real time programming.
CO3	Account for how real time operating systems are designed and functions.
CO4	Describe what a real time network is.
CO5	Use real time system programming languages and real time operating systems for real time applications.
CO6	Analyse real time systems with regard to keeping time and resource restrictions.

2. Syllabus:

- **INTRODUCTION TO REAL-TIME SYSTEMS** **(10 Hours)**
  Hard Versus Soft Real Time Systems, Reference Models of Real Time Systems, Operating System Services, I/O Subsystems, Network Operations Systems, Real Time Embedded Systems, Operating Systems Interrupt Routines in RTOS Environments, RTOS Task Scheduling Models, Interrupt Latency And Response Time, Standardization Of RTOS

- **REAL-TIME SCHEDULING AND SCHEDULABILITY ANALYSIS** **(09 Hours)**
  Task, Process And Threads, Commonly Used Approaches To Real Time Scheduling, Clock-Driven Scheduling, Priority Driven Scheduling Of Periodic Tasks, Hybrid Schedules, Event Driven Schedules, Earliest Dead Line First (EDF) Scheduling, Rate Monotonic Algorithm (RMA), Real Time Embedded Operating Systems: Standard & Perspective, Real Time Operating Systems: Scheduling Resource Management Aspects,Quasi-Static Determining Bounds On Execution Times

- **INTER-PROCESS COMMUNICATION AND SYNCHRONIZATION OF PROCESSES,TASKS AND THREADS** **(05 Hours)**
  Multiple Process in An Application, Data Sharing By Multiple Tasks And Routines Inter Process Communication

- **REAL-TIME OPERATING SYSTEMS** **(12 Hours)**
  Handling Resources Sharing and Dependencies Among Real Time Tasks, Resource Sharing Among real Time tasks, Priority Inversion, Priority Inheritance Protocol (PIP), Highest Locker Protocol (HLP), Priority Ceiling Protocol (PCP), Different Types of Priority Inversion Under PCP, Important Features of PCP, Handling Task Dependencies, Real time communication, Real time systems for multiprocessor systems, Real-time databases.

- **COMMERCIAL REAL TIME OPERATING SYSTEMS** **(06 Hours)**
  Time Services, Unix As Real Time OS, Non-Primitive Kernel, Dynamic Priority Levels, Unix Based Real Time OS, Extension to the Traditional Unix Kernal, Host Target Approach, Preemption Point Approach, RT Linux, Windows CE as Real Time OS, Real Time POSIX Standard, MC/OS-II

(Total Contact Hours: 42)

3. List of Practicals:

1. Concepts of Multi-threading using pThreads library
2. Semaphore, Mutual exclusion and Condition variable using pThreads
3. Data synchronization using pThreads.
4. Introduction to FreeRTOS and Target hardware
5. LED blinking using FreeRTOS library
6. UART transmission using FreeRTOS library
7. Multiple GPIOs and LED using FreeRTOS library
8. Implementation of Round-Robin algorithm using FreeRTOS
9. Implementation of EDF Algorithms using FreeRTOS
10. Implementation of RMA Algorithm using FreeRTOS
11. Implementation of Resource Access Control using FreeRTOS

4. Books Recommended:

12. Rajib Mall, “Real Time Systems Theory and Practice”, 1st Ed., Pearson Education, 2007.
13. Wayne Wolf, “Computers as Components: Principles of Embedded Computing System Design”, 2nd Ed., Morgan Kaufman, 2008.
14. Liu Jane, “Real-time Systems”, 1st Ed., PHI, 2000.
15. Albert M. K. Cheng, “REAL-TIME SYSTEMS Scheduling, Analysis, and Verification”, 1st Ed., Wiley Interscience, 2002.
16. Richard Zurawski, “Embedded Systems Handbook”, 1st Ed., CRC Taylor Francis, 2006.

OPTICAL WIRELESS COMMUNICATION

L	T	P	Credit
3	0	0	03

EC 431 **Scheme**

1. **Course Outcomes (COs):**

At the end of the course the students will be able to:

CO1	Describe atmospheric channels for the intended terrestrial free space optical link.
CO2	Apply the concepts of OWC to calculate the system performance under background noise effects.
CO3	Analyze various modulation/demodulation techniques in designing of transmitter/receiver for OWC system.
CO4	Evaluate various detection techniques under various atmospheric conditions
CO5	Design the OWC system under different weather conditions.

2. **Syllabus:**

- **INTRODUCTION** **(06 Hours)**
  General introduction, optical channel - Beam divergence, atmospheric losses, weather condition influence, atmospheric turbulence effects viz., scintillation, beam wander, beam spreading, etc.

- **CHANNEL MODELLING** **(07 Hours)**
  Linear time invariant model, channel transfer function, optical transfer function, models of turbulence induced fading viz., lognormal, exponential, K distribution, I- distribution, gamma-gamma distribution, Optical wave models - Plane, spherical and Gaussian, range equation, transmitting and receiving antenna gains.

