Proposed Course Structure and Syllabus of PG 1st Semester to 4th Semester, Electronics and Telecommunication Engineering

Department of Electronics and Telecommunication Engineering
Indian Institute of Engineering Science and Technology, Shibpur
Howrah, 711103
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1ˢᵗ Sem. Course Structure for PG Specialization Communication Engineering and Signal Processing

Sl. No	COURSE TITLE	CODE	L	T	P	Credit	Marks
1	Advanced Digital Communication	ET5101	3	0	0	3	100
2	Advanced Digital Signal Processing	ET5102	3	0	0	3	100
3	Probability and Random Processes for Signal Processing	ET5103	3	0	0	3	100
4	Dep. Elective-I (From Elective List)		3	0	0	3	100
5	Open Elective-I (From Elective List)		3	0	0	3	100
6	Advanced Communication Lab	ET5171	0	0	3	2	100
7	Advanced Digital Signal Processing Lab	ET5172	0	0	3	2	100
8	Design and Simulation Lab	ET5182	0	0	3	2	100
		TOTAL				21	800

1ˢᵗ Semester Course Structure for PG Specialization RF and Photonics

Sl. No	COURSE TITLE	CODE	L	T	P	Credit	Marks
1	Computational Electromagnetics	ET5104	3	0	0	3	100
2	Microwave Devices and Circuits	ET5105	3	0	0	3	100
3	Photonic Devices and Circuits	ET5111	3	0	0	3	100
4	Dep. Elective-I (From Elective List)		3	0	0	3	100
5	Open Elective-I (From Elective List)		3	0	0	3	100
6	Applied Electromagnetics Lab	ET5174	0	0	3	2	100
7	Photonic Devices and Circuits Lab	ET5181	0	0	3	2	100
8	Design and Simulation Lab	ET5182	0	0	3	2	100
		TOTAL				21	800

1ˢᵗ Semester Course Structure for PG Specialization Microelectronics and VLSI Design

Sl. No	COURSE TITLE	CODE	L	T	P	Credit	Marks
1	Advanced Semiconductor Devices	ET5107	3	0	0	3	100
2	Analog VLSI Design	ET5108	3	0	0	3	100
3	VLSI Fabrication Technology	ET5110	3	0	0	3	100
4	Dep. Elective-I (From Elective List)		3	0	0	3	100
5	Open Elective-I (From Elective List)		3	0	0	3	100
6	Advanced Semiconductor Devices Lab	ET5177	0	0	3	2	100
7	VLSI Design Lab	ET5178	0	0	3	2	100
8	Design and Simulation Lab	ET5182	0	0	3	2	100
		TOTAL				21	800

2nd Semester Course Structure for PG Specialization Communication Engineering and Signal Processing

Sl. No	COURSE TITLE	CODE	L	T	P	Credit	Marks
1	Information Theory and Coding	ET5201	3	0	0	3	100
2	Digital Voice and Picture Communication	ET5202	3	0	0	3	100
3	Wireless Networks	ET5203	3	0	0	3	100
4	Dep. Elective-II (From Elective List)		3	0	0	3	100
5	Open Elective-II (From Elective List)		3	0	0	3	100
6	M. Tech thesis Part - I (Term Paper)	ET5291	0	0	8	4	200
7	Term Paper Seminar and Viva-voce	ET5292	0	0	0	2	100
		TOTAL				21	800

2nd Semester Course Structure for PG Specialization RF and Photonics

Sl. No	COURSE TITLE	CODE	L	T	P	Credit	Marks
1	RF Integrated Circuits	ET5212	3	0	0	3	100
2	Antenna Theory and Applications	ET5213	3	0	0	3	100
3	Optical Communication	ET5214	3	0	0	3	100
4	Dep. Elective-II (From Elective List)		3	0	0	3	100
5	Open Elective-II (From Elective List)		3	0	0	3	100
6	M. Tech thesis Part - I (Term Paper)	ET5291	0	0	8	4	200
7	Term Paper Seminar and Viva-voce	ET5292	0	0	0	2	100
		TOTAL				21	800

2nd Semester Course Structure for PG Specialization Microelectronics and VLSI Design

Sl. No	COURSE TITLE	CODE	L	T	P	Credit	Marks
1	Digital VLSI Design	ET5207	3	0	0	3	100
2	Low Power VLSI Design	ET5210	3	0	0	3	100
3	VLSI Physical Design	ET5211	3	0	0	3	100
4	Dep. Elective- II (From Elective List)		3	0	0	3	100
5	Open Elective- II (From Elective List)		3	0	0	3	100
6	M. Tech thesis Part - I (Term Paper)	ET5291	0	0	8	4	200
7	Term Paper Seminar and Viva-voce	ET5292	0	0	0	2	100
		TOTAL				21	800

3rd Semester Course Structure for PG (All Specialization)

Sl. No	COURSE TITLE	CODE	L	T	P	Credit	Marks
1	M. Tech Thesis Part - II (Progress Report)	ET6191	0	0	24	12	300
2	Progress Report Seminar and Viva-voce	ET6192	0	0	0	6	100
		TOTAL				18	400

4th Semester Course Structure for PG (All Specialization)

Sl.	COURSE TITLE	CODE	L	T	P	Credit	Marks
1	M. Tech Final Thesis	ET6291	0	0	30	22	400
2	Thesis Seminar and Viva-voce	ET6292	0	0	0	8	200
		TOTAL				30	600

LIST OF ELECTIVE PAPERS PG

DEP. ELECTIVE-I

Speciali zation	Communication Engineering and Signal Processing	RF and Photonics	Microelectronics and VLSI Design
	Electromagnetic Interference and Compatibility (ET5122)	Electromagnetic Interference and Compatibility (ET5122)	Electromagnetic Interference and Compatibility (ET5122)
	VLSI for Signal Processing (ET5123)	VLSI for Signal Processing (ET5123)	VLSI for Signal Processing (ET5123)
	Optical Networks(ET5125)	Optical Networks (ET5125)	VLSI Testing (ET5124)

DEP. ELECTIVE- II

Speciali zation	Communication Engineering and Signal Processing	RF and Photonics	Microelectronics and VLSI Design
	Detection and Estimation Theory (ET5223)	Electromagnetic Metamaterials (ET5227)	Electromagnetic Metamaterials (ET5227)
	Quantum Optics (ET5228)	Quantum Optics (ET5228)	Quantum Optics (ET5228)
	Radar Engineering (ET5229)	Radar Engineering (ET5229)	Microsensors and Actuators (ET5230)

OPEN ELECTIVE-I

1. Electronic Communication Systems (ET5161)

OPEN ELECTIVE-II

1. Wireless Communications for IoT (ET5262)

Detailed Syllabus

1st Semester Syllabus for PG

Specialization: **Communication Engineering and Signal Processing**

Advanced Digital Communication (ET 5101)

L-T-P: 3-0-0   **Credit: 3**   **Full Marks:100**

Sl. No.	Topics	Class Hours
1	**Background**: Review of random variables and random processes: PDF, CDF, mean, variance, correlation of random variables; classification of random processes, autocorrelation, cross-correlation, power spectral density, Gaussian process; narrowband noise; response of LTI systems to random signals; introduction random vectors	8
2	**Signal Space Analysis**: Geometric representation of signals; conversion of continuous AWGN channel into a vector channel; Likelihood functions; coherent detection of signals in noise :ML decoding, correlation receiver; probability of symbol and bit error	8
3	**Pass band Modulation techniques:** Review of BPSK, BFSK, QPSK modulation-demodulation schemes-constellation diagram, PSD and error analysis; MSK, GMSK and QAM modulations-transmitter , receiver architecture, constellation diagram, PSD and error analysis	8
4	**Spread spectrum modulation:** brief history, importance, definition, classification (DHSS, FHSS), pseudo-noise sequence-autocorrelation and cross correlation, gold sequence; transmitter receiver architectures for DHSS and FHSS; signal space dimensionality and processing gain, CDMA and spread spectrum modulation	8
5	**OFDM:** data transmission using multiple carriers; multi-carrier modulation with overlapping sub channels; transmitter and receiver architectures of OFDM modulation, time-frequency representation of OFDM signals, cyclic prefix; challenges in OFDM: peak-to-average power ratio problem in OFDM, frequency and timing offset problem	8
	Total	40

Text Books/References:
1. S. Haykin, Digital Communications Systems, Wiley Publications
2. B. P. Lathi, Z. Ding, Modern Digital and Analog Communication Systems, Oxford University Press
3. K. Feher, Wireless Digital Communications, PHI Pvt. Ltd.
4. H. Stark, J. W. Woods, Probability and random processes with applications to signal processing, PHI pvt. Ltd.

