# 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*

**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 | Mini Project on Communication Engineering and Signal Processing | ET5173 | 0 | 0 | 3 | 2 | 100 |
| | | TOTAL | | | | 21 | 800 |

**1st Sem. Course Structure for PG Specialization Microwave Communication**

| 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 | Advanced Antenna Engineering | ET5106 | 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 | Microwave Circuits Lab | ET5175 | 0 | 0 | 3 | 2 | 100 |
| 8 | Mini Project on Microwave Communication | ET5176 | 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 | Mini Project on Microelectronics and VLSI Design | ET5180 | 0 | 0 | 3 | 2 | 100 |
| | | TOTAL | | | | 21 | 800 |

**2nd Sem. 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 Sem. Course Structure for PG Specialization Microwave Communication**

| Sl. No | COURSE TITLE | CODE | L | T | P | Credit | Marks |
|---|---|---|---|---|---|---|---|
| 1 | Microwave Integrated Circuits | ET5204 | 3 | 0 | 0 | 3 | 100 |
| 2 | Advanced wave propagation and Electromagnetic Metamaterials | ET5205 | 3 | 0 | 0 | 3 | 100 |
| 3 | Radar Engineering | ET5206 | 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 Sem. 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 Sem. Course Structure for PG (All Specialization)**

| Sl. No | 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

| Specialization | Communication Engineering and Signal Processing | Microwave Communication | Microelectronics and VLSI Design |
|---|---|---|---|
| | Optical Communication and Networking (ET5121) | Optical Communication and Networking (ET5121) | Optical Communication and Networking (ET5121) |
| | Electromagnetic Interference and Compatibility (ET5122) | Electromagnetic Interference and Compatibility (ET5122) | VLSI Testing (ET5124) |
| | VLSI for Signal Processing (ET5123) | VLSI for Signal Processing (ET5123) | VLSI for Signal Processing (ET5123) |

### DEP. ELECTIVE- II

| Specialization | Communication Engineering and Signal Processing | Microwave Communication | Microelectronics and VLSI Design |
|---|---|---|---|
| | Computer Networks (ET5221) | Computer Networks (ET5221) | Computer Networks (ET5221) |
| | Radar Signal Processing (ET5222) | Radar Signal Processing (ET5222) | Semiconductor Sensors (ET5226) |
| | Detection and Estimation Theory (ET5223) | RF IC and RF MEMS (ET5224) | RF IC and RF MEMS (ET5224) |

## OPEN ELECTIVE-I

1. Electronic Communication Systems (ET5161)

## OPEN ELECTIVE-II

1. Optoelectronics and Photonics (ET5261)

**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. No. | 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. No. | 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 |

## Mini Project on Communication Engineering and Signal Processing (ET5173)

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

Each of the will be allotted a mini project work on a relevant topic related to the core subjects in the specialization of Communication Engineering and Signal Processing. The students are expected to put some novel and developmental contributions through sincere research work on the respective topic. 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.

