

B. Tech. [Electronics and Communication Engineering (ECE)] – M. Tech. [Communication System and Signal Processing (CSSP)]

<p>Program Learning Objectives:</p>	<p>Program Learning Outcomes:</p>
<ol style="list-style-type: none"> 1. Develop a solid foundation in electronics and communication engineering principles, including circuit analysis, electronic devices, signal processing, microprocessor/microcontroller systems, analog communication systems, digital communication, and RF circuits etc. 2. Develop electronics and communication project management skills, including the ability to plan, execute, and complete within specified timelines and budgets. 3. Work collaboratively in multidisciplinary teams, demonstrating effective teamwork and communication to solve complex engineering problems. 4. Recognize the importance of ongoing professional development, engaging in activities such as certifications, workshops, and conferences to stay updated of industry trends. 	<p>The graduates of this program will have</p> <ol style="list-style-type: none"> 1. a successful career in an Academia/Industry/Entrepreneur. 2. strong fundamentals in electronics and communications engineering. 3. ability to design prototypes for real world problems related to electronics, communications and interdisciplinary fields. 4. ability to develop soft skills such as effective communications in both verbal and written forms, body language, time management, problem-solving, leadership, work in both team as well as individual in a professional manner.
<p>Program Goal 1: Academic excellence by providing a curriculum that aligns with industry standards and encourages critical thinking in the field of electronics and communication engineering.</p>	<p>Program Learning Outcome 1a: Highly skilled market ready man power to serve the emerging electronic sectors Program Learning Outcome 1b: Skilled Human resource to cater the needs of next generation communication sectors</p>
<p>Program Goal 2: A culture of research and innovation by promoting faculty and student involvement in cutting-edge projects in electronic and communication technologies.</p>	<p>Program Learning Outcome 2a: Trained researchers for implementing research projects in line with national priorities such as CPS, Semiconductors, Clean Energy, Green Technologies Program Learning Outcome 2b: Design and develop innovative smart electronics products as per the societal need.</p>
<p>Program Goal 3: To design dynamic and flexible course structures for UG and PG programs as per the changing requirement of the industries</p>	<p>Program Learning Outcome 3a: Industry relevant UG, PG, and research programs Program Learning Outcome 3b: Trained manpower as per the industry requirement</p>
<p>Program Goal 4: To promote entrepreneurship among the students in the field of electronics and communication engineering</p>	<p>Program Learning Outcome 4a: Realization of working prototype towards product development Program Learning Outcome 4b: Promotion of in house technology based ventures catering societal needs</p>

Program Goal 5: Equip students with strong communication skills, enabling them to articulate technical concepts clearly and effectively in both written and oral forms.	Program Learning Outcome 5a: Man power with enhanced soft skills to support the vision of developed India Program Learning Outcome 5b: Responsible citizen for the holistic growth of the country
Program Goal 6: To equip students with technical skills necessary for the design, analysis, and implementation of communication system technologies and networks.	Program Learning Outcome 6a: 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 6b: Demonstrate advanced knowledge and understanding of communication engineering principles, theories, and concepts.
Program Goal 7: To foster research and development skills, enabling students to contribute to the advancement of communication technologies through innovation and problem-solving.	Program Learning Outcome 7: 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 8: To prepare students for professional practice in communication engineering roles in industry, academia, research institutions, or government agencies.	Program Learning Outcome 8: Design, simulate, and implement communication systems and networks using appropriate tools, techniques, and methodologies.

Sl. No.	Subject Code	SEMESTER VII	L	T	P	C
1.	EC41XX	B. Tech. Elective - I	3	0	0	3
2.	EC41XX	B. Tech. Elective - II	3	0	0	3
3.	XX41PQ	IDE - III	3	0	0	3
4.	HS41PQ	HSS Elective - II	3	0	0	3
5.	EC4196	Summer Internship*	0	0	12	3
6.	EC4197	Project – I	0	0	12	6
7.	EC5101	Information Theory and Coding	3	1	0	4
TOTAL			15	1	24	25

***Note :**

For specific cases of internship after VIth Semester, the performance evaluation would be made on joining the VIIth Semester and graded accordingly in the VIIth Semester:

Note :

a) (i) Summer internship (*) period of at least 60 days' (8 weeks) duration begins in the intervening vacation between Semester VI and VII that may be done in industry / R&D / Academic Institutions including IIT Patna. The evaluation would comprise **combined grading based on host supervisor evaluation, project internship report after plagiarism check and seminar presentation at the Department (DAPC to coordinate)** with equal weightage of each of the three components stated herein.

a) (ii) Further, on return from internship, students will be evaluated for internship work through combined grading based on host supervisor evaluation, project internship report after

plagiarism check, and presentation evaluation by the parent department with equal weightage of each component.

b) (i) In the VIIth semester, students can opt for a semester long internship on recommendation of the DAPC and approval of the Competent Authority.

b) (ii) On approval of semester long internship, at the maximum two courses (properly mapped/aligned syllabus) at par with institute electives may be opted from NPTEL and / or SWAYAM and the other two more should be done at the institute through course overloading in any other semester (either before or after the internship) and/or during following summer semester.

b) (iii) The candidates opting two courses from NPTEL and / or SWAYAM would be required to appear in the examination at the Institute as scheduled in the Academic Calendar.

Sl. No.	Subject Code	SEMESTER VIII	L	T	P	C
1.	RM6201	Research Methodology	3	1	0	4
2.	EC5201	Wireless Communication	3	0	2	4
3.	EC5202	Advanced Communication Systems	3	0	2	4
4.	XX52PQ / XX62PQ	M. Tech. Elective - I	3	0	0	3
5.	EC4297	Project - II	0	0	12	6
TOTAL			12	1	16	21

Sl. No.	Subject Code	SEMESTER IX	L	T	P	C
1.	XX52PQ/ XX62PQ	M. Tech. Elective - II	3	0	0	3
2.	XX52PQ/ XX62PQ	M Tech Elective - III	3	0	0	3
3.	XX52PQ/ XX62PQ	M Tech Elective - IV	3	0	0	3
4.	EC5197	Project III**	0	0	16	8
TOTAL			9	0	8	17

Sl. No.	Subject Code	SEMESTER X	L	T	P	C
1.	EC5297	Project IV**	0	0	36	18
TOTAL			0	0	36	18

****Note: M. Tech. Project outside the Institute**

In the IXth Semester, students can opt for a semester long M. Tech. project subject to confirmation from an Institution of repute for research project, on the assigned topic at any external Institution (Industry / R&D lab / Academic Institutions) based on recommendation of the DAPC provided:

(i.) The project topic is well defined in objective, methodology and expected outcome through an abstract and statement of the student pertaining to expertise with the proposed supervisor

of the host institution and consent of the faculty member from the concerned department at IIT Patna as joint supervisor.

(ii.) The consent of both the supervisors (external and institutional) on project topic is obtained a priori and forwarded to the academic section through DAPC for approval by the competent authority for office record in the personal file of the candidate.