Advanced Digital Signal Processing (ET5102)

L-T-P: 3-0-0   **Credit: 3**   **Full Marks:100**

Sl. No.	Topics	Class Hours
1	**Digital Filters:** Digital filter design techniques, Analysis of finite word length effects, Structures of FIR and IIR filters, adaptive filters, FIR Wiener filter, Kalman filter, Lattice Filters	6
2	**Applications of DSP:** Introduction to DSP Controller, Peripherals, Types of Physical Memory and Introduction to Software tools, Applications of DSP to power system, power electronics, Instrumentation.	6
3	**Multirate digital signal processing:** Decimation and interpolation, Filters in sampling rate alteration systems, Polyphase decomposition and efficient structures, Digital filter banks	6
4	**Spectral estimation:** Periodogram, Bartlett's method, Welch's method, Blackman-Tukey method, ARMA modeling, Yule-Walker equation and solution	6
5	**Wavelet:** Families of wavelets: Orthogonal and biorthogonal, Continuous Wavelet Transform (CWT), Discrete Wavelet Transform (DWT), Haar wavelet, dyadic Multiresolution Analysis (MRA), Image compression standard: JPEG and JPEG 2000, Compressed Sensing	8
6	**IoT**: Advanced Signal Processing for Communication Networks and IoT Applications, digital signal control in IoT devices, Hardware Security Threats to DSP Applications in an IoT Network	8
	Total	40

Text Books/References:
1. Digital Signal Processing: Principles, Algorithms, and Applications - J. G. Proakis, D. G. Manolakis
2. Digital Signal Processing: A Computer Based Approach - S. K. Mitra
3. Discrete-time signal processing - A. V. Oppenheim, R. W. Schafer
4. Statistical Signal Processing and Modelling - M. H. Hayes

Probability and Random Processes for Signal Processing (ET5103)

L-T-P: 3-0-0   **Credit: 3**   **Full Marks:100**

Sl. No.	Topics	Class Hours
1	**Review of Random Variables**: Introduction, Definition of a Random Variable, Probability Distribution Function, Probability Density Function, Continuous, Discrete and Mixed Random Variable, Conditional and Joint Distribution and Density Functions	4
2	**Functions of Random Variables**: Introduction, Solving Problems Of Single Random Variable, Multiple Random Variables, Determining Respective pdfs	6
3	**Expectation and Introduction to Estimation**: Expected value of a random variable, Conditional Expectations, Moments: Joint Moments, Jointly Gaussian Random Variables, Moment Generating Functions, Characteristics Functions, Estimators for the Mean And Variance Of The Normal Law: confidence intervals for the mean, confidence intervals for the variance	8
4	**Random Vectors**: Joint distributions and Densities, Multiple Transformation of Random Variables, Expectation vectors and Covariance matrices, Properties of Covariance matrices, Characteristics Functions of Random Vectors	6
5	**Random Sequences**: Basic Concepts, Infinite length Bernoulli trials, Basic Principles of Discrete time linear systems, Random Sequences and Linear Systems, WSS Random Sequences, Power Spectral Density, Markov Random Sequences, Markov Chains	8
6	**Random Processes**: Basic Definitions, Some important Random Processes, Continuous Time Linear Systems with Random Inputs White Noise, Some useful classifications of Random Processes, Stationarity, Wide sense Stationary processes and LSI Systems: Power Spectral Density	8
	Total	40

Text Books/References:
1. "Probability, Random Variables and Stochastic Processes", A. Papoulis and S. U. Pillai, McGraw Hill, 4th Edition
2. "Probability and Random Processes with Applications to Signal Processing", Henry Stark and John W. Woods, 3rd Edition

Advanced Communication Lab (ET5171)

L-T-P: 0-0-3   **Credit: 2**   **Full Marks: 100**

Sl.	Topics	Class Hours
1	Study of QPSK spectrum, modulation and demodulation using MATLAB and VSA.	6
2	Study of QPSK spectrum, modulation and demodulation using MATLAB, VSG and VSA.	6
3	Study of AM, FM modulation and Demodulation using LABVIEW and USRP hardware.	3
4	Study of BASK, B FSK modulation and demodulation using LABVIEW and USRP hardware.	3
5	Study of BPSK and QPSK modulation and demodulation using LABVIEW and USRP hardware.	3
6	Study of 4-PAM, 4 QAM, 16 QAM, BPSK, QPSK, 8 PSK experimentation using SDR (Wired) and LABVIEW.	6
7	Study of 4-PAM, 16 QAM, BPSK, QPSK, 8 PSK experimentation using and USRP hardware (Wireless) and LABVIEW.	6
	Total	33

Advanced Digital Signal Processing Lab (ET5172)

L-T-P: 0-0-3   **Credit: 2**   **Full Marks: 100**

Sl.	Topics	Class Hours
1	Introduction to adaptive filters, FIR Wiener filter, Kalman filter, Lattice Filters by MATLAB & DSK-6713 kit	6
2	Applications of filters in power electronics, Instrumentation by MATLAB & DSK-6713 kit	6
3	Multirate digital signal processing by MATLAB & DSK-6713 kit	3
4	Spectral estimation by MATLAB & DSK-6713 kit	3
5	Implementation of dyadic Multiresolution Analysis (MRA), JPEG 2000 and application of Compressed Sensing in audio signals by MATLAB & DSK-6713 kit	9
6	Digital signal control in IoT devices by Arduino and Raspberry pie, Hardware Security Threats to DSP Applications in an IoT Network by DSK-6713 kit	9
	Total	36

Design and Simulation Lab (ET5182)

L-T-P: 0-0-3   **Credit: 2**   **Full Marks: 100**

This Laboratory is based on Design and Simulation works based on the PG subjects. The students are expected to put some novel and developmental contributions through sincere research work on the Design and Simulation works assigned to them. It consists of, but not limited to, Electromagnetics simulation based on CST, HFSS and ADS ANSYS, Simulation knowledge of various optical devices using COMSOL multi-physics software, knowledge of CAD Tools for VLSI, assignments and projects using MATLAB.

Specialization**: <u>RF and Photonics</u>**

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<u>Computational Electromagnetics (ET5104)</u>

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L-T-P: 3-0-0   **Credit: 3**   **Full Marks:100**

Sl. No.	Topics	Class Hours
1	**Introduction of EM wave**: Overview of Vector Calculus, Integral of complex functions, Overview of Electrostatics, Magnetostatics, Maxwell Equations; Differential and Integral forms; Wave equations in loss-less, low-loss, inhomogeneous media; Uniform plane waves: propagation, reflection, refraction General solution of differential equations, PDEs, Solution of wave equations	10
2	**Finite Difference Method(FDM):** Solution of various EM problem using FDM, Solution of 1D wave eqn using FDTD, Boundary conditions in FDTD Computational issues in FDTD, Extension to 2 and 3 dimensions; Stability, Error analysis,PML boundaries, Treatment of curved bodies, Dispersive.	8
3	**Method of separation of variables**: Solution by separation of variables; Continuity Equation, Poynting's Theorem; Conservation of MomentumScalar and Vector Potentials: Definition, Retarded potentials, Radiated fields from dipoles	8
4	**Green's functions and MOM**: Calculus of variations; functionals; stationarity Method of weighted residuals, Integral equations; Method of Moments Input impedance of simple wire antennas: infinitesimal, short, half-wave dipoles, Charge distribution on a wire; Analysis of Stripline, Solution of antenna problems using MoM.	8
5	**Finite Element Method(FEM)**: Overview of computational issues: iterative techniques, Introduction of FEM.Solution of 1D EM problem using FEM.	6
	Total	40

Text Books/References:
1. Analytical and Computational Methods in Electromagnetics – R. Garg
2. Numerical techniques in Electromagnetics– M. N. O. Sadiku
3. Field computation by moment methods – R. Harrington

Microwave Devices and Circuits (ET5105)

L-T-P: 3-0-0 **Credit: 3** **Full Marks:100**

Sl. No.	Topics	Class Hours
1	**Introduction of Microwave device**: Two cavity Klystron Amplifier, multi-cavity Klystron amplifier, Reflex Klystron – power output, efficiency, different tuning mechanism. Magnetron, different structures – cylindrical, beam lid, critical magnetic field for operation,	4
2	**Solid state devices**: Travelling Wave Tubes (TWTs)- principle of bunching, TWT Amplifier: power output, gain, TWT Oscillator - Linear and Circular type. Introduction of IMPATT diode and Tunnel diode	6
3	**Transferred Electron Device** – Gunn diode, negative differential mobility, Equivalent circuit, Gunn diode oscillator, Different modes of operation,	6
4	**Introduction of High electron mobility transistor** (HEMT);	2
5	**Study of Scattering parameters** for microwave circuits	2
6	**Microwave Resonator:** different types of cavity resonators, Equivalent circuit of resonator, resonant frequency, Q-factor – with load and without load, various loss mechanism of resonator.	4
7	**Microwave Filters**: Design of band pass filter, Immittance inverter, ABCD representation, Design of immittance inverter using lumped and distributed elements, modification of BPF with immittance inverter. Chebyshev low pass filter, nth order Chebyshev function, order of filter, design of higher order microstrip band pass filter using Chebyshev approximation.	6
8	**Different types of planar transmission lines**- Slot line, strip line, microstrip line, coplanar line, parallel plate and fringing capacitances, even mode and odd mode propagation, expression for characteristic impedance, effective dielectric constant for different mode of excitation,	6
9	**Different types of Coupler and Power divider**: Coupled line coupler, Hybrid ring coupler, Lange coupler, Directional coupler, Wilkinson power divider	4
	Total	40

Text Books/References:
1. Microwave Engineering – Pozar, John Wiley and Sons.
2. Microwave Devices &Circuits – S. Y. Liao, Prentice Hall of India.

