Course Curriculum

(Course Structure and Syllabi)

for

Bachelor of Technology

in

Electronics and Communication Engineering

(Second Year Onwards)

Department of Electronics and Communication Engineering

National Institute of Technology Hamirpur

Hamirpur, Himachal Pradesh – 177005 (India)

2024

Curriculum for B. Tech. Programme

Course No.	Semester 3	Credits	Course Type
MA-218	Basic Sciences	3	Discipline Core
EC-211 to EC-215	Engineering Courses	14	Discipline Core
EC-216, EC-217	Engineering Course (Lab)	2	Discipline Core
EC-218	Basic Engineering Skills	1	Discipline Core
	Total	**20**	

Course No.	Semester 4	Credits	Course Type
EC-221 to EC-224	Engineering Course	13	Discipline Core
EC-241 to EC-243	Engineering Course	3	Discipline Elective
EC-225 to EC-227	Engineering Course (Lab)	3	Discipline Core
SA-201	LA/CA	1	Institute Elective
	Total	**20**	

Second Year													
3rd Semester							4th Semester						
SN	Code	Subject	L	T	P	C	SN	Code	Subject	L	T	P	C
1	EC-211	Digital Electronics and Logic Design	3	0	0	3	1	EC-221	Linear Integrated Circuits	3	0	0	3
2	EC-212	Analog Electronics	3	0	0	3	2	EC-222	Analog Communication Systems	3	0	0	3
3	EC-213	Communication Theory	3	0	0	3	3	EC-223	Microprocessors and Microcontrollers	3	0	0	3
4	EC-214	VLSI Technology	3	0	0	3	4	EC-224	Electromagnetic Field Theory	3	1	0	4
5	EC-215	Network Analysis and Synthesis	2	0	0	2	5	EC-241 to EC-243	Discipline Elective -I	3	0	0	3
6	MA-218	Numerical Analysis and Statistics	3	0	0	3	6	EC-225	Linear Integrated Circuits Lab	0	0	2	1
7	EC-216	Digital Electronics and Logic Design Lab	0	0	2	1	7	EC-226	Analog Communication Lab	0	0	2	1
8	EC-217	Analog Electronics Lab	0	0	2	1	8	EC-227	Microprocessors and Microcontrollers Lab	0	0	2	1
9	EC-218	Electronics Workshop	0	0	2	1	9	SA-201	LA/CA (Institute Elective)	0	0	2	1
		Total Hours = 23				20			Total Hours = 24				20

Discipline Elective-I

EC-241	Electronic Device Modeling
EC-242	Nano Technology
EC-243	Digital Arithmetic

Curriculum for B. Tech. Programme

Course No.	Semester 5	Credits	Course Type
EC-301 to EC-304	Open Elective	3	Institute Electives
EC-311 to EC-314	Engineering Course	12	Discipline Core
EC-351 to EC-353	Engineering Course	3	Discipline Elective
EC-315, EC-316	Engineering Course (Lab)	2	Discipline Core
	Total	**20**	

Course No.	Semester 6	Credits	Course Type
EC-321 to EC-323	Engineering Course	8	Discipline Core
EC-341 to EC-343, EC-361 to EC-363	Engineering Course	6	Discipline Elective
EC-381 to EC-382	Engineering Course	2	Stream Core
HS-321	HSS Course	2	Institute Core
EC-324, EC-325	Engineering Course (Lab)	2	Discipline Core
	Total	**20**	

Third Year													
5th Semester							6th Semester						
SN	Code	Subject	L	T	P	C	SN	Code	Subject	L	T	P	C
1	EC-311	Microwave Devices and Systems	3	0	0	3	1	EC-321	Digital Signal Processing	3	0	0	3
2	EC-312	Digital Communication and Systems	3	0	0	3	2	EC-322	Antenna and Wave Propagation	3	0	0	3
3	EC-313	Control Systems	3	0	0	3	3	EC-323	Electronic Measurements and Instrumentation	2	0	0	2
4	EC-314	VLSI Design	3	0	0	3	4	EC-341 to EC-343	Discipline Elective-III	3	0	0	3
5	EC-301 to EC-304	Open Elective	3	0	0	3	5	EC-361 to EC-363	Discipline Elective-IV	3	0	0	3
6	EC-351 to EC-353	Discipline Elective-II	3	0	0	3	6	EC-381 to EC-382	Stream Core-I	2	0	0	2
7	EC-315	Digital Communication Lab	0	0	2	1	7	HS-321	Engineering Economics and Accountancy	2	0	0	2
8	EC-316	VLSI Design Lab	0	0	2	1	8	EC-324	Digital Signal Processing Lab	0	0	2	1
							9	EC-325	Antenna and Microwave Systems Lab	0	0	2	1
		Total Hours = 22				20			Total Hours = 22				20

Open Elective

EC-301	Microcontroller and Embedded System
EC-302	MEMS and Sensor Design
EC-303	Communication Systems
EC-304	VLSI Design and Techniques

Discipline Elective-II

EC-351	Switching and Finite Automata Theory
EC-352	Data Structures and Algorithms
EC-353	Object Oriented Programming

Discipline Elective-III

EC-341	Data Communication and Computer Networks
EC-342	Spread Spectrum and Wideband Communication
EC-343	Satellite Communication and Radar

Discipline Elective-IV

EC-361	Digital Image Processing
EC-362	Speech Processing
EC-363	Estimation and Detection Theory

Stream Core-I

EC-381	Hardware Description Language
EC-382	Simulation of Communication Systems

Curriculum for B. Tech. Programme

Course No.	Semester 7	Credits	Course Type
EC-411 to EC-413	Engineering Courses	9	Discipline Core
EC-431 to EC-433	Engineering Courses	3	Discipline Elective
EC-451 to EC-452, EC-471 to EC-472	Engineering Courses	4	Stream Core
EC-414, EC-415	Engineering Course (Lab)	2	Discipline Core
EC-416	Engineering Courses	2	Discipline Core
	Total	**20**	

Course No.	Semester 8	Credits	Course Type
EC-461 to EC-469, EC-480 to EC-489	Free Elective/Engineering Course/Open Elective Course (Courses available in other departments in the even semester)	6	Free Electives/Stream Elective (offered by Department/Institute Elective (Open Elective)
EC-498	Holistic Assessment	2	Institute Core
EC-499	UG Project*	12	Discipline Core
	Total	**20**	

* Students opting for internship will complete the UG project and the remaining credit requirements will be fulfilled by opting Free Elective Courses.

Fourth Year															
7th Semester								8th Semester							
SN	Code	Subject	L	T	P	C		SN	Code	Subject	L	T	P	C	
1	EC-411	Computer Architecture and Organization	3	0	0	3		1	EC-461 to EC-469	***Stream Elective-I	3	0	0	3	
2	EC-412	Wireless Communication	3	0	0	3		2	EC-480 to EC-489	***Stream Elective-II	3	0	0	3	
3	EC-413	Optical Fiber Communication	3	0	0	3		3	EC-498	General Proficiency	0	0	0	2	
4	EC-431 to EC-433	Discipline Elective-V	3	0	0	3		4	EC-499	UG Project	0	0	0	12	
5	EC-451 to EC-452	Stream Core-II	2	0	0	2		5							
6	EC-471 to EC-472	Stream Core-III	2	0	0	2									
7	EC-414	Optical Fiber Communication Lab	0	0	2	1		6							
8	EC-415	Communication Systems and Network Simulation Lab	0	0	2	1		7							
9	EC-416	Industrial Training Evaluation*	0	0	4	2		8							
		Total Hours = 24				**20**				**Total Hours = 06**				**20**	

*** Students opting for the internship will complete the UG project and the remaining credit requirements will be fulfilled by opting Free Elective Courses. For free electives, students may register for courses from portals like MOOCs, SWAYAM etc. The credits earned in these courses will be included in the marks sheet of the students.

* The students should undergo vocational training during summer vacations after the sixth semester.