## **Specialization:** Microwave Communication

### Computational Electromagnetics (ET5104)

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

| Sl. No. | Topics | Class Hours |
|---|---|---|
| 1 | Overview of Vector Calculus, Integral of complex functions<br>Overview of Electrostatics, Magnetostatics,<br>Maxwell Equations; Differential and Integral forms;<br>Wave equations in loss-less, low-loss, inhomogeneous media;<br>Uniform plane waves: propagation, reflection, refraction<br>General solution of differential equations, PDEs, Solution of wave equations | 8 |
| 2 | Finite difference approximation;<br>Solution of 1D wave eqn using FDTD<br>Boundary conditions in FDTD<br>Computational issues in FDTD<br>Extension to 2 and 3 dimensions; Stability, Error analysis<br>PML boundaries<br>Treatment of curved bodies<br>Dispersive media; plasma | 8 |
| 3 | Equivalence principle; Image theory<br>Solution by separation of variables; Multi-pole expansion<br>Continuity Equation, Poynting's Theorem; Conservation of Momentum<br>Scalar and Vector Potentials: definition, Gauge transformations, retarded potentials<br>Radiated fields from dipoles | 8 |
| 4 | Green's functions; solution of Strum Liouville Differential equations<br>Calculus of variations; functionals; stationarity<br>Method of weighted residuals<br>Integral equations; Method of moments<br>Input impedance of simple wire antennas: infinitesimal, short, half-wave dipoles<br>Charge distribution on a wire; analysis of Stripline<br>Solution of antenna problems using MoM; scattering by cylinder | 8 |
| 5 | Overview of computational issues: iterative techniques, sparse matrix techiques<br>Fast multipole soln methods<br>Surface currents in MoM; RWG basis functions<br>Brief Introduction to FEM | 8 |
| | **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 | Two cavity Klystron Amplifier, Principle of velocity modulation, power output, efficiency, multi-cavity Klystron amplifier, Reflex Klystron – power output, efficiency, different tuning mechanism. | 5 |
| 2 | Magnetron, different structures – cylindrical, rising sun, beam lid, critical magnetic field for operation, principle of bunching, mode jumping, tuning of magnetron oscillator. | 4 |
| 3 | Travelling Wave Tubes (TWTs)- O-type, M-type, principle of bunching, TWT Amplifier: power output, gain, TWT Oscillator - Linear and Circular type. | 4 |
| 4 | IMPATT diode: SDR, DDR, DAR, lo-hi-lo structures, Mechanism for generation of negative resistance, Equivalent circuit, frequency and efficiency of the device, IMPATT diode as an amplifier and oscillator, power combiner, Fabrication process for IMPATT. | 4 |
| 5 | Tunnel diode – structure, quantum mechanical tunneling effect, Current equation, V-I relationship, Equivalent circuit, expression for cut-off frequencies, Tunnel diode amplifier with series and shunt load. | 4 |
| 6 | Transferred Electron Effect, Transferred Electron Device – Gunn diode, negative differential mobility, Equivalent circuit, Gunn diode oscillator, Different modes of operation, | 4 |
| 7 | 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 |
| 8 | 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. | 5 |
| 9 | 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 |
| | **Total** | 40 |

**Text Books/References:**


1. Micorwave Engineering – Pozar, McGraw Hill Book Co.
2. Micorwave devices & Circuts – S. Y. Liao, Prentice Hall of India.


## Advanced Antenna Engineering (ET5106)

**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 definitions:** Antenna impedance, beam width, gain, directivity, efficiency, effective area, and polarization. | 4 |
| 3 | **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 | **Full wave simulation techniques for antenna design** : Finite element method, Finite difference time domain method, Methods of moments. | 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


## 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. | 3 |
| 2 | Familiarization with HFSS software: Design of different metamaterial unit cells (Epsilon negative & Mu negative) using HFSS and determine various parameters. | 3 |
| 3 | Design and analysis of printed antenna for biomedical applications: Determine S parameters with in-vitro test. | 3 |
| 4 | Study And familiarize with different types of wireless power transfer systems: I. Inductive coupling based WPT, II. Resonant coupling based WPT, III. Radiation based WPT system | 9 |
| 5 | Study of FSS using Frequency Selective Surface measurement panel. | 3 |
| 6 | Study of different type of absorbing material for radar application. | 3 |
| | **Total** | 24 |

## Microwave Circuits Lab (ET5175)

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

| Sl. No. | Topics | Class Hours |
|---|---|---|
| 1 | 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 |
| 2 | 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 | 6 |
| 3 | Study of different types of attenuator and investigating its characteristics: Pin modulator/ variable attenuator, PIN diode switchable attenuator | 6 |
| 4 | Study of different types of power divider circuits: Wilkinson equal power divider and unequal power divider | 3 |
| 5 | Study of different MMIC circuits like : Mixer, Microwave Amplifier and Voltage controlled Oscillator (VCO) | 6 |
| 6 | Study of satellite communication system, microwave circuits and antennas in a satellite transponder | 3 |
| | **Total** | 30 |

## Mini Project on Microwave Communication (ET5176)

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

Each of the will be allotted a mini project work on a relevant topic related to the core subjects in the specialization of Microwave Communication The students are expected to put some novel and developmental contributions through sincere research work on the respective topic. 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.