Photonic Devices and Circuits(ET5111)

L-T-P: 3-0-0   **Credit: 3**   **Full Marks:100**

Sl no	Topics	Class hours
1	**Laser:** Light matter interaction, population inversion, Fabry Perot Cavity, gas lasers, high power lasers, gain and absorption in semiconductor laser, direct current modulation, gain suppression and frequency chirp, carrier in quantum well, gain in quantum well, DFB laser, VCSEL	6
2	**Guided wave in dielectric waveguide:** Confined modes in symmetric and asymmetric slab waveguide, effective index theory, rectangular waveguides, modes in optical fiber.	4
3	**Wave propagation in periodic medium:** Periodic layered medium, Bloch waves, Bragg reflector, Couple wave analysis, periodic waveguides, spectral filter, chirped and tapered index grating, photonic crystals.	6
4	**Integrated optical couplers:** Direct focusing, Butt coupling, Prism coupling, Grating coupling, Coupling between waveguides, Directional coupler, Supermodes, phase matching, frequency selective coupling, mode converters.	6
5	**Optical modulator**: Electro-optic effect, Electro-optic modulation, high frequency modulation, electro-absorption modulators, electro-optic effect in liquid crystals, Acousto-optic effect, Bragg diffraction, Bragg cell and beam deflectors.	6
6	**Optical resonators:** Fundamental Gaussian Beam in a Lens like Medium, ABCD Law, Ring resonators, multi-cavity etalon.	6
7	**Optical metamaterials:** light confinement in metal-dielectric interface, photonic crystals, plasmonic sensors, topological photonic crystals, optical metamaterial	4
	Total	**40**

Textbook/References:
1. Photonics: Optical Electronics for Modern Communication, Yariv and Yeh (Oxford)
2. Integrated Optics: Theory and Technology, R.G. Hunsperger, Springer

Applied Electromagnetics Lab (ET5174)

L-T-P: 0-0-3   **Credit: 2**   **Full Marks: 100**

Sl. No.	Topics	Class Hours
1	Measurement of dielectric properties of solid and liquid materials with DAK 3.5 kit & VNA: Comparison of the theoretical and measured values at 5 different frequency points.	4
2	Familiarization with HFSS/CST software: Design of different microwave circuits and system.	4
3	Design and analysis of printed antenna for various applications: Determine S parameters, radiation pattern and modern antenna for 5G and 6G application	4
4	Study of different types of microwave filters viz. Low pass filters, High pass filters, Band pass filters, band reject filters and finding out their filtering characteristics	6
5	Study of different types of directional coupler and its properties viz. Branch line coupler, Coupled line coupler, Hybrid ring coupler, Folded Lange coupler, Unfolded Lange coupler, Different types of power divider circuits: Wilkinson equal power divide	6
	Total	24

Photonic Devices and Circuits Lab (ET5181)

L-T-P: 0-0-3   **Credit: 2**   **Full Marks: 100**

Sl. No.	Topics	Class Hours
1	Laser and LED source characterization	3
2	Voltage vs current and spectral characterization of photodiode	3
3	Characterize light propagation through optical fiber, determine numerical aperture and bending loss	3
4	Study of electro optic modulation using RF controlled Mach-Zehnder modulator	3
5	Characterize 2X2 3dB coupler and measurement of insertion loss	3
6	Study of spatial light modulation using digital hologram	3
7	Assemble and characterize a grating based spectrometer	3
8	Mode excitation and characterization in slab waveguide	3
	Total	24

Design and Simulation Lab (ET5182)

L-T-P: 0-0-3   **Credit: 2**   **Full Marks: 100**

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Specialization: **Microelectronics and VLSI Design**

Advanced Semiconductor Devices (ET5107)

L-T-P: 3-0-0   **Credit: 3**   **Full Marks:100**

Sl.	Topics	Class Hours
1	**Introduction of Semiconductor Devices:** Introduction, Ohmic contact, Rectifying contact, Current transport across a metal-semiconductor boundary, MOS capacitances, C-V characteristics at low and high frequencies,	6
2	**Physics of Advance MOSFET Structures:** Drift-Diffusion Approach for IV, Gradual Channel Approximation, Short geometry effects, Sub-threshold current and slope, Body effect, Leakage mechanisms in thin gate oxide, High-K-Metal Gate MOSFET devices and technology issues, Silicon on Insulator (SOI)	6
3	**Compound Semiconductor based devices:** Compound semiconductors, Heterojunction bipolar transistors (HBT), High electron mobility transistors (HEMT)	4
4	**Photonic Devices:** Light-emitting diodes (LEDs), Laser diodes, Photo detectors and transistors, and Solar cells	8
5	**Microwave frequency generating devices;** Gunn Diode, tunnel diode, IMPATT Diode.	6
6	**Power Electronic Devices:** Insulated-Gate Bipolar Transistor (IGBT), Physics and operation of Thyristors, Silicon Controlled Rectifier (SCR), Gate turn-off Thyristor (GTO)	4
7	**State-of-the-art Semiconductor Devices:** Emerging non-volatile memory materials and devices (Memristor), Carbon nanotube/nanowire, graphene, Fin-FET, Single electron transistor	6
	Total	40

Text Books/References:
1. S. M. Sze and Kwok K. Ng, "Physics of Semiconductor devices (3rd)", Wiley, 2007
2. Michael Shur, "Physics of Semiconductor Devices," Prentice Hall
3. Mark Lundstrom& Jing Guo, "Nanoscale Transistors: Device Physics, Modeling & Simulation", Springer, 2005.
4. Ben G. Streetman and Sanjay Banerjee "Solid State Electronic Devices", Pearson
5. YannisTsividis, "Operation and Modeling of the MOS Transistor", Oxford University Press, 2nd Edn.

Analog VLSI Design (ET5108)

L-T-P: 3-0-0   **Credit: 3**   **Full Marks:100**

Sl. No.	Topics	Class Hours
1	**Introduction:** Motivation for analog VLSI and mixed signal circuits in CMOS technologies and issues thereof.	1
2	**CMOS device fundamentals:** Basic MOS models, device capacitances, parasitic resistances, substrate models, trans-conductance, output resistance, fT, frequency dependence of device parameters.	3
3	**Single stage amplifiers:** Common source amplifier, source degeneration, source follower, common gate amplifier, cascade stage.	5
4	**Differential Amplifiers:** Basic differential pair, common mode response, differential pair with MOS loads, Gilbert Cell, device mismatch effects, input offset voltage.	4
5	**Current Mirrors, Current and Voltage Reference:** Basic current mirrors, cascode current mirrors, active current mirrors, low current biasing, supply insensitive biasing, temperature insensitive biasing, impact of device mismatch.	4
6	**Frequency Response of Amplifiers:** Miller effect, CS amplifier, source follower, CG amplifier, cascade stage, differential amplifier, Multistage amplifier.	4
7	**Feedback:** Feedback topologies, effect of load, modeling input and output ports in feedback circuits	3
8	**Noise:** Statistical characteristics, types of noise, single stage amplifiers, differential pair, noise bandwidth, impact of feedback on noise.	3
9	**Operational Amplifiers:** Performance parameters, One-stage and two-stage OpAmps, gain boosting, comparison, common mode feedback, input range, slew rate, power supply rejection, noise in Op Amps	6
10	**Stability and Frequency Compensation:** Multi pole systems, phase margin, frequency compensation	3
11	**High Performance CMOS Op-Amp:** Buffered Op-amps, High-speed/Frequency Op-amps, Differential output op-amps, low noise and low voltage op-amps	6
	Total	40

Textbook/References:
1. "Design of Analog CMOS Integrated Circuits", 1st Ed., Razavi, B., McGraw Hill, 2001.
2. "Analysis and Design of Analog Integrated Circuits", 4th Ed., Gray, P.R., Hurst, P. J., Lewis, S.H., Meyer, R.G., John Wiley and Sons, 2001.
3. "CMOS Circuit Design, Layout and Simulation", Baker, R. J., Li, H. W. and Boyce, D. E., Prentice-Hall of India, 1998.

VLSI Fabrication Technology (ET5110)

L-T-P: 3-0-0   **Credit: 3**   **Full Marks:100**

Sl. No.	Topics	Class Hours
1	**Introduction to IC Technology**: Basic fabrication steps and their Importance.	4
2	**Environment of IC Technology**: Concepts of Clean room and safety requirements, Concepts of Wafer cleaning processes and wet chemical etching techniques.	4
3	**Impurity Incorporation**: Solid State diffusion modeling and technology; Ion Implantation modeling, technology and damage annealing, characterization of Impurity profiles	6
4	**Oxidation**: Kinetics of Silicon dioxide growth both for thick, thin and ultra-thin films, Oxidation technologies in VLSI and ULSI, Characterization of oxide films, High k and low k dielectrics for ULSI	6
5	**Lithography:** Photolithography, E-beam lithography and newer lithography techniques for VLSI/ULSI, Mask generation.	6
6	**Chemical Vapour Deposition Techniques**: CVD techniques for deposition of polysilicon, silicon dioxide, silicon nitride and metal films; Epitaxial growth of silicon: modeling and technology.	6
7	**Metal Film Deposition**: Evaporation and sputtering techniques, Failure mechanisms in metal interconnects Multi-level metallization schemes.	4
8	**Plasma and Rapid Thermal Processing**: PECVD, Plasma etching and RIE techniques; RTP techniques for annealing, growth and deposition of various films for use in ULSI.	4
	Total	40

Text Books/References:
1. S.M.Sze(2nd Edition)"VLSI Technology", McGraw Hill Companies Inc.
2. C.Y. Chang and S.M.Sze (Ed), "ULSI Technology", McGraw Hill Companies Inc.
3. Stephena, Campbell, "The Science and Engineering of Microelectronic Fabrication", Second Edition, Oxford University Press.
4. James D.Plummer, Michael D.Deal, "Silicon VLSI Technology" Pearson Education.

