Two year Master of Technology (MTech) Degree Program
in
Communication System and Signal Processing (CSSP)

by

Department of Electrical Engineering Department
Indian Institute of Technology Patna
Bihta, Patna-801106

Academic Program: M.Tech. program in Communication System & Signal Processing

Program Learning Objectives:	**Program Learning Outcomes:**
Program Goal 1: To equip students with technical skills necessary for the design, analysis, and implementation of communication system technologies and networks.	**Program Learning Outcome 1a:** Demonstrate proficiency in one or more specialized areas within communication system engineering, such as wireless communication, optical communication, microwave and millimeter wave technologies, digital signal processing, or network engineering. **Program Learning Outcome 1b:** Demonstrate advanced knowledge and understanding of communication engineering principles, theories, and concepts.
Program Goal 2: To foster research and development skills, enabling students to contribute to the advancement of communication technologies through innovation and problem-solving.	**Program Learning Outcome 2:** Conduct independent research, including literature review, experimentation, data analysis, and interpretation, to address communication engineering challenges and contribute to knowledge advancement in the field.
Program Goal 3: To develop critical thinking and analytical skills for evaluating and solving complex communication engineering problems.	**Program Learning Outcome 3a:** Apply analytical and problem-solving skills to design, analyze, and optimize communication systems and networks. **Program Learning Outcome 3b:** Collaborate effectively in multidisciplinary teams to solve complex communication engineering problems, demonstrating leadership, interpersonal, and teamwork skills.
Program Goal 4: To prepare students for professional practice in communication engineering roles in industry, academia, research institutions, or government agencies.	**Program Learning Outcome 4a:** Design, simulate, and implement communication systems and networks using appropriate tools, techniques, and methodologies.

-

-

M.Tech. program in in Communication System & Signal Processing

Sl. No.	Subject Code	**SEMESTER I**	**L**	**T**	**P**	**C**
1.	XX51PQ	Technical Writing and Soft Skill	3	0	2	4
2.	EC5101	Information Theory and Coding	3	1	0	4
3.	EC5102	Advanced Digital Signal Processing	3	0	2	4
4.	EC5103	Antenna and Microwave Devices	3	0	2	4
5.	EC51XX/ EC61XX	DE-1	3	0	0	3
6.	EC51XX/ EC61XX	DE-2	3	0	0	3
7.	XX61PQ	IDE	3	0	0	3
	TOTAL		**18**	**1**	**6**	**25**

Sl. No.	Subject Code	**SEMESTER II**	**L**	**T**	**P**	**C**
1.	EC5201	Wireless Communication	3	0	2	4
2.	EC5202	Advanced Communication Systems	3	0	2	4
3.	EC52XX/ EC62XX	DE-3	3	0	0	3
4.	EC52XX/ EC62XX	DE-4	3	0	0	3
5.	EC52XX/ EC62XX	DE-5	3	0	0	3
6.	RM6201	Research Methodology	3	1	0	4
7.	IK6101	IKS	3	0	0	3
	TOTAL		**18**	**1**	**4**	**24**

Sl. No.	Subject Code	**SEMESTER III**	**L**	**T**	**P**	**C**
1.	EC6102	Summer Internship/ Mini Project*	0	0	12	3
2.	EC6101	Project I	0	0	30	15
	TOTAL					**18**

Sl. No.	Subject Code	**SEMESTER IV**	**L**	**T**	**P**	**C**
1.	EC6201	Project II	0	0	42	21
	TOTAL					**21**

GRAND TOTAL	**88**

Elective Courses:

Semester-I

DE-1	DE-2
EC5108 RF and Microwave Active Circuits	EC6154: Computer Vision
EC5109 Internet of Things (IoT) Networks	EC6114 Radio Frequency Design and Technology
EC6116 Advance Antenna and Microwave Devices	EC5111 VLSI Architectural Design and Implementation
EC5113 Radio Frequency Integrated Circuits	EC5159 Bio Sensors and Circuits
EC5114 Advanced Digital Image Processing	EC5104 Quantum Computing
	EC6157 VLSI Signal Processing

Semester-II

DE-3	DE-4	DE-5
EC5250 Patterns Recognition and Machine Learning	EC5104 Quantum Computing	EC5203 Communication Networks
EC5204 Multimedia Communication	EC6209 Adaptive filtering: From theory to practice	EC5206 Advanced Biomedical Signal Processing
EC6208 RF and Microwave Measurement Techniques	EE6215 Random Signals and Systems	EC6212 Optimization Theory and Techniques for Electrical Engineering
EC6210 Smart Antenna: From Theory to Practice	EC6211 Antenna Design and Characterization	EC5216 Silicon Photonics
EC5205 Optical Communication	EC6213 Statistical Signal Processing	EC6207 Microwave and Millimetre Wave Integrated Circuits (MMIC)
		EC6271: Generative AI for Video Surveillance System

Course Number	**EC5101**
Course Credit	3-1-0-4
Course Title	**Information Theory and Coding**
Learning Mode	Lectures
Learning Objectives	After learning this course, the students will be able 1. to know about the fundamental concepts of information theory 2. to understand coding, quantification, storage, and communication of information 3. to analyse source coding and channel coding 4. to get familiar with the basics of the error control coding
Course Description	This course deals with the Information theory and coding.
Course Outline	Information, Average Information, Information rate, Entropy, Joint Entropy and Conditional Entropy, Relative Entropy and Mutual Information, Chain rule for entropy, relative entropy, and mutual information.Source Coding: Fixed and Variable Length Codes, Kraft Inequality, Shannon-Fano Algorithm, Huffman Algorithm. Maximum Entropy Distribution for continuous and discrete random variables. Channel Capacity, Capacity of different channels: Noiseless binary channel, Noisy channel with nonoverlapping outputs, Binary symmetric channels, Binary erasure channel, symmetric channels, AWGN channels; Shannon Theorem. Maximum entropy distributions for continuous and discrete cases. Error Control Coding: Introduction, Forward & Backward error Correction, Hamming Weight and Hamming Distance, Hamming Codes, Linear Block Codes, Encoding and decoding of Linear Block-codes, Parity Check Matrix, Syndrome Decoding. Convolutional and Turbo Codes: Introduction, Polynomial description of Convolutional Codes, Generating function, Matrix description of Convolutional Codes, Viterbi Decoding of Convolutional codes, Turbo Codes, Turbo Encoder and Decoder, LDPC, Encoder and Decoder of LDPC.
Learning Outcome	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments, and Exams
Suggested Readings	**Text Books:** 1. Joy A. Thomas and Thomas M. Cover, Elements of Information Theory, 2nd Edition, 2006, John Wiley & Sons. 2. Shu Lin and Daniel Costello, Error Control Coding: Fundamentals and Applications, 2nd Edition, 2004, Pearson. 3. **References Books:** 1. R. Bose, Information Theory and applications, 3rd Edition, 2017, McGraw Hill Education India Private Limited 2. San Ling and Chaoping Xing, Coding Theory: A First Course, 2004, Cambridge University Press. 3. Todd K. Moon, Error Correction Coding: Mathematical Methods and Algorithms, 1st Edition, 2005, John Wiley & Sons.

Course Number	**EC5102**
Course Credit	3-0-2-4
Course Title	**Advanced Digital Signal Processing**
Learning Mode	Lectures and Practical
Learning Objectives	After learning this course, the students will be able 1. to recognize some of the most important advanced signal processing techniques, including multirate processing and its applications. 2. to use time-frequency analysis techniques for audio signals and its applications.

	3. to explain the relationship between time and frequency domain interpretations and implementations of signal processing algorithms. 4. to describe fundamental statistical signal processing concepts of signal detection and parameter estimation.
Course Description	This course deals with the Advanced Digital Signal Processing.
Course Outline	Multi-rate Digital Signal Processing: Brief review of digital signal processing, discrete cosine transforms (DCT), Multi-rate digital signal processing, Sampling rate conversion of bandpass signals, Filter design and implementation for sampling rate conversion, Multistage implementation of sampling rate conversion, Applications of multi-rate signal processing. Time-Frequency Methods: STFT, Wigner-Ville transformation, Introduction to wavelets, The Haar wavelet, The Haar multi-resolution analysis, The Haar filter bank, Haar bank filter bank analysis and synthesis, Z-domain analysis of multi-rate filter bank, Two channel filter bank, Perfect reconstruction, Brief introduction to Daubechies wavelets. The uncertainty principle, Spectral Estimation and Linear Prediction: Non-parametric spectrum estimation, Periodogram, Bartlett, Welch and Blackman, Tukey methods, Parametric methods for rational spectra (ARMA, MA, AR processes) and line spectra, Autocorrelation and model parameters. Linear prediction, Forward and backward linear prediction, Solution of the normal equations, Properties of linear prediction-error Filter, AR lattice and ARMA Lattice-Ladder filters, AR (Auto-Regressive) process and linear prediction, Yule-Walker, Burg and Least squares methods, Sequential estimation, Moving average (MA) and ARMA models. Subspace algorithms - MUSIC, ESPRIT, Root-MUSIC, Minimum variance method, Piscaranko's harmonic decomposition methods. **Experiments**: 1. Filtering for Audio/Speech/Biomedical Signals and Image, real-time speech/audio/colored signal processing. 2. Applications of sampling rate conversion 3. AR, MA, ARMA Process 4. Linear prediction (fixed and adaptive) 5. Prediction Error Filter for decorrelation applications 6. System/Plant Identification 7. Noise Cancellation 8. Real-time experiment using dSPACE/Microlabbox
Learning Outcome	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments, and Exams
Suggested Readings	**Text Books:** 1. J. G. Proakis and D. G. Manolakis, Digital Signal Processing Principles, Algorithms and Application, 4th Edition, 2007, Pearson Education India. 2. A. V. Openheim and R. W. Schafer, Discrete Time Signal Processing, 3rd Edition, 2009, Pearson. 3. P. Stoica and R. Moses, Spectral Analysis of Signals, 1st Edition, 2005, Prentice Hall. **Reference Books** 1. P. Sircar, Mathematical Aspects of Signal Processing, 1st Edition, 2016, Cambridge University Press. 2. P. P. Vaidyanathan, Signals, Systems, and Signal Processing, 1st Edition, 2024, Cambridge University Press. 3. L. R. Rabiner and B. Gold, Theory and Application of Digital Signal Processing, 1st Edition, 1975, Prentice Hall.