## **Specialization:** Microelectronics and VLSI Design

### Advanced Semiconductor Devices (ET5107)

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

| Sl. No. | Topics | Class Hours |
|---|---|---|
| 1 | **Introduction of Semiconductor Devices:** Introduction, Ohmic contact, Rectifying contact, Current transport across a metal-semiconductor boundary, Metal-Insulator-Semiconductor(MIS) System, Metal-Semiconductor-Field-Effect-Transistor (MESFET), Charge Coupled Devices (CCDs), Microwave transistors, Gunn Diode, Impatt Diode. | 3 |
| 2 | **Semiconductor Tunnel Devices:** Tunneling from the point of view of quantum measurement, Analysis of the Tunneling effect; Tunneling probability, Tunneling current density, Resonant tunneling.<br>Tunnel Diodes; Qualitative and quantitative explanation of the Tunnel Diode I-V characteristics, Indirect tunneling, Excess current, Thermal current in a tunnel diode, Dependence of tunnel diode characteristics on various parameters | 5 |
| 3 | **Photonic Devices:** Light-emitting diodes (LEDs), OLEDs, Laser diodes, Photo detectors, and Solar cells | 4 |
| 4 | **State-of-the-art Semiconductor Devices:** Emerging non-volatile memory materials and devices (Memristor), Carbon nanotube/nanowire, graphene, and $MoS_2$ based electronic devices, Recent devices. | 10 |
| 5 | **Physics of Advance MOSFET Structures:** Drift-Diffusion Approach for IV, Gradual Channel Approximation, Sub-threshold current and slope, Body effect, Pao&Sah Model, Detail 2D effects in MOSFET, High field and doping dependent mobility models, High field effects and MOSFET reliability issues (SILC, TDDB, & NBTI), Leakage mechanisms in thin gate oxide, High-K-Metal Gate MOSFET devices and technology issues, Intrinsic MOSFET capacitances and resistances, Meyer model | 10 |
| 6 | **MOSFET Structures:** SOI MOSFET**,** FDSOI and PDSOI, 1D Electrostatics of FDSOI MOS, VT definitions, Back gate coupling and body effect parameter, IV characteristics of FDSOI-FET, FDSOI-sub-threshold slope, Floating body effect, single transistor latch, ZRAM device, Bulk and SOI FET: discussions referring to the ITRS | 9 |
| 7 | **Power Electronic Devices:** Insulated-Gate Bipolar Transistor (IGBT), Power MOSFET (Vertical-MOS, Hexagonal Field Effect Transistor (HEXFET), Physics and operation of Thyristors, Silicon Controlled Rectifier (SCR), Gate turn-off Thyristor (GTO), Integrated gate-commutated Thyristor (IGCT), MOS Controlled Thyristor (MCT). | 7 |
| | **Total** | 48 |

**Text Books/References:**


1. S. M. Sze and Kwok K. Ng, “Physics of Semiconductor devices (3rd)”, Wiley, 2007
2. Supriyo Datta, “Quantum Transport Atom to Transistor”, Cambridge University Press, 2005
3. Michael Shur, “Physics of Semiconductor Devices,” Prentice Hall
4. Yuan Taur&Tak H. Ning, “Fundamentals of Modern VLSI Devices”, Cambridge, 1998
5. Mark Lundstrom& Jing Guo, “Nanoscale Transistors: Device Physics, Modeling & Simulation”, Springer, 2005.

6. YannisTsividis, “Operation and Modeling of the MOS Transistor”, Oxford University Press, 2nd Edn.
7. J.P. Colinge, “Silicon-on-Insulator Technology: Materials to VLSI”, Springer, 1997.