Discipline Elective-V

EC-431 FPGA SoC Design

EC-432 Neural Network and Deep Learning

EC-433 VLSI Testing

Stream Core-II

EC-451 Information Theory and Coding

EC-452 Analog IC Design

Stream Core-III

EC-471 Artificial Intelligence and Machine Learning

EC-472 Embedded Systems

Stream Elective-I

EC-461	Applied Linear Algebra for Signal Processing, Data Analytics, and Machine Learning
EC-462	RF and Microwave Circuit Design
EC-463	Low Power VLSI Design Techniques
EC-464	VLSI Interconnects and Packaging
EC-465	Internet of Things and Applications
EC-466	Wavelet Transform and Applications
EC-467	RF Microelectronics
EC-468	Embedded Networking and Device Driver Programming
EC-469	VLSI Verification

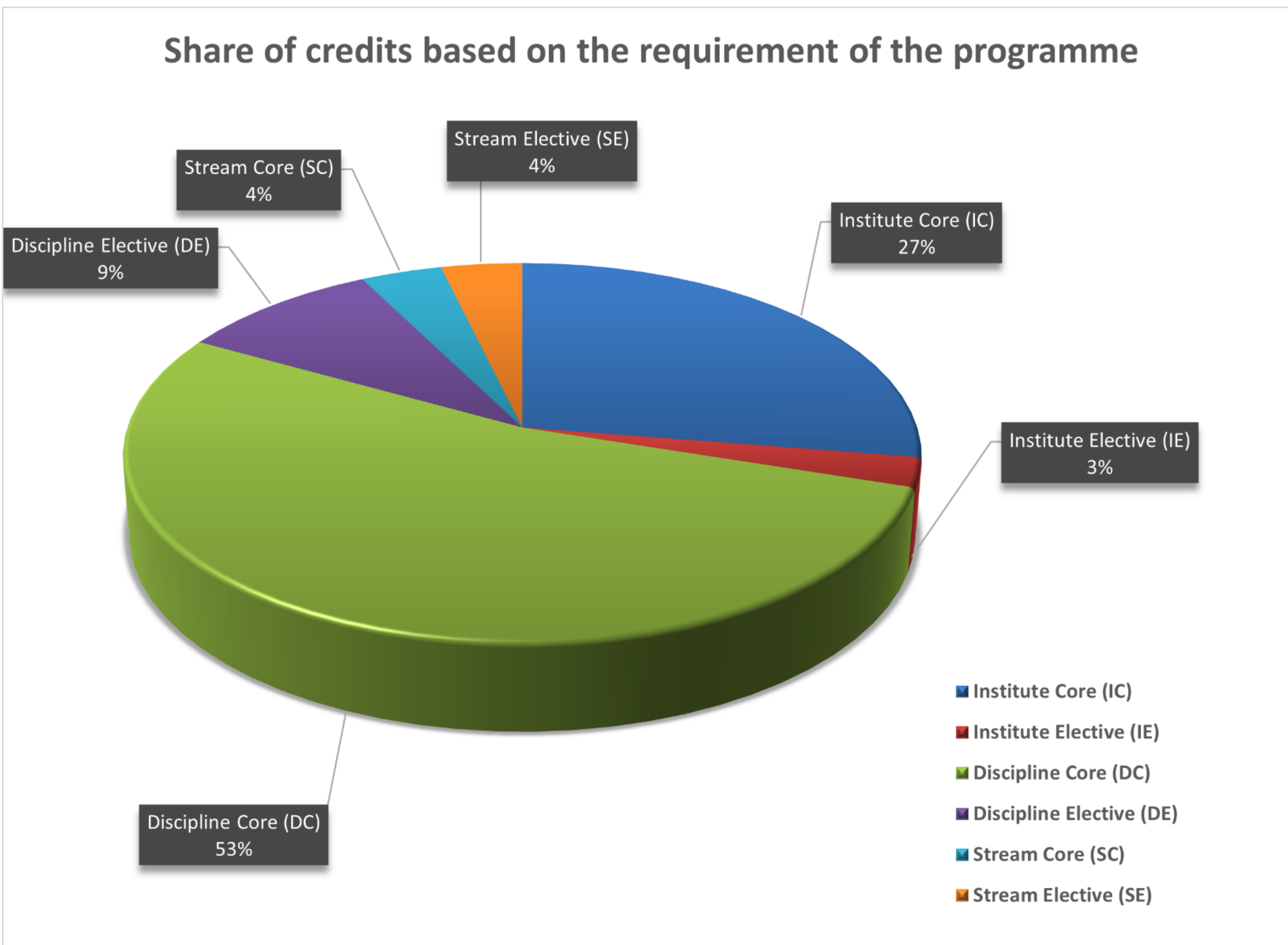
Stream Elective-II

EC-480	Compound Semiconductors: Properties & Applications
EC-481	Adaptive Signal Processing
EC-482	Advanced Antenna and Electromagnetic Metamaterials: Concept and Applications
EC-483	Nano Electronics: Devices and Materials
EC-484	Characterization of Semiconductor Materials & Devices
EC-485	Embedded Hardware Design
EC-486	Electromagnetic Interference and Compatibility
EC-487	Nanophotonics and Plasmonics: Concept and Applications
EC-488	Advanced IC Design
EC-489	Electronic Packaging

Type of Courses and Credits in Each Semester

Semester									
Type of Course	1st	2nd	3rd	4th	5th	6th	7th	8th	Total
IC	20	20	0	0	0	2	0	2	44
IE	0	0	0	1	3	0	0	4-10*	4
DC	0	0	20	16	14	10	13	12	85
DE	0	0	0	3	3	6	3	0	15
SC	0	0	0	0	0	2	4	0	6
SE	0	0	0	0	0	0	0	0-6*	6
Credits	20	20	20	20	20	20	20	20	160
									Total: 160

* Students are free to choose any combination out of Free Electives, IE and SE for 6 credits



Course Name: **Digital Electronics and Logic Design**
Course Code: **EC-211**
Course Type: **Core**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To impart knowledge about the concept of digital design, number system and codes.
- To introduce the fundamental concepts related to design of combinational logic circuits.
- To enable the students to understand the design of Sequential Circuits.

Unit Number	Course Content	Contact Hours
UNIT-01	**Introduction:** Analog versus Digital, Number systems, Binary Arithmetic (Addition, Subtraction,Multiplication and Division), Diminished radix and radix complements; BCD codes, Excess-3 code, Gray code, Hamming code, Error Detection and Correction. Digital to analog converter, Analog to digital converter	**08L**
UNIT-02	**Logic Gates and Logic Families:** Digital Logic Gates, characteristics of logic families, Various Logic Families: RTL, DTL, TTL , ECL, MOS and CMOS; Working and their characteristics.	**06L**
UNIT-03	**Combinational Logic Design:** Boolean Algebra, Basic Theorems and Properties of Boolean Algebra, Representation of function in SOP and POS form, NAND and NOR implementation Minimization of Logical functions: Karnaugh- Map method, Tabulation method, VEM method, Iterative Consensus & Generalized Consensus method, Design of Combinational circuits.	**12L**
UNIT-04	**MSI and PLD Components:** Binary Adder and Subtractor; Decoders and Encoders; Multiplexers and DE-Multiplexers circuits; Programmable Read Only Memory, Programmable Logic Arrays, Programmable Array Logic; Implementation of Combinatorial Logic using these devices, Semiconductor Memories.	**06L**
UNIT-05	**Sequential Logic Design:** Introduction and Classification of Sequential circuits, Latches & Flip-flops: Excitation Table of flip-flops, Interconversion of flip-flops, Design of Synchronous & Asynchronous Sequential circuits, Registers, Counters, finite state machine	**08L**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Understand about the concept of digital system.

CO2: Apply principles of minimization techniques to simplify digital functions.

CO3: Design and analyse the combinational electronic circuit based on digital logic.

CO4: Design and analyse the sequential electronic circuit based on digital logic.

Books and References

1. Digital Design: M. Morris Mano, Prentice Hall of India.
2. Digital Principle and Applications: Malvino and Leach, Tata Mc-Graw Hill.
3. Fundamentals of Digital Electronics: Anand Kumar, Prentice Hall of India.
4. Modern Digital Electronic: R.P.Jain Tata Mc-Graw Hill.
5. Digital Systems: Principles and Applications R. J. Tocci, Prentice Hall