- **BACKGROUND NOISE EFFECTS** **(07 Hours)**
  Background noise source, detector FOV, diffraction limited FOV, spatial modes, background noise power calculation.

- **MODULATION TECHNIQUES** **(07 Hours)**
  Power efficiency, BW efficiency, bit versus symbol error rates, error rate evaluation for isochronous modulation schemes viz., M-PPM, OOK, mxnPAPM schemes, subcarrier modulation, an isochronous modulation schemes - DPPM, DHPIM, DAPPM, psd and bandwidth requirement.

- **DETECTION TECHNIQUES** **(08 Hours)**
  Photon counter, PIN/APD, PMT, coherent techniques viz., homodyne and heterodyne, bit error rate evaluation in presence of atmospheric turbulence, concept of adaptive threshold.

- **WEATHER IMPAIRMENTS** **(07 Hours)**
  Effect of turbulence and weather conditions viz., drizzle, haze fog on error performance and channel capacity, link availability.

(Total Contact Hours: 42)

3. Books Recommended:

1. Z. Ghassemlooy, W. Popoola, S. Rajbhandari, “Optical Wireless Communications”, 1st Ed., CRC Press, 2013.
2. L. C. Andrews, R.L.Phillips, “Laser Beam Propagation through Random Media”, 2nd Ed., SPIE Press, USA, 2005.
3. J. H. Franz, V. K. Jain, “Optical Communications: Components and Systems”, 1st Ed., Narosa Publishing House, 2000.
4. D. Chadha, “Terrestrial Wireless Optical Communication”, 1st Ed., Tata McGraw-Hill, 2012.
5. Ramaswami Rajiv and Sivarajan K. N., "Optical Networks A Practical Perspective", Elsevier, 3rd Ed., Morgan Kaufmann Publishers, 2009.

ESTIMATION AND DETECTION THEORY

L	T	P	Credit
3	0	0	03

EC 433 **Scheme**

1. **Course Outcomes (COs):**

At the end of the course the students will be able to:

CO1	Describe random variables, random processes and the basic concepts of signal detection and estimation.
CO2	Apply detection and estimation algorithms for problems.
CO3	Analyze performance of different detection and estimation algorithms.
CO4	Evaluate performance of detection and estimation algorithms.
CO5	Design detector and estimator for the problems of interest.

2. **Syllabus:**

- **INTRODUCTION** **(02 Hours)**
  Recap of probability theory, random variable and random process, Summery of important PDFs

- **STATISTICAL DETECTION THEORY** **(04 Hours)**
  Neyman –Pearson Theorem, Receiver Operating Characteristics, Irrelevant Data, Minimum Probability of Error, Bayes Risk, Multiple Hypotheses Testing

- **DETECTION OF DETERMINISTIC SIGNAL** **(05 Hours)**
  Matched Filters, Generalized Matched Filters, Multiple Signals, Linear Model, Signal Processing Example

- **DETECTION OF RANDOM SIGNAL** **(05 Hours)**
  Estimator-Correlator, Linear Model, Estimator-Correlator for Large Data Records, General Gaussian Detection, Signal Processing Example

- **COMPOSITE HYPOTHESES TESTING** **(04 Hours)**
  Approaches: Bayesian Approach, Generalized Likelihood Ratio Test, Performance of GLRT for Large Data Records, Locally Most Powerful Detectors, , Multiple Hypotheses Testing

- **MINIMUM VARIANCE UNBIASED ESTIMATION** **(04 Hours)**
  Unbiased Estimators, Minimum Variance Criteria, Existence of the Minimum Variance Unbiased Estimator, Finding the Minimum Variance Unbiased Estimator, Extension to a Vector Parameter

- **CRAMER-RAO LOWER BOUND** **(06 Hours)**
  Estimator Accuracy Considerations, Cramer-Rao Lower Bound, General CRLB for Signals in White Gaussian Noise, Transformation of Parameters, Extension to a Vector Parameter, Vector Parameter CRLB for Transformations, CRLB for the General Gaussian Case, Signal Processing Examples

- **MAXIMUM LIKELIHOOD ESTIMATION** **(06 Hours)**
  Finding the MLE, Properties of the MLE, MLE for Transformed Parameters, Numerical Determination of the MLE, Extension to a Vector Parameter, Signal Processing Examples

- **LEAST SQUARES** **(06 Hours)**
  The Least Squares Approach, Linear Least Squares, Geometrical Interpretations, Order-Recursive Least Squares, Sequential Least Squares, Constrained Least Squares, Signal Processing Examples

(Total Contact Hours: 42)

3. Books Recommended:

1. Steven M. Key, "Fundamentals of Statistical Signal Processing (Volume II): Detection Theory", 1st Ed., Prentice Hall PTR, 1998.
2. Steven M. Key, "Fundamentals of Statistical Signal Processing (Volume I): Estimation Theory", 1stEd., Prentice Hall PTR, 1993.
3. H. V. Poor, "An Introduction to Signal Detection and Estimation", 2nd Ed., Springer, 1998.
4. H. L. Van Trees, "Detection, Estimation and Modulation Theory: Part I", 2nd Ed., John Wiley, NY, 2016.
5. H. L. Van Trees, "Detection, Estimation and Modulation Theory: Part II", 2nd Ed., John Wiley, NY, 2016.