## 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-stageOp Amps, 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. No. | Topics | Class Hours |
|---|---|---|
| 1 | **I-V characteristics of MOSFET**<br>• Depletion Mode n-Channel MOSFET (IRF 640N) is used.<br>• Obtain the $I_D$ vs. $V_{DS}$ curve for different Gate voltage ($V_{GS}$).<br>• Clearly show different regions of operation in the graph.<br>• Identify Gate Threshold Voltage ($V_{GS(TH)}$).<br>• Find out Trans-conductance ($g_m$), output resistance ($r_o$) and Early Voltage ($V_a$). | 6 |
| 2 | **C-V Characteristics of MOSFET**<br>• Depletion Mode n-Channel MOSFET (IRF 640N) is used.<br>• Obtain the $C_G$ vs. $V_{GS}$ curve. | 6 |

| | | |
|---|---|---|
| | • Explain different regions obtained in the graph.<br>• Identify Flat Band Voltage ($V_F$) and Threshold voltage ($V_{GS(TH)}$)<br>• Calculate doping concentration of the substrate.<br>• Calculate the barrier height of the Gate-Substrate junction. | |
| 3 | **I-V characteristics of Tunnel Diode:**<br>• Ge Tunnel diode (1N3939/1N3940) is used.<br>• Obtain the I vs. V curve.<br>• Indicate negative resistance region in the graph.<br>• Indicate Valley Voltage ($V_V$) and Peak Voltage ($V_P$) from obtained graph.<br>• Calculate Peak to Valley ratio ($I_P/I_V$).<br>• Calculate minimum negative resistance. | 6 |
| 4 | **I-V characteristics of SCR:**<br>• SCR (BT136-600D) is used.<br>• Obtain the I vs. V curve for different $I_g$.<br>• Indicate different regions in the graph.<br>• Obtain $V_{BF}$. | 3 |
| 5 | **I-V and C-V characteristics of Gas sensor:**<br>• Commercially available Metal Oxide based Gas sensor is used.<br>• Obtain the I vs. V curve for different Temperatures.<br>• Obtain the C vs. V curve for different Temperatures. | 3 |
| 6 | **I-V and C-V characteristics of Bio sensor:**<br>• Commercially available Bio sensor is used.<br>• Obtain the I vs. V curve.<br>• Obtain the C vs. V curve. | 6 |
| | **Total** | 30 |

## VLSI Design Lab (ET5178)

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

| Sl. No. | 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 |

## Mini Project on Microelectronics and VLSI Design(ET5180)

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

Each of the will be allotted a mini project work on a relevant topic related to the core subjects in the specialization of Microwave Communication The students are expected to put some novel and developmental contributions through sincere research work on the respective topic. 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.

# 1st Semester Dept. Elective-I Syllabus for PG

## Optical Communication and Networking (ET5121)

**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 | **Optical Networking Components/Building Blocks:** Light propagation in optical fiber, loss and bandwidth, chromatic dispersion, non linear effects, Solitons, couplers, isolators and circulators, multiplexers and filters, optical amplifiers, transmitters, detectors, switches, wavelength converters, | 8 |
| 3 | **Single and Multi-hop Networks:** SONET/SDH, ATM, IP, Storage-Area networks, Gigabit and 10-Gigabit Ethernet, WDM optical networks, WDM network elements: optical line terminals, optical line amplifiers, optical add/drop multiplexers, optical crossconnects; WDM network design: cost trade-offs, LTD and RWA problems, dimensioning wavelength-routing networks, statistical dimensioning models, maximum load dimensioning models; 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. | 12 |
| 4 | **Photonic packet switching:** Optical time division multiplexing, synchronization, header processing, buffering, burst switching, implementation and application | 6 |
| 5 | **Deployment considerations:** Evolving telecommunications network, designing the transmission layer using SM, TDM, WDM, long haul networks, metro networks | 2 |
| 6 | **Fiber-optic quantum information technologies**: Introduction, fiber nonlinearity as source of coherent photons, fiber nonlinearity as source of entangled photons, degenerate photon pair in telecom band. | 6 |
| 7 | **Free space communication:** Introduction, emission and reception of optical beams, line of sight propagation, optical communication, safety and confidentiality. | 4 |
| | **Total** | 40 |

**Text Books/References:**


1. Optical networks: a practical perspective by Ramaswami, Rajiv, Kumar Sivarajan, and Galen Sasaki, Morgan Kaufmann, 2009.
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