Course Name: **Analog Electronics** Course Code: **EC-212** Course Type: **Core**		
Contact Hours/Week: **3L**		Course Credits: **03**
Course Objectives ● To introduce the fundamental concepts relevant to bipolar junction transistor. ● To impart knowledge about the electrical modeling and analysis of small- and large-signal amplifiers. ● To enable the students to understand the factors that cause the gain to roll-off at high frequencies.		
Unit Number	**Course Content**	**Contact Hours**
UNIT-01	**Low Frequency Transistor Amplifier:** Equivalent Circuit of BJT using h-parameter for CB, CE and CC & configuration, Calculation of Transistor Parameter for CB, CE & CC using h-parameters, Comparison of Transistor Amplifier Configuration	**05L**
UNIT-02	**Multistage Amplifier:** General Cascaded System, RC Coupled Amplifier and its Frequency Response, Merits and Demerits, Cascade Amplifier, Darlington Compound Configuration, Multistage Frequency Effect	**05L**
UNIT-03	**High Frequency Response of Transistor Amplifier:** High Frequency Model for CE Configuration, Approximate CE High Frequency Model with Resistive Load, CE Short Circuit Current Gain, HF Current Gain with Resistive Load	**06L**
UNIT-04	**Large Signal Amplifier:** Analysis and Design of class A, B, AB, C Amplifiers, Push-pull Amplifiers, Transformer Less Output Stages, Distortion Calculations	**05L**
UNIT-05	**Tuned Amplifier:** General Behavior of Tuned Amplifiers, Series and Parallel Resonant Circuit, Calculations of Circuit Impedance at Resonance, Variation of Impedance with Frequency, Q Factor of a Circuit & Coil, Bandwidth of Series and Parallel Resonant Circuit	**05L**
UNIT-06	**Feedback Amplifier:** Feedback concept, Characteristics of Negative and Positive Feedback, Effect of Negative and Positive Feedback on Input Impedance, Output Impedance, Gain, Noise and Frequency Response	**05L**
UNIT-07	**Oscillators:** Classification of Oscillators, Frequency Stability of Oscillatory Circuits, Hartley Oscillator, Colpitt Oscillators, Clapp Oscillator, Crystal Oscillator, Phase Shift Oscillator and Wien Bridge Oscillator	**05L**
Course Outcomes Upon successful completion of the course, the students will be able to CO1: Develop the ability to analyze and design analog electronic circuits using discrete components. CO2: Understand the use of small-signal models to predict gain and behavior in transistor amplifier. CO3: Describe the design trade-offs in analog amplifier circuits. CO4: Design tuned amplifiers and apply them in a communications system.		
Books and References 1. Integrated Electronics: Analog and Digital Circuits and Systems by J. Millman and C. Halkias, McGraw-Hill, Inc. 2. Electronic Devices & Circuit Theory by R. Boylestad and L. Nashelsky, Pearson. 3. Microelectronic Circuits by A. Sedra and K. Smith, Oxford University Press. 4. Electronic Fundamental Applications: Integrated and Discrete Systems by J.D. Ryder, Prentice Hall.		

Course Name: **Communication Theory**
Course Code: **EC-213**
Course Type: **Core**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To understand the basic components of communication systems.
- To prepare the mathematical background for communication signal analysis.
- To analyze signals in the presence of various types of noise and estimation of channel capacity.

Unit Number	Course Content	Contact Hours
UNIT-01	**Frequency and Time Domain Representation and Analysis:** Introduction to Information, Messages & Signals, Classification of Signals, The Discrete and Continuous Spectrum, Power Spectrum, Energy Density Spectrum, Dirac Delta Functions, Sampling Theory and Approximations, Convolution of Signals, LTI Systems.	**10L**
UNIT-02	**Random Signal Theory:** Discrete Probability Theory, Continuous Random Variables, Statistically Independent Random Variables, Probability Density Functions of Sums, Transformation of Density Functions, Ergodic Process, Correlation Functions, Spectral Density, and White Noise.	**10L**
UNIT-03	**Noise:** Atmospheric, Thermal, Shot and Partition noise, Noise Figure and Experimental Determination of Noise Figure, Shot Noise in Temperature Limited Diodes and Space Charge Limited Diodes, Pulse Response, and Digital Noise.	**05L**
UNIT-04	**Transmission Through Networks:** Networks with Random Input, Auto-correlations, Spectral Density and Probability Density Input-output Relationships, Optimum System and Non-linear Systems, Maximum Criterion, Equivalent Noise Bandwidth.	**05L**
UNIT-05	**Basic Information Theory:** Definition of Information, Units of Information, Entropy, Uncertainty and Information Rate of Communication, Redundancy, Relation Between System Capacity and Information Content of Messages, Shannon's Theorem, Discrete Noisy Channel, Channel Capacity for Different Discrete Channels.	**06L**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Perform the time and frequency domain analysis of the signals in a communication system.

CO2: Analyze the performance of communication system and the need of information theory for information transfer.

CO3: Select the blocks in a design of communication system and system capacity.

Books and References

1. Elements of Communication Theory by J. C. Hancock, McGraw-Hill Education Publisher.
2. Principles of Communication System by Taub & Schilling, McGraw-Hill Education Publisher.
3. Communication Systems by S. Haykin, Wiley Publication.

Course Name: **VLSI Technology** Course Code: **EC-214** Course Type: **Core**		
Contact Hours/Week: **3L**		Course Credits: **03**
Course Objectives • To impart knowledge about the miniaturization of Electronic Systems. • To introduce the fundamental concepts relevant to VLSI fabrication. • To enable the students to understand the various VLSI fabrication techniques.		
Unit Number	**Course Content**	**Contact Hours**
UNIT-01	**Introduction to VLSI**: Concept Miniaturization of Electronic Systems & its impact on characterization.	**03L**
UNIT-02	**Monolithic Fabrication Techniques**: Crystal growth: Source of silicon; Single crystalline and Poly crystalline; Requirement of purity for electronics industry; Electronics grade silicon production; Crystal growth techniques: Bridgeman method, Float zone method, Czocharalski method, Modified Czocharalski method; refining; Silicon Wafer Preparation & Crystal Defects. **Epitaxial Process**: Need of epitaxial layer; vapors phase epitaxy -reactor design, Chemistry of epitaxial process, Transport mechanism doping & auto doping; selective epitaxy, Epitaxial process induced defects, Molecular beam epitaxy, Merits and demerits among epitaxial processes; recent trends in Epitaxy. **Oxidation**: Importance of oxidation; types of oxidation techniques; growth mechanism & kinetics; factors affecting the growth mechanisms; silicon oxidation model, dry & wet oxidation; oxidation induced faults; recent trends in oxidation. **Lithography**: Basic steps in lithography; Lithography techniques-optical lithography, Electron beam lithography, X-ray lithography, Ion beam lithography; resists and mask preparation of respective lithographies, Printing techniques-contact, Proximity printing and projection printing; merits and demerits of lithographies; recent trends in lithography at nano regime. **Etching**: Performance metrics of etching; types of etching- wet and dry etching; dry etching techniques-ion beam or ion-milling, Sputter ion plasma etching and reactive ion etching (RIE); merits and demerits of etching; etching induced defects; recent trends in epitaxy. **Diffusion and Ion Implantation**: Diffusion mechanisms; diffusion reactor; diffusion profile; diffusion kinetics; parameters affecting diffusion profile; Dopants and their behavior, choice of dopants; Ion Implantation- reactor design, impurity distribution profile, Properties of ion implantation, Low energy and high energy ion implantation. **Metallization**: Desired properties of metallization for VLSI; metallization choices; metallization techniques — vacuum evaporation, Sputtering.	**21L**
UNIT-03	**Packaging of VLSI Chip**: Introduction to packaging; packaging process; package design considerations, Various packages types.	**04L**
UNIT-04	**Isolation Techniques in Monolithic Components:** Isolation techniques in Diodes, BJT and MOSFETs (Enhancement and depletion mode)	**04L**
UNIT-05	**Monolithic Components- Prototype Fabrication**: Prototype fabrication of Diodes, npn BJT, pnp BJT, MOSFETs (Enhancement and depletion mode), n-MOS, p-MOS, CMOS, Resistors and Capacitors.	**04L**
Course Outcomes Upon successful completion of the course, the students will be able to CO1: Identify the material properties and ambient conditions for chips fabrication. CO2: Describe the analysis of technology scaling. CO3: Understand the complexities involved in the integrated circuits. CO4: Apply principles to Identify and Analyze the various steps for the fabrication of various components CO5: Assess the various reliability issues in VLSI technology.		
Books and References 1. VLSI Technology by S.M. Sze, Tata Mc-Graw Hill 2. VLSI Fabrication Principles by S.K. Gandhi, John Willey & Sons 3. Integrated Circuits by K. R. Botkar, Khanna Publishers 4. Micromachined Transducer by G.T.A. Kovacs, McGraw Hill, 1998 5. Principles of Microelectronics Technology by D. Nagchoudhary, PHI		

Course Name: **Network Analysis and Synthesis**
Course Code: **EC-215**
Course Type: **Core**

Contact Hours/Week: **2L** | Course Credits: **02**

Course Objectives

The basic objective of this course is to introduce the fundamental theory and mathematics for the analysis of electrical circuits, frequency response and transfer function of circuits. The students will be able extend these fundamental principles into a way of thinking for problem solving in mathematics, science, and engineering.