4. Reference Books:

1. H. L. Van Trees, "Detection, Estimation and Modulation Theory: Part III", 2nd Ed., John Wiley, NY, 2016.

PROCESSOR ARCHITECTURE

L	T	P	Credit
3	0	0	03

EC 435 **Scheme**

1. Course Outcomes (COs):

At the end of the course the students will be able to:

CO1	Discuss different processor architectures and system-level design processes.
CO2	Demonstrate the components and operation of a memory hierarchy and the range of performance issues influencing its design.
CO3	Analyze the organization and operation of current generation parallel computer systems, including multiprocessor and multicore systems.
CO4	Evaluate the principles of I/O in computer systems, including viable mechanisms for I/O and secondary storage organization.
CO5	Develop systems programming skills in the content of computer system design and organization.

2. Syllabus:

- **COMPUTER ABSTRACTIONS AND TECHNOLOGY** **(04 Hours)**
  Technologies for building processors and memory, Performance, Power wall, the switch from uniprocessors to Multiprocessors.

- **INSTRUCTION SET ARCHITECTURE OF 64-BIT RISC-V** **(08 Hours)**
  RISC-V addressing modes, instruction types, logical operations, instructions for making decisions, supporting procedures, RISC-V addressing for Wide Immediate and addresses, parallelism and instructions, comparison with MIPS and x86 Architectures.

- **PIPELINING** **(10 Hours)**
  An overview of pipelining, pipelined data-path and control, Data hazards: Forwarding versus Control, Control hazards, Exceptions, Parallelism via instructions, Real stuff: ARM Cortex-A53 and Intel Core i7 Pipelines, Case study: ILP and matrix multiply.

- **PARALLEL PROCESSORS** **(12 Hours)**
  Parallel programs, Flynn’s taxonomy, Hardware multithreading, multicore and shared memory multiprocessors, Graphics processing units, Clusters and message passing multiprocessors, Multiprocessor networks, Benchmarking of Intel Core i7 960 and NVIDA Tesla GPU, Case study: Multiprocessors and matrix multiply, Cache coherence, Advanced Cache optimizations, Real stuff: The ARM Cortex-A53 and Intel Core i7 memory hierarchy, Case study: Cache blocking and matrix multiply.

- **STORAGE AND INTERCONNECTION** **(08 Hours)**
  The basic principles of interconnection network design, On-Chip Interconnection Network, Router Architecture, Network interface design, Case Study: NoC

(Total Contact Hours: 42)

3. **Books Recommended:**

1. David A. Patterson, John L. Hennessy, “Computer Organization and Design: The Hardware Software Interface [RISC-V Edition]”, The Morgan Kaufmann Series in Computer Architecture and Design, 2017
2. John L Hennessy, “Computer architecture: a quantitative approach”, 6th Ed., Morgan Kaufmann Publishers, 2019
3. Leander Seidlitz, "RISC-V ISA Extension for Control Flow Integrity", Technische Universität München, 2019
4. Andrew Waterman, KrsteAsanović, The RISC-V Instruction Set Manual: Volume I: User-Level ISA, riscv.org, 2017
5. Andrew Waterman, KrsteAsanović, The RISC-V Instruction Set Manual: Volume II: Privileged Architecture, riscv.org, 2017

4. **Reference Books:**

1. William James Dally, Brian Patrick Towles, “Principles and Practices of Interconnection Networks”, Morgan Kaufmann, Year: 2004

EM INTERFERENCE AND COMPATIBILITY

L	T	P	Credit
3	0	0	03

EC 437 **Scheme**

1. Course Outcomes (COs):

At the end of the course the students will be able to:

CO1	Classify the different standards for EMC.
CO2	Implement the environments of radiation and conduction interference and methods to counter it.
CO3	Analyze the hazards of cross talk interference and model the methods to avoid it.
CO4	Evaluate the utility of different EMC methods in different environments.
CO5	Design a system for EMC.

2. Syllabus:

- **INTRODUCTION** **(04 Hours)**
  History of EMI/EMC, Analysis of EMI, Types of noise and interference, Electromagnetic Compatibility, Benefits of good EMC design, EMC regulations (Government, Commercial And Military), Examples of EMC related problems.

- **EMC REQUIREMENTS FOR ELECTRONIC SYSTEMS** **(05 Hours)**
  Radiated emission limits for Class A, Class B, FCC And CISPR, Measurement Of Emissions for Verification of Compliance, Radiated Emission and Susceptibility, Conducted Emissions and Susceptibility, Typical Product Emissions, Additional Product Requirements, Design Constraints for Products, Advantages of EMC Design.