Advanced Semiconductor Devices Lab (ET5177)

L-T-P: 0-0-3   **Credit: 2**   **Full Marks: 100**

Sl.	Topics	Class Hours
1	**I-V characteristics of MOSFET**	6
2	**C-V Characteristics of MOSFET**	6
3	**I-V characteristics of Tunnel Diode:**	6
4	**I-V characteristics of SCR:**	3
5	**I-V and C-V characteristics of Gas sensor:**	3
6	**I-V and C-V characteristics of Bio sensor:**	6
	Total	30

VLSI Design Lab (ET5178)

L-T-P: 0-0-3   **Credit: 2**   **Full Marks: 100**

Sl.	Topics	Class Hours
1	Lambda calculation for PMOS and NMOS and Trans-conductance Plot	3
2	Design and Simulation and Layout of i) CMOS Inverter ii) Single Transistor Amplifier	3
3	Design and Simulation and Layout of Common Source and Common Drain Amplifier	3
4	Design and Simulation and Layout of Cascade and Cascode Current Mirror	6
5	Design and Simulation and Layout of CMOS Op-Amp, Op-Amp Compensation	6
6	Design and Simulation and Layout of Switched capacitor circuits	3
7	Design and Simulation and Layout of ADC and DAC	6
	Total	30

Design and Simulation Lab (ET5182)

L-T-P: 0-0-3   **Credit: 2**   **Full Marks: 100**

This Laboratory is based on Design and Simulation works based on the PG subjects. The students are expected to put some novel and developmental contributions through sincere research work on the Design and Simulation works assigned to them. It consists of, but not limited to, Electromagnetics simulation based on CST, HFSS and ADS ANSYS, Simulation knowledge of various optical devices using COMSOL multi-physics software, knowledge of CAD Tools for VLSI, assignments and projects using MATLAB.

1st Semester Dept. Elective-I Syllabus for PG

Electromagnetic Interference and Compatibility (ET5122)

L-T-P: 3-0-0   **Credit: 3**   **Full Marks:100**

Sl. No.	Topics	Class Hours
1	**Introduction:** Electromagnetic environment - natural noise, man-made noise, CW and transient sources, home environment, practical examples	4
2	**Aspects of EMC:** Concepts, history, electrical dimensions and waves, EMC units, signal source specification	3
3	**EMC Requirements :** Requirements for products, typical product emissions, radiated susceptibility, conducted susceptibility, electrostatic discharge (ESD), measurement of radiated &conducted emissions for verification of compliance, design constraints for products, advantages of EMC design	5
4	**Signal Spectra :** Relationship between Time Domain and frequency Domain of Periodic Signals, Non-periodic Waveforms, Representation of Random (Data) Signals	4
5	**Non-ideal Behavior of Components:** Wires, resistors, capacitors, inductors, Printed Circuit Board (PCB). Effect of Component Leads, Mechanical Switches	4
6	**Antennas for EMC :** Typical antennas and their arrays, Characterization of Antennas	4
7	**Emissions and Susceptibility :** Conducted Emissions and Susceptibility, Radiated Emissions and Susceptibility, simple emission models	4
8	**Crosstalk :** Three-Conductor Transmission Lines and Crosstalk, Shielded Wires, Twisted Wires	3
9	**Shielding :** Shielding Effectiveness: Far-Field Sources, Near-Field Sources, Low-Frequency, Magnetic Field Shielding	4
10	**System Design for EMC :** Shielding, Ground, Printed Circuit Board (PCB) Design, System Configuration and Design,	5
	Total	40

Text Books/References:
1. Introduction to Electromagnetic Compatibility- Clayton R. Paul
2. Applied Electromagnetics And Electromagnetic Compatibility- D.L. Sengupta and Valdis V. Liepa
3. Engineering Electromagnetic Compatibility –V.P. Kodali.

VLSI for Signal Processing (ET5123)

L-T-P: 3-0-0   **Credit: 3**   **Full Marks:100**

Sl. No.	Topics	Class Hours
1	**Introduction:** VLSI design issues for signal processing and communication algorithms. graphical representation of DSP algorithms, signal flow graph, data flow graph (DFG) and dependence graph (DG), concept of critical path.	8
2	**Bit-level arithmetic:** Bit level arithmetic structures, bit serial to digit serial and word serial conversions, Booth recoding, Canonical Sign Digit representation, introduction to distributed arithmetic and redundant arithmetic, concept of systolic arrays	8
3	**VLSI architecture design for FFT processor:** VLSI architecture design of radix-2 FFT processor in serial and parallel mode, running DFT processor, radix-4 FFT processor.	10
4	**LMS learning algorithm**: Introduction to LMS adaptive algorithm, properties of LMS adaptive filter, VLSI architectures for adaptive FIR filter systems, introduction of pipelining in adaptive filter structures.	8
5	**VLSI architectural framework supporting machine learning:** Brief overview of deep neural networks, components of a single artificial neuron, algorithm to architecture mapping for machine learning with example, introduction of approximate computing to design neural network	6
	Total	40

Text Books/References:

1. Haykin, Simon S. *Adaptive filter theory*. Pearson Education India, 2005.
2. Widrow, Bernard, and Samuel D. Stearns. "Adaptive Signal Processing Prentice-Hall." *Englewood Cliffs, NJ* (1985).
3. Vaidyanathan, Parishwad P. *Multirate systems and filter banks*. Pearson Education India, 2006.
4. Naresh Shanbhag, K.K. Parhi, "Pipelined Adaptive Digital Filters": Kluwer Academic Publishers.
5. K.K. Parhi, VLSI Digital signal processing systems: Design and implementation, John Wiley, 1999.
6. U. Meyer-Baese, Digital Signal Processing with Field Programmable Gate Arrays, 4th Ed. Springer, 2014.
7. Field-Programmable Gate Arrays: Reconfigurable Logic for Rapid Prototyping and Implementation of Digital Systems by Richard C. Dorf, John V. Oldfield. ISBN: 9788126516612, Publisher: Wiley, 2008.

VLSI Testing (ET5124)

L-T-P: 3-0-0   **Credit: 3**   **Full Marks:100**

Sl. No.	Topics	Class Hours
1	Physical Faults and their modeling , Stuck-at Faults, Bridging Faults, Faulty Collapsing, Fault Simulation, Deductive Parallel and Concurrent Fault Simulation, Critical Path Tracing.	8
2	ATPG for Combinational Circuits, D-Algorithm, Boolean Difference, Podem, Random Deterministic and Weighted Random Test Pattern Generation, Aliasing and its Effect on Fault Coverage.	8
3	PLA Testing , Cross Point Fault Model and Test Generation, Memory Testing – Permanent , Intermittent and Pattern Sensitive Faults, Marching Tests, Delay Faults,	8
4	ATPG for Sequential Circuits; Time Frame Expansion; Controllability and Observability Scan Design	8
5	BIST and Totally Self checking Circuits; System level Diagnosis; Concept of Redundancy, Spatial Redundancy, Time Redundancy, Yield Modeling, Reliability and effective area utilization.	8
	Total	40

Text Books/References:
1. D. Baik, K. K. Saluja and S. Kajihara, Random Access Scan: a solution to test power, test data volume and test time, International Conference on VLSI Design, Jan. 2004
2. H. Fujiwara, `A new class of sequential circuits with combinational test generation complexity, IEEE Trans. on Computers, Vol. 49, No. 5, Sep 2000, pp. 895-905
3. S. Ohtake, T. Masuzawa, and H. Fujiwara, A non-scan DfT method for controllers to achieve complete fault efficiency, Proc. of the IEEE Asian Test Symposium (ATS) 1998, pp. 204-211.
4. T. Iwagaki, S. Ohtake, and H. Fujiwara, A design methodology to realize delay testable controllers using state transition information, Proc. of the IEEE European Test Symposium (ETS) 2004, pp. 168-173.
5. Y. Bonhomme et al., Power driven chaining of flip-flops in scan architecture, Proc. of the IEEE International Test Conference (ITC) 2002, pp. 796-803.

Optical Networks (ET5125)

L-T-P: 3-0-0   **Credit: 3**   **Full Marks:100**

Sl. No.	Topics	Class Hours
1	**Introduction to optical network**: Telecom network overview and architecture, optical networks, the optical layer, transparency and all-optical networks, optical packet switching, transmission basics, network evolution	2
2	**Components:** couplers, isolators and circulators, multiplexers: Gratings, Diffraction Pattern, Bragg Gratings, Fiber Gratings, Fabry-Perot Filters, Multilayer Dielectric Thin-Film Filters, Mach-Zehnder Interferometers, Arrayed Waveguide Grating, Acousto-Optic Tunable Filter, High Channel Count Multiplexer Architectures, switches, wavelength converter.	8
3	**Wavelength Division Multiplexing (WDM)**: principles of operations, various WDM components, Figures of Merit, specialty of DWDM, All optical MUX & DEMUX, WDM optical networks, WDM network elements: optical line terminals, optical line amplifiers, optical add/drop multiplexers, optical cross connects, Techniques of Mode Division Multiplexing, modal crosstalk.	4
4	**WDM network design**: cost trade-offs, LTD and RWA problems, dimensioning wavelength-routing networks, statistical dimensioning models, maximum load dimensioning models;	6
5	**Single and Multi-hop Networks:** SONET/SDH, ATM, IP, Storage-Area networks, Gigabit and 10-Gigabit Ethernet, Control and management: network management functions, optical layer services and interfacing, layers within the optical layer, multivendor interoperability, performance and fault management, configuration management, optical safety	8
6	**Photonic packet switching**: Optical time division multiplexing, synchronization, header processing, buffering, burst switching, implementation and application.	4
7	**Optical access network**: Access Network Architectures: Evolution and Trends, Passive Optical Networks, Physical Layer Technologies, Access Control Technologies in TDM-PON, Security and Privacy, Survivability, Energy Efficiency in PON, Technologies Beyond 10G PON	8
	Total	40

Text Books/References:

1. Optical networks: a practical perspective by Ramaswami, Rajiv, Kumar Sivarajan, and Galen Sasaki, Morgan Kaufmann, 2009.
2. Springer handbook of optical networks edited by Biswanath Mukherjee, IoannisTomkos, Massimo Tornatore, Peter Winzer, Yongli Zhao, Springer, 2020.
3. Optical Fiber Telecommunications V A (Fifth Edition), Components and Subsystems, Optics and Photonics, 2008.