Unit Number	Course Content	Contact Hours
UNIT-01	**NETWORK THEOREMS** Superposition and Reciprocity theorem, Thevenin's and Norton's theorem, Millman's theorem, maximum power transfer theorem, compensation, Tellegan's theorem, analysis of circuits using theorems.	**07L**
UNIT-02	**TRANSIENT ANALYSIS OF NETWORKS** Network elements, Transient response of R-L, R-C, R-L-C for DC and sinusoidal excitation, Initial condition, Solution using differential equation approach and Laplace transform method.	**07L**
UNIT-03	**NETWORK ANALYSIS** State variable method, Analytic and numerical solutions, Two Port Networks, Graph theoretic analysis for large scale networks, Formulation and solution of network graph of simple networks, State space representation, Analysis using PSPICE.	**07L**
UNIT-04	**NETWORK SYNTHESIS** Network realizability, Causality and stability, Hurwitz Polynomials, Positive real functions, Properties of RC, RL & LC networks, Foster and Cauer forms of realization, Transmission zeroes, Synthesis of transfer functions.	**07L**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Apply different network theorems to solve complex circuit problems.
CO2: Identify the transient and steady state response of different types of circuits.
CO3: Solve network problems using graphical method.
CO4: Realise the network for a given response

Books and References

1. Network Analysis and Synthesis by Franklin F. Kuo, Wiley; Second edition, 2006
2. Network Analysis, by M. E. V. Valkenburg, Pearson, 3rd edition., 2015.
3. Network and systems by D.Roy – Choudhary, New Age; Second edition 2013

Course Name: **Numerical Analysis and Statistics**
Course Code: **MA-218**
Course Type: **Core**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To introduce the fundamental concepts relevant to function of complex variable, numerical differentiation and integration and numerical solution of linear, non-linear and system of equations.
- To have the idea of evaluation of real integrals using complex variable, and to understand the concept of approximating & interpolating polynomials and finding values of function at arbitrary point.
- To impart knowledge of various numerical technique to solve ODE, and to incorporate the concept of probability to find the physical significance of various distribution phenomenon.

Course Content

Unit No	**Course Content**	**Lectures**
Unit-01	**Introduction to Complex Numbers:** Applications of De Moivre's theorem, Exponential, Circular, Hyperbolic and Logarithmic functions of a complex variable, Inverse Hyperbolic functions, Real and imaginary parts of Circular and Hyperbolic functions..	05
Unit-02	**Functions of Complex Variable:** Limit and derivative of complex functions, Cauchy-Riemann equations, Analytic functions and its applications, Complex integration, Cauchy's theorem, Cauchy's integral formula, Series of complex function, Taylor series, singularities and Laurent's series, Cauchy's residue theorem and its application for the evaluation of real definite integrals	06
Unit-03	**Interpolation:** Least square curve fit, Finite differences and difference operators, Newton's interpolation formulae, Gauss forward and backward formulae, Lagrange's interpolation.	05
Unit-04	**Numerical Integration and Differentiation:** Integration by trapezoidal and Simpson's rules 1/3 and 3/8 rule, Taylor series method, Picard's method, Euler's method, Modified Euler's method, Runge-Kutta method.	08
Unit-05	**Numerical Solution of Linear and Non Linear Equations:** Non Linear Equations: Bisection Method, Regula Falsi Method, Newton-Raphson Method, Iteration method. Linear Equations: Jacobi and Gauss Seidal Iteration methods.	06
Unit-06	**Probability and Statistics:** Review of probability, Conditional probability and sampling theorems, Discrete and Continuous Probability Distribution, Probability Mass & Probability Density Functions, Distribution function, Discrete and Continuous probability distributions, Binomial, Poisson and Normal distributions.	06

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1. Understand and analyze the concept of Numerical Solution of Linear and Non-Linear Equations, Ordinary Differential Equations and Function of complex variables.
CO2. Identify an appropriate technique to solve the linear, non-linear equations, ordinary differential equations.
CO3. Formulate the problems on related topics and solve analytically.
CO4. Apply the concepts of linear, non-linear equations, differential equations and complex analysis in various engineering problems.
CO5. Apply the concepts of probability theory in various engineering problems and demonstrate the concepts through examples and applications.

Books and References

1. Complex variables and Applications: by R. V. Churchill, T. J. Brown & R. F. Verhey, McGraw Hill.
2. A first course in complex analysis with applications: by Dennis D. Zill & P. D. Shanahan, Jones and Bartlett.
3. Numerical Methods for Scientific and Engineering Computations: by M. K. Jain, S. R. K. Iyenger and R. K. Jain, New Age International Publishers, New Delhi
4. Numerical Methods for Engineers and Scientists (2 nd Ed.): by J D Hoffman, CRC Press.
5. Numerical Analysis Mathematics and Scientific computing (3 rd ed.): by D. Kincaid and W. Cheney, American Mathematical Society.
6. Probability and Statistics for Engineers and Scientists by R.E. Walpole, S. L. Myers and K. Ye, Pearson

Course Name: **Digital Electronics and Logic Design Lab**
Course Code: **EC-216**

Contact Hours/Week: **2P** Course Credits: **01**

Course Objectives

- Familiarization with digital integrated circuits and equipment.
- Implementation and design of combinational logic circuits using different gates.
- To understand concepts of sequential circuits and to analyze and design sequential circuits.

List of Experiments

1. To study about the logic gates and verify their truth table.
2. Relization of AND and OR gates using
   (i) Diodes and resistors.
   (ii) Universal gates
3. Design and implement half adder and full adder circuits and verifies the truth table using logic gates.
4. Design and implement half subtractor and full subtractor circuits and verifies the truth table using logic gates.
5. Design and implement 4-bit binary to gray code converter and gray to binary code converter circuits.
6. Design and implement BCD to excess-3 code converter and excess-3 to BCD code converter.
7. Design and implement
   (i) 2-Bit magnitude comparator using basic gates
   (ii) 8-Bit magnitude comparator using IC 7485
8. Design and implement multiplexer and demultiplexer using logic gates and study of IC 74150 and IC 74154.
9. Design and implementation of the function using multiplexer
   (i) $F(A,B,C)=\Sigma m(1,2,5,6)$
   (ii) $F(A,B,C)=\Sigma m(0,2,5,6,7)$
10. Design and implement encoder and decoder using logic gates and study of IC 7445 and IC 74147.
11. Realization of SR, JK, D and T flip flop using gates.
12. Design and implement 3-bit synchronous up counter.
13. Design and implement 3-bit asynchronous up/down counter.
14. Design BCD to seven segment display with decoder Using IC 7447.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Understand the digital signals, applications of ICs and logic circuits.
CO2: Develop skills for designing combinational logic circuits and their practical implementation on breadboard.
CO3: Analyze, design and implement sequential logic circuits.

Course Name: **Analog Electronics Lab** Course Code: **EC-217**	
Contact Hours/Week: **2P**	Course Credits: **01**

Course Objectives

- To provide skills for designing various oscillator circuits
- To provide skills for understanding frequency stability in amplifiers
- To enable the students to plot the characteristic property of various transducers

1. To study the working of Hartley Oscillator and measure the frequency of oscillations
2. To study the working of Colpit's Oscillator and measure the frequency of oscillations
3. To study the functioning of Crystal Oscillator and measure the frequency of oscillations
4. To study the frequency response of two-stage RC coupled amplifier and find the voltage gain
5. To identify the type of feedback used in an amplifier and determine the voltage gain
6. To study the push-pull amplifier and plot the frequency response
7. To study the transformer coupled amplifier and determine the frequency response
8. To study the voltage gain and frequency response of FET amplifier
9. To study the astable, monostable and bistable multivibrators and their timing parameters.

Note: The concerned Course Coordinator may prepare the actual list of experiments/problems at the start of semester based on above generic list.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Analyze and design analog electronic circuits using discrete components

CO2: Design and implement an analog circuit project application utilizing knowledge and kills learned

CO3: Establish the biasing of an FET amplifier

CO4: Calculate power efficiency of large–signal amplifier

Course Name: **Electronics Workshop**
Course Code: **EC-218**

Contact Hours/Week: **2P** Course Credits: **01**

Course Objectives

- To understand basic electronic components and hardware systems.
- Familiarization and hands-on with various instruments and tools used in electronic system repair and service.
- Hands-on training with familiarization, identification, testing, assembling, dismantling, fabrication and repairing electronic systems.

List of Experiments

1. Familiarization/Identification of electronic components with specification (Functionality, type, size, color coding, package, symbol, cost etc. [Active, Passive, Electrical, Electronic, Electro-mechanical, Wires, Cables, Connectors, Fuses, Switches, Relays, Crystals, Displays, Fasteners, Heat sink etc.)Pulse Code Modulation & Demodulation.
2. Drawing of electronic circuit diagrams using BIS/IEEE symbols and introduction to EDA tools, Interpret data sheets of discrete components and IC's, Estimation and costing.
3. Familiarization/Application of testing instruments and commonly used tools and instruments such as : Multimeter, Function generator, Power supply, CRO, Soldering iron, De-soldering pump, Pliers, Cutters, Wire strippers, Screw drivers, Tweezers, Crimping tool, Hot air soldering and de-soldering station etc.
4. Testing of electronic components [Resistor, Capacitor, Diode, Transistor, UJT and JFET using multimeter.
5. Inter-connection methods and soldering practice. [Bread board, Wrapping, Crimping, Soldering - types - selection of materials and safety precautions, soldering practice in connectors and general purpose PCB, Crimping.]
6. Printed circuit boards (PCB) [Types, Single sided, Double sided, PTH, Processing methods, Design and fabrication of a single sided PCB for a simple circuit with manual etching (Ferric chloride) and drilling.]
7. Mini Project: Designing and assembling of any electronic circuit/system on general purpose PCB, test and show the functioning.