- **CONDUCTED EMISSION AND SUSCEPTIBILITY** **(07 Hours)**
  Measurement Of Conducted Emission: LISN, Common and Differential Mode Currents, Power Supply Filters, Basic Properties of Filters, a Generic Topology, Effect of Filter Elements on Common and Differential Mode Currents, Separation of Conducted Emissions In to Common And Differential Mode Components For Diagnostic Purpose, Power Supplies: Linear and SMPS, Effect of Power Supply Components on Conducted Emissions, Power Supply and Filter Placement, Conducted Susceptibility.

- **RADIATED EMISSION AND SUSCEPTIBILITY** **(07 Hours)**
  Simple Emission Models for Wires And PCB Lands: Differential Mode Versus Common Mode Currents, Differential Mode Current Emission Model, Common Mode Current Emission Model, Current Probes, Simple Susceptibility Models for Wires And PCB Lands: Shielded Cables and Surface Transfer Impedance.

- **CROSS TALK** **(10 Hours)**
  Three Conductor Transmission Lines and Crosstalk, Transmission Line Equations for Lossless Lines, The Per Unit Length Parameters: Homogeneous versus Inhomogeneous Media, Wide Separation Approximation for Wires, Numerical Methods for Other Structures, The Inductive-Capacitive Coupling Approximation Model: Frequency Domain Inductive-Capacitive Coupling Model, Time Domain Inductive-Capacitive Coupling Model, Lumped Circuit Approximate Models, Shielded Wires, Inductive and Capacitive Coupling, Effect of Shield Grounding, Effect of Pigtails, Effects of Multiple Shields, MTL Model Predictions, Twisted Wires, Inductive and Capacitive Coupling, Effects of Twist, Effects of Balancing.

- **SHIELDING** **(05 Hours)**
  Shielding Effectiveness, Far Field Sources, Exact Solution, and Approximate Solution, Near Field Sources: Near Field versus Far Field, Electric Sources, Magnetic Sources, Low Frequency, Magnetic Fielding Shielding, Effect of Apertures.

- **SYSTEM DESIGN FOR EMC** **(04 Hours)**
  Shielding and Grounding, PCB Design, System Configuration and Design, Electrostatic Discharge, Diagnostic Tools.

(Total Contact Hours: 42)

3. <u>Books Recommended:</u>

1. Paul Clayton, Introduction to Electromagnetic Compatibility, 2nd Ed., Wiley Interscience, 2006.
2. Ott H. W., Noise Reduction Techniques in Electronic Systems, 2nd Ed., Wiley Interscience, 1988.
3. Goedbloed, Electromagnetic Compatibility, 1st English Language Ed., Prentice Hall, 1993.
4. Kaiser K. L., Electromagnetic Shielding, 1st Ed., CRC Press, 2006.
5. V. Prasad Kodali, Engineering Electromagnetic Compatibility, Principles, Measurement and Technologies, IEEE Press, 1996.

4. <u>Reference Books:</u>

1. Michel Mardiguian,"EMI Troubleshooting Techniques", 1st Ed., McGraw-Hill Professional, 1999.

VLSI SYSTEMS

L	T	P	Credit
3	0	0	03

EC 439 **Scheme**

1. Course Outcomes (COs):

At the end of the course the students will be able to:

CO1	Classify the different standards for EMC.
CO2	Implement the environments of radiation and conduction interference and methods to counter it.
CO3	Analyze the hazards of cross talk interference and model the methods to avoid it.
CO4	Evaluate the utility of different EMC methods in different environments.
CO5	Design a system for EMC.

2. Syllabus:

- **INTERCONNECT** **(08 Hours)**
  The Wire, Interconnect Parameter, Electrical And Spice Wire Model, RLC Parasitic, Signal Integrity And High Speed Behavior Of Interconnects: Ringing, Cross Talk And Ground Bounce. Layout Strategies At IC And Board Level For Local And Global Signals, Power Supply Decoupling, Advance Interconnect Techniques.

- **DESIGNING OF SEQUENTIAL LOGIC CIRCUIT** **(08 Hours)**
  Static And Dynamic Latches And Registers, Design And Optimization Of Pipelined Stages, Timing Issues In Digital Circuits, Handling Multiple Clock Domains, Synchronous And Asynchronous Design Styles, Interface Between Synchronous And Asynchronous Blocks, Set-Up And Hold Time Violation, Concept Of Meta-Stability.

- **SYSTEM HARDWARE DECOMPOSITION** **(04 Hours)**
  Data Path And Control Path, Register Transfer Level Description, Control Path Decomposition (Interfacing With FSM), Pitfalls of Decomposition, Control Flow And Data Flow Pipelines, Communication Between Subsystems, Control Dead Locks.

- **SUBSYSTEM DESIGN** **(12 Hours)**
  Logic Design Consideration For Arithmetic Building Blocks: Adders, Multipliers, Shifters Logic Design Consideration For Memory Architecture: Address Decoder, Sense Amplifier, Voltage Reference, Drivers/Buffers, Timing And Control Shared Memory Data Hazards And Consistency, Mutual Exclusion.

- **DESIGN FOR TEST** **(10 Hours)**
  Introduction, Test Procedure, Issues In Design For Testability, Ad-Hoc Testing, Scan-Based Test, Boundary Scan Design, Built-In-Self Test (BIST), Test Pattern Generation, Fault Models, Automatic Test Pattern Generation (ATPG).