(iii.) Confidentiality and Non Disclosure Agreement (NDA) between the two organizations with clarity on intellectual property rights (IPR) must be executed prior to initiating the semester long project assignment and committing the same to external organization and vice versa.

(iv.) The evaluation in each semester at Institute would be mandatory and the report from Industry Supervisor will be given due weightage as defined in the Academic Regulation. Further, the final assessment of the project work on completion will be done with equal weightage for assessment of the host and Institute supervisors, project report after **plagiarism check**. The award of grade would comprise **combined assessment based on host supervisor evaluation, project report quality and seminar presentation at the Department (DAPC to coordinate)** with equal weightage of each of the components stated herein.

(v.) In case of poor progress of work and / or no contribution from external supervisor, the student need to revert back to the Institute essentially to fulfill the completion of M. Tech. project as envisaged at the time of project allotment. However, the recommendation of DAPC based on progress report and presentation would be mandatory for a final decision by the competent authority.

Grand Total (Semester I to X) : 210

ELECTIVE GROUPS

B. Tech. Elective - I						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	EC4101	Introduction to Quantum Computing	3	0	0	3
2.	EC4102	Deep Learning for Video Surveillance Systems	3	0	0	3
3.	EC4103	FPGA based System Design	3	0	0	3

B. Tech. Elective - II						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	EC4104	Introduction to Information Theory	3	0	0	3
2.	EC4105	Digital Image Processing	3	0	0	3
3.	EC4106	Graph Signal Processing	3	0	0	3

M. Tech. Elective - I						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	EC5205	Patterns Recognition and Machine Learning	3	0	0	3
2.	EC5206	Multimedia Communication	3	0	0	3
3.	EC5207	Optical Communication	3	0	0	3

4.	EC5209	Communication Networks	3	0	0	3
5.	EC5210	Advanced Biomedical Signal Processing	3	0	0	3
6.	EC5211	Silicon Photonics	3	0	0	3
7.	EC6201	RF and Microwave Measurement Techniques	3	0	0	3
8.	EC6202	Smart Antenna: From Theory to Practice	3	0	0	3
9.	EC6203	Adaptive filtering: From theory to practice	3	0	0	3
10.	EC6204	Antenna Design and Characterization	3	0	0	3
11.	EC6205	Statistical Signal Processing	3	0	0	3
12.	EC6206	Optimization Theory and Techniques for Electrical Engineering	3	0	0	3
13.	EC6207	Microwave and Millimetre Wave Integrated Circuits (MMIC)	3	0	0	3
14.	EC6208	Generative AI for Video Surveillance System	3	0	0	3
15.	EE6214	Random Signals and Systems	3	0	0	3

M. Tech. Elective – II						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	EC5107	RF and Microwave Active Circuits	3	0	0	3
2.	EC5108	Internet of Things (IoT) Networks	3	0	0	3
3.	EC5109	Radio Frequency Integrated Circuits	3	0	0	3
4.	EC6101	Advance Antenna and Microwave Devices	3	0	0	3

M. Tech. Elective - III						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	EC5111	VLSI Architecture Design and Implementation	3	0	0	3
2.	EC5118	Bio Sensors and Circuits	3	0	0	3
3.	EC5119	Quantum Computing	3	0	0	3
4.	EC6103	Radio Frequency Design and Technology	3	0	0	3
5.	EC6104	VLSI Signal Processing	3	0	0	3
6.	EC6106	Computer Vision	3	0	0	3

M. Tech. Elective - IV						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	EE5106	Energy Storage Systems	3	0	0	3
2.	EE6108	V2G and G2V Technology	3	0	0	3
3.	EC6108	Emerging Technologies for Beyond 5G	3	0	0	3

Sl. No.	Subject Code	SEMESTER VII	L	T	P	C
1.	EC41XX	B. Tech. Elective - I	3	0	0	3
2.	EC41XX	B. Tech. Elective - II	3	0	0	3
3.	XX41PQ	IDE - III	3	0	0	3
4.	HS41PQ	HSS Elective - II	3	0	0	3
5.	EC4196	Summer Internship*	0	0	12	3
6.	EC4197	Project – I	0	0	12	6
7.	EC5101	Information Theory and Coding	3	1	0	4
TOTAL			15	1	24	25

B. Tech. Elective - I						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	EC4101	Introduction to Quantum Computing	3	0	0	3
2.	EC4102	Deep Learning for Video Surveillance Systems	3	0	0	3
3.	EC4103	FPGA based System Design	3	0	0	3

Course Number	EC4101
Course Credit	3-0-0-3
Course Title	Introduction to Quantum Computing
Learning Mode	Lectures
Learning Objectives	Complies with Program Goal 1, 2 and 3
Course Description	The course deals with the key components and architecture of quantum computing systems, including qubits, quantum gates, and quantum circuits. It also focuses on comprehending the principles of quantum information theory, including quantum entanglement, quantum entropy, and quantum teleportation. Implementation and analysis of quantum algorithms, such as Shor's algorithm for factoring and Grover's algorithm for search problems is also included.
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 gates: X, Z, Y, H, R, S, T, Square root of NOT Quantum Circuits: Single qubits and multiple qubits operations and quantum teleportation Quantum Algorithms: Deutsch's algorithm, Deutsch-Jozsa algorithm, Simon's algorithm Quantum Tools and Applications: Goal Challenges, Lights and Photon, Decoherence, Ion Trap, Quantum Simulation
Learning Outcomes	Complies with PLO 1b, 2a and 3a
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	<p>Textbooks:</p> <ol style="list-style-type: none"> Nielsen, M. A., and Chuang, I. L., Quantum computation and quantum information, 10th Anniversary Edition, 2010, Cambridge university press. Yanofsky, N. S., and Mannucci, M. A., Quantum computing for computer scientists, 1st Edition, 2008, Cambridge University Press. <p>Reference Books:</p> <ol style="list-style-type: none"> Johnston, E. R., Harrigan, N., and Gimeno-Segovia, M., Programming quantum computers: essential algorithms and code samples, 1st Edition, 2019, O'Reilly Media.