Note: *The concerned Course Coordinator will prepare the actual list of experiments/problems at the start of semester based on above generic list.*

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Identify and test the active and passive electronic components

CO2: Test, assemble, dis-assemble, test and repair electronic hardware systems.

CO3: Use the electronic workshop tools efficiently and effectively.

Course Name: **Linear Integrated Circuits** Course Code: **EC-221** Course Type: **Core**		
Contact Hours/Week: **3L**		Course Credits: **03**
Course Objectives ● To impart strong foundation of IC based design. ● To introduce the various applications of operational amplifiers and its integration with other devices. ● To learn circuits design using op amps for power management, signal conditioning and communication		
Unit Number	**Course Content**	**Contact Hours**
UNIT-01	**Differential And Cascode Amplifiers** Emitter coupled differential amplifiers & its circuit configurations, FET differential amplifier, Differential amplifier with swamping resistor, constant current bias & current mirror. Cascade differential amplifier stages. Level translator, Cascode configuration	**8L**
UNIT-02	**Introduction to Operational Amplifiers** The basic operational amplifier & its schematic symbol, Block diagram representation of OP-AMP, Power supply requirements of an OP-AMP, Evolution of OP-AMP, Specification of a typical OP-AMP(741).	**3L**
UNIT-03	**The Practical Op-Amp And Its Frequency Response** Input offset voltage, input bias current, input offset current. Total output offset voltage, thermal drift, error voltage, variation of OP-AMP parameter with temperature & supply voltage. Supply voltage rejection ration (SVRR), CMRR-Measurement of OP-AMP parameters, Frequency response of compensator networks, Open loop voltage gain as a function of frequency, Slew rate, causes of slew rates and its effects in application	**6L**
UNIT-04	**Operational Amplifier Configurations & Linear Application** Open loop OP-AMP configurations- The differential amplifier, inverting amplifier, non-inverting amplifier, negative feedback configurations - inverting and non-inverting amplifiers, voltage followers & high input impedance configuration, differential amplifiers, closed loop frequency response & circuit stability, single supply operation of OP-AMP, summing, scaling and averaging amplifier, voltage to current & current to voltage converters, integrators & differentiators, logarithmic & anti logarithmic amplifiers	**6L**
UNIT-05	**Active Filters & Oscillators** Advantages of active filters, classification of filters, response characteristics of butter worth, chebyshev, causal filters, first order and second order butter worth filters- low pass and high pass types. Band pass & band reject filters. Oscillator principles, types of oscillators - phase shift, Wien Bridge & quadrature. Square wave, triangular wave and saw tooth wave generators, voltage controlled oscillator	**5L**
UNIT-06	**Comparators & Converters** Basic comparator & its characteristics, zero crossing detector, voltage limiters, clippers & clampers, small signal half wave & full wave rectifiers, sample and hold circuit, ADC, DAC	**5L**
UNIT-07	**Voltage Regulators** Fixed Voltage Regulator, Adjustable voltage regulators, Switching regulators, special regulators	**3L**
Course Outcomes Upon successful completion of this course students will be able to : CO1: Understand and design the basic circuits using op-amp and perform operations and their troubleshooting CO2: To learn how to detect, amplify, store, create and manipulate signals using operational amplifiers\ CO3: To design and analyze the responses of IC based designed circuits in the area of power management, signal conditioning, analog and digital communication CO4: To develop IC based projects in the above areas		
Books and References 1. OP-AMP and Linear Integrated Circuits, Ramakant A. Gayakwad, PHI Publication. 2. Design with Operation Amplifiers and Analog Integrated circuits, Sergei Franco, TMH. 3. Integrated Electronics: Analog and Digital Circuits & System, Millman & Halkias, TMH. 4. Linear Integrated Circuits, D. Choudhari, S. Jain, New Age International limited.		

Course Name: **Analog Communication Systems**
Course Code: **EC-222**
Course Type: **Core**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To introduce the concepts of analog communication systems.
- To equip students with various issues related to analog communication such as modulation, demodulation, transmitters and receivers and noise performance.
- Differentiate between different modulation techniques and necessities of the same.

Unit Number	Course Content	Contact Hours
UNIT-01	Modulation Techniques Various Frequency Bands Used for Communication, Types of Communication and Need of Modulation. Introduction to AM, FM, PM, Frequency Spectrum of AM Waves, Representation of AM, Power Relation in AM Waves, Need and Description of SSB, Suppression of Carrier, Suppression of Unwanted Side-bands, Independent Sideband System, Vestigial Sideband System, Mathematical Representation of FM, Frequency Spectrum of AM Waves, Phase Modulation, Comparison Between Analog and Digital Modulation, Wideband and Narrow Band FM.	**08L**
UNIT-02	AM Transmitters and Receivers AM Transmitters: Generation of AM, Low Level and High Level Modulation, AM Transmitter Block Diagram, AM Modulator circuits, DSB S/C Modulator. AM Receiver: Tuned Radio Frequency (TRF) Receiver. Super Heterodyne Receiver, RF Section and Characteristics, Mixers, Frequency Changing and Tracking, IF Rejection and IF Amplifiers. Detection and Automatic Gain Control (AGC), AM Receiver Characteristics.	**07L**
UNIT-03	FM Transmitters and Receivers FM Transmitters: Basic Requirements and Generation of FM, FM Modulation Methods: Direct Methods, Variable Capacitor Modulator, Varactor Diode Modulator, FET Reactance Modulator, Transistor Reactance Modulator, Pre-emphasis, Direct FM Modulator, AFC in Reactance Modulator, Disadvantages of Direct Method, Indirect Modulators, RC Phase Shift Modulators, Armstrong FM Systems. FM Receivers: Limiters, Single and Double-Tuned Demodulators, Balanced Slope Detector, Foster-Seeley or Phase Discriminator, De-emphasis, Ratio Detector, Block Diagram of FM Receivers, RF Amplifiers, FM Receiver Characteristics.	**10L**
UNIT-04	SSB Transmitters and Receivers Generator of SSB, Balanced Modulator Circuit, Filter Method, Phase Shift Method, Third Method, Phase Cancellation Method, Demodulation of SSB, Product Demodulator, Diode Detection Technique of SSB.	**05L**
UNIT-05	Pulse Modulation Techniques Pulse Amplitude Modulation and Demodulation, Pulse Width Modulation and Demodulation, Pulse Position Modulation and Demodulation, Sampling Theorem, Time Division Multiplexing, Frequency Division Multiplexing.	**05L**

Course Outcomes

Upon successful completion of the course, the students will be able to
CO1: Differentiate AM and FM transmission.
CO2: To analyse various methods of base band /band pass analog transmission and detection.
CO3: Gain the knowledge of components of analog communication system

Books and References

1. Electronic communication Systems by G. Kennedy, McGraw-Hill Education Publisher.
2. Principals of Communication System by Taub & Schilling, McGraw-Hill Education Publisher.
3. Electronic communication Systems by S. Haykin, Wiley India Pvt. Limited Publisher.

Course Name: **Microprocessors and Microcontrollers**
Course Code: **EC-223**
Course Type: **Core**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

To give an in-depth understanding of the architectures of 8085 and 8051 Chips. Knowledge of this course will enable the students to design and develop the 8085 and 8051 based applications in real time.

Unit Number	Course Content	Contact Hours
UNIT-01	**8085 ARCHITECTURE AND ORGANISATION** Introduction to Microprocessor, Microcomputer system, Microprocessor operations, Internal Architecture of 8085, System Bus, Pin description of 8085, Need and generation of control signals, types of Registers & Timing and Control Unit.	**05L**
UNIT-02	**INSTRUCTION SET OF 8085** Instruction formats, addressing Modes, Timing effect of Addressing modes, Instruction set classification, Instruction Cycle, Machine cycles, Timing diagram, Stack and Subroutine, Interrupt types, interrupt systems and polling, Interrupt control logic, Assembly language programming.	**06L**
UNIT-03	**MEMORY AND I/O DEVICES INTERFACE** Serial and Parallel communication interface, Hardware (Circuit level) description of Registers, RAM, ROM and Secondary memories, DMA controller, memory mapped I/O & I/O mapped I/O, Generating Control Signals, Interfacing 2KX8 EPROM, 2KX8 RAM, Interfacing I/O ports to 8085, Hand shake Signals , Block diagram and working of PPI-8255, Interfacing 8255 to 8085 and LED Interface.	**06L**
UNIT-04	**INTRODUCTION TO 8051 MICROCONTROLLER** Comparison of Microprocessors and Microcontrollers, Architecture of 8051, Special Function & General Purpose Registers, Pin diagram of 8051, Instruction set, addressing modes, Role of PC and DPTR, Flags and PSW, CPU, Registers, RAM and ROM organization, Special Function Registers, I/O pins, ports and circuits, External memory, Counter and Timers, Serial Transmission and Interrupts programming.	**06L**
UNIT-05	**TIMER / COUNTER AND SERIAL COMMUNICATION IN 8051** Timer registers - Timer0, Timer1. Configuration of TMOD, TCON registers. Timer Mode1and Mode2 programming. Counter mode. Serial communication modes and protocols, RS-232 pin configuration and connection. Serial port programming (Transmitting a character, and receiving a character using serial communication) using Assembly.	**06L**
UNIT-06	**PROGRAMMING AND APPLICATIONS OF 8051** Assembly language programming, Jump Loop and Call Instructions, I/O Port Programming, Addressing Modes, Arithmetical and Logical Instructions,.Stepper Motor Interfacing, DC motor interfacing, PWM generation using 805.	**05L**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Understand the architecture cum programming models of 8085 and 8051

CO2: Know about the instruction set of 8085 and 8051.