Course Number	**EC5103**
Course Credit	3-0-2-4
Course Title	**Antenna and Microwave Devices**
Learning Mode	Lectures and Practical

Learning Objectives	**Course Learning Outcome (CLO):** After successful completion of this course, the students will 1. Understand the basic principles of electromagnetic theory as they apply to antennas and microwave devices. 2. Define and explain key antenna parameters such as gain, directivity, efficiency, bandwidth, and polarization. 3. Describe the function and characteristics of various microwave components, including passive and active devices. 4. Use simulation software (e.g., HFSS, CST, ADS) for modeling and optimizing antennas and microwave systems. 5. Solve complex engineering problems related to antenna and microwave device design, considering practical constraints and requirements.
Course Description	This course deals with the Antenna and Microwave Devices.
Course Outline	Maxwell Equations, Generation and Propagation of EM Waves in Guided and Unguided Media, Transmission Lines, Microstrip Lines, RF Fabrication Techniques. Network Parameters, High Frequency Network Parameters, Scattering Parameters, Smith Chart Concepts, Impedance Matching, matching using stubs, Microstrip Line Designing and Characterization. Microstrip Filter Design by Insertion Loss Method, Introduction to microwave devices and systems, Microwave link budget analysis. Radiation principle of EM wave, boundary conditions, antenna parameters, polarization of waves. Antenna parameters: gain, directivity, efficiency, bandwidth, and polarization. Antenna types: dipole, monopole, loop, patch, and array antennas, Antenna impedance and matching techniques. Antenna synthesis, Antenna analysis. Microwave source: Klystron, Magnetron, Travelling Wave Tube, Backward Wave Oscillator, IMPATT Diode, TRAPATT Diode, GUNN Diode, Schottky/Esaki Diode. **Experiments:** 1. Designing, development and characterisation of • Microstrip line • Low pass filter • Coupled line filters • Power dividers • Microstrip patch antenna 2. Measurement of scattering parameters of two-port network
Learning Outcome	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments, and Exams
Suggested Readings	**Text Books:** 1. David M. Pozar, “Microwave Engineering”, 4th Edition, 2011, Wiley. 2. Robert E. Collin, “Foundations for Microwave Engineering”, 2nd Edition, 2007, Wiley. **Reference Books:** 1. Constantine A. Balanis, “Antenna Theory: Analysis and Design", 3r Edition, 2009, Wiley. 2. Samuel Y. Liao, “Microwave devices and circuits”. 3rd Edition, 2003, Pearson Education India. 3. Mongia, R. K., Hong, J., Bhartia, P., & Bahl, I. J., “RF and microwave coupled-line circuits” 2007, Artech house, 2007. 4. Stephen A. Maas, “The RF and microwave circuit design cookbook”, 1998, Artech House.

Course Number	**EC5201**
Course Credit	3-0-2-4
Course Title	**Wireless Communication Systems**
Learning Mode	Lectures and Practical
Learning Objectives	After learning this course, the students will be able 1. to understand the concepts of the cellular architecture. 2. to understand the basics of radio propagation. 3. to develop mathematical skills to model communication system. 4. to understand the challenges associated with data transmission over wireless medium. 5. to get familiar with the mitigation strategies to achieve reliable communication over wireless medium.
Course Description	This course deals with the wireless communication system.
Course Outline	Random Signal Theory: Joint Probability, Statistical independence, Cumulative Distribution function and Probability Density function, Error function, Rayleigh and Gaussian Probability Density, Stationary and Ergodic Process, Power Spectral Density of digital data. Propagation & Fading: Free-space propagation model, Outdoor propagation models (Okumura model & Hata model), Indoor propagation model, Shadow fading and outage analysis, Multipath fading, time dispersive and frequency dispersive channels, delay spread and coherence bandwidth, LCR and ADF. Multiple-Input Multiple-Output (MIMO): Zero Forcing Receiver, MIMO MMSE Receiver, SVD and MIMO Capacity, Asymptotic MIMO Capacity, Alamouti and Space-time Codes, OSTBC and V-Blast Receivers. MIMO-OFDM. Evolution of wireless technologies: 1G to 5G and Beyond. Code Division Multiple Access (CDMA): Spreading Codes, Pseudo-Noise (PN) Sequence, Multi-Users CDMA, Near-Far Problem, Power Control and Advantages of CDMA. Orthogonal Frequency-Division Multiplexing (OFDM): Overview of Multicarrier Communications, Cyclic Prefix, Bit Error Rate, Frequency Offset, Peak-to-Average Power Ratio (PAPR), and SC-FDMA. **Experiments:** 1. Simulation in Wireless Communication Using MATLAB 2. Effect of fading on the performance of M-PSK and M-QAM modulation. 3. Effect of fading on the capacity of additive white Gaussian noise (AWGN) channel. 4. Implementation of optimal power allocation Water-Filling Algorithm. 5. Implementation of diversity techniques to mitigate the effect of multipath fading 6. MIMO receiver design 7. Implementation of BPSK modulation using Software Defined Radio (SDR) 8. Characterization of small-scale fading using SDR
Learning Outcome	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments, and Exams
Suggested Readings	***Text Books:*** 1. A. Goldsmith, Wireless Communications, 2009, Cambridge University Press. 2. D. Tse, P. Viswanath, Fundamentals of Wireless Communications, 2005, Cambridge Press. **Reference Books:** 1. G. L. Stuber, Principles of Mobile Communication, 1996, Kluwer Acdemic. 2. J. G. Proakis, Digital Communications, 1995, McGraw-Hill. 3. T. S. Rappaport, Wireless Communications: Principles and Practice, 1996, Prentice Hall. 4. A. J. Viterbi, CDMA Systems: Principles of Spread Spectrum Communication, 1995, Addison Wesley.

Course Number	**EC5202**
Course Credit	3-0-2-4
Course Title	**Advanced Communication Systems**
Learning Mode	Lectures and Practical
Learning Objectives	After learning this course, the students will be able 1. to understand different modulation schemes and their application to the real world. 2. to understand the various degradations caused at the receiver side. 3. to design the optimal receivers and their performance evaluation. 4. to understand the basics of channel estimation.
Course Description	This course deals with the Advanced Communication system.
Course Outline	Overview of Random Variables, Random Processes and Linear Algebra: Signal Space Concepts, Orthogonal Representation of Signals, Gram-Schmidt Procedure and Karhunen-Loeve (KL) Expansion. Communication Channel Models, Bandpass & Lowpass Signals Digital Modulation Schemes and their Performance Analysis: Memoryless and with Memory Modulation Methods, Pulse Amplitude Modulation (PAM), Phase Modulation, Quadrature Amplitude Modulation (QAM), Continuous-Phase Frequency-Shift Keying (CPFSK), and Continuous-Phase Modulation (CPM) Optimum Receiver in Presence of Additive White Gaussian Noise: Maximum a Posteriori Probability (MAP) and Maximum Likelihood (ML) Receivers, Coherent versus Non-coherent Detection, Binary Signal Detection in AWGN, M-ary Signal Detection in AWGN. Probability of Error Analysis Receiver Synchronization: Signal Parameter Estimation, Carrier Phase Estimation, Symbol Timing Estimation, Joint Estimation of Carrier Phase and Symbol Timing Channel Estimation and Equalization: Zero-Forcing Algorithm, Least-Mean-Square (LMS) Algorithm, Recursive Least Square Algorithms, Linear and Decision Feedback Equalization, Channel Impulse Response, Pilot Symbol, Non-Data-aided and Data-aided Channel Estimation. Introduction to Quantum Communications, Aerial Communications, Haptics Communications, and Holographic Communications. **<u>Experiments:</u>** • Simulation-based experiment ○ Different modulation formats, signal generation ○ Noise generation : white and color ○ BER and SER analysis of different modulation format ○ Design of digital receivers: ZF, Matched ○ Realization of different channels: wireless, optical, wired • Hardware Kit/SDR-based modulation format generation • Hardware Kit/SDR-based signal reception
Learning Outcome	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments, and Exams
Suggested Readings	***Text Books:*** 3. A. Goldsmith, Wireless Communications, 2009, Cambridge University Press. 4. D. Tse, P. Viswanath, Fundamentals of Wireless Communications, 2005, Cambridge Press. **Reference Books:** 5. G. L. Stuber, Principles of Mobile Communication, 1996, Kluwer Acdemic. 6. J. G. Proakis, Digital Communications, 1995, McGraw-Hill. 7. T. S. Rappaport, Wireless Communications: Principles and Practice, 1996, Prentice Hall. 8. A. J. Viterbi, CDMA Systems: Principles of Spread Spectrum Communication, 1995, Addison Wesley.

Course Number	**EC5104**
Course Credit	3-0-0-3
Course Title	**Quantum Computing**
Learning Mode	Lectures
Learning Objectives	1. Analyze and explain the key components and architecture of quantum computing systems, including qubits, quantum gates, and quantum circuits. 2. Develop the ability to implement and analyze quantum algorithms, such as Shor's algorithm for factoring and Grover's algorithm for search problems. 3. Evaluate and apply quantum error correction techniques to mitigate the impact of errors in quantum computations. 4. Investigate and comprehend quantum communication protocols, including quantum key distribution (QKD) and teleportation, and their applications in secure communication. 5. Comprehend the principles of quantum information theory, including quantum entanglement, quantum entropy, and quantum teleportation.
Course Description	This course deals with the Quantum Computing.
Course Outline	Introduction: History, Motivation, Need of quantum bits, quantum states, quantum computations, quantum information, and quantum algorithms Overview of complex numbers and Linear Algebra, Introduction to quantum mechanics and its postulates, Bloch sphere Quantum Circuits: Single qubits and multiple quibits operations, architecture, quantum gates; quantum teleportation, quantum Fourier Transform: phase estimation Quantum Algorithms: Deutsch's algorithm, Deutsch-Jozsa algorithm, Simon's algorithm, Grover algorithm and Shor's factoring algorithm Quantum Information and Error Corrections: Classical vs quantum noise, quantum operations, quantum error correction, entropy and information Quantum Tools and Applications: Goal Challenges, Lights and Photon, Decoherence, Ion Trap, Linear Optics, NMR, Quantum Simulation
Learning Outcome	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments, and Exams
Suggested Readings	**Text Books**: 1. Nielsen, Michael A., and Isaac L. Chuang. Quantum computation and quantum information. Cambridge university press, 2010. 2. Johnston, Eric R., Nic Harrigan, and Mercedes Gimeno-Segovia. Programming quantum computers: essential algorithms and code samples. O'Reilly Media, 2019.

Course Number	**EC5105**
Course Credit	3-0-0-3
Course Title	**Satellite Communication**
Learning Mode	Lectures
Learning Objectives	After completing this course the students will be able to 1. Understand the concept of conventional and future satellite communication technology 2. Understand the concept of different orbits of satellite 3. Design and estimate the satellite link budget 4. Understand the challenges and solutions to establish satellite-to-satellite and ground-to-satellite communication link 5. Gain knowledge on different transmitter and receiver configurations for satellite communication
Course Description	This course deals with the Satellite Communication.
Course Outline	Introduction to Satellite Communications: Origin, History, Current Technology State and Overview of Satellite System Engineering. Orbital Aspects of Earth Satellites: Orbital Mechanics and Orbital Elements, Azimuth and Elevation, Coverage Angle and Slant Range, Placement of a Satellite in a Geostationary Orbit.

	Satellite Link Design: Basic Radio Transmission Theory, System Noise Temperature and G/T Ratio, Uplink and Downlink Design, Interference Analysis, Carrier-to-Noise plus Interference Ratio, Interference to and from Adjacent Satellite Systems, Terrestrial Interference, Cross-polarization Interference, Intermodulation Interference, Design of Satellite Links for Specified Carrier-to-Noise plus Interference Ratio, Digital Satellite Link. Propagation on Satellite-Earth Paths and Its Influence on Link Design: Absorbitive Attenuation Noise by Atmospheric Gases, Rain Attenuation, Noise due to Rain, Rain Depolarization, Tropospheric Multipath and Scintillation Effects. Multiple Access Techniques in Satellite Communications: Frequency Division Multiple Access, FDMA, SCPC, MCPC. Time Division Multiple Access, TDMA: random (ALOHA, S-ALOHA) and time synchronized access. Code Division Multiple Access, CDMA, Fixed and On-demand Assignment. Satellite Networking: Advantages and Disadvantages of Multibeam Satellites, Interconnection by Transponder Hopping, Interconnection by On-board Switching, Interconnection by Beam Scanning, On-Board Processing, Intersatellite Links. Types of Satellite Networks: Fixed Point Satellite Network, INTELSAT, Mobile Satellite Network, INMARSAT, Low Earth Orbit and Medium Earth Orbit Satellite Systems, Very Small Aperture Terminal (VSAT) Network, Direct Broadcast Satellite Systems, Global Positioning System.
Learning Outcome	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments, and Exams
Suggested Readings	**Text Books:** 1. Digital Satellite Communications, 2/e, McGraw-Hill, 1990.Tri T. Ha 2. Satellite Communications, John Willey and Sons, 2000T. Pratt, C.W. Bostian 3. Satellite Communications Systems Engineering, Pearson Education, 2/e; 2003 W.L. Prichard, H.G. Suyderhoud and R.A. Nelson **Reference Books:** 1. E. G. Larsson and P. Stoica, Information Theory, Space-Time Block Coding for Wireless Communications, Cambridge University Press, 2003

Course Number	**EC5216**
Course Credit	3-0-0-3
Course Title	**Silicon Photonics**
Learning Mode	Lectures
Learning Objectives	After learning this course, the students will be able 1. to understand the fundamental concepts and operating principles of silicon photonic devices and circuits. 2. to design primary passive and active silicon photonic integrated circuits and interconnects. 3. to get familiar with different applications of silicon photonic devices.
Course Description	This course deals with the Silicon Photonics.