1st Semester Open Elective-I Syllabus for PG

Electronic Communication Systems (ET5161)

L-T-P: 3-0-0   **Credit: 3**   **Full Marks:100**

Sl. No.	Topic	Class Hours
1	**INTRODUCTION**: Communications systems (Transmitter, Receiver, channel), Modulation, Bandwidth Requirement, Review of Noise. Fundamental limits of electronic communication systems	4
2	**ANALOG COMMUNICATION**: Introduction, Review of Amplitude Modulation (DSB-FC, DSB-SC, SSB-SC, VSB), Review of Frequency Modulation (NBFM, WBFM, Carson's rule), Review of Phase Modulation. Review of Radio Receiver (AM Receivers, Super-heterodyne Receiver).	6
3	**PULSE COMMUNICATION**: : Sampling, Quantization Pulse Modulation (PAM, PCM, PWM, PPM), Delta Modulation, Adaptive Delta Modulation.	4
4	**DIGITAL COMMUNICATION**, Digital Modulation schemes (ASK, PSK, FSK, QAM, OFDM: Bandwidth Requirement, BER Calculation; Spread Spectrum modulation).	8
5	**CELLULAR COMMUNICATION SYSTEM**: Overview of Cellular Wireless Communication systems, Path-loss & Shadowing, Statistical Multipath Channel Models, Performance of Digital Modulation over wireless channel, Diversity, Introduction of multiple access techniques.	10
6	**SATELLITE COMMUNICATION SYSTEM**: Fundamentals of Satellite communication systems, Satellite Network Architecture, Earth Stations and Network Technology, Modulation, Multiple Access & Impairments, Satellite Link analysis.	4
7	**FIBER OPTIC COMMUNICATION SYSTEM**: Basic overview of light, Optical Transmitter (LASER, LED), Optical Receiver (Photo detector), Figure of merits, Fibre optic cable, Mode of transmission.	4
	Total	40

Text Books/References:
1. "Modern Digital and Analog Communication Systems", B.P.Lathi, Oxford, 4th Edition
2. "Communications Systems", Simon Haykin., Wiley, 4th Edition
3. "Wireless Communications", Andrea Goldsmith, Cambridge University Press.,
4. "Optical Fiber Communication", Gerd Keiser, Mcgraw Hill, 5th Edition
5. "Introduction to Satellite Communication", Bruce R. Elbert, Artech House, 3rd Edition

2nd Semester Syllabus for PG

Specialization: Communication Engineering and Signal Processing

Information Theory and Coding (ET5201)

L-T-P: 3-0-0 **Credit: 3** **Full Marks:100**

Sl. No.	Topic	Class Hours
1	**Foundations:** Review of probability theory, Entropy, Relative Entropy and Mutual Information, Entropy Rates, Asymptotic Equipartition Property	6
2	**Data Compression**: Kraft inequality, Optimal codes, Huffman codes, Shannon-Fano-Elias coding, Arithmetic coding, Optimality of the Shannon code, Gambling and Data Compression	6
3	**Kolmogorov Complexity**: Definitions, Kolmogorov complexity and entropy, Kolmogorov complexity of integers, Algorithmically random and incompressible sequences, Universal probability, Universal gambling, Occam's razor, Kolmogorov complexity and universal probability	6
4	**Channel Capacity**: Symmetric channels, Channel coding theorem, Jointly typical sequences, Zero-error codes, Fano's inequality, Hamming codes, Joint source channel coding theorem, Differential Entropy, Gaussian Channel	6
5	**Information Theory and Statistics**: Law of large numbers, Universal source coding, Conditional limit theorem, Hypothesis testing, Stein's lemma, Chernoff bound, Lempel-Ziv coding, Fisher information and the Cramer-Rao inequality	6
6	**Rate Distortion Theory**: Quantization, Calculation of the rate distortion function, Converse to the rate distortion theorem, Achievability of the rate distortion function, Strongly typical sequences and rate distortion, Characterization of the rate distortion function, Computation of channel capacity and the rate distortion function	4
7	**Channel coding:** Block codes and Convolution codes	6
	Total	40

Text Books/References:
1. Elements of Information Theory – T. M. Cover, J. A. Thomas
2. Information Theory, Coding and Cryptography Paperback – R. Bose

Digital Voice and Picture Communication (ET5202)

L-T-P: 3-0-0 **Credit: 3** **Full Marks:100**

Sl. No.	Topics	Class Hours
1	**Fundamentals:** Digital Coding of Waveforms, Bit Rate and Coder Complexity, Information Theoretical Limits, Speech and Image Waveform Characterization, Sampling and Reconstruction of Band limited Waveforms, Quantization	4
2	**Voice Coding**: PCM, Delta Modulation (DM), Quantization Noise in Signal Integration, Adaptive Quantizer, Double Integration, Second-Order Prediction and Sigma DM, Adaptive Delta Modulation, Transmission Error Effect, Linear Prediction of Speech, LPC Vocoder	8

3	**Image Coding:** Need for image coding/ compression, Lossy and Lossless Compression, Run-Length Coding, Delayed Decision Coding, Concept of Sub-band Coding, DCT, DWT, Embedded Zero Tree Wavelet Encoding, Adaptive Transform Coding of Speech and Images		8
4	**Video Coding:** Basic Building Blocks, Video Coding Standards, Motion Estimation Techniques and Fast Motion Estimation.		8
5	**Advanced Coding Concepts:** Audio Coding AC-3, Decoder (AC-3), MPEG-1, JPEG 2000		4
6	**Internetworking:** Concept of VoIP, H.323 Protocol, PSTN, Video Conferencing, ISDN, 4G Multimedia Conferencing		8
		Total	40

Text Books/References:
1. Digital coding of waveforms : principles and applications to speech and video - N.S. Jayant, P. Noll
2. Recommendation for Space Data System Standards, Voice And Audio Communications, Recommended Standard - CCSDS 766.2-B-1, Blue Book, November 2017

<u>Wireless Networks (ET5203)</u>

L-T-P: 3-0-0   **Credit: 3**   **Full Marks:100**

Sl. No.	Topics	Class Hours
	Introduction	7
1	1.1 Fundamentals of Communication Networks: Network criteria, Network models, Categories of networks, Interconnection of networks: Internetwork, OSI model, TCP/IP protocol.	
	1.2 Wireless Networks vs. Wired Networks: Similarities and differences between wireless and wired networks; Spectrum for Wireless Networks, spectrum allocation issues	
	1.3 Cellular Systems and Infrastructure-based Wireless Networks: Cellular system design, Frequency reuse in cellular systems, Dynamic resource allocation in cellular systems, Area spectral efficiency, Interference models, Power control impact on interference. 1.4 Infrastructure less wireless networks : Wireless Ad Hoc Networks, Wireless Sensor Networks	
	PHY Layer Issues in Wireless Networks	12
	2.1 Path-loss and Shadowing: Radio wave propagation, Transmit and receive signal models, Free-space path loss, Ray tracing, Simplified and empirical path loss model, Shadow fading. Combined path loss and shadowing, Outage probability under path loss and shadowing.	
2	2.2 Statistical Multi-path Channels: Time-varying channel impulse response, Narrowband fading models, Wideband fading models, Discrete-time model, Spatio-temporal models.	
	2.3 Performance of Digital Modulation over Wireless Channels: AWGN channels: Error probability for BPSK, QPSK, MPSK, MPAM, MQAM, FSK, CPFSK.	
	2.4 Multi-Carrier Modulation and Spread-Spectrum: OFDM, Discrete implementation of OFDM, Subcarrier fading mitigation techniques; Spread spectrum modulation, Pseudorandom (PN) sequences (Spreading codes), Direct sequence spread spectrum, RAKE receivers, Frequency-hopping techniques.	
3	**Multiplexing and multi-user Access**	6

	Multiplexing schemes, Multiple-access schemes, Frequency division multiple access, Time division multiple access, CDMA, Space division multiple access, OFDMA, Hybrid methods of multiple access, Multiple access for packet radio systems. Case Study: Multiple access and interference management in cellular systems.	
	Network and Transport Layer Issues in Wireless Networks	7
4	Introduction - Mobile IP: IP packet delivery, Agent discovery, tunneling and encapsulation, IPV6- Network layer in the internet- Mobile IP session initiation protocol - mobile ad-hoc networks: Routing, Destination Sequence distance vector, Dynamic source routing. TCP enhancements for wireless protocols - Traditional TCP: Congestion control, fast retransmit/fast recovery, Implications of mobility - Classical TCP improvements: Indirect TCP, Snooping TCP, Mobile TCP, Time out freezing, Selective retransmission, Transaction oriented TCP - TCP over 3G wireless networks.	
	Wireless Broad-band Networks	4
5	Wi-Fi, Bluetooth, Wi-Max, 3G, 4G, Next generation broadband wireless networks and navigational services, Wireless Local Area Networks (WLAN), IEEE 802.11 WLAN.	
	Security in Wireless Networks:	4
6	Introduction, Security and Privacy Needs of a Wireless System, Required Features for a Secured Wireless Communications System, Methods of Providing Privacy and Security in Wireless Systems, Wireless Security and Standards, IEEE 802.11 Security, Security in GSM, GPRS, and UMTS, Data Security.	
	Total	40

Text Books/References:
1. K. Pahalvan and P. Krishnamurthy, "Principles of Wireless Networks: A Unified Approach", Pearson Education.
2. W. Stallings, "Wireless Communications and Networking", Pearson Education.
3. A. Goldsmith, Wireless Communications, Cambridge University Press.
4. Upena Dalal, "Wireless Communication and Networks", Oxford University Press.
5. Vijay K. Garg, "Wireless Communications and Networking", Elsevier.
6. R. Prasad and L. Munoz, "WLANs and WPANs: Towards 4G Wireless", Artech House.
7. S. Haykin and M. Moher, "Modern Wireless Communication", Pearson Education.
8. R. Pandya, "Mobile and Personal Communication Systems and Services", Prentice-Hall of India.