(Total Contact Hours: 42)

3. Books Recommended:

1. Rabaey Jan M., Chandrakasan Anantha and Borivoje Nikolic, "Digital Integrated Circuits (Design Perspective)", Prentice Hall of India, 2nd Ed., 2003.
2. Smith M. J. S.,"Application Specific Integrated Circuits", Addison Wesley, 1st Ed., 1999.

3. Dally W. J. and Poulton J. W.,"Digital System Engineering", Cambridge University Press, 1st Ed., 1998.
4. Hall S. H., Hall G. W. and McCall J. A.,"High Speed Digital System Design", John Wiley & Sons, 1st Ed., 2000.
5. Bakoglu H. B.,"Circuit Interconnect And Packaging For VLSI", Addison-Wesley, 1st Ed., 1990.
6. Weste Neil H. E., Harris D. and Banerjee A. ,"CMOS VLSI Design", Addison Wesley, 3rd Ed., 2004.
7. Laung-Terng Wang, Cheng-Wen Wu and Xiaoqing Wen,"VLSI Test principles And Architectures Design For Testability", Morgan Kaufmann Publishers, 1st Ed., 2006.

QUANTUM COMPUTING

L	T	P	Credit
3	0	0	03

EC 441 **Scheme**

1. **Course Outcomes (COs):**

At the end of the course the students will be able to:

CO1	To appreciate quantum mechanics for quantum computing
CO2	To summarize the quantum algorithms
CO3	To review quantum circuits and quantum fourier transform
CO4	To overview quantum information
CO5	To understand and design quantum computers

2. **Syllabus:**

- **QUANTUM MECHANICS FOR QUANTUM COMPUTING** **(06 Hours)**
  Linear Algebra, The postulates of Quantum mechanics, The density operator, The Schmidt decomposition and purifications, Qubits And The Framework Of Quantum Mechanics, Introduction to computer science: Models for computation, The analysis of computational problems, Perspectives on computer science

- **QUANTUM ALGORITHMS** **(12 Hours)**
  INTRODUCTORY QUANTUM ALGORITHMS: Probabilistic Versus Quantum Algorithms; Phase Kick-Back; The Deutsch Algorithm; The Deutsch–Jozsa Algorithm; Simon's Algorithm,
  Algorithms With Superpolynomial Speed-Up: Quantum Phase Estimation; Eigenvalue Estimation; Finding-Orders; Finding Discrete Logarithms; Related Algorithms and Techniques,
  ALGORITHMS BASED ON AMPLITUDE AMPLIFICATION: Grover's Quantum Search Algorithm; Amplitude Amplification; Quantum Amplitude Estimation and Quantum Counting; Searching Without Knowing the Success Probability; Related Algorithms and Techniques

- **QUANTUM CIRCUITS and QUANTUM FOURIER TRANSFORM** **(08 Hours)**
  Quantum circuits: Single qubit operations; Controlled operations; Measurement; Universal quantum gates; Summary of the quantum circuit model of computation; Simulation of quantum systems, The quantum Fourier transform and its applications: The quantum Fourier transform; Phase estimation; Applications: order-finding and factoring; General applications of the quantum Fourier transform

- **QUANTUM INFORMATION** **(08 Hours)**
  Quantum noise and quantum operations: Classical noise and Markov processes; Examples of quantum noise and quantum operations; Examples of quantum noise and quantum operations; Applications of quantum operations, Quantum error-correction: Classical Error Correction, The Classical Three-Bit Code, Fault Tolerance, Theory of Quantum Error Correction, Constructing quantum codes, Stabilizer codes, Three- and Nine-Qubit Quantum Codes, Fault-Tolerant Quantum Computation

- **QUANTUM COMPUTERS** **(08 Hours)**
  Guiding principles, Conditions for quantum computation, Quantum Hardware, Quantum Instruction Sets & Quantum Circuits, Micro-architectures, compiles, and programming languages for quantum processors, Programming a quantum algorithm with pyQuil

(Total Contact Hours: 42)

3. Books Recommended:

1. Michael A. Nielsen, Isaac L. Chuang, "Quantum Computation and Quantum Information: 10th Anniversary Edition", Cambridge University Press; 1st edition, 2011
2. P Kaye, R Laflamme and M Mosca, "An Introduction to Quantum Computing", Oxford University Press, 2007
3. David McMahon, "Quantum computing explained", Wiley-interscience, John Wiley & Sons, Inc. Publication 2008
4. P. Krantz, M. Kjaergaard , F. Yan, T.P. Orlando , S. Gustavsson and W. D. Oliver, "A Quantum Engineer's Guide to Superconducting Qubits", 2019
5. Arthur O. Pittenger, "An Introduction to Quantum Computing Algorithms", Birkhäuser Basel Publisher, 2000
6. David J. Griffiths, "Introduction to Quantum Mechanics", 2 nd Edition, Prentice Hall New Jersey 1995

FUNDAMENTALS OF NANOELECTRONICS

L	T	P	Credit
3	0	0	03

EC 451 **Scheme**

1. Course Outcomes (COs):

At the end of the course the students will be able to:

CO1	Describe various carrier transport mechanisms, properties of semiconductor materials, and novel devices using mathematical equations.
CO2	Demonstrate physics needed for special classes of nanoelectronic devices and their applications.
CO3	Analyze nanoelectronic devices and their suitability in the semiconductor industry.
CO4	Evaluate the technological, economical and social impact of nanostructuring processes, small devices and systems.
CO5	Develop novel devices, processes and applications based on them.