Course Outline	Introduction to Silicon Photonics. SOI platform. SOI, SiN, InP, and LNOI platforms. Guided modes in Silicon Photonic Waveguides. Concept of the effective index. Coupled Mode theory. Coupling of light to waveguides: grating couplers, butt coupling, mode transformers, inverted tapers. Waveguides loss mechanisms: absorption scattering. Plasma dispersion effect, thermo-optic effect, and stress-optic effect. Passive silicon photonic devices: Mach Zehnder interferometer, ring resonator, directional couplers, waveguide bends, multiplexers. Active silicon photonic devices: Source, Modulators, photodetector. Fundamentals of silicon photonics device fabrication and integration. Applications of silicon photonic devices: Communication, Sensing, Neuromorphic computing. Types of Satellite Networks: Fixed Point Satellite Network, INTELSAT, Mobile Satellite Network, INMARSAT, Low Earth Orbit and Medium Earth Orbit Satellite Systems, Very Small Aperture Terminal (VSAT) Network, Direct Broadcast Satellite Systems, Global Positioning System.
Learning Outcome	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments, and Exams
Suggested Readings	**Text Books:** 1. G T Reed & AP Knights, Silicon Photonics: An Introduction, 2004, Wiley. 2. G T Reed, Silicon Photonics: The state of the art, 2008, Wiley. 3. M J Deen and P K Basu, Silicon Photonics: Fundamentals and Devices,2012, Wiley **Reference Books:** 1. L. Pavesi and D J Lockwoodt, Silicon Photonics, 2004, Springer 2. L Pavesi and David J. Lockwood, Silicon Photonics III Systems and Applications, 2016, Springer 3. J Ahmed, M Y Siyal, F Adeel, A Hussain, Optical Signal Processing by Silicon Photonics, 2013, Springer 4. A Yariv and P Yeh, Photonics, Sixth Edition, Oxford University Press

Course Number	**EC6271**
Course Credit	**L-T-P-C: 3-0-0-3**
Course Title	Generative AI for Video Surveillance System
Learning Mode	Lectures
Learning Objectives	Complies with Program Goals 6 and 7
Course Description	This course introduces students to the theoretical foundations and practical applications of generative artificial intelligence (AI) in video surveillance systems. Students will learn about various generative models and their applications in video synthesis, anomaly detection, and activity recognition within surveillance scenarios.
Course Outline	**Module 1: Image and Video Processing** • Basics of Image Processing • Basics of Video Compression and Motion Analysis • Background Modelling • Object detection and classification • Human Activity Recognition • Video Object Tracking **Module 2: Video Surveillance Systems** • Foreground and Background Detection • Segmentation and Tracking • Behaviour analysis of individuals and groups • Static and Dynamic analysis of crowds

<table>
<tr><td></td><td>

Module 3: Introduction to Generative AI

Overview of generative AI and its applications
Introduction to generative models
Key concepts: generative models vs. discriminative models, probability distributions

Module 4: Fundamentals of Deep Learning

Introduction to deep learning and neural networks
Training neural networks: backpropagation, optimization algorithms
Regularization techniques: dropout, L1/L2 regularization
Convolutional Neural Networks (CNNs), Recurrent Neural Networks (RNNs) and Long and Short Term Memory (LSTM) for generative tasks

Module 5: Variational Autoencoders (VAEs)

Introduction to autoencoders
Understanding VAEs: encoder, decoder, and latent space
Variational inference and the reparameterization trick
Applications of VAEs: image generation, data compression

Module 6: Generative Adversarial Networks (GANs)

Introduction to GANs and their components (generator, discriminator)
GAN training process: minimax game, adversarial loss
Architectural variations: DCGAN, WGAN, Conditional GAN, SR GAN, Cycle GAN
GAN applications: image synthesis, style transfer, super resolution

Module 7: Transformers

Introduction and Evolution: Explore Transformer evolution and key components.
Transformer Architecture: Study encoder-decoder stacks and attention mechanisms.
Training Strategies: Compare pre-training, fine-tuning, and optimization techniques.
Applications: Examine text, image, and video generation tasks.
Recent Trends: Review Vision Transformers, Video Vision Transformers, GPT, DALL-E and BERT.

Module 8: Hands-on Projects and Case Studies

Practical implementation of generative AI models using popular frameworks (e.g., TensorFlow, PyTorch)
Guided projects and assignments to reinforce concepts learned
Case studies showcasing real-world applications of generative AI

</td></tr>
<tr><td>Learning Outcomes</td><td>Complies with PLOs 6a, 6b, 7 and 8a</td></tr>
<tr><td>Assessment Method</td><td>Quizzes/Assignments, Mid Sem, and End Sem</td></tr>
<tr><td>Suggested Readings</td><td>

<u>Text and References</u>

1. M. H. Kolekar, “Intelligent video surveillance systems: an algorithmic approach”, Chapman and Hall/CRC; 2018 Jun 27.
2. F. Chollet, “Deep learning with Python”, Simon and Schuster; 2021 Dec 7.
3. J. Babcock, R. Bali, “Generative AI with Python and TensorFlow 2: Create images, text, and music with VAEs, GANs, LSTMs, Transformer models”, Packt Publishing Ltd; 2021 Apr 30.
</td></tr>
</table>

Course Number	**EC5108**
Course Credit	3-0-0-3
Course Title	**RF and Microwave Active Circuits**
Learning Mode	Lectures
Learning Objectives	**1. Proficiency in Active Circuit Design and Analysis:** Students will develop proficiency in analyzing and designing active circuits commonly used in RF and microwave applications, including amplifiers, oscillators, mixers, and modulators. **2. Knowledge of RF Transceiver Architecture:** Students will gain insight into RF transceiver architectures used in communication systems, including receiver front-end design, transmitter driver stages, frequency synthesis, and frequency conversion.
Course Description	This course deals with the RF Microwave Active Circuits.
Course Outline	**Network Parameters**, High Frequency Network Parameters, Scattering Parameters, Signal Flow Graphs, Smith Chart Concepts, Impedance Matching, Microstrip Line Designing and Characterization. **Microstrip Design**- Filter Design by Insertion Loss Method, Fundamentals of Power Divider and Branch Line Coupler. **Small Signal Amplifiers**- low noise, maximum gain, stability, Broad band amplifiers- matching circuits, travelling wave amplifiers. **Power Amplifiers**- Efficiency, CAD, device modeling, measurement. **Mixers**- Single ended, balanced, double balanced, different configurations for microstrip, waveguide etc., noise properties, simulatiion using harmonic balance.
Learning Outcome	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments, and Exams
Suggested Readings	**Text Books:** 1. David M. Pozar, "Microwave Engineering", Wiley, 4th Edition. 2. Robert E. Collin, "Foundations for Microwave Engineering", Wiley, 2nd Edition. **Reference Books:** 1. Liao, Samuel Y. Microwave devices and circuits. Pearson Education India, 1989. 2. Mongia, R. K., Hong, J., Bhartia, P., & Bahl, I. J., "RF and microwave coupled-line circuits" Artech house, 2007. 3. Maas, Stephen A., "The RF and microwave circuit design cookbook" Artech House, 1998. 4. Gilmore, Rowan, and Les Besser, "Practical RF Circuit Design for Modern Wireless Systems: Active Circuits and Systems", Volume 2. Vol. 1. Artech House, 2003. 5. Howe, Harlan. Stripline circuit design. Dedham, MA: Artech House, 1974

Course Number	**EC5109**
Course Credit	3-0-0-3
Course Title	**Internet of Things (IoT) Networks**
Learning Mode	Lectures
Learning Objectives	After the successful completion of the course the students will be able to: 1. Fundamentally understand the building blocks of the Internet of Things networks. 2. Learning and implementation of various algorithms in the course 3. Design an IoT based network for a given application
Course Description	This course deals with the IoT Networks.
Course Outline	**Things and Internet**: Overview of Things/Sensors, Smart Object, Open Systems Interconnection (OSI) Model, Transmission Control Protocol/Internet Protocol (TCP/IP) Model, IPv4 & IPv6 Addressing, Routing, Delays in the Networks **Markov Chain**: Discrete-Time Markov Chain, Continuous-Time Markov Chain, Types of Markov Chain, Time Reversed Markov Chain, Applications

	Queuing Theory: Little's Formula, Queuing Model - Single and Multiple Servers (M/M/1, M/M/c), Finite and Infinite Queue Length/Population, M/G/1 model, Burke's Theorem, Jackson's Networks **IoT Protocols**: Short-Range and Long Range Protocols - Bluetooth, Zigbee, Wireless LAN, and LoRaWAN. Application Protocols. **Smart Device Localization**: Range-based Localization using Received Signal Strength (RSS), Time and Angle Measurements. Range-Free Localization. Performance Metrics. Applications **IoT Analytics**: Bayesian Fusion, Dempster-Shafer Fusion, Decision Fusion, Types of Learning. Artificial Neural Networks, Bias–Variance Tradeoff, Applications **Fog Computing**: Cloud Computing, Fog Computing, Edge Computing, Technology for Fog Computing, Task Offloading, Applications
Learning Outcome	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments, and Exams
Suggested Readings	**Texts Books:** 1. Rayes, A., and Salam, S., Internet of Things from hype to reality: the road to digitization, 2nd Edition, 2016, Springer International Publishing. 2. Kumar S., Fundamentals of Internet of Things, 1st Edition, 2021, Chapman and Hall/CRC. 3. Bertsekas, D.P., and Gallager, R. G., Data Networks, 2nd Edition, 2021, Athena Scientific. **Reference Books:** 1. Raj, P., and Raman, A.C., The Internet of Things: Enabling technologies, platforms, and use cases, 1st Edition, 2017, Auerbach Publications.