Course Number	EC4102
Course Credit	3-0-0-3
Course Title	Deep Learning for Video Surveillance Systems
Learning Mode	Lectures
Learning Objectives	Complies with Program Goal 1, 2 and 3
Course Description	The course deals with video surveillance tasks such as monitoring and processing of video footage, and understanding and analyzing of machine and deep learning models. The course also develop competence to take logical, scientific and correct decisions while predicting model outcomes. Aptitude and ability of performance measurement and management of video surveillance cameras is also covered.
Course Outline	<p>Introduction to Video Surveillance Systems: Introduction to image processing methods, Edge detection and linking, Image transforms, Introduction to video processing techniques, Video compression standards. Motion detection using optical flow method, motion modeling, Background modeling, Basic building blocks of video surveillance systems.</p> <p>Introduction to Deep Learning: Introduction to neural networks with linear algebra, Matrix mathematics and probability, Introduction to multilayer perceptron networks, forward and back propagation, Hyper-parameter tuning, Regularization and optimization in neural networks, Introduction to tensor-flow.</p> <p>Convolutional Neural Nets: Introduction to convolutional neural networks, Key concepts like convolution and pooling. Stacking convolutional layers for object detection.</p> <p>Recurrent Neural Nets: Introduction to recurrent neural networks (RNN, LSTM, GRU) for sequence level tasks (time series, video). Bidirectional and deep recurrent nets. Use them for activity recognition.</p> <p>Object Detection and Classification using Deep Learning: Haar like feature based object detection, Viola Jones object detection framework, Deep learning based object classification.</p> <p>Object Tracking using Deep Learning: Video monitoring for detection and tracking of single as well as multiple interacting objects, Region-based tracking, Contourbased tracking, Feature-based tracking, Model-based tracking, KLT tracker, Meanshift based tracking.</p> <p>Deep Learning based Human Activity Recognition: Template based activity recognition, CNN based activity recognition, RNN based activity recognition, abnormal behavior detection in crowded environments using deep learning</p> <p>Camera Networks for Surveillance: Types of CCTV (closed circuit television) camera- PTZ (pan-tilt zoom) camera, IR (Infrared) camera, IP (Internet protocol) camera, wireless security camera, multiple view geometry, camera network calibration, PTZ camera calibration, camera placement, smart imagers and smart cameras, Introducing graph signal processing, consensus networks.</p> <p>Emerging Techniques of Deep Learning in Visual Surveillance System: Augmented surveillance system, Operator attention based visual surveillance system, EEG and eye tracking based visual surveillance system, ONVIF standard for the interface of IP-based physical security products.</p>
Learning Outcomes	Complies with PLO 1b, 2a and 3b
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	<p>Textbooks:</p> <ol style="list-style-type: none"> 1. M H Kolekar, "Intelligent Video Surveillance Systems: An Algorithmic Approach", CRC press Taylor and Francis Group, 2018 2. Q. Huihuan, X. Wu, Y. Xu, "Intelligent Surveillance Systems", Springer Publication, 2011. 3. Ian Goodfellow, Yoshua Bengio and Aaron Courville, "Deep Learning", The MIT Press, 2017. <p>Reference Books:</p> <ol style="list-style-type: none"> 1. Murat A. Tekalp, "Digital Video Processing", Prentice Hall, 1995. 2. Pradeep K Atrey, Mohan Kankanhalli, A Cavallaro, "Intelligent Multimedia Surveillance: Current Trends and Research" Springer Publication, 2013. 3. Y. Ma and G. Qian (Ed.), "Intelligent Video Surveillance: Systems and Technology", CRC Press, 2009. 4. H. Aghajan and A. Cavallaro (Ed.), Multi-Camera Network: Principles and Applications", Elsevier, 2009.

Course Number	EC4103
Course Credit	3-0-0-3
Course Title	FPGA based System Design
Learning Mode	Lectures
Learning Objectives	Complies with Program Goal 1, 2 and 3
Course Description	The course deals with design of complex digital systems & use the design flow for using FPGA. This also gives exposure to Softcore Processor IP, Memory and other IO IPs and digital IPs, understanding of IP integration for large scale FPGA based digital System. Also, it covers performance analysis and issues of large scale digital system on FPGA and completion of a significant project on the FPGA platform.
Course Outline	Introduction to reconfigurable and FPGA based system Design; Basic and Advanced FPGA Fabrics; Combinational, Sequential logic and FSM realization on FPGA; FPGA Architecting: Speed, Area and Power; Issues on FPGA based system Design: Area, Timing and Power; Design Methodologies: Behavioral /high level Design and Implementation methodologies: RTL, IP Core, System Generator; Processor and memory cores; Timing analysis; Clock distribution and management systems; IP Cores for FPGA: Block and Distributed memory, FIFO, CORDIC, Clock distribution and management systems; Large scale System Design: Platform FPGA, Multi-FPGA System; Busses and I/O communication system; System Design and Implementation using FPGA: DSP and Communication Blocks and Cryptography blocks Introduction to FPGA based Embedded system platform: Soft processor, AHB Bus and I/O interfacing – Case studies.
Learning Outcomes	Complies with PLO 1b, 2b and 3b
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	Text/Reference Books: <ol style="list-style-type: none"> 1. Wayne Wolf, “FPGA Based System Design”, Prentice Hall Modern Semiconductor Design Series, 2004. 2. Steve Kilts, “Advanced FPGA design – Architecture, Implementation and Optimization”, Wiley publications,2007. 3. Ron Sass and Andrew G. Schmidt, Morgan Kaufmann (MK), “Embedded System design with Platform FPGAs”, Elsevier,2010.

B. Tech. Elective - II						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	EC4104	Introduction to Information Theory	3	0	0	3
2.	EC4105	Digital Image Processing	3	0	0	3
3.	EC4106	Graph Signal Processing	3	0	0	3

Course Number	EC4104
Course Credit	3-0-0-3
Course Title	Introduction to Information Theory
Learning Mode	Lectures
Learning Objectives	Complies with Program Goal 1, 2 and 3
Course Description	The course deals with the fundamental concepts of information theory, understanding of coding, quantification, storage, and communication of information and analysis of source coding and channel coding.
Course Outline	Overview of random variable, Function of a random variable and its distribution, Discrete distributions, Continuous distributions, Random vector and its joint distribution. The concept of Amount of 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, Bandwidth-SNR Trade-off, Channel Capacity Theorem, Shannon Limit. Maximum entropy distributions for continuous and discrete cases.
Learning Outcomes	Complies with PLO 1b, 2a and 3b
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	<p>Textbooks:</p> <ol style="list-style-type: none"> 1. T.M. Cover and J. A. Thomas, Elements of Information Theory, 2nd edition, 2006, Wiley. 2. R. Bose, Information Theory and applications, 2nd Edition, 2008, TMH. <p>Reference Books:</p> <ol style="list-style-type: none"> 1. J. G. Proakis, Digital Communications, 1995, McGraw-Hill. 2. Ross, Sheldon. A First Course in Probability. 8th Edition, 2009, Pearson Prentice Hall.