CO3: Learn the use of instruction sets in Assembly language programming of 8085 and 8051. .

Books and References

1. Microprocessor Architecture, Programming & application with 8085 by Ramesh Gaonkar, ,Fifth Edition, Penram Publications
2. The 8051 Microcontroller and Embedded Systems” by Mohammad Ali Mazidi and Janice Gillispie Maszidi, Pearson education, 2003, ISBN- 9788131710265.
3. Microprocessors and Microcontrollers by Sunil Mathur and Jeebananda Panda, PHI.

Course Name: **Electromagnetic Field Theory**
Course Code: **EC-224**
Course Type: **Core**

Contact Hours/Week: **3L+1T** Course Credits: **04**

Course Objectives

- To understand the basic concepts of vector analysis, co-ordinate transformation and space derivative.
- To introduce the fundamental concepts relevant to the electrostatic field and application of Gauss' law.
- To introduce the fundamental concepts relevant to the magnetostatic field and application of Biot-Savart's law.
- To introduce the concept of Maxwell's equations and how electromagnetic wave propagates.
- To give the understating of wave propagation in guided media.

Unit Number	Course Content	Contact Hours
UNIT-01	**INTRODUCTION** Fundamental of vector algebra, Scalar & vector fields, Introduction and transformation on different coordinate systems: rectangular, cylindrical and spherical coordinate system, introduction to line, Surface and volume integrals, Definition of gradient, Divergent and curl of a vector and their physical significance.	**07L**
UNIT-02	**ELECTROSTATICS** Principle of Coulomb's law, Definition of electric field intensity from point charges, Field due to continuous distribution of charges on an infinite and finite line, Electric Field due to an infinite uniformly charged sheet, Gauss's law and its applications, Electric flux density, Potential fields duo to electric dipole, Laplace's and Poison's equations	**08L**
UNIT-03	**MAGNETOSTATICS** Definition and explanation on Magnetic Field intensity due to a finite and infinite wire carrying current, Magnetic field intensity on rectangular loop carrying current, Ampere's Circuital law and its applications, Biot-Savart's law, Lorentz force equation for a moving charge, Magnetic Vector Potential	**08L**
UNIT-04	**TIME VARYING EM FIELD** Maxwell's equation in differential and integral vector form and their interpretations, Continuity of currents, Conduction and displacement current, Boundary conditions, Helmholtz equations, uniform plane wave in dielectric and conductor media, Skin effect and depth of penetration, reflection and refraction of plane waves at boundaries for normal incidence and surface impedance, Energy Flow and Poynting theorem	**10L**
UNIT-05	**TRANSMISSION LINE** Transmission line model, Parameters and properties of transmission line equations, Reflections in transmission lines, Voltage, current and impedance relations-open, Short circuit and matched lines, Standing wave ratio, Impedance matching, Quarter and half wave lines, Single stub and double stub matching.	**09L**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Describe the fields using vector algebra and filed transformation from one co-ordinate system to other
CO2: Describe the force between charges and equipotential surfaces and electrostatic shielding/ screening.
CO3: Describe the magnetic field due to a current element and force on a charge particle due to magnetic field.
CO4: Describe the electromagnetic wave phenomenon and power carried by an electromagnetic wave.
CO5: Understand how the transmission line theory bridges the gap between circuit theory and field theory.

Books and References

1. Elements of Engineering Electromagnetics by Matthew N.O. Sadiku, Oxford University Press.
2. Electromagnetic Waves and Radiating Systems by Jordan and Balmain, PHI, Second Ed.
3. Engineering Electromagnetics by William Hayt, TATA McGraw-Hill.
4. Electromagnetic by J.D. Kraus, McGraw-Hill.

Course Name: **Linear Integrated Circuits Lab**
Course Code: **EC-225**

Contact Hours/Week: **2P** Course Credits: **01**

Course Objectives

- To learn practical applications of operational amplifier.
- To design and develop circuits using operational amplifiers.
- To learn how to detect, amplify, store, create and manipulate signals using operational amplifiers.

List of Experiments

1. To demonstrate the relationship between input and output in for the inverting and non-inverting configuration of the Op-Amp. 741.
2. To verify the function of OP-Amp's a summer and as a difference amplifier.
3. To perform the mathematical operation of differentiation using basic and practical circuit of Op-Amp's.
4. To perform the mathematical operation of integration using basic and practical circuit of Op-Amp's.
5. To study the half wave and full wave rectifier circuits using Op-Amp's
6. To design a first order butter worth low pass and high pass filter and determining its frequency response.
7. To plot the frequency response of the band pass filter for a specified frequency range.
8. To design a square, triangular and sawtooth wave generator using Op-Amp's.
9. To design the Wien Bridge oscillator using Op-Amp's.
10. To study the clipping and clamping circuits using operational amplifiers.

Note: *The concerned Course Coordinator will prepare the actual list of experiments/problems at the start of semester based on above generic list.*

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: To learn the basic applications of the operational amplifier

CO2: To learn how to detect, amplify, store, create and manipulate signals using operational amplifiers

CO3: To design and analyze the responses of IC based designed circuits in the area of power management, signal conditioning, analog and digital communication

Course Name: **Analog Communication Lab**
Course Code: **EC-226**

Contact Hours/Week: **2P** Course Credits: **01**

Course Objectives

- To understand practical implementation of various analog modulation schemes.
- To analyse and measure the performance of various analog modulation schemes.
- To understand practical implementation of pulse modulation, TDM and FDM.

1. 1.Amplitude Modulation and Demodulation
2. DSB SC Modulation and Demodulation
3. SSB SC Modulation and Demodulation
4. Frequency Modulation and Demodulation
5. To Observe and Measure Frequency Deviation and Modulation Index.
6. Pre Emphasis - De Emphasis.
7. PAM Generation and Reconstruction
8. PWM Generation and Reconstruction
9. PPM Generation and Reconstruction
10. Verification of Sampling Theorem
11. Time Division and Frequency Division Multiplexing
12. Phase Locked Loop

Note: The concerned Course Coordinator may prepare the actual list of experiments/problems at the start of semester based on above generic list.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Design and implement AM and FM based analog communication systems.

CO2: Design and implement Pulse modulation systems.

CO3: Design and implement FDM and TDM systems.

CO4: Analyse the performance measure of Analog Communication Systems.

Course Name: **Microprocessors and Microcontrollers Lab**
Course Code: **EC-227**

Contact Hours/Week: **2P** Course Credits:**01**

Course Objectives

- To provide skills for designing flowcharts and writing algorithms
- To provide skills for writing Embedded programs
- To enable the students to debug programs

List of Experiments

1. On 8085 kit, find the Factorial of a number
2. On 8085 kit, find if a number is prime or a perfect square
3. On 8051 kit, write a program to perform serial data transfer
4. On 8051 kit, generate square wave for a given frequency and duty cycle
5. On cortex M3, write a program to perform LED binking
6. On cortex M3, write a program to verify Digitalout
7. On cortex M3, write a program to display clock on 7-segment display
8. On cortex M3, write a program to generate Analog output
9. On cortex M3, write a program to read in Analog input
10. On cortex M3, write a program to debug using serial pc
11. On cortex M3, write a program to generate PWM output
12. On cortex M3, write a program to perform counting on LCD counter
13. On cortex M3, write a program to learn Interrupt function
14. On cortex M3, write a program to understand 12c master and slave communication
15. On Intel Galileo Gen 2, plot a graph for analog input
16. On Intel Galileo Gen 2 write an Array in Arduino

Note: *The concerned Course Coordinator will prepare the actual list of experiments/problmes at the start of semester based on above generic list.*

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Write algorithms and programming task involved for a given problem
CO2: Design and develop modular programming skills
CO3: Trace and debug a program

Course Name: **Microwave Devices and Systems**
Course Code: **EC-311**
Course Type: **Core**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- Develop students' understanding of the basic concepts and theories of microwave engineering.
- Equip students with the skills and knowledge needed to design, analyse, and optimize microwave systems and devices.
- Provide students with practical experience in the use of state-of-the-art microwave test equipment.
- Develop students' ability to apply microwave engineering concepts to solve real-world problems in a range of fields.