Course Number	**EC5111**
Course Credit	3-0-0-3
Course Title	**VLSI Architectural Design and Implementation**
Learning Mode	Lectures
Learning Objectives	Understanding the representation and implementation methods of VLSI system architectures Understanding the Architectural design and implementation methods of basic algorithms. Understanding the various trade-off computer arithmetic architectures and their analysis Understanding the design and analysis of high-performance architectures Understanding the architectural design exploration of basic digital signal processing and Machine learning algorithms Understanding the basics of VLSI Chip testing method and architecture.
Course Description	This course deals with the VLSI design and implementation.
Course Outline	Introduction to VLSI System Design and Implementation; Architectural mapping with case studies: Data path, Control path Synthesis; Control Strategies: Hardware implementation of various control structures; Micro-program control techniques; Design issues: Timing, Area, power analysis; FSM Architecture and Synthesis, HDL design and implementation of VLSI architecture; Semiconductor Memory and Peripheral Architectures; Computer arithmetic architecture design and analysis: Introduction to integer and floating-point arithmetic, Adders, Subtractors, Sequential and Array multipliers & dividers, square root, Absolute Difference Value, CORDIC. Hardware architecture design and performance analysis: Sequential/Folding architectures; bit and word serial architecture; High performance architectures: pipelined, parallel and Systolic Array with examples; Architectural performance Analysis: Throughput and Latency; Low Power VLSI Architectures; Basic Hardware Architectures for Digital Signal processing and machine learning algorithms. Introduction to VLSI Chip testing methods and Architectures: Introduction to Chip Fault Model, DFT Architecture, BIST Architecture.

Learning Outcome	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments, and Exams
Suggested Readings	**Text Books:** 1. Peter Pirsch, "Architectures for Digital Signal Processing", John Willy & sons,2nd Edition,2014. 2. K. K. Parhi, " VLSI Digital Signal Processing Systems: Design and Implementation", A Wiley-Interscience publications,2011. **Reference Books:** 1. Behrooz Parhami, " Computer Arithmetic: Algorithm and Hardware Design", Behrooz Parhami, Oxford University Press, 2nd Edition,2009. 2. A. Bellaouar, M. I. Elmarsny, "Low Power Digital VLSI Design", A. Bellaouar, M. I. Elmarsny, Kluwe academic Publication,1995. 3. L. Wamhammer, DSP Integrated Circuit,, Academic Press,1999.

Course Number	**EC5112**
Course Credit	3-0-0-3
Course Title	**Opto-Electronics Materials and Devices**
Learning Mode	Lectures
Learning Objectives	1. understand the basic working mechanism of the devices 2. understand the governing equations to be able to perform calculations to characterize the performance of the devices 3. have the practical knowledge and an understanding of the trade-offs when using these devices in their respective applications.
Course Description	This course deals with the Opto Electronics and Devices.
Course Outline	UNIT I ELEMENTS OF LIGHT AND SOLID-STATE PHYSICS Wave nature of light, Polarization, Interference, Diffraction, Light Source, review of Quantum Mechanical concept, Review of Solid-State Physics, Review of Semiconductor Physics and Semiconductor Junction Device. UNIT II DISPLAY DEVICES AND LASERS Introduction, Photo Luminescence, Cathode Luminescence, Electro Luminescence, Injection Luminescence, Injection Luminescence, LED, Plasma Display, Liquid Crystal Displays, Numeric Displays, Laser Emission, Absorption, Radiation, Population Inversion, Optical Feedback, Threshold condition, Laser Modes, Classes of Lasers, Mode Locking, laser applications. UNIT III OPTICAL DETECTION DEVICES Photo detector, Thermal detector, Photovoltaics, Photo Conductors, Sensors, Detector Performance. UNIT IV OPTOELECTRONIC MODULATOR Introduction, Analog and Digital Modulation, Electro-optic modulators, Magneto Optic Devices, Acoustoptic devices, Optical, Switching and Logic Devices. UNIT V OPTOELECTRONIC INTEGRATED CIRCUITS Introduction, hybrid and Monolithic Integration, Application of Opto Electronic Integrated Circuits, Integrated transmitters and Receivers, Guided wave devices.
Learning Outcome	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments, and Exams

Suggested Readings	**Text Books:** **Text Books** 1. Pallab Bhattacharya "Semiconductor Opto Electronic Devices", Prentice Hall of India Pvt., Ltd., New Delhi, 2006. 2. Jasprit Singh, "Opto Electronics – As Introduction to materials and devices", McGraw-Hill International Edition, 1998 **Reference Books** 1. S C Gupta, Opto Electronic Devices and Systems, Prentice Hal of India,2005. 2. J. Wilson and J.Haukes, "Opto Electronics – An Introduction", Prentice Hall, 1995.

Course Number	**EC5113**
Course Credit	3-0-0-3
Course Title	**Radio Frequency Integrated Circuits**
Learning Mode	Lectures
Learning Objectives	fter studying this course, the students will be able to: 1. Analyse a wireless transceiver and its various sub components like LNAs, Mixers, VCOs, RF Power amplifiers. 2. Design the transceivers for wireless communication. Additionally, they will be able to design many standalone circuits like Low noise and power amplifiers, Oscillators and Frequency synthesizers, PLL.
Course Description	This course deals with the RFIC.
Course Outline	Prerequisite: Basic Electronics and Basic Electromagnetic Engineering. Introduction: Basic concepts in RFIC Design – 1dB point and IIP3; Receiver and Transmitter Architectures. Low Noise RF Amplifiers (LNAs) – Electrical Noises, Two port Noise theory, LNA characteristic parameters and basic topologies, Input impedance and Noise Factors of various LNAs, Differential and Broadband Amplifier, Stability; Mixers – Mixer Operation and linearity, Passive and Active Mixers, Single & Double-Balanced Mixers, Conversion Gain and Port-to-Port Feedthrough (or leakage), Image Reject and Single Sideband Mixers, Noise in Mixers; Oscillators – Oscillator as a Feedback System, Negative Resistance Oscillator, Colpitts, Hartley, Clapp, Pierce crystal Oscillators, Quadrature Oscillators, Voltage Controlled-Oscillator, Phase Noise in Oscillators; Frequency Synthesizers – Phase Locked Loop (PLL), Analysis of PLL Synthesizers blocks – PD, PFD, Charge Pump, Phase Noise in PLL Synthesis, PLL Frequency Synthesizers, Integer-N and Fractional-N PLL Synthesizers, PLL System of second order, its frequency response, bandwidth, Designing a PLL of 2nd order; RF Power Amplifiers – Efficiency, Analysis of Basic Classes – A, AB, B, C, Class B Push-Pull Arrangements, Switch mode Classes – D, E, F Amplifiers, Doherty Power Amplifier, Linearization Techniques.
Learning Outcome	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments, and Exams

Suggested Readings	**Text Books:** 1. Thomas H Lee, The Design of CMOS Radio Frequency Integrated Circuits, 2/e, 2003, Cambridge University Press 2. Behzad Razavi, RF Microelectronics, 2/e, 2012, Pearson India 3. Steven Cripps, RF Power amplifier for wireless communications, 2/e, 2006, Artech House 4. Herbert Krauss, Charles Bostian, and Frederick Raab, Solid state radio engineering, 1/e, 1980, John Wiley and Sons 5. Andrei Grebennikov, Marc J. Franco, Switchmode RF and Microwave Power Amplifiers, 3/e, 2021, Academic Press **References:** 1. Richard C-H Li, RF Circuit Design, 2/e, 2012, John Wiley 2. Ronald E Best, Phase-locked Loops, 6/e, 2007, McGraw Hill 3. John W M Rogers and Calvin Plett, Radio Frequency Circuit Design, 2/e, 2010, Artech House 4. Les Besser and Rowan Gilmore, Practical RF Circuit Design for Modern Wireless Systems, vol. 2, 1/e, 2003, Artech House

Course Number	**EC5114**
Course Credit	**L-T-P-C: 3-0-0-3**
Course Title	**Advanced Digital Image Processing**
Learning Mode	Lectures
Learning Objectives	Complies with Program Goals 1 and 2
Course Description	Advanced Digital Image Processing involves the manipulation and analysis of digital images using computational algorithms. The course covers topics such as image enhancement, restoration, segmentation, feature extraction, and compression. It also includes applications in fields such as medical imaging, remote sensing, robotics, and multimedia systems.
Course Outline	DIGITAL IMAGE FUNDAMENTALS: Elements of Visual Perception; Image Sensing and Acquisition; Image Sampling and Quantization; Basic Relationships between Pixels; Monochromatic Vision Models; Colour Vision Models; Colour Fundamentals; Colour Models; Conversion of Colour Models; Colour Transformations. ENHANCEMENT & RESTORATION : Homomorphic filtering, inverse and minimum error filtering, Noise types and related filtering. IMAGE ANALYSIS AND REPRESENATION: Introduction; Image Segmentation - Point, Line, Edge, Boundary Detection; Colour Image Segmentation; Thresholding- Basic Global Thresholding, Multiple Thresholding, Variable Thresholding; Region Based Segmentation; Representation: Chain codes, Signatures, Boundary segments, Skeletons, Description: Boundary Descriptors, Regional Descriptors. MORPHOLOGICAL PROCESSING & COMPRESSION: Morphological Image Processing – Logic Operations involving Binary Images; Dilation and Erosion; Basic Morphological Algorithms – Boundary Extraction, Region Filling, Thickening Image Compression – Compression Model, Different Coding schemes like Arithmetic Coding, LZW coding etc. Baseline jpeg, jpeg 2000, Mpeg etc. CLASSIFICATION AND APPLICATIONS of Object Recognition and Classification, Statistical classification, Structural /Syntactic Classification, 3D Image Processing, 3D Visualization: Surface rendering, Volume rendering; Applications: Motion Analysis, Image Fusion, Image super resolution
Learnng Outcome	Complies with PLOs 1a, 1b, 2 and 3a
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem

Suggested Readings	**Text/References** 1. 1. Rafael C. Gonzalez and Richard E. Woods, Digital Image Processing, Pearson 2. 2. Milan Sonka, Vaclav Hlavac and Roger Boyle, Image Processing, Analysis and Machine Vision, Springer 3. 3. Anil K. Jain, Fundamentals of Digital Image Processing, Prentice Hall

Course Number	**EC5159**
Course Credit	**L-T-P-C: 3-0-0-3**
Course Title	**Bio Sensors and Circuits**
Learning Mode	Lectures
Learning Objectives	Complies with Program Goals 1 and 2
Course Description	Bio Sensors and Circuits focus on the design and implementation of circuits and systems for biological sensing applications. The course covers topics such as sensor technologies (e.g., optical, electrochemical), signal conditioning, data acquisition, and integration with biological systems for healthcare monitoring, environmental sensing, and biomedical research.
Course Outline	Transducers Principles, Biochemical Transducers: Electrode theory, electrode impedance, metal-electrolyte interface and electrode-tissue interface, Bio-potential electrodes: microelectrodes, body surface electrodes, needle electrodes, electrodes for ECG, EEG, and EMG. Electrodes: hydrogen electrodes, Ag/AgCl electrodes, Calomel electrodes, specific ion electrodes, pH electrode, O2 and CO2 electrode, Optical Sensor and Radiation Detectors: Principles of optical sensors and types of optical sensors, Optical fibers, LASERs, Radiation detectors: Proportional counter, Gas-ionization chamber, Geiger counters, Scintillation detectors., Biological Sensors: Receptors in the human body, Ion exchange membrane electrodes, enzymatic biosensors, Basic principles of MOSFET biosensors & BIOMEMS, basic idea about Smart sensors, Biomedical Measurement
Learning Outcomes	Complies with PLOs 1a, 1b, 2 and 3a
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Readings	**Text/References** 1. Josheph J. Carr and John M. Brown, “Introduction to Biomedical Equipment Technology”, 4th Edition, Pearson Education, 2001. 2. John. G. Webster, “Medical Instrumentation- Application and Design”, 4th Edition, John Wiley & Sons, 2010. 3. Willis J. Tompkins, “Biomedical Digital Signal Processing” Prentice-Hall of India, 1993. 4. Rangraj M. Rangayyan, “Biomedical Signal analysis- A Case Study Approach”, Wiley India Pvt. Ltd., 2009. 5. Suresh R. Devashahayan, “Signals and Systems in Biomedical Engineering”, Revised 2nd Edition, Kluwer academics/ Plenum publication, 2013. 6. Josheph J. Carr and John M. Brown, “Introduction to Biomedical Equipment Technology”,4th Edition, Prentice Hall, 2000. 7. Leslie Cromwell, Fred J. Weibell, and Erich A. Pfeiffer “Biomedical Instrumentation and Measurements”, 2nd Edition, Prentice-Hall of India, 2000.