Course Number	EC4105
Course Credit	3-0-0-3
Course Title	Digital Image Processing
Learning Mode	Lectures
Learning Objectives	Complies with Program Goal 1, 2 and 3
Course Description	The course deals with the fundamental concepts of digital image processing, including filtering, transforms, morphology, colour and image analysis. It also covers the basic image processing algorithms in C or Matlab or Python and make ready the students for advanced version of the course.
Course Outline	Introduction to Digital Image Processing & Applications, Sampling, Quantization, Basic Relationship between Pixels, Imaging Geometry, Image Transforms, Image Enhancement, Image Restoration, Image Segmentation, Morphological Image Processing, Shape Representation and Description, Object Recognition and Image Understanding, Texture Image Analysis, Motion Picture Analysis, Image Data Compression.
Learning Outcomes	Complies with PLO 1b, 2a and 3b
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	<p>Textbooks:</p> <ol style="list-style-type: none"> 1. Rafael C. Gonzalez and Richard E. Woods, Digital Image Processing, Pearson 2. Anil K. Jain, Fundamentals of Digital Image Processing, Prentice Hall <p>Reference Books:</p> <ol style="list-style-type: none"> 1. Milan Sonka, Vaclav Hlavac and Roger Boyle, Image Processing, Analysis and Machine Vision, Springer

Course Number	EE4106
Course Credit	3-0-0-3
Course Title	Graph Signal Processing
Learning Mode	Lectures
Learning Objectives	Complies with Program Goal 1, 2 and 3
Course Description	The course deals with explanation of basic graph theory concepts and their extension to graph signal processing, and implementation of filtering, sampling, and reconstruction techniques for graph signals. It also covers spectral analysis of graph signals using the graph Fourier transform, and design and evaluation of graph filters for practical applications in various domains.
Course Outline	Introduction: Why Graph Signal Processing: concepts, applications and challenges Introduction to graph concepts: Linear algebra review, graph shift, graph shift invariance, graph signals, graph filtering, graph Fourier transform, graph convolution and modulation, graph frequency and graph spectral analysis of graph signals, Spectral graph theory: Orthogonal transforms review, Frequency interpretation – Nodal Theorems, Graph filtering: Vertex and Spectral interpretations, Advanced Topic 1: Shift invariance, localization and uncertainty principles, Advanced Topic 2: Down sampling, Advanced Topic 3: Wavelets, Advanced Topic 4: Multiresolution and graph approximation, Advanced Topic 5: Directed Graphs, Geometric Learning to extend deep learning models to learning with data supported by graphs.
Learning Outcomes	Complies with PLO 1b, 2a and 3b
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	<p>Textbooks:</p> <ol style="list-style-type: none"> 1. F. R. Chung, Spectral graph theory, volume 92, AMS Bookstore, 1997. 2. D. M. Cvetkovic, P. Rowlinson, and S. Simic, An introduction to the theory of graph spectra. Cambridge University Press Cambridge, 2010. 3. D. K. Hammond, P. Vandergheynst, and R. Gribonval. Wavelets on graphs via spectral graph theory. Applied and Computational Harmonic Analysis, 30(2):129--150, 2011. <p>Reference Books:</p> <ol style="list-style-type: none"> 1. P. Milanfar. A tour of modern image filtering: new insights and methods, both practical and theoretical. Signal Processing Magazine, IEEE , 30(1):106--128, 2013. 2. S. K. Narang and A. Ortega. Perfect reconstruction two-channel wavelet filter banks for graph structured data. Signal Processing, IEEE Transactions on , 60(6):2786--2799, 2012. 3. A. Sandryhaila and J. M. Moura. Discrete signal processing on graphs. IEEE transactions on signal processing, 61(5-8):1644--1656, 2013. 4. D. I. Shuman, S. K. Narang, P. Frossard, A. Ortega, and P. Vandergheynst. The emerging field of signal processing on graphs: Extending high-dimensional data analysis to networks and other irregular domains. Signal Processing Magazine, IEEE, 30(3):83--98, 2013. 5. D. Spielman, Spectral graph theory, Lecture Notes, Yale University, 2009.

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 <ol style="list-style-type: none"> 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, 3a, 6a, 7, and 8
Assessment Method	Quiz, Assignments, and Exams
Suggested Readings	<p>Text Books:</p> <ol style="list-style-type: none"> 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. <p>References Books:</p> <ol style="list-style-type: none"> 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.

Sl. No.	Subject Code	SEMESTER VIII	L	T	P	C
1.	RM6201	Research Methodology	3	1	0	4
2.	EC5201	Wireless Communication	3	0	2	4
3.	EC5202	Advanced Communication Systems	3	0	2	4
4.	XX52PQ / XX62PQ	M. Tech. Elective - I	3	0	0	3
5.	EC4297	Project - II	0	0	12	6
TOTAL			12	1	16	21

Course Number	RM6201
Course Credit (L-T-P-C)	3-1-0-4
Course Title	Research Methodology
Learning Mode	Lectures
Learning Objectives	The objective of the course is to train student about the modelling of scalar and multi-objective nonlinear programming problems and various classical and numerical optimization techniques and algorithms to solve these problems
Course Description	Advanced Optimization Techniques, as a subject for postgraduate and PhD students, provides the knowledge of various models of nonlinear optimization problems and different algorithms to solve such problems with its applications in various problems arising in economics, science and engineering.
Course Content	<p>Module I (6 lecture hours) – Research method fundamentals: Definition, characteristics and types, basic research terminology, an overview of research method concepts, research methods vs. method methodology, role of information and communication technology (ICT) in research, Nature and scope of research, information based decision making and source of knowledge. The research process; basic approaches and terminologies used in research. Defining research problem and hypotheses framing to prepare a research plan.</p> <p>Module II (5 lecture hours) - Research problem visualization and conceptualization: Significance of literature survey in identification of a research problem from reliable sources and critical review, identifying technical gaps and contemporary challenges from literature review and research databases, development of working hypothesis, defining and formulating the research problems, problem selection, necessity of defining the problem and conceiving the solution approach and methods.</p> <p>Module III (5 lecture hours) - Research design and data analysis: Research design – basic principles, need of research design and data classification – primary and secondary, features of good design, important concepts relating to research design, observation and facts, validation methods, observation and collection of data, methods of data collection, sampling methods, data processing and analysis, hypothesis testing, generalization, analysis, reliability, interpretation and presentation.</p> <p>Module IV (16 lecture hours) - Qualitative and quantitative analysis: Qualitative Research Plan and designs, Meaning and types of Sampling, Tools of qualitative data Collection; observation depth Interview, focus group discussion, Data editing, processing & categorization, qualitative data analysis, Fundamentals of statistical methods, parametric and nonparametric techniques, test of significance, variables, conjecture, hypothesis, measurement, types of data and scales, sample and sampling techniques, probability and distributions, hypothesis testing, level of significance and confidence interval, t-test, ANOVA, correlation, regression analysis, error analysis, research data analysis and evaluation using software tools (e.g.: MS Excel, SPSS, Statistical, R, etc.).</p> <p>Module V (10 lecture hours) – Principled research: Ethics in research and Ethical dilemma, affiliation and conflict of interest; Publishing and sharing research, Plagiarism and its fallout (case studies), Internet</p>

	research ethics, data protection and intellectual property rights (IPR) – patent survey, patentability, patent laws and IPR filing process.
Learning Outcome	<p>On successful completion of the course, students should be able to:</p> <ol style="list-style-type: none"> 1. Understand the terminology and basic concepts of various kinds of nonlinear optimization problems. 2. Develop the understanding about different solution methods to solve nonlinear Programming problems. 3. Apply and differentiate the need and importance of various algorithms to solve scalar and multi-objective optimization problems. 4. Employ programming languages like MATLAB/Python to solve nonlinear programming problems. 5. Model and solve several problems arising in science and engineering as a nonlinear optimization problem.
Assessment Method	Quiz /Assignment/ Project / MSE / ESE