## 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.


# 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


## Wireless Networks (ET5203)

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

| Sl. No. | Topics | Class Hours |
|---|---|---|
| 1 | **Introduction** | 7 |
| | 1.1 Fundamentals of Communication Networks:<br>Network criteria, Network models, Categories of networks, Interconnection of networks: Internetwork, OSI model, TCP/IP protocol. | |
| | 1.2 Wireless Networks vs. Wired Networks:<br>Similarities and differences between wireless and wired networks; Spectrum for Wireless Networks, spectrum allocation issues | |
| | 1.3 Cellular Systems and Infrastructure-based Wireless Networks:<br>Cellular system design, Frequency reuse in cellular systems, Dynamic resource allocation in cellular systems, Area spectral efficiency, Interference models, Power control impact on interference.<br>1.4 Infrastructure less wireless networks : Wireless Ad Hoc Networks, Wireless Sensor Networks | |
| 2 | **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 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. | |
| 4 | **Network and Transport Layer Issues in Wireless Networks** | 7 |
| | 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.<br>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. | |
| 5 | **Wireless Broad-band Networks** | 4 |
| | Wi-Fi, Bluetooth, Wi-Max, 3G, 4G, Next generation broadband wireless networks and navigational services, Wireless Local Area Networks (WLAN), IEEE 802.11 WLAN. | |
| 6 | **Security in Wireless Networks:** | 4 |
| | 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:** Microwave Communication

### Microwave Integrated Circuits (ET5204)

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

| Sl. No | Topics | Class Hours |
|---|---|---|
| 1 | Basic concepts of microwave integrated circuits | 2 |
| 2 | Design and Fabrication Technology for MIC and MMIC | 4 |
| 3 | Planar Transmission Lines, strip line, Microstrip, CPW, slot line | 4 |
| 4 | Print Coupled Lines, symmetric, uniform and non-uniform coupling, design of Couplers | 4 |
| 5 | Distributed and Lumped Elements of Integrated Circuits | 2 |
| 6 | Common Features and Parameters of Networks, Analysis of Symmetrical Networks | 2 |
| 7 | Microstrip based Dividers and Combiners | 2 |
| 8 | Microwave Filters: Microstrip based LP, BP,BS | 2 |
| 9 | Diode Control Devices, PIN diode | 2 |
| 10 | RF MEMS, Phase Shifters | 3 |
| 11 | Microstrip based Circulators and Isolators using ferrite materials | 3 |
| 12 | Amplifier design, LNA, parametric amplifiers | 3 |
| 13 | Design of oscillators, Mixers, frequency divider | 3 |
| 14 | Subassemblies using components and control devices<br>System applications in Radio system, Satellite Communication, Broadcast System, Medical Electronics | 4 |
| | **Total** | 40 |

**Text Books/References:**


1. Ivan Kneppo, Kluwer , “Microwave Integrated Circuits”.
2. Yoshihiro Konishi CRC press, “Microwave Integrated Circuits”
3. Leo G. Maloratsk, Elsevier Inc., “Passive RF & Microwave Integrated Circuits”
4. K.C.Gupta and Amarjit Singh, Wiley, “Microwave integrated circuits”


### Advanced Wave Propagation and Electromagnetic Metamaterials (ET5205)

**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; Singlelayer case: Reflection and Transmission; Multilayer cases); | 4 |
| 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); | 2 |
| 3 | Wave Functional Materials: photonic/phononic crystal; Brief idea about Numerical Methods and Fast Algorithms. | 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 | 6 |
| 5 | 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 | Cutoff Frequencies, Analytical Dispersion Relation, Bloch Impedance, Effect of Finite Size in the Presence of Imperfect Matching, Real Distributed 1D CRLH Structures, Two dimensional metamaterials. Material parameters extraction. | 4 |
| 7 | Microwave 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 | 2 |
| 8 | Definition of small antennas, Limits of small antennas, Chu limit, Metamatetial based electrically small antennas, Efficiency, Q factor. Application of metamaterials in leaky wave antennas | 4 |
| 9 | Time domain analysis and studies of various UWB antennas with and without Metamaterial loading. | 6 |
| 10 | Metamaterial Cloaking Definition and general concepts, Comparison between electromagnetic invisibility and other low observability techniques. | 4 |
| | **Total** | 40 |