Course Number	**EC6114**
Course Credit	3-0-0-3
Course Title	**Radio Frequency Design and Technology**
Learning Mode	Lectures
Learning Objectives	The students will be able to learn the design of microwave coupler and power dividers, filters and their implementation, microwave amplifiers, active microwave devices, oscillators and mixers. A slight introduction of network analysis is covered. It also highlights the distortions caused by the noise in microwave circuits. Microwave systems are also discussed.

Course Description	This course deals with the RFDT.
Course Outline	Planar Transmission Lines and Lumped Elements for MICs: Fundamentals of the theory of transmission lines, Foundations of Microstrip lines, Striplines, Higher modes in microstrips and striplines, Slotlines, Coplanar waveguides. Microstrip Transmission line, propagation module, Scattering parameters. Microwave Planar Filters: Periodic structures, Filter design by the Image Parameter method, Filter design by the Insertion Loss method, Filter transformations, Filter implementation, Stepped-Impedance Low-Pass filters, Coupled line filters, Filters using coupled resonators. 3-Port Network Design: Power Divider network. 4-Port Network Design: Introduction; Even-and odd-mode analysis; Branch-line couple, Branch-line coupler with improved coupling performance, Branch-line coupler with multiple sections. Measurement Fundamentals, VNA, Spectrum analyzer, and techniques. Software defined Radio, design and analysis. Radar systems, graphene, and metamaterials.
Learning Outcome	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments, and Exams
Suggested Readings	**Text Books:** 1. David M. Pozar, Microwave Engineering, Wiley India Private Limited; Fourth edition (14 May 2013). 2. C. A. Balanis: Antenna Theory: Analysis and Design, John Wiley, 2005, 3/e. **Reference Books:** 1. R. E. Collin, Foundations for Microwave Engineering, Wiley-Blackwell; 2nd Edition 2. D. M. Sullivan: Electromagnetic Simulation using the FDTD Method, Wiley-IEEE, 2000, 1/e. 3. B. S. Guru & H. R. Hiziroglu: Electromagnetic Field Theory Fundamentals, Thomson, 1997, 1/e

Course Number	**EC6116**
Course Credit	3-0-0-3
Course Title	**Advance Antenna and Microwave Devices**
Learning Mode	Lectures
Learning Objectives	After successful completion of this course, the students will 1. Understand the basic principles of electromagnetic theory as they apply to antennas and microwave devices. 2. Define and explain key antenna parameters such as gain, directivity, efficiency, bandwidth, and polarization. 3. Describe the function and characteristics of various microwave components, including passive and active devices. 4. Use simulation software (e.g., HFSS, CST, ADS) for modeling and optimizing antennas and microwave systems. 5. Solve complex engineering problems related to antenna and microwave device design, considering practical constraints and requirements.
Course Description	This course deals with the Advance antenna and devices.
Course Outline	Pre-requisites: Engineering Electromagnetics Microwave Network Theory, Equations, Wave Propagation, Medium and free space, Transmission Lines, Microstrip Lines, RF Fabrication Techniques. High power microwave devices, two port, three port and 4 port microwave devices, design analysis and fabrication. Microwave link budget analysis. Antenna principle and Antenna Types, Designs and analysis, Antenna Simulation and Measurement techniques, Antenna optemisations, boundary conditions, antenna parameters, Impedance matching and modal analysis, equivalent circuit analysis. Antenna synthesis, Antenna analysis.

	Advance Antennas- Transmitarray antennas, reflector antennas, lens antennas, slot antennas, Leaky wave antenna, reconfigurable antennas. Metamaterial inspired antennas, wave propagation in metamaterial, design and analysis of metamaterial, frequency sellective surfaces, EBG Structures, metasurfaces, reconfigurable metasurfaces. Selected advanced topics in Antennas and Microwave Technology.
Learning Outcome	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments, and Exams
Suggested Readings	**Text Books:** 1. David M. Pozar, "Microwave Engineering", 4th Edition, 2011, Wiley. 2. Robert E. Collin, "Foundations for Microwave Engineering", 2nd Edition, 2007, Wiley. 3. Constantine A. Balanis, "Antenna Theory: Analysis and Design", 3r Edition, 2009, Wiley. **Reference Books:** 1. Samuel Y. Liao, "Microwave devices and circuits". 3rd Edition, 2003, Pearson Education India. 2. Mongia, R. K., Hong, J., Bhartia, P., & Bahl, I. J., "RF and microwave coupled-line circuits" 2007, Artech house, 2007. 3. Stephen A. Maas, "The RF and microwave circuit design cookbook", 1998, Artech House.

Course Number	**EC6157**
Course Credit	**L-T-P-C: 3-0-0-3**
Course Title	**VLSI Signal Processing**
Learning Mode	Lectures
Learning Objectives	Complies with Program Goals 1 and 2
Course Description	VLSI Signal Processing involves the design and implementation of signal processing algorithms and systems using Very-Large-Scale Integration (VLSI) technology. The course covers topics such as digital signal processing (DSP) algorithms, efficient hardware implementations, optimization techniques, and applications in areas such as telecommunications, audio processing, image processing, and biomedical signal processing.
Course Outline	Introduction to DSP systems: Representation of DSP algorithms; Iteration Bound: Definition, Examples, Algorithms for computing Iteration bound; Pipelining and Parallel Processing: Definitions, Pipelining and parallel processing of FIR filters, Pipelining and parallel processing for low power; Retiming: Definitions and Properties, Solving system of Inequalities, Retiming techniques; Unfolding: Definition, An algorithm for unfolding, Applications of unfolding; Folding: Definition, Folding transformations, Register minimization techniques, Register minimization in folded architectures; Systolic Architecture Design: Introduction, Systolic array design methodology, FIR systolic arrays, Selection of scheduling vector, Matrix-Matrix multiplication and 2D systolic array design; CORDIC based Implementations: Architecture, Implementation of FIR filter and FFT algorithm; Bit-Level arithmetic architectures: Parallel multipliers, Bit-serial multipliers, Bit-Serial FIR filter design and Implementation; Redundant arithmetic: Redundant number representation, Carry-free radix-2 addition and subtraction, radix-2 hybrid redundant multiplication architectures; Low-power design: Theoretical background, Scaling versus power consumption, Power analysis, Power reduction techniques, Power estimation approaches.
Learning Outcomes	Complies with PLOs 1a, 1b, 2 and 3a
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Readings	<u>**Text/References**</u> 1. U. Meyer-Baese, "DSP with FPGA", Springer,4th Edition, 2014. 2. K. K. Parhi, "VLSI DSP Systems", Wiley, 2003. 3. R.G. Lyons, "Understanding Digital Signal Processing", Pearson Education,3rd Edition, 2011.

Course Number	**EC5203**
Course Credit	3-0-0-3
Course Title	**Communication Networks**
Learning Mode	Lectures
Learning Objectives	**Course Learning Outcome (CLO) :** The students will be able to understand: 1. the network layered architecture and the protocol stack 2. the principles upon which the Internet and other computer networks are built; 3. how those principles translate into deployed protocols
Course Description	This course deals with the Communication Networks.
Course Outline	Overview of Communications Networks — Introduction to Internet, Layering Concept, OSI Model, TCP/IP Model, Introduction to Protocols, Topology, Performance Metrics, Devices at different layers Overview of Data link Control and Media access control: Ethernet, Wireless LANs, Bluetooth, WiFi, 6LowPAN, Zigbee. Packet and Circuit Switching, Queuing Theory, Stop and wait protocol, sliding window protocol, Medium access protocols: Aloha, slotted aloha, CSMA, CSMA CD, and collision - free protocols, FDDI, token ring Routing: Protocols, Types of Routing, Algorithms, IP Protocol, Addressing: IPV4 Address, IPv6 Addressing, Transition from IPv4 to IPv6 Transport Layer: Protocols - User Datagram Protocols (UDP) and Transmission Control Protocols (TCP), Flow, Error and Congestion Control: Congestion avoidance, QoS in networks Application Layer: Client Server Model, World Wide Web and HTTP, DNS, Electronic Mail Selected advanced topics in Antennas and Microwave Technology.
Learning Outcome	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments, and Exams
Suggested Readings	**Text Books:** 1. Alberto Leon-Garcia and Indra Widjaja, Communication Networks, 2nd Edition, 2017, McGraw Hill Education. 2. A. S. Tanenbaum, Computer Networks, 5th edition, Prentice-Hall, Inc., 2010. **Reference Books:** 1. J. Kurose and K. Ross, "Computer Networking: A Top-Down Approach Featuring the Internet" 2. W. Stallings, Data and Computer Communications, 10th edition, Prentice-Hall, Inc., 2013. 3. R. Gallager and D. P. Bertsekas, Data Networks, 2nd edition, Prentice-Hall, Inc., 1991.
Course Number	**EC5204**
Course Credit	3-0-0-3
Course Title	**Multimedia Communication**
Learning Mode	Lectures
Learning Objectives	After learning this course, the students will be able 1. to understand the fundamental knowledge on multimedia system and Multimedia Communication. 2. to understand the knowledge on Multimedia Information Systems. 3. to understand the real-time constraints in Multimedia Communication. 4. to develop problem statement on Multimedia Communication for research direction
Course Description	This course deals with the Multimedia Communication.
Course Outline	Introduction to Multimedia System: Architecture and components, Multimedia distributed processing model, Synchronization, Orchestration and Quality of Service (QOS) architecture. Audio and Speech: Data acquisition, Sampling and Quantization, Human Speech production mechanism, Digital model of speech production, Analysis and

	synthesis, Psycho-acoustics, low bit rate speech compression, MPEG audio compression. Images and Video: Image acquisition and representation, Composite video signal NTSC, PAL and SECAM video standards, Bilevel image compression standards: ITU (formerly CCITT) Group III and IV standards, JPEG image compression standards, MPEG video compression standards. Multimedia Communication: Fundamentals of data communication and networking, Bandwidth requirements of different media, Real time constraints: Audio latency, Video data rate, multimedia over LAN and WAN, Multimedia conferencing. Hypermedia presentation: Authoring and Publishing, Linear and non-linear presentation, Structuring Information, Different approaches of authoring hypermedia documents, Hyper-media data models and standards. Multimedia Information Systems: Operating system support for continuous media applications: limitations is usual OS, New OS support, Media stream protocol, file system support for continuous media, data models for multimedia and hypermedia information, content based retrieval of unstructured data.
Learning Outcome	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments, and Exams
Suggested Readings	**Text Books:** 1. J. D. Gibson, Multimedia Communications: Directions and Innovations, 2000, Elsevier. 2. A. Puri and T. Chen, Multimedia Systems, Standards, and Networks, 1st Edition, 2000, CRC Press. 5. Iain E.G. Richardson, H.264 and MPEG-4 Video Compression, 2004, John Wiley & Sons. **Reference Books:** 1. Ralf Steinmetz and Klara Nahrstedt, Multimedia Systems, 2004, Springer. 2. K. Sayood, Introduction to Data Compression, 2017, Morgan-Kaufmann. 3. Borivoje Furht, Handbook of Multimedia Computing, 1998, CRC Press

Course Number	**EC5205**
Course Credit	3-0-0-3
Course Title	**Optical Communication**
Learning Mode	Lectures
Learning Objectives	After learning this course, the students will be able 1. to know the basic elements of optical fiber transmission link. 2. to know about the design and operating principle of modern optical communication systems. 3. to get familiar with various components used in optical communication systems. 4. to understand the different kind of losses, distortions, and other degradation factors caused during signal transmission and their mitigation techniques for high speed communication.
Course Description	This course deals with the Optical Communication.
Course Outline	Introduction: Fiber optic communication, Free space optical communication, Visible light communication, chip-to-chip optical communication. Optical fiber fundamentals: Light propagation, types of optical fibers, Numerical aperture, step index fiber, graded index fiber, concept of modes, single mode fiber, multimode fiber. Bit rate distance product in multimode fiber. Impairment in optical fiber: Loss, chromatic dispersion, Polarization mode dispersion. Bit rate distance product in single mode fiber. Fiber Nonlinearity: Self phase modulation, cross phase modulation, four wave mixing. Passive optical components. Optical Sources and Detectors: LED, LD, DFB-laser, PIN photodetector, APD. Optical Modulator. Wavelength division Multiplexing (WDM). Modulation formats: OOK, DPSK, DQPSK, PDM-QPSK. Optical System Performance Metrics: Eye opening penalty, Q, BER, OSNR.