Unit Number	Course Content	Contact Hours
UNIT-01	**INTRODUCTION OF MICROWAVE AND WAVEGUIDE** Need of microwave, Advantages and application of microwave signals, Frequency Allocations and Frequency Plans, Rectangular Waveguide and its Analysis, Circular Waveguide and its Analysis, Modes of Propagation, Dominant Modes, Cut-off wavelength, Mode Excitation.	**07 L**
UNIT-02	**MICROWAVE TUBES** Limitations of Conventional Tubes at Microwave Frequency, Two cavity, Multi-cavity Klystron Amplifiers their Analysis, Reflex Klystron and their analysis, Basics of Magnetrons, Traveling Wave Tube and their Applications.	**07 L**
UNIT-03	**MICROWAVE DEVICES** Scattering Matrix of Microwave Waveguide Junction, Properties of Scattering Matrix, E-Plane Tee, H-plane Tee, Magic Tee, Directional Couplers, Ferrite Devices, Gyrator, Isolator, Circulators.	**06L**
UNIT-04	**MICROWAVE SOLID-STATE DEVICES** Gunn Diode and its Modes of Operation, Avalanche IMPATT Diode, TRAPATT Diode, Operations and V-I Characteristics of Tunnel Diode, Schottky Diode, Varactor Diodes, PIN Diode and its Applications.	**05 L**
UNIT-05	**MICROWAVE COMPONENT AND MEASUREMENT DEVICES** VSWR meter, Frequency meter, Spectrum analyser, Network analyser, Tunable detector, Slotted line carriage, Power meter, Phase Shifter, Matched Load, Waveguide Transition, Attenuators.	**06 L**
UNIT-06	**MICRO-STRIP LINES:** Introduction on Micro Strip Lines, Characteristic impedance of micro Strip Lines, Losses in Micro Strip Lines, Quality Factor of Micro Strip, Parallel Strip Lines, Coplanar Strip Lines and Shielded Strip Lines.	**05 L**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Demonstrate an understanding of the behaviour of electromagnetic waves in waveguides.

CO2: Understand the operating principles and applications of microwave tubes.

CO3: Understand the properties and behaviour of various passive microwave devices such as waveguide junction, directional couplers, power dividers, etc.

CO4: Understand the performance of microwave components, measuring devices and solid-state devices.

CO5: Analyse the characteristics of micro-strip lines including impedance, losses, etc.

Books and References

1. Microwave Devices and Circuits by Samuel Y. Liao, Prentice-Hall, U.S.A.
2. Microwave Engineering by David M. Pozar, Wiley Publication, New Delhi.
3. Foundations for Microwave Engineering by R.E. Collins, Wiley Inter-science, New York.
4. Microwave Engineering by S. Das, Oxford University Press.

Course Name: **Digital Communication and Systems**
Course Code: **EC-312**
Course Type: **Core**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To impart knowledge about the key modules of digital communication systems with emphasis on digital modulation techniques.
- To introduce the fundamental concepts relevant to reception of digital signals
- To enable the students to understand the concept and basics of information theory and the basics of channel coding/decoding.

Unit Number	Course Content	Contact Hours
UNIT-01	**Introduction:** Concepts of Digital Communication, Advantages/Disadvantages of Digital Communication Systems over Analog Communication Systems. Block Diagram of Basic Digital Communication Transmitter/Receiver.	**02L**
UNIT-02	**Analog to Digital Conversion:** Noisy Communications Channels, Sampling Theorem: Low Pass Signals And Band Pass Signals, Pulse Amplitude Modulation, Channel Bandwidth For PAM Signal, Natural Sampling, Flat Top Sampling, Signal Recovery & Holding, Quantization of Signal, Quantization Error, Pulse Code Modulation (PCM), Delta Modulation, Adaptive Delta Modulation.	**08L**
UNIT-03	**Digital Modulation Techniques:** Binary Phase Shift Keying, Differential Phase Shift Keying, Differential Encoded PSK, QPSK, Quadrature Amplitude Shift Keying (QASK), Binary Frequency Shift Keying.	**8L**
UNIT-04	**Data Transmission:** Base Band Signal Receiver, Probability of Error, Optimum Filter, White Noise-Matched Filter, Probability of Error of The Matched Filter, Coherent Reception: Correlation, Application of Coherent Reception In PSK And FSK. Correlation Receiver for QPSK.	**7L**
UNIT-05	**Noise in Pulse Code & Delta Modulation Systems:** PCM Transmission, Calculation of Quantization Noise, O/P Signal Power, The Effect of Thermal Noise, O/P Signal to Noise Ratio in PCM, Delta Modulation, Quantization Noise in Delta Modulation, The O/P Signal to Quantization Noise Ratio in Delta Modulation, O/P Signal to Noise Ratio in Delta Modulation.	**6L**
UNIT-06	**Information Coding and Decoding:** Coding for Error Detection and Correction, Basics of Block Coding and Decoding, Introduction to Cyclic Codes, Basic Convolution Coding /Decoding and Viterbi Algorithm.	**05L**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Apply the knowledge of statistical theory of communication and explain the conventional digital communication system.

CO2: Apply the knowledge of signals and system and evaluate the performance of digital communication system in the presence of noise.

CO3: Apply the knowledge of digital electronics and describe the error control codes like block code, cyclic code.

CO4: Design as well as conduct experiments, analyze and interpret the results to provide valid conclusions for digital modulators and demodulator using hardware components and communication systems using CAD tool.

Books and References

1. Principles of communication systems by Taub & Schilling, McGraw-Hill Education (India).
2. Communication Systems by Simon Haykin, John-Wiley & Sons, Inc.
3. Digital Communication by J.G. Proakis, McGraw – Hill.
4. Digital Communications: Fundamentals & Applications by B. Sklar, Pearson Education.
5. Introduction to Digital Communication by R.E. Zimer & R.L. Peterson, PHI.

Course Name: **Control Systems**
Course Code: **EC-313**
Course Type: **Core**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To discuss basic concepts of linear systems.
- To provide a basic understanding of mathematical model of linear systems.
- To introduce the fundamental concept of different control components.
- To enable the students to understand the concepts of time and frequency domain analysis.
- The students can be able to learn stability analysis.
- To discuss the concept of state variable.

Unit Number	Course Content	Contact Hours
UNIT-01	**Basic Concepts:** Historical Review, Definitions, Classification, Relative Merits and Demerits of Open and Closed Loop Systems.	**03L**
UNIT-02	**Mathematical Models of Control System:** Linear and Non-Linear Systems, Transfer Function, Mathematical Modeling of Electrical, Mechanical and Thermal Systems, Analogies, Block Diagrams and Signal Flow Graphs.	**07L**
UNIT-03	**Control Components:** DC Servomotor, AC Servomotor, Potentiometers, Synchronous, Stepper Motor.	**05L**
UNIT-04	**Time and Frequency Domain Analysis:** Transient and Frequency Response of First and Second Order Systems, Correlationship Between Time and Frequency Domain Specifications, Steady-State Errors and Error Constants, Concepts and Applications of P, PD, PI and PID Types of Control.	**07L**
UNIT-05	**Stability Analysis:** Definition, Routh-Hurwitz Criterion, Root Locus Techniques, Nyquist Criterion, Bode Plots, Relative Stability, Gain Margin and Phase Margins.	**07L**
UNIT-06	**State Variable Analysis:** Introduction, Concept of State, State Variables & State Models, State Space Representation of Linear Continuous Time Systems, State Models for Linear Continuous Time Systems, State Variables and Linear Discrete Time Systems, Solution of State Equations, Concept of Controllability & Observability.	**07L**

Course Outcomes

Upon successful completion of the course, the students will be able to
CO1: Demonstrate fundamentals of (feedback) control systems.
CO2: Explain mathematical model for different systems.
CO3: Explain different control components.
CO4: Explain the relation between time and frequency domain specification and employ controllers such as P, PD, PI and PID control design.
CO5: The use and significance of the different tools for control system design and analysis such as Nyquist plots, Bode plots, and Evans plots (root locus).
CO6: Demonstrate concept of state variable and state model.

Books and References

1. Discrete-Time Control Systems by K. Ogata, Prentice Hall India Learning Pvt. Ltd.
2. An Introduction to Control Systems by K. Warwick, World Scientific Publishing Co. Pvt. Ltd.
3. Control System Fundamentals by W. S. Levine, CRC Press.
4. Modern Control Systems by R. C. Dorf and R. H. Bishop, Prentice Hall.

Course Name: **VLSI Design**
Course Code: **EC-314**
Course Type: **Core**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To introduce the fundamental concepts of MOSFETs and physical design of VLSI circuits.
- To impart knowledge about various CMOS VLSI Design styles.
- To design MOS memories and learn high performance VLSI design techniques.
- To enable the students to understand the parameters on which the circuit performance depends and their control strategies.