**Text Books/References:**


1. Antenna Theory - Analysis and Design – C. A. Balanis
2. Electromagnetic waves and radiating systems- Jordan & Balmain
3. Electromagnetic Metamaterials: Transmission Line Theory and Microwave Applications – C. Caloz, T. Itoh


## Radar Engineering (ET5206)

**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 Detection, Radar Cross Section of Targets: simple targets – sphere, cone-sphere, Transmitter Power, PRF and Range Ambiguities, System Losses. | 6 |
| 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. | 6 |
| 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. | 6 |
| | **Total** | 40 |

**Text Books/References:**


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

## **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:** | 6 |
| | 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 | |
| 2 | **Partitioning:** | 8 |
| | 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 | |
| 3 | **Floor Planning:** | 8 |
| | 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 | |
| 4 | **Placement:** | 6 |
| | 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 | |
| 5 | **Global Routing:** | 4 |
| | Problem Formulation and Classification | |
| | Maze Routing Algorithm (Lee Algo and Headlock Algo) | |
| | Shortest Path Based Algorithm | |
| | Steiner Tree Based Algorithm | |
| 6 | **Detailed Routing:** | 4 |
| | 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 | |
| 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

## Computer Networks (ET5221)

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

| Sl. No. | Topics | Class Hours |
|---|---|---|
| 1 | **Introduction:** Building a network, Applications of computer networks, requirements, network architecture: layering and protocols, OSI architecture, internet architecture, implementing network software, performance metrics: bandwidth, latency | 3 |
| 2 | **The application layer**: Overview of few traditional applications- electronic mail , the web and HTTP, name services; web services, File transfer- FTP | 6 |
| 3 | **The transport layer:** Process-to-process delivery: client-server paradigm, multiplexing, demultiplexing, connectionless versus connection oriented services; TCP: TCP services, TCP flow control. TCP error control, UDP: UDP operation, use of UDP | 7 |
| 4 | **The network Layer:** Forwarding and routing, virtual circuits and datagram networks; The internet protocol(IPv4): forwarding and addressing, IPv6; routing algorithms: distance vector, link state | 7 |
| 5 | **The link layer:** Services provided by link layer, error detection and correction; multiple access links and protocols: random access(ALOHA, CSMA) controlled access (token passing), channelization (FDMA, TDMA, CDMA) | 7 |
| 6 | **The mobile and wireless networks**: Wireless links and networks characteristics, Review of PHY layer protocols of popular IEEE 802.11 standards; Cellular data networks: from 3G to 4G | 6 |
| 7 | **Security in Computer networks:** concept of network security, principles of cryptography; digital signatures, authentication protocol, firewalls | 4 |
| | **Total** | 40 |

**Text Books/References:**

1. "Computer Networking: A top down approach", J. F. Kurose, K. W. Ross, Pearson
2. "Data and Computer Communication", W. Stallings, Pearson
3. "Data Communications and Networking", B. Forouzan, Mc Graw Hill

## Radar Signal Processing (ET5222)

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

| Sl. No | Topics | Class Hours |
|---|---|---|
| 1 | Analysis of Discrete timed signal, Sampling Theorem | 4 |

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|---|---|---|
| 2 | Estimation of freq. Content in Discrete Fourier Transform, Random Discrete Signal Analysis | 2 |
| 3 | Review of Probability, Auto & cross-correlation Power & Cross spectral density functions Cross Spectra, spectral Analysis of Random signals | 4 |
| 4 | Sampling auto correlation functions, Window functions, spectral estimates parametric & non parametric estimates | 6 |
| 5 | Detection of signals in noise, opt-detection algorithms , Min Prob if error, Neymen–pearson criterion for radar app | 4 |
| 6 | Radar sub-optimum processor, Detection of variable amplitude signals, Matched filters, Bayes estimators, Max. likelihood estimation of parameters of linear systems | 4 |
| 7 | Radar Eq. & Cross section Methods for RCS Estimation, GO, POGTD & PTD techniques | 2 |
| 8 | Ray Tracing, RCS of simple & complex Tangels, RCS enhancements. Scattering by imperfectly conducting surfaces, characterisation of absorbers. | 4 |
| 9 | Methods of RCS reduction. Freq. Domain target signature, Real Array imaging Radars. | 6 |
| 10 | Synthetic Array Radars & various DSP techniques. | 4 |
| | **Total** | 40 |