	Link Analysis: Single channel point to point, WDM point-to-point. Optically Amplified Systems.
Learning Outcome	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments, and Exams
Suggested Readings	**Text Books:** 1. G. P. Agrawal, Fiber-optic communication systems, 3rd Edition, 2007, Wiley India Pvt Ltd. 2. P Bhattacharya, Semiconductor optoelectronic devices, 2nd Edition, Phi Le **Reference Books:** 1. R. Ramaswami, K. N. Sivarajan, G. H. Sasaki, Optical Networks: A Practical Perspective, 2009, Elsevier direct. 2. G. P. Agrawal, Nonlinear fiber optics, 4th Edition, Academic Press. 3. M. Cvijetic, Optical transmission systems engineering, 2004, Artech House Publishers. 4. A Gumaste, T Antony, DWDM network designs and engineering solutions, 2002, Cisco Press.

Course Number	**EC5206**
Course Credit	3-0-0-3
Course Title	**Advanced Biomedical Signal Processing**
Learning Mode	Lectures
Learning Objectives	**Course Learning Outcome (CLO):** Course training via lectures, tutorial & workshop sessions enable with. 1. Various Biomedical Signal Processing and Monitoring Tasks. 2. Ability to understand and analyze machine and deep learning biomedical models. 3. Competence to take logical, scientific and correct decisions while predicting model outcomes. 4. Aptitude and ability of performance measurement and management of various biomedical instruments.
Course Description	This course deals with the Advanced Biomedical Signal Processing.
Course Outline	**Introduction of biomedical signals**: Nervous system, Neuron anatomy, Basic Electrophysiology, Biomedical signal's origin and dynamic characteristics, biomedical signal acquisition and processing, Different transforms techniques. **The Electrical Activity of Heart**: Heart Rhythms, Components of ECG signal, Heart beat Morphologies, Noise and Artifacts, Muscle Noise Filtering, QRS Detection Algorithm, ECG compression techniques (Direct Time Domain (TP, AZTECH, CORTES, SAPA, Entropy Coding), Frequency Domain (DFT, DCT, DWT, KLT, Walsh Transform), Parameter Extraction: Heart rate variability, acquisition and RR Interval conditioning, Spectral analysis of heart rate variability. **The Electrical Activity of Brain**: Electroencephalogram, Types of artifacts and characteristics, Filtration techniques using FIR and IIR filters, Independent component analysis, Nonparametric and Model-based spectral analysis, Joint Time-Frequency Analysis, Event Related Potential, Noise reduction by Ensemble Averaging and Linear Filtering, Single-Trail Analysis and adaptive analysis using basis functions. **The Electrical Activity of Neuromuscular System**: Human muscular system, Electrical signals of motor unit and gross muscle, Electromyogram signal recording, analysis, EMG applications. **Frequency-Time Analysis of Bioelectric Signal and Wavelet Transform**: Frequency domain representations for biomedical Signals, Higher-order spectral analysis, correlation analysis, wavelet analysis: continuous wavelet transform, discrete wavelet transform, reconstruction, recursive multi resolution decomposition, causality analysis, nonlinear dynamics and chaos: fractal dimension, correlation dimension, Lyapunov exponent. **Machine Learning Tools for Medical Signal Classification**: Support Vector Machine, Hidden Markov Model, Neural Networks. Medical Applications: Application of Event Related Potential in understanding human psychology,

	Cognitive neuroscience and higher order brain function: Attention, language, memory and executive functions and damage to the nervous system, Application of EEG and ECG signal processing over different cognitive and physical task
Learning Outcome	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments, and Exams
Suggested Readings	**Text Books** 1. Willis J. Tompkins, Biomedical Digital Signal Processing: C Language Examples and Laboratory Experiments for the IBM PC, Prentice Hall India 2. Eugene N. Bruce, Biomedical Signal Processing and Signal Modeling, John Wiley & Sons, 2006. 3. Rangaraj M. Rangayyan, Biomedical Signal Analysis: A Case-Study Approach, John Wiley & Sons, 2002 4. Steven J. Luck, An Introduction to the Event-Related Potential Technique, Second Edition, THE MIT PRESS 5. Leif Sornmo and Pablo Laguna, Bioelectrical Signal Processing in Cardiac and Neurological Applications, Academic Press, 2005 **Reference Books** 1. Hojjat Adeli & Samanway Ghosh-Dastidar, Automated EEG based Diagnosis of Neurological Disorders, CRC Press. 2. Thomas P. Trappenberg, Fundamentals of Computational Neuroscience, Oxford University Press. 2002. 3. Mike X Cohen, Analyzing Neural Time Series Data Theory and Practice, THE MIT PRESS 4. Nait-Ali, Amine, Advanced Biosignal Processing, Spingers(Ed.). 2009 5. C. Koch, Biophysics of Computation. Information Processing in Single Neurons, Oxford University Press: New York, Oxford 6. Peter Dayan and LF Abbott, Theoretical Neuroscience Computational and Mathematical Modeling of Neural Systems, MIT 2001. 7. F. Rieke and D. Warland and R. de Ruyter van Steveninck and W. Bialek, Spikes: Exploring the Neuronal Code, A Bradford Book. MIT Press.

Course Number	**EC5211**
Course Credit	3-0-0-3
Course Title	**VLSI Technology**
Learning Mode	Lectures
Learning Objectives	1. Understand the fabrication process of IC technology, basic steps of fabrication. Learn the basic theory of crystal growth and preparation. 2. Understand the uses of formation and process of silicon dioxide growth, all important Tube furnaces. To learn different types oxidation such as Chemical vapor Deposition, and LPCVD of poly silicon. Oxidation, Kinetics of oxidation. 3. Understands the series of processes that establishes the shapes, dimensions and placement of required physical components of IC on the wafer surface layer, understands different types lithography. 4. To demonstrate an understanding of semiconductor physics and the operation of the most common semiconductor devices at describe the factors that influences the presence of charge carriers in a semiconductor. 5. Understands the effect of contaminations on device processing, device performance.
Course Description	This course deals with the VLSI Technology.
Course Outline	General Overview of current status of VLSI Technology- Interaction between Technology and Design, - Interaction between Physics and Technology, - Limits of Technology, Environment for Integrated Circuits Manufacture, - Clean Rooms and Wafer cleaning procedures., - Technology Processes in Fabrication, - Oxidation, Diffusion, Ion Implantation, Etching and Deposition, techniques., - Characterization of Processes.

	Lithography and Mask generation techniques - Advanced Unit-Processors for ULSI Circuit Technologies., - Use of RTP, - Plasma processes in the fabrication in the fabrication of circuits., Basic Bipolar process Technologies., NMOS Technology, Mask sequence based fabrication process for NMOS transistors, - Silicon Gate and Metal Gate Technologies. Limitations of NMOS Technology. CMOS Technology - Process Sequence for CMOS Technology, Advanced CMOS Processes, “Design – Rules” for NMOS and CMOS Technologies as “Constraints” for Layouts. Process Simulation - Use of SUPREM-IV ans STEP Simulators for process Design, - Some Examples of actual technologies.
Learning Outcome	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments, and Exams
Suggested Readings	**Text Books:** 1. S.K. Ghandhi, “VLSI Fabrication principles”, John Wiley Inc., New York, 1983 **Reference Books:** 1. S.M. Sze “VLSI Technology”, 2nd Edition, McGraw Hill Co. Inc., New York, 1988 2. C. Y. Chang and S. M. Sze, “VLSI Technology”, McGraw Hill Co. Inc., New York, 1996

Course Number	**EC5211**
Course Credit	3-0-0-3
Course Title	**VLSI Technology**
Learning Mode	Lectures
Learning Objectives	1. Understand the fabrication process of IC technology, basic steps of fabrication. Learn the basic theory of crystal growth and preparation. 2. Understand the uses of formation and process of silicon dioxide growth, all important Tube furnaces. To learn different types oxidation such as Chemical vapor Deposition, and LPCVD of poly silicon. Oxidation, Kinetics of oxidation. 3. Understands the series of processes that establishes the shapes, dimensions and placement of required physical components of IC on the wafer surface layer, understands different types lithography. 4. To demonstrate an understanding of semiconductor physics and the operation of the most common semiconductor devices at describe the factors that influences the presence of charge carriers in a semiconductor. 5. Understands the effect of contaminations on device processing, device performance.
Course Description	This course deals with the VLSI Technology.
Course Outline	General Overview of current status of VLSI Technology- Interaction between Technology and Design, - Interaction between Physics and Technology, - Limits of Technology, Environment for Integrated Circuits Manufacture, - Clean Rooms and Wafer cleaning procedures., - Technology Processes in Fabrication, - Oxidation, Diffusion, Ion Implantation, Etching and Deposition, techniques., - Characterization of Processes. Lithography and Mask generation techniques - Advanced Unit-Processors for ULSI Circuit Technologies., - Use of RTP, - Plasma processes in the fabrication in the fabrication of circuits., Basic Bipolar process Technologies., NMOS Technology, Mask sequence based fabrication process for NMOS transistors, - Silicon Gate and Metal Gate Technologies. Limitations of NMOS Technology. CMOS Technology - Process Sequence for CMOS Technology, Advanced CMOS Processes,

	"Design – Rules" for NMOS and CMOS Technologies as "Constraints" for Layouts. Process Simulation - Use of SUPREM-IV ans STEP Simulators for process Design, - Some Examples of actual technologies.
Learning Outcome	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments, and Exams
Suggested Readings	**Text Books:** 1. S.K. Ghandhi, "VLSI Fabrication principles", John Wiley Inc., New York, 1983 **Reference Books:** 1. S.M. Sze "VLSI Technology", 2nd Edition, McGraw Hill Co. Inc., New York, 1988 2. C. Y. Chang and S. M. Sze, "VLSI Technology", McGraw Hill Co. Inc., New York, 1996