Specialization: **RF and Photonics**

RF Integrated Circuits (ET5212)

L-T-P: 3-0-0   **Credit: 3**   **Full Marks:100**

Sl. No	Topics	Class Hours
1	**CMOS Analog Design Brief revisit:** CMOS device fundamentals, Small signal model under low and high frequencies, Single stage MOS amplifiers, Differential amplifiers, Current mirrors.	6
2	**Noise:** Introduction, Thermal noise, Shot noise, Flicker noise, Popcorn noise, Classical two-port noise theory, examples of noise calculation.	2
3	**Parasitics and Layout effects:** Parasitics modeling, Interconnects, Pre-layout and post-layout design optimization overview.	4
4	**Oscillators and Synthesizers:** Introduction, The problem with purely linear Oscillators, Resonators, A catalogue of tuned oscillators, Negative resistance oscillators, Frequency synthesizer.	4
5	**LNA design:** Introduction, LNA topologies- power match vs. noise match, Power constrained noise optimization, Design examples, Linearity and large-signal performance, Spurious free dynamic range.	4
6	**Mixers:** Introductions, Mixer fundamentals, Nonlinear systems as linear mixers, Multiplier-based mixers, Sub sampling mixers.	4
7	**RF power amplifiers:** Introduction, class A, B, AB, and C power amplifiers, class D amplifiers, class E amplifiers, Class F amplifiers, summary of PA characteristics, RF PA design examples.1dB compression point and IIP 3	6
8	**RF Filters and Phase Shifters:** Modelling of mechanical filters, micromachined filters, micromachined filters for millimeter wave frequencies; Various types of MEMS phase shifters.	3
9	**Case Study of RF Design:** Designing a complete analog RF circuit from specifications.	3
10	**Selected Topics on RF IC:** MMIC, Millimeter Wave Circuits, Teraheartz Systems	4
	Total	40

Textbook/References:
1. Behzad Razavi, "RF Microelectronics", Pearson, 2nd edition. 2012.
2. Gernot Hueber, Ali M. Niknejad, "Millimeter-Wave Circuits for 5G and Radar", The Cambridge RF and Microwave Engineering Series, 2019.
3. Thomas H. Lee, "The Design of CMOS Radio-Frequency Integrated Circuits" Cambridge Univ. Press, 2001.
4. B. Jayant Baliga, "Silicon RF Power MOSFETS", World Scientific Publishing, 2005.
5. Robert Caverly, "CMOS RFIC Design Principles", ARTECH HOUSE, INC, 2007.

Antenna Theory and Applications (ET5213)

L-T-P: 3-0-0   **Credit: 3**   **Full Marks:100**

Sl. No.	Topics	Class Hours
1	**Antenna fundamentals :** Concept of radiation, application of network theorems to Antennas, field of current element and small loops, radiation from half wave dipole and linear antenna, effect of ground,	5
2	**Basic antenna parameters:** Antenna impedance, beam width, gain, directivity, efficiency, effective area, and polarization.	4
3	**Various antennas:** Helical antennas, Microwave antenna, Aperture antennas, reflectors, horns, slot antennas, monopole antenna, traveling wave antenna.	5
4	**Micro-strip antennas:** Basic configuration and advantages; Radiation mechanism; Basic characteristics; Feeding techniques; printed circuit antennas. Compactness of antenna.	4
5	**Antenna arrays:** Multiplication of pattern, electronic beam control.	4
6	**Digital beam forming: Smart antenna in mobile applications.**	3
7	**Active Integrated Antennas:** Active devices and passive elements; Types of active antenna modules, active antenna characteristics and measurements.	3
8	**Millimeter wave antennas:** Periodic dielectric antennas; Uniform wave guide leaky wave antenna; Tapered slot antennas and printed circuit antennas.	4
9	**Antenna measurement:** Out door and compact range measurement arrangements, anechoic chamber, pattern, gain and polarization measurement.	4
10	**Modern antenna for 5G and 6G application**	4
	Total	40

Text Books/References:
1. Antenna theory: Analysis & Design – C.A. Balanis
2. Electromagnetic Waves and Radiating Systems- Jordan & Balmain
3. Antennas and wave propagation –J.D. Kraus, R.J. Marhefka, A.S. Khan

Optical Communication (ET5214)

L-T-P: 3-0-0   **Credit: 3**   **Full Marks:100**

Sl. No.	Topics	Class Hours
1	**Introduction**: Optical Transmission System Concepts, Optical Networking, Optical Interconnects , Optical Computers	2
2	**Optical sources and detectors:** Principle of optical sources, LED, theory of laser, spectral features of lasers, gas lasers, semiconductor lasers, modes of laser cavity, single mode laser, optical transmitter, negative electron affinity detector, characteristics parameters of external photo-effect detector, photo conductive detector, pn junction detector, quantum efficiency, PIN, spectral characteristics, APD, commercial optical detection, Figures of merit of photodetectors (Responsivity, Q.E., Long wavelength cut-off, Noise equivalent power (NEP), Speed of Response, Bandwidth).	12
3	**Introduction to optical fiber**: Wave equation, modes in optical fiber, classification of optical fibers, dispersion, inter and intra-modal dispersion, crosstalk, BER. Non-linear effects, Solitons, Group velocity dispersion and chirping, soliton based communication.	6
4	**Fundamentals of optical communication:** principle of direct and coherent detection receivers, receiver performance, sensitivity, selectivity, signals in communication systems, transmission channel, eye pattern, probability of error, noise, intersymbol interference, BER.	6
5	**Coherent and incoherent systems:** analysis, optimization, influence of laser noise, homodyne system, ASK, PSK and phase controlled homodyne systems, heterodyne system with coherent and incoherent detection, ASK, FSK and DPSK heterodyne system, probability density function and BER.	8
6	**Free space communication:** Introduction, comparison with microwave system, coherent optical space communication, problems and drawbacks, free space propagation formulas, optical transmitter, background noise, pointing, acquisition and tracking, receiver, link budget.	6
	Total	40

Text Books/References:
1. Optical Communications Components and Systems, J. Franz and V. K. Jain, CRC press, India.
2. Introduction to fiber optics- A. K. Ghatak.
3. Free-Space Optics Propagation and Communication- O. Bouchet, H. Sizun, C. Boisrobert, F. de Fornel, P. Favennec
4. Optical Fiber Telecommunications V A (Fifth Edition), Components and Subsystems, Optics and Photonics, 2008, Pages 829-880

Specialization: **Microelectronics and VLSI Design**

Digital VLSI Design (ET5207)

L-T-P: 3-0-0   **Credit: 3**   **Full Marks:100**

Sl. No.	Topics	Class Hours
1	**INTRODUCTION:** Historical Perspective, Overview of VLSI Design Methodologies, VLSI Design flow, VLSI Design Style, Design Quality	2
2	**MOS TRANSISTOR:** The Metal Oxide Semiconductor (MOS) Structure, The MOS System under External Bias, Structure and Operation of MOS Transistor (MOSFET), MOSFET Current-Voltage Characteristics, MOSFET Scaling and Small-Geometry Effects, MOSFET Capacitances	6
3	**MODELING OF MOS TRANSISTORS USING SPICE:** Basic Concepts, Model Equations, Capacitance Models, Comparison of the SPICE MOSFET Models	2
4	**MOS INVERTERS: STATIC CHARACTERISTICS:** Resistive-Load Inverter, Inverters with n-Type MOSFET Load, CMOS Inverter	4
5	**MOS INVERTERS: SWITCHING CHARACTERISTICS AND INTERCONNECT EFFECTS :** Delay-Time Definitions, Calculation of Delay Times, Inverter Design with Delay Constraints, Estimation of Interconnect Parasitic, Calculation of Interconnect Delay, Switching Power Dissipation of CMOS Inverter	4
6	**COMBINATIONAL MOS LOGIC CIRCUITS:** MOS Logic Circuits with Depletion nMOS Loads, CMOS Logic Circuits, Complex Logic Circuits, Pass transmission logic, CMOS Transmission Gate logic	6
7	**SEQUENTIAL MOS LOGIC CIRCUITS:** Behavior of Bistable Elements, The SR Latch Circuit, Clocked Latch and Flip-Flop Circuits, CMOS D-Latch and Edge-Triggered Flip-Flop	4
8	**DYNAMIC LOGIC CIRCUITS:** Basic Principles of Pass Transistor Circuits, Voltage Bootstrapping, Synchronous Dynamic Circuit Techniques, High-Performance Dynamic CMOS Circuits 37	4
9	**SEMICONDUCTOR MEMORIES:** Read-Only Memory (ROM) Circuits, Static Read-Write Memory (SRAM) Circuits, Dynamic Read-Write Memory (DRAM) Circuits	4
10	**LOW-POWER CMOS LOGIC CIRCUITS:** Overview of Power Consumption, Low-Power Design Through Voltage Scaling, Estimation and Optimization of Switching Activity, Reduction of Switched Capacitance, Adiabatic Logic Circuits	4
	Total	40

Text Books/References:
1. CMOS Digital Integrated Circuits, S. M. Kang and Y. Leblebici.
2. VLSI Design Techniques for Analog and Digital Circuits, R. L. Geiger, P. E. Allen and N. R. Strader.
3. Digital Integrated Circuits, J.M. Rebaey.
4. Introduction to Digital Systems, M. Ercegovac, T. Land and J.H. Moreno.