Textbooks & Reference Books:

1. C. R. Kothari, Research methodology: Methods and Techniques, 3rd Edn., New age International 2014.
2. Mark N K. Saunders, Adrian Thornhill, Phkip Lewis, “Research Methods for Studies, 3/c Pearson Education, 2010.
3. K.N. Krishnaswamy, apa iyer, siva kumar, m. Mathirajan, “Management Research Methodology”, Pearson Education, 2010.
4. Ranjit Kumar; “Research Methodology: A Step by Step Guide for Beginners; 2/e; Pearson Education, 2010.
5. Suresh C. Sinha, Anil K. Dhiman, ess ess, 2006 “Research Methodology” Panner Selvam.R. “Research Methodology”, Prentice Hall of India, New Delhi, 2004.
6. C.G. Thomas, Research methodology and scientific writing, Ane books, Delhi, 2015.
7. H. J. Ader and G. J. Mellenbergh, Research Methodology in the Social, Behavioural and Life Sciences Designs, Models and Methods, 3rd Edn., Sage Publications, London, 2000.

Course Number	EC5201
Course Credit	3-0-2-4
Course Title	Wireless Communication Systems
Learning Mode	Lectures and Practical
Learning Objectives	<p>After learning this course, the students will be able</p> <ol style="list-style-type: none"> 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	<p>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.</p> <p>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.</p> <p>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.</p> <p>Evolution of wireless technologies: 1G to 5G and Beyond.</p> <p>Code Division Multiple Access (CDMA): Spreading Codes, Pseudo-Noise (PN) Sequence, Multi-Users CDMA, Near-Far Problem, Power Control and Advantages of CDMA.</p> <p>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.</p> <p>Experiments:</p> <ol style="list-style-type: none"> 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	<p>Text Books:</p> <ol style="list-style-type: none"> 1. A. Goldsmith, Wireless Communications, 2009, Cambridge University Press. 2. D. Tse, P. Viswanath, Fundamentals of Wireless Communications, 2005, Cambridge Press. <p>Reference Books:</p> <ol style="list-style-type: none"> 1. G. L. Stuber, Principles of Mobile Communication, 1996, Kluwer Academic. 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 <ul style="list-style-type: none"> 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	<p>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)</p> <p>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</p> <p>Receiver Synchronization: Signal Parameter Estimation, Carrier Phase Estimation, Symbol Timing Estimation, Joint Estimation of Carrier Phase and Symbol Timing</p> <p>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.</p> <p>Introduction to Quantum Communications, Aerial Communications, Haptics Communications, and Holographic Communications.</p> <p>Experiments:</p> <ul style="list-style-type: none"> • Simulation-based experiment <ul style="list-style-type: none"> ○ 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	<p>Text Books:</p> <ol style="list-style-type: none"> 3. A. Goldsmith, Wireless Communications, 2009, Cambridge University Press. 4. D. Tse, P. Viswanath, Fundamentals of Wireless Communications, 2005, Cambridge Press. <p>Reference Books:</p> <ol style="list-style-type: none"> 5. G. L. Stuber, Principles of Mobile Communication, 1996, Kluwer Academic. 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.

M. Tech. Elective - I						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	EC5205	Patterns Recognition and Machine Learning	3	0	0	3
2.	EC5206	Multimedia Communication	3	0	0	3
3.	EC5207	Optical Communication	3	0	0	3
4.	EC5209	Communication Networks	3	0	0	3
5.	EC5210	Advanced Biomedical Signal Processing	3	0	0	3
6.	EC5211	Silicon Photonics	3	0	0	3
7.	EC6201	RF and Microwave Measurement Techniques	3	0	0	3
8.	EC6202	Smart Antenna: From Theory to Practice	3	0	0	3
9.	EC6203	Adaptive filtering: From theory to practice	3	0	0	3
10.	EC6204	Antenna Design and Characterization	3	0	0	3
11.	EC6205	Statistical Signal Processing	3	0	0	3
12.	EC6206	Optimization Theory and Techniques for Electrical Engineering	3	0	0	3
13.	EC6207	Microwave and Millimetre Wave Integrated Circuits (MMIC)	3	0	0	3
14.	EC6208	Generative AI for Video Surveillance System	3	0	0	3
15.	EE6214	Random Signals and Systems	3	0	0	3

Course Number	EC5205
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 Johnsonbaugh and Steve Jost, Pattern Recognition and Image Analysis, Prentice Hall, 1999.