Course Number	**EC6207**
Course Credit	3-0-0-3
Course Title	**Microwave and Millimetre Wave Integrated Circuits (MMIC)**
Learning Mode	Lectures
Learning Objectives	**Course Learning Outcome (CLO):** Students will gain a comprehensive understanding of the fundamental principles of MMICs, including their structure, fabrication techniques, and advantages over discrete component-based circuits in microwave and millimeter-wave applications. Students will develop proficiency in designing MMICs for specific microwave and millimeter-wave applications
Course Description	This course deals with the MMIC.
Course Outline	**Prerequisite:** Engineering Electromagnetics **Introduction to Microwaves and Millimeter Waves**, Transmission Lines for Microwave and Millimeter Waves- Microstrip, Suspended Microstrip, Suspended Stripline, Fin-lines, Dielectric Integrated Guides. **Microwave and Millimeter wave Switches**, P-i-n diode switches: basic configurations, Insertion loss and isolation of series and shunt switches, Series and shunt switches in microstrip, Device reactance compensation, Isolation improvement techniques, SPDT switches, Application of p-i-n diode switches, Design Examples. **Microwave and Millimeter Wave Phase Shifters**-Analog versus digital Phase Shifters, Principle of ferrite Phase Shifters, Reciprocal versus non-reciprocal phase shifters, Different types of p-i-n diode phase shifters. **Small Signal Amplifiers**, Low Noise, Maximum Gain, Stability, Narrow band Design, Broadband Design, Noise Analysis. **Microwave and Millimeter Wave Mixers**, Millimeter Wave Transceiver Design.
Learning Outcome	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments, and Exams
Suggested Readings	**Text Books:** 1. B. Bhat and Shiban K Koul, Strip line like Transmission line for Microwave Integrated Circuits, 1989 New Age Publishers, India Delhi. 2. D.M. Pozar, Microwave Engineering, 4th Edition, 2013 John Wiley, USA. 3. T.C. Edwards, Foundations for Microstrip Circuit Design, 1981 John Wiley, USA. **Reference Books:** 1. T.T. Ha, Solid-State Microwave Amplifier Design, 1981 John Wiley, USA. 2. G. Gonzales, Microwave Transistor Amplifiers: Analysis and Design, 1997 Prentice Hall, USA. 3. Shiban K Koul and B. Bhat, Microwave Phase shifters, Volume-I and II, 1992 Artech House, USA.

Course Number	**EC6208**
Course Credit	3-0-0-3
Course Title	**RF and Microwave Measurement Techniques**

Learning Mode	Lectures
Learning Objectives	**Course Learning Outcome (CLO):** Throughout the course, emphasis is placed on both theoretical understanding and practical skills development to enable students to proficiently perform RF and microwave measurements in professional settings.
Course Description	This course deals with the microwave measurement.
Course Outline	**Prerequisite: Engineering Electromagnetics** **Network Parameters**: High Frequency Network Parameters, Scattering Parameters. **Measurement Fundamentals**: Basics of RF parameters and terminology, impedance matching and reflection coefficient measurements, **VNA & SA:** Theory of operation of network analyzer, and spectrum analyzer, Basics of spectrum analysis and measurements using spectrum analyzers. **VNA calibration**, Calibration techniques (e.g., TRL, SOLT), synthesized signal generation, noise measurement, **Measurement of antenna properties**: resonance, bandwidth, radiation pattern, gain,
Learning Outcome	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments, and Exams
Suggested Readings	**Text Books:** 1. Joel P. Dunsmore, Handbook of Microwave Component Measurements: With Advanced VNA Techniques, 2012 Wiley USA. 2. A. Mariscotti, RF and Microwave Measurements: Device Characterization, Signal Integrity, and Spectrum Analysis, 2015 ASTM USA. **Reference Books:** 1. Inder Bahl, Kai Chang, Vijay Nair, RF and Microwave Circuit and Component Design for Wireless Systems, 2002 Wiley USA. 2. A.S. Khan, Microwave Engineering: Concepts and Fundamentals, 2014 CRC Press USA.

Course Number	**EC6209**
Course Credit	3-0-0-3
Course Title	**Adaptive filtering: From theory to practice**
Learning Mode	Lectures
Learning Objectives	**Course Learning Outcome (CLO):** After successful completion of this course, the students will have 1. ability to use iterative techniques to solve parameter estimation problems both in linear and nonlinear scenarios. 2. ability to choose the appropriate method for signal processing systems based on the theoretical guarantees of iterative and recursive methods. 3. ability to understand the problem of finding the minimum error criteria and using computer-based simulations to understand the theoretical concepts of adaptive signal processing and various applications.
Course Description	This course deals with the adaptive filtering.
Course Outline	**Prerequisite:** Signals and Systems, Digital Signal Processing **Linear Optimum Filtering:** Wiener filtering, Linear Prediction, Kalman Filters **Linear Adaptive Filtering:** Fundamentals, Linear Estimation Problem, Newton Algorithm, Steepest-Descent Method, Steepest-Descent Algorithm, LMS Algorithm, LMF algorithm, LMS/F Algorithm, Normalized LMS Algorithm and its family, Affine Projection Algorithm and its family, RLS Algorithm and its family, Stability and performance analysis of adaptive algorithms, sparse adaptive filters, affine and convex combination of adaptive filters, block adaptive filters, Transform-Domain Adaptive Filters, multi-delay filters, Subband adaptive filtering and its family, Multiband-structured subband adaptive filtering and and its family, Adaptive IIR filters. Applications of Linear Adaptive Filtering: Plant modelling, Adaptive line enhancer, inverse adaptive modelling, channel equalization, Stereophonic acoustic echo

	cancellation, active noise control, acoustic feedback cancellation, noise reduction, adaptive beamforming, speech enhancement, other state-of-the-art applications. **Nonlinear Adaptive Filtering:** Introduction, Volterra Series Algorithm, Adaptive Bilinear Filters, Multilayer Perceptron Algorithm, Radial Basis Function Algorithm, FLANN adaptive filter and its family, spline adaptive filter, robust adaptive filter and its family. Applications of nonlinear Adaptive Filtering: Nonlinear plant modeling, nonlinear active noise control, impulsive noise control, other state-of-the-art applications.
Learning Outcome	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments, and Exams
Suggested Readings	**Text Books:** 1. P. S. R. Diniz, Adaptive Filtering, 3rd Edition, 2008, Springer. 2. P. S. R. Diniz, M. L. R. de Campos, W. A. Martins, M. V. S. Lima and J. A. Apolinário, Online Learning and Adaptive Filters, 1st Edition, 2022, Cambridge University Press. 3. S. Haykin, Adaptive Filter Theory, 5th Edition, 5th Edition, 2013, Pearson Education. **Reference Books:** 1. A. H. Sayed, Adaptive Filters, 1st Edition, 2008, Wiley-IEEE Press. 2. K. A. Lee, W. S. Gan, and S. M. Kuo, Subband Adaptive Filtering: Theory and Implementation, 1st Edition, 2009, John Wiley & Sons.

Course Number	**EC6210**
Course Credit	3-0-0-3
Course Title	**Smart Antenna: From Theory to Practice**
Learning Mode	Lectures
Learning Objectives	Successful completion of this will be helpful to design an antenna array whose beam can be controlled and directed at a targeted user/direction. After successful completion of this course the students will have: 1. Understanding the concept of Phased Array. 2. Understanding the concept of multipath propagation. 3. Understanding the concept of Angle of Arrival estimation. 4. Understanding the concept of beam forming. 5. Implementation based on computer based simulations and learning of various algorithms.
Course Description	This course deals with the smart antenna.
Course Outline	**Prerequisite:** Engineering Electromagnetic, Matrix Algebra Introduction, antenna basic parameters, Friis-formula, vector potential, linear antenna, loop antenna. Linear array**,** Array weighting, circular array, planar array, fixed beam array, fixed sidelobe canceling, retro-directive array. **Propagation channel characteristic:** Flat earth model, multipath propagation mechanism, propagation channel basics. Improving signal quality: equalization, diversity, channel coding, MIMO. **Fundamental of matrix algebra:** Array correlation matrix, AOA estimation: Bartlett, Capon, Linear prediction, maximum entropy, MUSIC, ESPRIT. **Fixed weight beamforming algorithm:** Maximum likelihood, minimum variance. Adaptive beamforming: least mean square, simple matrix inversion, recursive least square, conjugate gradient method.
Learning Outcome	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments, and Exams

Suggested Readings	**Text books:** 1. Frank B. Gross, Smart Antennas for Wireless Communication, 1999 McGraw Hill USA. 2. Constantine A. Balanis, Antenna Theory: Analysis & Design, 3rd Edition 2009 Wiley USA. **Reference Book:** 1. T.S. Rappaport & J.C. Liberti, Smart Antennas for Wireless Communication, 1999 Prentice Hall USA. 2. R. Janaswamy, Radio Wave Propagation and Smart Antennas for Wireless Communication, 2001 Kluwer USA.

Course Number	**EC6211**
Course Credit	3-0-0-3
Course Title	**Antenna Design and Characterization**
Learning Mode	Lectures
Learning Objectives	Following are the major learning outcome of the course- 1. To learn antenna fundamentals and its practical aspects. 2. To understand designing techniques and various applications of antenna technologies. 3. Students will learn several simulation and designing techniques of high frequency antennas. 4. To know about the application and designing of next generation radiation blocks.
Course Description	This course deals with the Antenna design and characterisation.
Course Outline	**Pre-requisites: Engineering Electromagnetics** Antenna fundamentals and definitions; Radiation integral and Auxiliary Potential Functions, Reaction and reciprocity theorems; Wire antennas infinitesimal dipole, small dipole, finite length dipole, half-wave dipole, and loop antennas; Antenna arrays – two-element array, N-element linear array, planar array, and circular array; Different Types of Antennas: Dipoles and Matching Techniques, Travelling Wave Antennas, Broadband Antennas, Frequency Independent Antennas, Antenna Miniaturization, and Fractal Antennas, Aperture, and Horn Antennas, Microstrip Antennas, Antenna Polarization, Microstrip Patch Antennas, Reflector Antennas; Antenna Measurements: Antenna Ranges, Radiation Patterns, Gain Measurements, Directivity, Measurements, Radiation Efficiency, Impedance Measurements, Current Measurements, Polarization Measurements; Antennas for millimeter-wave communication;
Learning Outcome	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments, and Exams
Suggested Readings	**Text Books:** 1. C.A. Balanis, “Antenna Theory Analysis and Design”, Wiley & Sons, Third Edition. 2.Gosling, William. “Radio Antennas and Propagation: Radio Engineering Fundamentals”, Elsevier, 1998. **Reference Books:** 1. Kraus, John Daniel, and Ronald J. Marhefka. "Antennas for all applications.", aaa. 2002. 2.Kraus, John D., Ronald J. Marhefka, and Ahmad S. Khan, “Antennas and wave propagation”, Tata McGraw-Hill Education, 2006. 3.Sharawi, Mohammad S., “Printed MIMO antenna engineering”, Artech House, 2014.