Low Power VLSI Design (ET5210)

L-T-P: 3-0-0   **Credit: 3**   **Full Marks:100**

Sl. No	Topics	Class Hours
1	**Fundamentals:,**	8
	Basics of MOS circuits	
	Sources of Power Dissipation (Short-circuit Power, Switching Power, Gliching Power)	
	Static Power Dissipation	
	Overview of Low-Power Design Concept along with Limitations	
2	**Supply Voltage Scaling Approaches:**	8
	Device feature size scaling	
	Multi-V_{dd} Circuits	
	Architectural level approaches: Parallelism, Pipelining	
	Voltage scaling using high-level transformations	
	Dynamic voltage scaling	
	Power Management	
3	**Switched Capacitance Minimization Approaches:**	8
	Hardware Software Tradeoff	
	Bus Encoding	
	Two's complement vs Sign Magnitude	
	Architectural optimization	
	Clock Gating	
	Logic styles	
4	**Leakage Power minimization Approaches**	8
	VTMOS Approach	
	MTMOS Approach	
	Power Gating	
	Transistor Stacking	
	DTCMOS	
5	**Case Study: Basic Low Power Circuit Modules**	8
	Adiabatic Switching Circuits	
	Low Power Adder Design Techniques, Current Mode Adders	
	Low Power Multiplier Design Techniques	
	Low power SRAM Circuit Design Techniques	
	Low power DRAM Circuit Design Techniques	
	Total	40

Textbook/References:
1. "Design of Analog CMOS Integrated Circuits", 1st Ed., Razavi, B., McGraw Hill, 2001.
2. "Analysis and Design of Analog Integrated Circuits", 4th Ed., Gray, P.R., Hurst, P. J., Lewis, S.H., Meyer, R.G., John Wiley and Sons, 2001.
3. "CMOS Circuit Design, Layout and Simulation", Baker, R. J., Li, H. W. and Boyce, D. E., Prentice-Hall of India, 1998.

VLSI Physical Design (ET5211)

L-T-P: 3-0-0   **Credit: 3**   **Full Marks:100**

Sl. No.	Topics	Class Hours
1	**Fundamentals:** VLSI Design Process Different Layout Styles: Full Custom, Gate array, Standard-Cell, Micro-cell, PLA, FPGA Difficulties in Physical Design Computational Complexity Definitions of Nets, Net List, Weighted Nets, Grids, Trees etc. Concept of Graph Theory	6
2	**Partitioning:** Concept of partitioning and Problem formulation (Design Style Specific Partitioning) Classification of Partitioning Algorithms Kernighan-Lin Algorithm along with its Extension (Fiduccia-Mattheyses Algo) Simulated Annealing and Evolution Metric Allocation Method	8
3	**Floor Planning:** Problem Formulation and Classification of Floor Planning Constraint Based and Integer Programming Based Floor Planning Rectangular Dualization Simulated Evolution Method Time Driven Floor Planning Chip Planning PIN Assignment	8
4	**Placement:** Problem Formulation and Classification Simulation Based Placement Algorithms Partitioning Based Placement Algorithms Cluster Growth and Quadratic Assignment Algorithms Resistive Network Optimization Branch and Bound Technique	6
5	**Global Routing:** Problem Formulation and Classification Maze Routing Algorithm (Lee Algo and Headlock Algo) Shortest Path Based Algorithm Steiner Tree Based Algorithm	4
6	**Detailed Routing:** Problem Formulation and Classification Single Layer, Two Layer and Three Layer Techniques Switch-Box Routing (Greedy Router) Computational Geometry Based Router Comparison of Switch Box Router	4
7	**Specialized Routing Methods**	2
8	**The Algorithms for Compaction**	2
	Total	40

Text Books/References:
1) VLSI physical design automation-Sadique M Sait & Habib Youssef
2) Computational aspects of VLSI- Jeffry D. Ullman
3) An introduction to VLSI physical design- M. Sarrafzadeh, C.K.Wong
4) VLSI physical Design- Navin Sharwani

2nd Semester Dept. Elective- II Syllabus for PG

Detection and Estimation Theory (ET5223)

L-T-P: 3-0-0   **Credit: 3**   **Full Marks:100**

Sl. No.	Topics	Class Hours
1	**Background**: Review of Gaussian variables and processes; problem formulation and objective of signal detection and signal parameter estimation in discrete-time domain.	2
2	**Classical Detection and Estimation theory:** Introduction, simple binary hypothesis, Decision criteria, performance, Receiver Operating Characteristic hypothesis, Random parameters, Bayes estimation, real parameter estimation ,multiple parameter estimation, Composite Hypothesis, Generic Gaussian Problem(Equal covariance matrices, equal mean vector)performance bounds and approximation	6
3	**Representation of Random Process**: Introduction, deterministic functions(Orthogonal Representation),Random Process Characterization, Homogeneous Integral Function, Eigen Function, Periodic Function, Infinite time interval, spectral decomposition, MAP estimation Vector Random Process	4
4	**Signal Detection in Continues Time:**Introduction, Mathematical prelim-Densities in function space, Grenander's Theorem and KL divergence, Matched filter detector and its performance; generalized matched filter; detection of sinusoid with unknown amplitude, phase, frequency and arrival time, linear model, Estimator-correlator, linear model, general Gaussian detection, detection of Gaussian random signal with unknown parameters, weak signal detection.	12
5	**Signal Detection In Discrete Time:** Introduction, Model and detector structure, performance evaluation in detection process: direct performance evaluation, chernoff bounds, asymptotic relative efficiency sequential detector	4
6	**Estimation of Signal Parameters:** Minimum variance unbiased estimation, Fisher information matrix, Cramer-Rao bound, sufficient statistics, minimum statistics, complete statistics; linear models; best linear unbiased estimation; maximum likelihood estimation, invariance principle; estimation efficiency; Bayesian estimation: philosophy, nuisance parameters, risk functions, minimum mean square error estimation, maximum a posteriori estimation.	6

7	**Linear Estimator (Signal Estimation In Continues Time):** properties of optimum processor, realizable linear filter- stationary process, infinite past: wiener filter, solution of wiener hopf equation, errors in optimum system, unrealisable filters, closed form error expression, optimum feedback system, Kalman bucy filter- differential equation representation of linear system and random process generation	6
	Total	40

Text Books/References:
1. H.V.Poor, An Introduction to Signal Detection and Estimation, 2ndEd. Springer-Verlag, 1994.
2. H.L.VanTrees, Detection, Estimation and Modulation Theory, Part 1 and 2, JohnWileyInter-Science.
3. E.L.Lehman, Testing Statistical Hypothesis, John Wiley, 1986.
4. M.D.Srinath, P.K.Rajasekaran and R.Vishwanathan, An Introduction to Statistical Signal Processing with Applications, PrenticeHall, 1996.
5. To review probability: A. Papoulis, Probability, random variables, and stochastic processes,
6. McGraw-Hill International Edition.

Electromagnetic Metamaterials (ET5227)

L-T-P: 3-0-0   **Credit: 3**   **Full Marks:100**

Sl. No.	Topics	Class Hours
1	**Introduction**: Wave equations (Electromagnetic), Waves in Homogeneous Media: Solutions to wave equations, and Green's functions Waves in Complex Media: One dimensional layered media: (Scattering by a single interface; Single layer case: Reflection and Transmission; Multilayer cases);	6
2	**Two and three dimensional cases with isotropic scatterers**: Single scatterer, Multiple scatterers. Effective Medium Theory: Introduction to random media; EMT based on transmission and reflection coefficients (parameter retrieval);	6
3	**Wave Functional Materials**: photonic/phononic crystal.	4
4	**Electrodynamics of Left-Handed Media**, Wave Propagation in Left-Handed Media, Energy Density and Group Velocity, Negative Refraction, Synthesis of Negative Magnetic Permeability and electric permittivity	4
5	**Metamaterials structure**s: Split ring resonator and wire structure, Design and Analysis of the Edge and Broad Coupled SRR, The Double and Multiple Split SRR, Spirals Resonators, 1/2/3 Dimensional SRR-Based Left-Handed Metamaterials	4
6	Real Distributed 1D CRLH Structures, Two dimensional metamaterials. Material parameters extraction.	4
7	**Applications of Metamaterial**: Concepts of Filters; Stopband Filters, Bandpass Filters Based on Alternate Right-/Left-Handed (ARLH) Sections Implemented by Means of SRRs. Miniaturization of Microwave Components Antenna Applications, Time domain analysis and studies of various UWB antennas with and without Metamaterial loading	6
8	**Metamaterial Cloaking** Definition and general concepts, Comparison between electromagnetic invisibility and other low observability techniques, fundamentals of optical metamaterials.	6
	Total	40

Text Books/References:
1. Electromagnetic Metamaterials: Transmission Line Theory and Microwave Applications – C. Caloz, T. Itoh.
2. Metamaterials: Physics and Engineering Explorations,
   Nader Engheta; Richard W Ziolkowski

Quantum Optics(ET5228)

L-T-P: 3-0-0   **Credit: 3**   **Full Marks:100**

Sl no	Module Name and Topics	Class hours
1	**Introduction:** Quantum theory, axioms, quantum statistics, Schrödinger and Heisenberg picture.	6
2	**Classical theory**: Planck's law, Einstein rate equations, models of chaotic light source, lossless beam splitter, Mach Zehnder interferometer, Degree of first and second order coherence, interference fringe, intensity fluctuation of chaotic light.	8
3	**Quantum mechanics of atom-radiation interaction**: time dependent quantum mechanics, form of interaction Hamiltonian, expression of Einstein coefficients, Fermi golden rule, radiative broadening.	6
4	**Quantization of radiation**: Quantum mechanical harmonic oscillator, quantization of EM field, canonical commutation relation, pure states and statistical mixture, time development of quantum optical system, interaction of quantized field with atoms.	6
5	**Single mode quantum optics**: single mode field operator, number states, coherent states, chaotic light, squeezed states, beam splitter input output relation, single photon input, non-classical light.	6
6	**Multimode quantum optics**: multimode states, continuous mode field operators, photon bunching and anti-bunching, Mach-Zehnder interferometer, photon pair state, two photon interference.	6
	Total	**40**

Textbook/References:
1. The quantum theory of light, R Loudon, Oxford
2. Essential Quantum Optics:From Quantum Measurements to Black Holes, U Leonhardt Cambridge
3. Introduction to Quantum Optics From the Semi-classical Approach to Quantized Light, G. Grynberg, A. Aspect, C. Fabre, Cambridge university press, 2010.