Course Number	EC5206
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	EC5207
Course Credit	3-0-0-3
Course Title	Optical Communication
Learning Mode	Lectures
Learning Objectives	<p>After learning this course, the students will be able</p> <ol style="list-style-type: none"> 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	<p>Introduction: Fiber optic communication, Free space optical communication, Visible light communication, chip-to-chip optical communication.</p> <p>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.</p> <p>Bit rate distance product in single mode fiber.</p> <p>Fiber Nonlinearity: Self phase modulation, cross phase modulation, four wave mixing.</p> <p>Passive optical components. Optical Sources and Detectors: LED, LD, DFB-laser, PIN photodetector, APD.</p> <p>Optical Modulator. Wavelength division Multiplexing (WDM).</p> <p>Modulation formats: OOK, DPSK, DQPSK, PDM-QPSK. Optical System Performance Metrics: Eye opening penalty, Q, BER, OSNR.</p> <p>Link Analysis: Single channel point to point, WDM point-to-point. Optically Amplified Systems.</p>
Learning Outcome	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments, and Exams
Suggested Readings	<p>Text Books:</p> <ol style="list-style-type: none"> 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 <p>Reference Books:</p> <ol style="list-style-type: none"> 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	EC5209
Course Credit	3-0-0-3
Course Title	Communication Networks
Learning Mode	Lectures
Learning Objectives	<p>Course Learning Outcome (CLO) : The students will be able to understand:</p> <ol style="list-style-type: none"> 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	<p>Overview of Communications Networks — Introduction to Internet, Layering Concept, OSI Model, TCP/IP Model, Introduction to Protocols, Topology, Performance Metrics, Devices at different layers</p> <p>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</p> <p>Routing: Protocols, Types of Routing, Algorithms, IP Protocol, Addressing: IPV4 Address, IPV6 Addressing, Transition from IPV4 to IPV6</p> <p>Transport Layer: Protocols - User Datagram Protocols (UDP) and Transmission Control Protocols (TCP), Flow, Error and Congestion Control: Congestion avoidance, QoS in networks</p> <p>Application Layer: Client Server Model, World Wide Web and HTTP, DNS, Electronic Mail</p> <p>Selected advanced topics in Antennas and Microwave Technology.</p>
Learning Outcome	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments, and Exams
Suggested Readings	<p>Text Books:</p> <ol style="list-style-type: none"> 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. <p>Reference Books:</p> <ol style="list-style-type: none"> 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	EC5210
Course Credit	3-0-0-3
Course Title	Advanced Biomedical Signal Processing
Learning Mode	Lectures
Learning Objectives	<p>Course Learning Outcome (CLO): Course training via lectures, tutorial & workshop sessions enable with.</p> <ol style="list-style-type: none"> 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	<p>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.</p> <p>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.</p> <p>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-Trial Analysis and adaptive analysis using basis functions.</p> <p>The Electrical Activity of Neuromuscular System: Human muscular system, Electrical signals of motor unit and gross muscle, Electromyogram signal recording, analysis, EMG applications.</p> <p>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.</p> <p>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</p>
Learning Outcome	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments, and Exams
Suggested Readings	<p>Text Books</p> <ol style="list-style-type: none"> 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 <p>Reference Books</p> <ol style="list-style-type: none"> 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	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	EC6201
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: <ol style="list-style-type: none"> 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: <ol style="list-style-type: none"> 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	EC6202
Course Credit	3-0-0-3
Course Title	Smart Antenna: From Theory to Practice
Learning Mode	Lectures
Learning Objectives	<p>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:</p> <ol style="list-style-type: none"> 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	<p>Prerequisite: Engineering Electromagnetic, Matrix Algebra</p> <p>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.</p>
Learning Outcome	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments, and Exams
Suggested Readings	<p>Text books:</p> <ol style="list-style-type: none"> 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. <p>Reference Book:</p> <ol style="list-style-type: none"> 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	EC6203
Course Credit	3-0-0-3
Course Title	Adaptive filtering: From theory to practice
Learning Mode	Lectures
Learning Objectives	<p>Course Learning Outcome (CLO): After successful completion of this course, the students will have</p> <ol style="list-style-type: none"> 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	<p>Prerequisite: Signals and Systems, Digital Signal Processing</p> <p>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 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.</p>
Learning Outcome	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments, and Exams
Suggested Readings	<p>Text Books:</p> <ol style="list-style-type: none"> 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. <p>Reference Books:</p> <ol style="list-style-type: none"> 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	EC6204
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- <ol style="list-style-type: none"> 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: <ol style="list-style-type: none"> 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: <ol style="list-style-type: none"> 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	EC6205
Course Credit	3-0-0-3
Course Title	Statistical Signal Processing
Learning Mode	Lectures
Learning Objectives	<p>After learning this course, the students should be able to:</p> <ol style="list-style-type: none"> 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	<p>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.</p> <p>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.</p> <p>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.</p> <p>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.</p>
Learning Outcome	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments, and Exams
Suggested Readings	<p><u>Text Books:</u></p> <ol style="list-style-type: none"> 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. <p><u>Reference Books:</u></p> <ol style="list-style-type: none"> 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.

Course Number	EC6206
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: <ol style="list-style-type: none"> 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	<p><u>Text Books:</u></p> <ol style="list-style-type: none"> 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. <p><u>Reference Books:</u></p> <ol style="list-style-type: none"> 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	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: <ol style="list-style-type: none"> 1. B. Bhat and Shibani 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: <ol style="list-style-type: none"> 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. Shibani K Koul and B. Bhat, Microwave Phase shifters, Volume-I and II, 1992 Artech House, USA.

Course Number	EC6208
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	<p>Module 1: Image and Video Processing</p> <ul style="list-style-type: none"> • Basics of Image Processing • Basics of Video Compression and Motion Analysis • Background Modelling • Object detection and classification • Human Activity Recognition • Video Object Tracking <p>Module 2: Video Surveillance Systems</p> <ul style="list-style-type: none"> • Foreground and Background Detection • Segmentation and Tracking • Behaviour analysis of individuals and groups • Static and Dynamic analysis of crowds <p>Module 3: Introduction to Generative AI</p> <ul style="list-style-type: none"> • Overview of generative AI and its applications • Introduction to generative models • Key concepts: generative models vs. discriminative models, probability distributions <p>Module 4: Fundamentals of Deep Learning</p> <ul style="list-style-type: none"> • 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 <p>Module 5: Variational Autoencoders (VAEs)</p> <ul style="list-style-type: none"> • Introduction to autoencoders • Understanding VAEs: encoder, decoder, and latent space • Variational inference and the reparameterization trick • Applications of VAEs: image generation, data compression <p>Module 6: Generative Adversarial Networks (GANs)</p> <ul style="list-style-type: none"> • 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 <p>Module 7: Transformers</p> <ul style="list-style-type: none"> • Introduction and Evolution: Explore Transformer evolution and key components. • Transformer Architecture: Study encoder-decoder stacks and attention mechanisms.

	<ul style="list-style-type: none"> • 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. <p>Module 8: Hands-on Projects and Case Studies</p> <ul style="list-style-type: none"> • 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
Learning Outcomes	Complies with PLOs 6a, 6b, 7 and 8a
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Readings	<p><u>Text and References</u></p> <ol style="list-style-type: none"> 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.

Course Number	EE6214
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	<p>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.</p> <p>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.</p> <p>Random process in frequency domain: Periodogram and power spectral density, Wiener-Khinchine-Einstein Theorem, concept of bandwidth, spectral estimation.</p> <p>Linear system: Discrete time and continuous time LTI system, concept of convolution, system described in frequency domain, state space description of the system.</p> <p>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.</p> <p>Processing of random signals: Noise in systems, noise bandwidth, SNR, bandlimited random process, noise reduction, matched filter, Wiener filter.</p> <p>The Kalman filter: Mean square estimation, discrete Kalman filter, innovation, Kalman filter vs Wiener filter, properties of Kalman filter, Kalman Bucy filter, engineering examples.</p>
Learning Outcomes	Complies with PLOs 1a, 2a, and 3a.
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Readings	<p>Text</p> <ol style="list-style-type: none"> 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. <p>References</p> <ol style="list-style-type: none"> 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

Sl. No.	Subject Code	SEMESTER IX	L	T	P	C
1.	XX52PQ/ XX62PQ	M. Tech. Elective - II	3	0	0	3
2.	XX52PQ/ XX62PQ	M Tech Elective - III	3	0	0	3
3.	XX52PQ/ XX62PQ	M Tech Elective - IV	3	0	0	3
4.	EC5197	Project III**	0	0	16	8
TOTAL			9	0	8	17

M. Tech. Elective – II						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	EC5107	RF and Microwave Active Circuits	3	0	0	3
2.	EC5108	Internet of Things (IoT) Networks	3	0	0	3
3.	EC5109	Radio Frequency Integrated Circuits	3	0	0	3
4.	EC6101	Advance Antenna and Microwave Devices	3	0	0	3