2. Syllabus:

- **FUNDAMENTALS OF NANOSCALE PHYSICS** **(12 Hours)**
  Top-Down and Bottom-Up Approach, Potential of Nanotechnology and Nanoelectronics, Classical Particles, Quantum Mechanics of Electrons, Free and Confined Electrons, Quantum Structures

- **BAND THEORY OF SOLIDS** **(08 Hours)**
  Electrons in Periodic Potential, Kronig-Penney Model of Band Structure, Band Theory of Solids, Graphene and Carbon Nanotubes.

- **SINGLE, FEW AND MANY ELECTRONS PHENOMENA** **(11 Hours)**
  Tunnel Junctions, Applications of Tunneling, Coulomb Blockade and Single Electron Transistor, Particle Statistics, Density of States.

- **QUANTUM STRUCTURES** **(11 Hours)**
  Quantum Wells, Quantum Wires and Quantum Dots, Ballistic Transport and Spin Transport.

(Total Contact Hours: 42)

3. Books Recommended:

1. Hanson, G. W., “Fundamentals of Nanoelectronics”, 1st Ed., Pearson Education, 2009.
2. Rogers, Pennathur and Adams, “Nanotechnology: Understanding Small Systems”, CRC Press, Tayler and Francis Group, 2008.
3. Mahalik N. P., “Micromanufacturing and Nanotechnology”, Springer, 2006.
4. Kohler and Fritzsche, “Nanotechnology: An Introduction ToNanostructuring Techniques”, 1st Edition, 1st Reprint, Wiley-VCH, 2004.
5. Fahrner W. R. (Ed),“Nanotechnology And Nanoelectronics: Materials, Devices, Measurement Techniques”, Springer Publications, 2005.

4. Reference Book:

1. Kumar Vijay, “Nanosilicon”, 1st Ed., Elsevier Ltd., 2008

TESTING AND VERIFICSTION OF VLSI CIRCUITS

L	T	P	Credit
3	0	0	03

EC 453 **Scheme**

1. Course Outcomes (COs):

At the end of the course the students will be able to:

CO1	Develop test patterns required to detect faults in a circuit
CO2	Determine the testability of a circuit
CO3	Design methods/techniques to improve the testability of digital circuits
CO4	Design Logic BIST circuits
CO5	Specify the formal verification techniques

2. Syllabus:

- **INTRODUCTION** **(10 Hours)**
  Scope Of Testing And Verification In VLSI Design Process, Issues In Test And Verification Of Complex Chips, Embedded Cores And SOCs

- **VLSI TESTING OF FAULT MODELS** **(12 Hours)**
  Fundamentals Of Automatic Test Pattern Generation, Design For Testability, Scan Design, Test Interface And Boundary Scan, System Testing and Test For SOC, Delay Fault Testing

- **Mu TESTING OF LOGIC AND MEMORIES** **(10 Hours)**
  Test Automation, Design Verification Techniques Based On Simulation, Analytical And Formal Approaches

- **VERIFICATION** **(10 Hours)**
  Functional Verification, Timing Verification, Formal Verification, Basics of Equivalence Checking And Model Checking, Hardware Emulation

(Total Contact Hours: 42)

3. Books Recommended:

1. Bushnell M. and Agrawal V. D.,“Essentials Of Electronic Testing For Digital, Memory And Mixed-Signal VLSI Circuits”,Kluwer Academic Publishers,2000.
2. Abramovici M., Breuer M. A. and Friedman A. D.,“Digital Systems Testing And Testable Design”,IEEE Press,1990.
3. Kropf T., “Introduction To Formal Hardware Verification”, Springer Verlag,2000.
4. Rashinkar P., Paterson and Singh L.,“System-On-A-Chip Verification-Methodology And Techniques”,Kluwer Academic Publishers,2001.
5. Neil H. E. Weste and David Harris,“Principles Of CMOS VLSI Design”,Addison Wesley, 3rd Edition,2004

AD-HOC NETWORKS

L	T	P	Credit
3	0	0	03

EC 455 **Scheme**

1. <u>Course Outcomes (COs):</u>

At the end of the course the students will be able to:

CO1	Describe the basic knowledge of architecture, issues, protocols of Mobile Adhoc Networks and the standard Adhoc networks-Bluetooth, WiFi, WiMAX, WSN etc.
CO2	Apply protocols and techniques in MANETs, developing algorithms for recent standard Adhoc networks overcoming the constraints
CO3	AnalyzeWireless Sensor Network Architecture.
CO4	Evaluate various techniques and protocols/algorithms, case study and problem solving as per given data.
CO5	Design of Wireless Sensor Network for IoT application.