Radar Engineering (ET5229)

L-T-P: 3-0-0   **Credit: 3**   **Full Marks:100**

Sl. No.	Topics	Class Hours
1	**Basics of Radar:** Introduction, Maximum Unambiguous Range, Radar Waveforms, Definitions with respect to pulse waveform - PRF, PRI, Duty Cycle, Peak Transmitter Power, Average transmitter Power. Simple form of the Radar Equation, Radar Block Diagram and Operation, Radar Frequencies, Applications of Radar.	6
2	**The Radar Equation:** Prediction of Range Performance, Detection of signal in Noise, Minimum Detectable Signal, Receiver Noise, SNR, Modified Radar Range Equation, Envelope Detector — False Alarm Time and Probability, Probability of	6

	Detection, Radar Cross Section of Targets: simple targets – sphere, cone-sphere, Transmitter Power, PRF and Range Ambiguities, System Losses.	
3	**MTI and Pulse Doppler Radar:** Introduction, Principle, Doppler Frequency Shift, Simple CW Radar, Sweep to Sweep subtraction and Delay Line Canceler, MTI Radar with – Power Amplifier Transmitter, Delay Line Cancelers — Frequency Response of Single Delay- Line Canceler, Blind Speeds, Clutter Attenuation, MTI Improvement Factor, N- Pulse Delay-Line Canceler.	6
4	**Tracking Radar:** Tracking with Radar- Types of Tracking Radar Systems, Monopulse Tracking- Amplitude Comparison Monopulse (one-and two-coordinates), Phase Comparison Monopulse.	4
5	**Sequential Lobing**, Conical Scan Tracking, Block Diagram of Conical Scan Tracking Radar, Tracking in Range, Comparison of Trackers.	6
6	**The Radar Antenna:** Functions of The Radar Antenna, Antenna Parameters, Reflector Antennas and Electronically Steered Phased array Antennas.	4
7	**Radar Receiver:** The Radar Receiver, Receiver Noise Figure, Super Heterodyne Receiver, Duplexers and Receivers Protectors, Radar Displays.	4
8	**Synthetic aperture radar(SAR), scanning radar, MIMO radar**	4
	Total	40

Text Books/References:
1. Radar: Principles, Technology, Applications – Byron Edde
2. Introduction to Radar Systems – Merrill I. Skolnik

Microsensors and Actuators (ET5230)

L-T-P: 3-0-0   **Credit: 3**   **Full Marks: 100**

Sl. No.	Module Names and Topics	Class hours
1	**Basics of Sensors and Actuators:** Introduction, Classification of Sensors and Actuators, Static and Dynamic Characterization, Calibration of Sensors and Actuators	4
2	**Fabrication Technologies:** Micromechanical Process Design, Bulk Micromachining, Surface Micromachining, Non-lithographic patterning	5
3	**Mechanical Sensors:** Principle of operation, ,Piezoresistivity, Piezoresistive Sensors, Capacitive Sensors	4
4	**Magnetic Sensors:** Principle of operation, Magnetic Effects and Magnetic Materials, Integrated Hall Sensors, Magnetotransistors, Other Magnetic Sensors	4
5	**Thermal Sensors:** Principle of operation, Heat Transfer, Thermal Structures, Thermal-Sensing Elements, Thermal and Temperature Sensors	4
6	**Chemical and Biological Sensors:** Principle of operation of gas sensors, Interaction of Gaseous Species at Semiconductor Surface, The Electrical Properties of Compressed Powders, FET Devices for Gas and Ion Sensing Principle of operation of biosensors, Mass Transport in Biosensors, FET and Impedance Based Sensing	8
7	**Actuators:** Working principles of actuators, piezoelectric and piezoresistive actuators, micrcopumps, micrcovalves	4
8	**Interfacing Electronics:** Sensor interfacing with microcontroller, design of front end analog blocks, algorithms for reliability enhancement, low power design	7
	Total	40

Text Books/References:

1. Semiconductor Sensors-S. M. Sze
2. Micro-sensors: Principles and Applications- Julian W. Gardner, Florin Udrea
3. Silicon Sensors – S.Middlehoek and S.A.Audet
4. Piezoelectric Sensors and Actuators: Fundamentals and Applications, Springer,2018 Senturia S. D.

2nd Semester Open Elective- II Syllabus for PG

Wireless Communications for IoT (ET 5262)

L-T-P: 3-0-0   **Credit: 3**   **Full Marks: 100**

Sl. No.	Topics	Class hours
1.	**Introduction to IoT:** Cyber-Physical Systems, 6 layers of IoT architecture with examples, overview of IoT applications, IoT Physical devices and End Points, IoT System Design Examples (for applications like fitness tracker, smart parking etc.), IoT Design Methodology & Life Cycle, Difference between Human type communication (HTC) and machine type communication (MTC).	6
2	**Wireless Channel:** RF propagation models, Large Scale Fading, Small scale Fading (Fast Fading, Slow Fading, Flat Fading, Selective Fading), Bit error rate, Equalization, Diversity, MIMO.	4
3	**Networking for IoT:** Introduction to IoT Network, Communication & Networking Requirements in IoT, Network Models & Architecture (Client-server, P2P etc.), Wireless sensor networks, Localization of sensor nodes, Other Ad Hoc networks (MANET, VANET), Common network standards (Bluetooth, RFID, NFC, LORA, LoraWan) etc., M2M communication (MQTT, COAP protocols).	8
4	**Multiple Access in IoTs:** Frequency division multiple access, Time division multiple access, Random access, ALOHA, S-ALOHA, CSMA-CA, OFDMA	6
5	**Energy-Efficient (Green) IoT Communications:** Importance of Energy-efficiency for IoT communication, Energy efficiency metrics for green communications, Energy-efficient protocols for wireless networks (LEACH routing protocol, RPL Routing protocol, etc.), Power management techniques for improving energy efficiency: sleep mode, femtocell and relaying techniques, RF energy harvesting.	8
6	**Security issues in IoT:** Cyber-attacks on IoT- Case study, Security solutions for IoT: hardware/software.	4
7	**Selected topics in the IoT:** Smart-grid, Industrial IoT etc., Federated Learning, Edge computing, IoT Cloud Services, other emerging topics in IoT communications.	4
	Total	40

Textbooks/ References:

1. Internet of Things: Principles and paradigms. R. Buyya, and A.V Dastjerdi (Elsevier), 2016.
2. Precision - Internet Of Things, by Timothy Chou (Mc Graw Hill), 2017.
3. The Internet of Things: Enabling Technologies, Platforms, and Use Cases, by Pethuru Raj and Anupama C. Raman (CRC Press), 2017.
4. Internet of Things by Raj Kamal (Mc Graw Hill), 2017.

2nd Sem. M. Tech thesis Part - I (Term Paper) (ET5291)

L-T-P: 0-0-6   **Credit: 3**   **Full Marks: 100**

In addition to the course work, the students, individually, will be allotted a project work on a relevant topic related to his/her respective specialization. The students are expected to undergo an extensive literature survey on the respective project topic which, eventually, will lead him/her towards a definite direction of research by quantifying the potential gaps in the existing works. Each of the students will have to present his progress and further course of action before a panel of experts who will evaluate their performances based on the presentation and a brief questionnaire session thereafter.

3rd Sem. M. Tech Thesis Part - II (Progress Report) (ET6191)

L-T-P: 0-0-24   **Credit: 12**   **Full Marks: 300**

In the 3rd Semester, the students are likely to carry out their research works on the relevant research topics upon which they performed the literature survey and quantified the scopes of work in the Term Paper of previous semester. Upon completion of the semester, each of the students will have to demonstrate their progress so far, before a panel of experts who will evaluate their performances based on the presentation and a brief questionnaire session thereafter.

4th Sem. M. Tech Final thesis (ET6291)
L-T-P: 0-0-30   **Credit: 22**   **Full Marks: 400**

In the 4th Semester, the students are likely to consolidate their research works by inferring some developments in their outputs over that of the exiting works available in the literature. It will be highly encouraged if the students can come up with some research outputs that can be practically materialized and utilized for real-time applications of significance. Upon completion of the semester, each of the students will have to demonstrate their research outcomes through proper presentation before a panel of experts who will evaluate their performances based on the merits of the research outcomes and a brief questionnaire session thereafter.