**Text Books/References:**


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


## 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<br>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.


## RF IC and RF MEMS (ET5224)

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

| Sl. No | Topics | Class Hours |
|---|---|---|
| 1 | Introduction to RF IC.<br>**Noise:** Introduction, Thermal noise, Shot noise, Flicker noise, Popcorn noise, Classical two-port noise theory, examples of noise calculation. | 2 |
| 2 | **Oscillators and Synthesizers:** Introduction, The problem with purely linear Oscillators, Resonators, A catalogue of tuned oscillators, Negative resistance oscillators, Frequency synthesizer. | 4 |
| 3 | **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 |
| 4 | **Mixers:** Introductions, Mixer fundamentals, Nonlinear systems as linear mixers, Multiplier-based mixers, Sub sampling mixers. | 4 |
| 5 | **RF power amplifiers:** Introduction, class A, AB, B, and C power amplifiers, class D amplifiers, class E amplifiers, Class F amplifiers, summery of PA characteristics, RF PA design examples. | 6 |

| | | |
|---|---|---|
| 6 | **Introduction:** MEMS for RF applications, MEMS technology and fabrication, mechanical modeling of MEMS devices, MEMS materials and fabrication techniques. | 3 |
| 7 | **MEMS Switches:** Introduction to MEMS switches; Capacitive shunt and series switches: Physical description, circuit model and electromagnetic modeling; Techniques of MEMS switch fabrication and packaging; Design of MEMS switches. | 7 |
| 8 | **Inductors and Capacitors:** Micromachined passive elements; Micromachined inductors: Effect of inductor layout, reduction of stray capacitance of planar inductors, folded inductors, variable inductors and polymer-based inductors; MEMS Capacitors: Gap-tuning and area-tuning capacitors, dielectric tunable capacitors. | 4 |
| 9 | **RF Filters and Phase Shifters:** Modelling of mechanical filters, micromachined filters, surface acoustic wave filters, micromachined filters for millimeter wave frequencies; Various types of MEMS phase shifters; Ferroelectric phase shifters. | 4 |
| 10 | **Integration and Packaging:** Role of MEMS packages, types of MEMS packages, module packaging, packaging materials and reliability issues. | 2 |
| | **Total** | 40 |

**Textbook/References**:


1. Robert Caverly, "CMOS RFIC Design Principles", ARTECH HOUSE, INC, 2007.
2. Xiaopeng Li, Ismail, Mohammed, "Multi-standard CMOS wireless receivers Analysis and design" The Springer International Series in Engineering and Computer Science, Vol. 675, 2002.
3. Thomas H. Lee, "The Design of CMOS Radio-Frequency Integrated Circuits" Cambridge Univ. Press, 2001.
4. Varadan, V.K., Vinoy, K.J. and Jose, K.J., "RF MEMS and their Applications", John Wiley & Sons, 2002.


## Semiconductor Sensors (ET5226)

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

| Sl. No. | Topics | Class Hours |
|---|---|---|
| 1 | **Classification and Terminology of Sensors:** Introduction, Semiconductor Sensors, Classification of Semiconductor Sensors, Sensor Characterization, Evolution of Semiconductor Sensors | 4 |
| 2 | **Semiconductor Sensor Technologies:** Basic Fabrication Processes, Micromechanical Process Design, Bulk Micromachining, Surface Micromachining, Other Micromachining Techniques | 4 |