2. <u>Syllabus:</u>

- **INTRODUCTION** **(04 Hours)**
  Introduction To Generations In Wireless Systems, Introduction To Mobile Ad-Hoc Networks (MANETS), Classification Of Mobile Data Networks, MANET issues, Wireless Channel Related Issues

- **MAC LAYER ISSUES OF ADHOC NETWORKS** **(04 Hours)**
  CSMA with Hidden and Exposed Terminal Issues, MACA and MACAW protocols

- **NETWORK LAYER ISSUES IN ADHOC NETWORKS** **(06 Hours)**
  Challenges, Proactive and Reactive Algorithms, Limitations of Bellman Ford Algorithm, DSDV, WRP, CGSR protocols, DSR, AODV, Location aided, hybrid protocols, multicast protocols

- **TRANSPORT LAYER ISSUES** **(06 Hours)**
  Challenges, data flow control mechanisms, congestion control protocols, security aspects

- **BLUETOOTH** **(04 Hours)**
  Bluetooth Network Structure: Piconet & Scatternet, Bluetooth Specifications, Bluetooth Protocol Stack, Bluetooth Media Access Control Consideration, Asynchronous Connectionless And Synchronous Connection Oriented Communication Link, Modified Bluetooth

- **WIFI - IEEE802.11 STANDARDS** **(04 Hours)**
  Various 802.11 Protocols (a to s), WiFi Architecture, Security Enhancement, QoS Enhancement, Physical & MAC Layer Aspects Of 802.11 a,b,g,n; WiFi MAC: Point Coordinate Function, Distributed Coordinate Function, Hybrid Coordinate Function

- **WIMAX - IEEE802.16 STANDARDS** **(04 Hours)**
  Various 802.16 (a to e) Protocols, WiMAX Air Interface / Physical Layer, WiMAX Architecture, WiMAX Protocol Architecture, WiMAX AndWiFi Interworking, WiMAX Mode: TDD And FDD, QoS In WiMAX

- **WIRELESS SENSOR NETWORK** **(06 Hours)**
  Sensor node architecture, Sensor Network architecture, Zigbee IEEE 802.15.4, Mobile Computing Aspects, Introduction to IoT

- **UWB** **(02 Hours)**
  UWB Air Interface

- **IEEE802.20 AND BEYOND** **(02 Hours)**

(Total Contact Hours: 42)

3. <u>Books Recommended:</u>

1. Toh C. K. “Ad-hoc Mobile Wireless Networks-Protocol and Systems”, LPE, 2nd Ed., Pearson Education, 2009.
2. William C.Y. Lee, “Wireless& Cellular Telecommunication”, 3rd Ed., McGraw-Hill, 2005.
3. Upena Dalal, “Wireless Communication”, 1st Ed., Oxford University, 2009.
4. Vijay K. Garg, “Wireless Network Evolution 2G to 3G”, 2nd Ed., Pearson Education, 2004.
5. C. Siva Rama Murthy, B. S. manoj, “Adhoc Wireless Networks-Architectures and Protocols”, 1st Ed., Pearson, 2007.

COGNITIVE RADIO

L	T	P	Credit
3	0	0	03

EC 457 **Scheme**

1. **Course Outcomes (COs):**

At the end of the course the students will be able to:

CO1	Explain the fundamentals of SDR and CR with basic differences.
CO2	Compare the various spectrum sensing techniques for optimum selection.
CO3	Evaluate the performance of spectrum sensing and spectrum management techniques over cognitive radio.
CO4	Design and analyze the performance parameters over CR architecture for the specified techniques and parameters.

2. **Syllabus:**

- **SOFTWARE DEFINED RADIO (SDR)** **(08 Hours)**
  Essential functions of the SDR, SDR architecture, design principles of SDR, traditional radio implemented in hardware and SDR, transmitter architecture and its issues, A/D & D/A conversion, parameters of practical data converters, techniques to improve data converter performance, complex ADC and DAC architectures, digital radio processing, reconfigurable wireless communication systems.

- **COGNITIVE RADIO (CR) FEATURES AND CAPABILITIES** **(08 Hours)**
  CR functions, CR architecture, components of CR, CR cycle, CR and dynamic spectrum access, interference temperature, CR architecture for next generation networks, CR standardization, Concept of primary and secondary users, Licensed and unlicensed spectrums in CR.

- **SPECTRUM SENSING AND IDENTIFICATION** **(09 Hours)**
  Primary signal detection, energy detector, cyclostationary feature detector, matched filter, cooperative sensing, spectrum opportunity, spectrum opportunity detection, fundamental trade-offs: performance versus constraint, sensing accuracy versus sensing overhead.