Course Number	**EE6215**
Course Credit	**L-T-P-C: 3-0-0-3**
Course Title	**Random Signals and Systems**
Learning Mode	Lectures

Learning Objectives	Complies with Program Objectives 1 and 2.
Course Description	The course is designed to meet the requirements of Ph.D. and M. Tech students to get sufficient knowledge on random processes and its effects on linear systems.
Course Outline	Probability and statistics of multivariable (a quick revision): Bayes theorem, multiple random variable, discrete random variable, probability mass function and probability density function, a few well known distributions, moments. Random process: Concept of random process, ensemble, mathematical tools for studying random process, correlation function, stationarity, ergodicity, a few known stochastic processes: random walk, Poisson process, Gaussian random process, Markov chains, Brownian motion etc., pseudorandom process, nonlinear transformation of random process. Random process in frequency domain: Peridogram and power sprectral density, Weiner-Khintchine-Einstein Theorem, concept of bandwidth, spectral estimation. Linear system: Discrete time and continuous time LTI system, concept of convolution, system described in frequency domain, state space description of the system. Linear systems with random inputs: Linear system fundamentals, response of a linear system, convolution, mean, autocorrelation and cross correlation function in LTI system, power spectral density in LTI, cross power spectral density in LTI. Processing of random signals: Noise in systems, noise bandwidth, SNR, bandlimited random process, noise reduction, matched filter, Wiener filter. The Kalman filter: Mean square estimation, discrete Kalman filter, innovation, Kalman filter vs Wiener filter,properties of Kalman filter, Kalman Bucy filter, engineering examples.
Learning Outcomes	Complies with PLOs 1a, 2a, and 3a.
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Readings	**<u>Text</u>** 4. Miller, Scott, and Donald Childers, “probability and random processes: with applications to signal processing and communications”, Academic Press, 2012. 5. Wim C. van Etten, “Introduction to random signals and Noise”, Chichester, England: Wiley, 2005. 6. Peyton Z. Peebles, “Probability, random variables, and random signal principles”. McGraw Hill Book Company, 1987. **<u>References</u>** 1. Geoffrey R. Grimmett, and David Stirzaker, “Probability and random processes”, Oxford university press, 2001. 2. Alberto Leon-Garcia, “Probability, statistics, and random processes for Electrical engineering”, Upper Saddle River, NJ: Pearson/Prentice Hall, 2008. 3. Grewal, Mohinder, and Angus P. Andrews, “Kalman filtering: theory and practice with MATLAB”, John Wiley & Sons, 2014. 4. Alberto Leon-Garcia, “Probability, statistics, and random processes for Electrical engineering”, Upper Saddle River, NJ: Pearson/Prentice Hall, 2008. 5. Kay, Steven M, “Fundamentals of statistical signal processing”, Prentice Hall PTR, 1993. 6. H.L. Van Trees, “Detection, estimation, and modulation theory, part I”, New York, NY: John Wiley & Sons, Inc., 1971. 7. Brown, Robert Grover, and Patrick YC Hwang., “Introduction to random signals and applied Kalman filtering”, New York: Wiley, 1992. 8. Shovan Bhaumik, and Paresh Date, “Nonlinear estimation: methods and applications with deterministic Sample Points”, CRC Press, 2019. 9. Steven Key, “Intuitive probability and random processes using MATLAB®”, Springer Science & Business Media, 2006. 10. D. J. Gordana, “Random signals and processes primer with MATLAB”, Springer Science & Business Media, 2012

Course Number	**EC5250**
Course Credit	3-0-0-3

Course Title	**Pattern Recognition and Machine Learning**
Learning Mode	Lectures
Learning Objectives	**Course Learning Outcome (CLO):** After learning this course, the students will be able 1. to know various tools and techniques of pattern recognition. 2. to develop skills to characterize and implement big data analytics. 3. to understand the application of pattern recognition in different real-life problems.
Course Description	This course deals with the Pattern recognition and ML.
Course Outline	Introduction: Feature extraction and Pattern Representation, Concept of Supervised and Unsupervised Classification, Introduction to Application Areas. Statistical Pattern Recognition: Bayes Decision Theory, Minimum Error and Minimum Risk Classifiers, Discriminant Function and Decision Boundary, Normal Density, Discriminant Function for Discrete Features, Parameter Estimation. Dimensionality Problem: Dimensionality Reduction, Fisher Linear Discriminant and Multiple Discriminant Analysis. Nonparametric Pattern Classification: Density Estimation, Nearest Neighbour Rule, Fuzzy Classification. Linear Discriminant Functions: Separability, Two Category and Multi Category Classification, Linear Discriminators, Perceptron Criterion, Relaxation Procedure, Minimum Square Error Criterion, Widrow-Hoff Procedure, HoKashyap Procedure, Kesler's Construction. Neural Network Classifier: Single and Multilayer Perceptron, Back Propagation, Learning Hopfield, Network Fuzzy and Neural Network. Time Varying Pattern Recognition: First Order Hidden Markov, Model Evaluation, Decoding Learning. Unsupervised Classification: Clustering, Hierarchical Clustering, Graph Based Method, Sum of Squared Error Technique, Iterative Optimization.
Learning Outcome	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments, and Exams
Suggested Readings	**Texts/References:** 1. Richard O. Duda, Peter E. Hart and David G. Stork, Pattern Classification, John Wiley & Sons, 2001. 2. Earl Gose, Richard Johsonbaugh and Steve Jost, Pattern Recognition and Image Analysis, Prentice Hall, 1999.

Course Number	**EC6154**
Course Credit	3-0-0-3
Course Title	**Computer Vision**
Learning Mode	Lectures
Learning Objectives	1. Understanding geometric transformations, Learning how to extract 3D information from 2D images. 2. Understanding knowledge of edge enhancement, filtering and stereo graphics projection etc. 3. Gaining hands-on experience with image segmentation useful for higher order image analysis and understanding. 4. Different types of clustering, object detection etc. Neural network fundamentals for AI applications etc.
Course Description	This course deals with the Computer Vision.
Course Outline	Computer vision introduction, image formation, perspective projection, camera response & HDR imaging, nature of image sensors, image filtering, template matching, Fourier transform, convolution and deconvolution, edge and corner detection, canny edge detection, Active contours, Hough transform, SIFT detector and descriptor, Image homography, Image warping and image blending, Face detection, nearest neighbor classifier, support vector machine, Radiometry and reflectance property, Photometric stereo, reflectance map, shape from normal, shape from shading, stereographic projection, shading illusion, dept from focus and depth from defocus, photometric stereo systems, camera calibration, simple stereo, uncalibrated stereo, epipolar geometry, stereo vision in nature, optical flow, Lucas Kanade method, structure from motion, object

	tracking, gaussian mixture model, feature detection for tracking, image segmentation by k-means, mean-shift and graph cut based methods. PCA and SVD and shape verses appearance. Neural network, Gradient descent, back propagation algorithm.
Learning Outcome	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments, and Exams
Suggested Readings	**Text Books:** 1. Computer Vision - A modern approach, by D. Forsyth and J. Ponce, Prentice Hall Robot Vision, by B. K. P. Horn, McGraw-Hill. **Reference Books:** 1. Computer Vision: Algorithms and Applications: Richard Szeliski, 2011, Springer. 2. Antonio Torralba, Phillip Isola, and William T. Freeman, “Foundations of Computer Vision”, 2024, The MIT Press.

Course Number	**EC6212**
Course Credit	3-0-0-3
Course Title	**Optimization Theory and Techniques for Electrical Engineering**
Learning Mode	Lectures
Learning Objectives	A student who successfully completes this course will be able to: 1. Understand the mathematical concepts underlying the optimization problems and their solutions 2. Classify optimization problems according to their mathematical properties 3. Formulate and solve the optimization problems 4. Design computationally-efficient solutions for difficult optimization problems
Course Description	This course deals with the Optimization theory.
Course Outline	Introduction of Optimization Theory; Introduction to Linear Programming; Convex Optimization Problem: Convex Sets, Convex Functions, Convex Optimization Problems: LP, QCQP, SOCP; Duality Theory, KKT Conditions. Numerical Optimization Techniques: Bisection Method, Golden Section Method, Newton Rapson Method, Interior Point Method. Introduction to Multi-objective Optimization Problems. Combinatorial Optimization: Integer Programming, Graphs and Graph Algorithms, Hard Problems, Heuristics, and Approximations. Application of Optimization Theory in Communication Systems, Signal Processing, Network Design, and Power & Control Systems.
Learning Outcome	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments, and Exams
Suggested Readings	**Text Books:** 1. Stephen Boyd and Lieven Vandenberghe, Convex Optimization, Cambridge University Press. 2. C. H. Papadimitriou and Kenneth Steiglitz. Combinatorial optimization: algorithms and complexity, 1998, Courier Corporation. 3. M.S.Bazaraa , H.D.Sherali and C.Shetty , Nonlinear Programming, Theory and Algorithms, John Wiley and Sons, New York, 1993. **Reference Books:** 1. Dimitri P. Bertsekas, Convex Analysis and Optimization, Athena-Scientific, 2003. 2. D. P. Palomar, Y. C. Eldar, Convex Optimization in Signal Processing and Communications, Cambridge Press, 2010. 3. Dimitris Bertsimas and John N. Tsitsiklis, Introduction to Linear Optimization, Athena-Scientific, 2003. 4. Suresh Chandra, Jayadeva and Aparna Mehra, Numerical Optimization with

	Applications, Alpha Science International 2009. 5. D. B. West, Introduction to graph theory, 2nd Edition, 2001, Prentice hall. 6. Charles Byrne, A First Course in Optimization, 1st edition, 2014, Chapman and Hall/CRC.

Course Number	**EC6213**
Course Credit	3-0-0-3
Course Title	**Statistical Signal Processing**
Learning Mode	Lectures
Learning Objectives	After learning this course, the students should be able to: 1. explain, describe, and understand the notion of a random process and statistical time series; 2. characterise random processes in terms of its statistical properties, including the notion of stationarity and ergodicity; 3. define, describe, and understand the notion of the power spectral density of stationary random processes; analyse and manipulate power spectral densities; 4. analyse in both time and frequency the affect of transformations and linear systems on random processes, both in terms of the density functions, and statistical moments; 5. explain the notion of parametric signal models, and describe common regression-based signal models in terms of its statistical characteristics, and in terms of its affect on random signals; 6. apply least squares, maximum-likelihood, and Bayesian estimators to model based signal processing problems.
Course Description	This course deals with the Statistical Signal Processing.
Course Outline	Introduction to stochastic processes and their definitions, description of stochastic processes using probability density functions (pdfs). Second-order statistical descriptions. Types of random processes: IID random processes, uncorrelated, orthogonal processes, Wiener process, Markov processes, wide sense periodic and wide-sense cyclo-stationary processes. Notion of stationary and nonstationary processes. Notion of ergodicity, and the notion of time-averages being equal to ensemble averages in the mean-square sense. Introduction to random processes in the frequency domain. Power spectral density (PSD) and its properties. Cross-power spectral density (CPSD) and the properties of the CPSD. Complex spectral density functions and their relationships with PSDs. Linear systems with stationary random inputs, basic relationships between the input and output for stationary random processes, including input-output cross-correlation, output autocorrelation, and output power. Linearity of the expectation operator. Study of LTI and LTV systems with stationary and non-stationary inputs. Introduction to linear signal models, nonparametric vs parametric signal models, Types of pole-zero models, Yule-Walker equations, all-zero models, applications and examples. Introduction of Estimation Theory, properties of estimators: bias, variance, mean-squared error (MSE), Cramer-Rao lower-bound (CRLB), likelihood function, least square. Estimating signals in noise using parametric signal models, Bayesian estimation of sinusoids in noise, applications of Bayesian estimation methods.
Learning Outcome	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments, and Exams

Suggested Readings	**<u>Text Books:</u>** 1. S. M. Kay, Fundamentals of Statistical Signal Processing: Estimation Theory, 1993, Prentice-Hall, Inc. 2. Papoulis A. and S. Pillai, Probability, Random Variables, and Stochastic Processes, Fourth edition, 2002, McGraw Hill, Inc. **<u>Reference Books:</u>** 1. M. H. Hayes, Statistical Digital Signal Processing and Modeling, 2002, John Wiley & Sons, Inc. 2. D.G. Manolakis, V.K. Ingle and S.M. Kogon, Statistical and Adaptive Signal Processing, 2000, McGraw Hill.