| | | |
|---|---|---|
| 3 | **Acoustic Sensors:**<br>Principle of operation, Acoustic Waves, Piezoelectric Materials, Acoustic Sensing, SAW Sensors, Sensor Applications | 4 |
| 4 | **Mechanical Sensors:**<br>Principle of operation, ,Piezoresistivity, Piezoresistive Sensors, Capacitive Sensors | 4 |
| 5 | **Magnetic Sensors:**<br>Principle of operation, Magnetic Effects and Magnetic Materials, Integrated Hall Sensors, Magnetotransistors, Other Magnetic Sensors | 4 |
| 6 | **Radiation Sensors:**<br>Principle of operation, HgCdTe Infrared Sensors, Visible-Light Color Sensors, High-Energy Photodiodes, Silicon Drift Chamber X-Ray Sensors | 4 |
| 7 | **Thermal Sensors:**<br>Principle of operation, Heat Transfer, Thermal Structures, Thermal-Sensing Elements, Thermal and Temperature Sensors | 4 |
| 8 | **Chemical Sensors:**<br>Principle of operation, Interaction of Gaseous Species at Semiconductor Surface, Catalysis, the Acceleration of Chemical Reactions, The Electrical Properties of Compressed Powders, Thin-Film Sensors, Thick-Film and Pressed-Pellet Sensors, FET Devices for Gas and Ion Sensing | 4 |
| 9 | **Biosensors:**<br>Principle of operation, Immobilization of Biological Elements, Mass Transport in Biosensors, Transduction Principles, Packaging of Biosensors | 4 |
| 10 | **Integrated Sensors:**<br>System Organization and Functions, Interface Electronics, Fabrication Techniques, Examples of Integrated Sensors | 4 |
| | **Total** | **40** |

**Text Books/References:**


1. Semiconductor Sensors-S. M. Sze
2. Micro-sensors: Principles and Applications- Julian W. Gardner, Florin Udrea
   Sensor Technology and Devices- Ljubiša Ristić


# 2nd Semester Open Elective- II Syllabus for PG

## Optoelectronics and Photonics (ET5261)

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

| Sl. No | Topics | Class Hours |
|---|---|---|
| 1 | Basics of Laser: Planck's Law, Einstein's A & B coefficients, line-shape, optical gain, three and four level system, optical pumping, Fabrey-Perot cavity, Lasers, output power from laser, EDFA, E-K diagram, density of states, quasi Fermi level and inversion, Homojunction, heterojunction and QW Laser. | 6 |
| 2 | Optical detector: Negative electron affinity detector, characteristics parameters of external photoeffect 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). | 6 |

| | | |
|---|---|---|
| 3 | Theory of waveguide: Maxwell's equation, wave equation, solution of wave equation, Transverse electromagnetic wave and Poynting vector, boundary condition, phase and group velocity, infinite slab waveguide, EM analysis, wave vector, modes, Modes in rectangular waveguide, wave equation in cylindrical coordinate, modes in step index fiber. | 10 |
| 4 | Wavelength Division Multiplexing (WDM): principles of operations, various WDM components, Figures of Merit, specialty of DWDM, All optical MUX & DEMUX, Dispersion: total dispersion, single mode waveguide dispersion, dispersion management, fiber fabrication process and measurement technique like OTDR, Attenuation, Scattering. | 4 |
| 5 | Photonic crystal: 1D, 2D and 3D photonic crystal, photonic bandgap, modes of photoni crystal, defect modes, Photonic crystal fiber, light confinement in solid and hollow core PCF, supercontinuum generation, bandgap guidance, topological photonic insulator. | 8 |
| 6 | Fundamentals of Plasmonics: theory of plasmon, light confinement, plasmonic sensors, plasmonics of nanoparticle, metal enhance fluorescence, fundamentals of optical metamaterials. | 6 |
| | **Total** | 40 |

**Textbook/Reference:**


1. Photonics: Optical electronics in Modern Communication , A. Yariv, P Yeh, 6th edition, Oxford University Press, New York, 2007.
2. Semiconductor devices for High-Speed Optoelectronics- Giovanni Ghione
3. Fundamentals of Optoelectronics- Clifford R. Pollock
4. Introduction to Fibre optics, A K. Ghatak and K. Thyagrajan, Cambridge University Press
5. Photonic Crystal molding the flow of light- J. D. Joannopoulos, S. G. Johnson, J. N. Wynn, R. D. Meade
6. Plasmonic Fundamentals and applications- S. A. Maier


## 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.