- **SPECTRUM MANAGEMENT OF COGNITIVE RADIO NETWORKS** **(08 Hours)**
  spectrum decision, spectrum sharing and spectrum mobility, mobility management of heterogeneous wireless networks, research challenges in CR Spectrum switching

- **COGNITIVE RADIO NETWORKS (CRN) ARCHITECTURE** **(09 Hours)**
  Terminal architecture of CRN, diversity radio access networks, routing in CRN, Control of CRN, Self-organization in mobile communication networks, security in CRN, cooperative communications, cooperative wireless networks, user cooperation and cognitive systems.

(Total Contact Hours: 42)

3. **Books Recommended:**

1. Kwang-Cheng Chen and Ramjee Prasad, “Cognitive Radio Networks”, John Wiley & Sons, Ltd, 2009.
2. Alexander M. Wyglinski, Maziar Nekovee, and Y. Thomas Hou, “Cognitive Radio Communications and Networks - Principles and Practice”, Elsevier Inc., 2010.

3. Bruce Fette, “Cognitive radio technology”, Elsevier, 2nd edition, 2009.
4. Jeffrey H. Reed “Software Radio: A Modern Approach to radio Engineering”, Pearson Education Asia.
5. Linda Doyle, “Essentials of Cognitive Radio”, Cambridge University Press, 2009.
6. Wei Zang, Handbook of Cognitive Radio, Reference Work, SpringerLink, 2019
7. Setoodeh P and Simon Hykin, Fundamentals of Cognitive Radio, Wiley Publication, 2017

BIOMEDICAL INSTRUMENTATION

L	T	P	Credit
3	0	0	03

EC 459 **Scheme**

1. Course Outcomes (COs):

At the end of the course the students will be able to:

CO1	Model biological systems.
CO2	Comprehend the principles of transducers in bio-instrumentation.
CO3	Analyze the ECG, EEG and EMG.
CO4	Measure bio medical signal parameters.
CO5	Study pace makers, defibrillators, surgical instruments etc.

2. Syllabus:

- **ANATOMY AND PHYSIOLOGY** **(06 Hours)**
  Elementary Ideas of Cell Structure, Heart and Circulatory System, Control Nervous System, Musclo-Skeletal System, Respiratory System Body Temperature and Reproduction System.

- **CLASSIFICATION OF BIOMEDICAL EQUIPMENT** **(02 Hours)**
  Diagnostic, Therapeutic and Clinical Laboratory Equipment.

- **BIOELECTRIC SIGNALS AND THEIR RECORDING** **(08 Hours)**
  Bioelectric Signals (ECG, EMG, ECG, EOG & ERG) and Their Characteristics, Bio-Electrodes, Electrodes Tissue Interface, Contact Impedance, Effects of High Contact Impedance, Types of Electrodes, Electrodes for ECG, EEG and EMG.

- **TRANSDUCERS FOR BIOMEDICAL APPLICATION** **(10 Hours)**
  Resistive Transducers - Muscle Force and Stress (Strain Gauge), Spirometry, Humidity, (Gamstrers), Respiration (Thermistor), Inductive Transducers: Flow Measurements, Muscle Movement (LVDT), Capacitive Transducers: Heart Sound Measurement, Pulse Pick Up, Photoelectric Transducers, Pulse Transducers, Blood Pressure, Oxygen Analyses Piezoelectric Transducers: Pulse Pickup, Ultrasonic Blood Flowmeter, Chemcial Transducer: Ag-Agfallas (Electrodes, PH Electrode).

- **BIOLDECTRIC SIGNAL RECORDING MACHINES** **(06 Hours)**
  Physiological Pre-Amplifier and Specialized Amplifiers, ECG Lead Systems Details of ECG, EMG and EEG Machines.

- **PATIENT MONITORING SYSTEM** **(04 Hours)**
  Heart Rate Measurement, Pulse Rate Measurement, Respiration, Rate Measurement, Blood Pressure Measurement, Microprocessor Applications in Patient Monitoring.

- **DEFIBRILLATORS AND PACEMAKERS** **(04 Hours)**
  Rationale of using Defibrillators, Theory of Defibrillators Circuits, Types of Defibrillators, Safety issues in Defibrillators, Theory of Pacemakers, Types of Pacemakers, Pacemaker Circuit, Technical Specification of Pacemaker, Defibrillator and Pacemaker Simulators.

- **SAFETY ASPECT OF MEDICAL** **(02 Hours)**
  Gross Current, Micro Current Shock, Safety Standards Rays and Considerations, Safety Testing Instruments, Biological Effects of X-Rays and Precautions.

(Total Contact Hours: 42)

3. Books Recommended:

1. John. G. Webster,"MedicalInstrumentation",John Wiley, 4th Ed., 2009
2. Goddes L. A. and Baker L. E.,"Principles of Applied Biomedical Instrumentation",John Wiley, 3rd Ed., 1989.
3. Carr Joseph J. and Brown John M,"Biomedical Instrumentation And Measurement",Pearson, 4th Ed., 2001.
4. Cromwell,"BiomedicalInstrument",Prentice Hall, 3rd Ed., 2000.
5. R.S. Khandpur,"Hand book of Medical Instruments",TMH, 2nd Ed.,2003.