Course Number	EC5107
Course Credit	3-0-0-3
Course Title	RF and Microwave Active Circuits
Learning Mode	Lectures
Learning Objectives	<p>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.</p> <p>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.</p>
Course Description	This course deals with the RF Microwave Active Circuits.
Course Outline	<p>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, simulation using harmonic balance.</p>
Learning Outcome	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments, and Exams
Suggested Readings	<p>Text Books:</p> <ol style="list-style-type: none"> 1. David M. Pozar, "Microwave Engineering", Wiley, 4th Edition. 2. Robert E. Collin, "Foundations for Microwave Engineering", Wiley, 2nd Edition. <p>Reference Books:</p> <ol style="list-style-type: none"> 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	EC5108
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: <ol style="list-style-type: none"> 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	<p>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</p> <p>Markov Chain: Discrete-Time Markov Chain, Continuous-Time Markov Chain, Types of Markov Chain, Time Reversed Markov Chain, Applications</p> <p>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</p> <p>IoT Protocols: Short-Range and Long Range Protocols - Bluetooth, Zigbee, Wireless LAN, and LoRaWAN. Application Protocols.</p> <p>Smart Device Localization: Range-based Localization using Received Signal Strength (RSS), Time and Angle Measurements. Range-Free Localization. Performance Metrics. Applications</p> <p>IoT Analytics: Bayesian Fusion, Dempster-Shafer Fusion, Decision Fusion, Types of Learning. Artificial Neural Networks, Bias-Variance Tradeoff, Applications</p> <p>Fog Computing: Cloud Computing, Fog Computing, Edge Computing, Technology for Fog Computing, Task Offloading, Applications</p>
Learning Outcome	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments, and Exams
Suggested Readings	<p>Texts Books:</p> <ol style="list-style-type: none"> 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. <p>Reference Books:</p> <ol style="list-style-type: none"> 1. Raj, P., and Raman, A.C., The Internet of Things: Enabling technologies, platforms, and use cases, 1st Edition, 2017, Auerbach Publications.

Course Number	EC5109
Course Credit	3-0-0-3
Course Title	Radio Frequency Integrated Circuits
Learning Mode	Lectures
Learning Objectives	<p>After studying this course, the students will be able to:</p> <ol style="list-style-type: none"> 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	<p>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.</p>
Learning Outcome	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments, and Exams
Suggested Readings	<p>Text Books:</p> <ol style="list-style-type: none"> 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 <p>References:</p> <ol style="list-style-type: none"> 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	EC6101
Course Credit	3-0-0-3
Course Title	Advance Antenna and Microwave Devices
Learning Mode	Lectures
Learning Objectives	<p>After successful completion of this course, the students will</p> <ol style="list-style-type: none"> 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	<p>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 optimisations, 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.</p> <p>Metamaterial inspired antennas, wave propagation in metamaterial, design and analysis of metamaterial, frequency selective surfaces, EBG Structures, metasurfaces, reconfigurable metasurfaces. Selected advanced topics in Antennas and Microwave Technology.</p>
Learning Outcome	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments, and Exams
Suggested Readings	<p>Text Books:</p> <ol style="list-style-type: none"> 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", 3rd Edition, 2009, Wiley. <p>Reference Books:</p> <ol style="list-style-type: none"> 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.

M. Tech. Elective - III						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	EC5111	VLSI Architecture Design and Implementation	3	0	0	3
2.	EC5118	Bio Sensors and Circuits	3	0	0	3
3.	EC5119	Quantum Computing	3	0	0	3
4.	EC6103	Radio Frequency Design and Technology	3	0	0	3
5.	EC6104	VLSI Signal Processing	3	0	0	3
6.	EC6106	Computer Vision	3	0	0	3

Course Number	EC5111
Course Credit	3-0-0-3
Course Title	VLSI Architectural Design and Implementation
Learning Mode	Lectures
Learning Objectives	<p>Understanding the representation and implementation methods of VLSI system architectures</p> <p>Understanding the Architectural design and implementation methods of basic algorithms.</p> <p>Understanding the various trade-off computer arithmetic architectures and their analysis</p> <p>Understanding the design and analysis of high-performance architectures</p> <p>Understanding the architectural design exploration of basic digital signal processing and Machine learning algorithms</p> <p>Understanding the basics of VLSI Chip testing method and architecture.</p>
Course Description	This course deals with the VLSI design and implementation.
Course Outline	<p>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;</p> <p>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.</p> <p>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.</p> <p>Introduction to VLSI Chip testing methods and Architectures: Introduction to Chip Fault Model, DFT Architecture, BIST Architecture.</p>
Learning Outcome	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments, and Exams
Suggested Readings	<p>Text Books:</p> <ol style="list-style-type: none"> 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. <p>Reference Books:</p> <ol style="list-style-type: none"> 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	EC5118
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, O ₂ and CO ₂ 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	<p><u>Text/References</u></p> <ol style="list-style-type: none"> 1. Joseph 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. Joseph 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	EC5119
Course Credit	3-0-0-3
Course Title	Quantum Computing
Learning Mode	Lectures
Learning Objectives	<ol style="list-style-type: none"> 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	<p>Introduction: History, Motivation, Need of quantum bits, quantum states, quantum computations, quantum information, and quantum algorithms</p> <p>Overview of complex numbers and Linear Algebra, Introduction to quantum mechanics and its postulates, Bloch sphere</p> <p>Quantum Circuits: Single qubits and multiple qubits operations, architecture, quantum gates; quantum teleportation, quantum Fourier Transform: phase estimation</p> <p>Quantum Algorithms: Deutsch's algorithm, Deutsch-Jozsa algorithm, Simon's algorithm, Grover algorithm and Shor's factoring algorithm</p> <p>Quantum Information and Error Corrections: Classical vs quantum noise, quantum operations, quantum error correction, entropy and information</p> <p>Quantum Tools and Applications: Goal Challenges, Lights and Photon, Decoherence, Ion Trap, Linear Optics, NMR, Quantum Simulation</p>
Learning Outcome	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments, and Exams
Suggested Readings	<p>Text Books:</p> <ol style="list-style-type: none"> 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	EC6103
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 coupler, 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: <ol style="list-style-type: none"> 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: <ol style="list-style-type: none"> 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	EC6104
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	EC6106
Course Credit	3-0-0-3
Course Title	Computer Vision
Learning Mode	Lectures
Learning Objectives	<ol style="list-style-type: none"> 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	<p>Text Books:</p> <ol style="list-style-type: none"> 1. Computer Vision - A modern approach, by D. Forsyth and J. Ponce, Prentice Hall Robot Vision, by B. K. P. Horn, McGraw-Hill. <p>Reference Books:</p> <ol style="list-style-type: none"> 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.

M. Tech. Elective - IV						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	EE5106	Energy Storage Systems	3	0	0	3
2.	EE6108	V2G and G2V Technology	3	0	0	3
3.	EC6108	Emerging Technologies for Beyond 5G	3	0	0	3

Course Number	EE5106
Course Credit	L-T-P-C: 3-0-0-3
Course Title	Energy Storage Systems
Learning Mode	Lectures
Learning Objectives	Complies with Program Goals 1 and 2
Course Description	The emerging energy generation sources such as solar and wind generates energy in variable patterns. Hence, energy storage is becoming of major importance to store and supply energy without any interruption. The energy storage can be in mechanical, electrochemical, or chemical forms. So, the course is designed to meet the requirements of M. Tech students to get sufficient knowledge on energy storage techniques. Also, it may be useful for PhD students to explore their research areas in the energy storage systems.
Course Outline	<p>Energy storage systems overview - Scope of energy storage, needs and opportunities in energy storage, Technology overview and key disciplines, comparison of time scale of storages and applications, Energy storage in the power and transportation sectors. Importance of energy storage systems in electric vehicles, Current electric vehicle market.</p> <p>Thermal storage system-heat pumps, hot water storage tank, solar thermal collector, application of phase change materials for heat storage-organic and inorganic materials, efficiencies, and economic evaluation of thermal energy storage systems.</p> <p>Chemical storage system- hydrogen, methane etc., concept of chemical storage of solar energy, application of chemical energy storage system, advantages and limitations of chemical energy storage, challenges, and future prospects of chemical storage systems.</p> <p>Electromagnetic storage systems - double layer capacitors with electrostatically charge storage, superconducting magnetic energy storage (SMES), concepts, advantages and limitations of electromagnetic energy storage systems, and future prospects of electromagnetic storage systems.</p> <p>Electrochemical storage system (a) Batteries-Working principle of battery, primary and secondary (flow) batteries, battery performance evaluation methods, major battery chemistries and their voltages- Li-ion battery & Metal hydride battery vs lead-acid battery (b) Supercapacitors- Working principle of supercapacitor, types of supercapacitors, cycling and performance characteristics, difference between battery and supercapacitors, Introduction to Hybrid electrochemical supercapacitors. (c) Fuel cell: Operational principle of a fuel cell, types of fuel cells, hybrid fuel cell-battery systems, hybrid fuel cell-supercapacitor systems.</p> <p>Battery design for transportation, Mechanical Design and Packaging of Battery Packs for Electric Vehicles, Advanced Battery-Assisted Quick Charger for Electric Vehicles, Charging Optimization Methods for Lithium-Ion Batteries, Thermal run-away for battery systems, Thermal management of battery systems, State of Charge and State of Health Estimation Over the Battery Lifespan, Recycling of Batteries from Electric Vehicles</p>
Learning Outcomes	Complies with PLOs 1a, 2a, and 3a.
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Reading	<p>Textbooks:</p> <ol style="list-style-type: none"> 1. Frank S. Barnes and Jonah G. Levine, Large Energy Storage Systems Handbook (Mechanical and Aerospace Engineering Series), CRC press, 2011. 2. Ralph Zito, Energy storage: A new approach, Wiley, 2010. 3. Pistoia, Gianfranco, and Boryann Liaw, Behaviour of Lithium-Ion Batteries in Electric Vehicles: Battery Health, Performance, Safety, and Cost. Springer International Publishing AG, 2018. 4. Robert A. Huggins, Energy storage, Springer Science & Business Media, 2010. <p>References:</p> <ol style="list-style-type: none"> 1. Paul Denholm, Erik Ela, Brendan Kirby and Michael Milligan, The Role of Energy Storage with Renewable Electricity Generation, National Renewable Energy Laboratory (NREL) -a National Laboratory of the U.S. Department of Energy.

Course Number	EE6108
Course Credit	L-T-P-C: 3-0-0-3
Course Title	V2G and G2V Technology
Learning Mode	Lectures
Learning Objectives	Complies with Program Goals 1 and 2
Course Description	The course is designed to meet the requirements of M. Tech. And Ph.D. The course aims at giving a broad overview of charging concept, energy management in V2G to G2V concept and Fast charging.
Course Outline	Introduction to advanced concepts: DC fast charging, charging infrastructure, Energy Management Strategies, EV charging infrastructure and technology, Bidirectional power converters Energy Flow management through power converters, Grid integration, Load management, Renewable Energy Integration, Grid Ancillary Services and technology, electrification challenges, Smart Charging and Communication
Learning Outcomes	Complies with PLOs 1a, 2a, and 3a.
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested reading	Text/References: <ol style="list-style-type: none"> 1. Emadi, A. (Ed.), Miller, J., Ehsani, M., "Vehicular Electric Power Systems" Boca Raton, CRC Press, 2003. 2. Sheldon S. Williamson, "Energy Management Strategies for Electric and Plug-in Hybrid Electric Vehicles", Springer, 2013. 3. Larminie, James, and John Lowry, "Electric Vehicle Technology Explained" John Wiley and Sons, 2011

Course Number	EC6108
Course Credit	3-0-0-3
Course Title	Emerging Technologies for Beyond 5G
Learning Mode	Lectures
Learning Objectives	After learning this course, the students should be able to: <ol style="list-style-type: none"> 1. understand the evolution of different generation of telecom technology 2. understand about next generation communication system 3. know about the role of frequency in communication system 4. know about the vehicle-to-everything communications 5. know about the basics of molecular, quantum, and aerial communication
Course Description	This course deals with the Statistical Signal Processing.
Course Outline	Introduction to telecom standards and evolution of different generation of communication system, services, key performance index, protocols. Next generation communication system and network architecture. Hybrid RF and optical system working at different frequencies, such mmWave and THz. Vehicle-to-everything (V2X) communications: introduction, architecture, QoS requirement, and resource allocation. Molecular communications: introduction of molecular communications, propagation and channel models, capacity analysis, modulation techniques, applications of molecular technology. Quantum communications: introduction and applications of quantum communications, photon polarization. Introduction to drone and its applications, international rules, regulations, standards & practices, civil aviation requirements, classification & categorization of drones. Aerial communication and networking: air-to-ground channel models, data collection using drone, computation in sky, fronthaul and backhaul links for aerial communications, deployment of swarm of drones. Tactile Internet (TI): introduction to TI and its application, haptic communication, human-machine interaction, quality of service requirements for TI and resource allocations for haptic data transmission.
Learning Outcome	Complies with PLO 1b, 2a, 3a, 6a, 7, and 8
Assessment Method	Quiz, Assignments, and Exams
Suggested Readings	<p><u>Text Books:</u></p> <ol style="list-style-type: none"> 1. Huang, Kao-Cheng, and Zhaocheng Wang. Millimeter wave communication systems, John Wiley & Sons, 2011. 2. Kürner, Thomas, Daniel M. Mittleman, and Tadao Nagatsuma, eds. THz Communications: Paving the Way Towards Wireless Tbps. Cham, Switzerland: Springer, 2022. <p><u>Reference Books:</u></p> <ol style="list-style-type: none"> 1. Chen, Shanzhi, et al. Cellular Vehicle-to-Everything (C-V2X). Springer Nature, 2023. 2. Nakano, Tadashi. Molecular communication. Cambridge University Press, 2013. 3. Protecting Information: From Classical Error Correction to Quantum Cryptography, S. Loepp & W. K. Wothers, Cambridge Press, 2006 4. Quantum Computation and Quantum Information, M. Nielsen and I. L. Chuang, Cambridge Press, 2006.