Unit Number	Course Content	Contact Hours
UNIT-01	**MOSFETS**: Fundamentals of Enhancement Mode MOSFETs, Depletion Mode MOSFETs, Weak & strong Inversion Conditions, Threshold Voltage Concept in MOSFETs, Current-Voltage (IV), Characteristics of a MOSFET, Limitations in IV Model, MOSFET parasitics. Trends & Projections in VLSI Design & Technology, Flow of VLSI Circuit Design, Scaling in MOS devices.	**06L**
UNIT-02	**VLSI Design Styles**: NMOS and CMOS Process flow, Concept of Noise Margin, Resistive MOS inverter design, voltage transfer characteristics, Inverter Threshold Voltage. Active loads and their importance, NMOS Inverter design, Critical voltages for inverter design, CMOS Inverter design and properties, CMOS Delay and Power Dissipation, Parallel & Series Equivalent circuits, Static CMOS Circuit Design.	**11L**
UNIT-03	**VLSI Physical Design**: Stick Diagrams, Physical Design Rules, Layout Designing, Euler's Rule for Physical Design, Reliability issues in CMOS VLSI, Latching.	**05L**
UNIT-04	**High Performance Logics**: Precharge -Evaluate logic, Dynamic CMOS logic circuits. Transmission gate logic.	**06L**
UNIT-05	**MOS Memory Design**: Types of MOS memories, ROM memory design, SRAM cell design and DRAMs.	**06L**
UNIT-06	**CMOS Amplifiers**: Single stage MOS Amplifiers: Common Source amplifier, Common Gate amplifier, Common Drain amplifier. Differential Amplifier analysis. Merits and advantages of differential amplifiers.	**06L**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Comprehend and utilize digital and analog VLSI circuit design techniques and their advancements.
CO2: Identify, select and design any static and dynamic CMOS VLSI logic circuits for practical applications and memory design.
CO3: Analyse CMOS circuits with equivalent parameters and build upon the theoretical, mathematical and experimental models.
CO4: Use EDA tools and SPICE for analysis, verification and physical design simultaneously for efficient and optimal design of VLSI circuits.
CO5: Generate interest and competence in self-directed continuing professional development and for sustainable research and development in VLSI design for societal and global interest.

Books and References

1. CMOS Digital Integrated Circuits-Analysis & Design by S.M. Kang and Y. Leblebici, TMH.
2. Design of Analog CMOS Integrated Circuits by B. Razavi, TMH.
3. Solid State Electronic Devices by B.G. Streetman and S. Banerjee, PHI.
4. Principles of CMOS VLSI Design- A Systems Perspective by Neil H E Weste and K. Eshraghian.
5. Introduction to VLSI by K. Eshraghian and Pucknell, PHI.

Course Name: **Digital Communication Lab** Course Code: **EC-315**	
Contact Hours/Week: **2P**	Course Credits: **01**

Course Objectives

- To understand practical implementation of various digital modulation schemes.
- To analyze and measure the performance of various digital modulation schemes.
- To understand practical implementation of line coding formats.

List of Experiments

1. Time Division Multiplexing & De-multiplexing.
2. Pulse Code Modulation & Demodulation.
3. Delta Modulation and Demodulation.
4. Adaptive Delta Modulation and Demodulation.
5. Binary Phase Shift Keying (BPSK) Modulation and Demodulation.
6. Frequency Shift Keying (FSK) Modulation and Demodulation.
7. Amplitude Shift Keying (ASK) Modulation and Demodulation.
8. Quadrature Phase Shift Keying (QPSK) Modulation and Demodulation
9. To Study Characteristics of Gaussian Noise and to Measure its Spectral Height in Frequency Band over Which Its Spectral Density is flat.
10. To Study Line Coding Techniques.
11. To Study the Characteristics of The Phase Shifter, Multiplier and The Integrate-And-Dump Filter.

Note: *The concerned Course Coordinator will prepare the actual list of experiments/problems at the start of semester based on above generic list.*

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Design and implement BPSK, QPSK, ASK and BFSK based digital communication systems.

CO2: Design and implement PCM, DM and ADM based digital communication systems.

CO3: Analyze the performance measure of Digital Communication Systems.

Course Name: **VLSI Design Lab**
Course Code: **EC-316**

Contact Hours/Week: **2P** Course Credits: **01**

Course Objectives

- To learn Physical Design i.e. Layout making of VLSI circuits.
- Programming in SPICE and its use for design and analysis.
- To extract various design parameters from simulation results.
- Provide students with an opportunity to practice on EDA softwares & tools for VLSI Design.

List of Experiments

1. Familiarity with Tanner L-EDIT EDA Tools: To study the main features and utilities of the tools for design and physical design of circuits. Report the pros and cons of the tool.
2. To find dc and transient response of a CMOS Inverter Circuit and its Physical Design using minimum dimension criteria. Hence extract various design parameters from simulation results.
3. To simulate transient response of CMOS NAND Gate (Fig.1). Physical Design the logic gate or design the layout, using minimum dimension criteria.

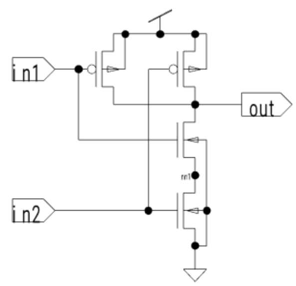


Fig.1. CMOS NAND Gate.

4. Simulate firstly minimum dimension CMOS inverter circuit using SPICE. Hence analyze and plot power and delay variations with voltage scaling, and ii)Load variations.
5. Simulate CMOS NAND, NOR and XOR circuits using SPICE. Hence analyze and plot their power and delay variations i)For dimension, load and frequency variations.
6. Design a differential amplifier circuit for a voltage gain of 10. Design its layout.
7. Physical Design of a complex circuit AOI/ OAI, making layout using Euler's method, for delay, power and area centric designs.
8. Design a four input CMOS NAND and NOR gates with the constraint propagation delay not exceeding 10ns. Compare LVS.
9. Familiarization with Cadence or Xilinx EDA tools. To study the main features and utilities of the tools for design and physical layout design. Report the same in practical file.
10. Design NAND NOR, XOR circuits using EDA Tools, for delay and power centric design criteria.
11. Physical design a full adder circuit using minimum number of CMOS NAND gates.
12. Design triangular wave generator using OP-Amps in SPICE.

Note: *The concerned Course Coordinator will prepare the actual list of experiments/problems at the start of semester based on above generic list.*

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Identify and abstract the programming task involved for a given VLSI problem.

CO2: Design and develop programming skills for VLSI circuit design.

CO3: Trace and debug any VLSI related program.

Course Name: **Digital Signal Processing**
Course Code: **EC-321**
Course Type: **Core**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

Digital Signal processing explains the basics of discrete time signals and systems. It focuses on the operation on the signals in time and frequency domain. It covers the different design techniques for FIR and IIR filters and also their realization structures.

Unit Number	Course Content	Contact Hours
UNIT-01	**DISCRETE-TIME SIGNALS AND SYSTEMS** Basic Elements of a Digital Signal Processing System, Advantages of Digital Signal Processing, Classification of Signals, The Concept of Frequency In Continuous-Time and Discrete-Time Domain, Discrete-Time Signals and Systems, Analysis Of Discrete-Time Linear Shift-Invariant Systems, Linearity, Causality And Stability Criterion, Discrete-Time Systems Described By Difference Equations.	**07L**
UNIT-02	**DISCRETE-TIME FOURIER TRANSFORM** The Fourier Transform Of Discrete-Time Signals (DTFT), Properties Of The DTFT, The Frequency Response Of An LTI Discrete-Time System, The Fourier Series Of Discrete-Time Signals (DTFS).	**05L**
UNIT-03	**DISCRETE FOURIER TRANSFORM:** Frequency Domain Sampling And The DFT, Properties Of The DFT, Linear Filtering Methods Based On The DFT, Efficient Computation Of The DFT: Decimation-In-Time And Decimation-In Frequency Fast Fourier Transform Algorithms.	**07L**
UNIT-04	**Z-TRANSFORM** Introduction To The Z-Transform & The Inverse Z-Transform, Properties Of The Z-Transform, Relationship Between The Fourier Transform And The Z-Transform, Rational Z-Transforms & The System Function, Analysis Of Linear Time-Invariant Systems In The Z-Domain.	**05L**
UNIT-05	**DIGITAL FILTER STRUCTURES** Digital Filter Categories, Realization Structures For FIR & IIR Digital Filters, Representation Of Numbers: Fixed-Point, Floating Point, Error Resulting From Rounding And Truncation.	**04L**
UNIT-06	**DIGITAL FILTER DESIGN** General considerations; design of IIR filter from Analog filters: IIR filter design using Approximation of derivative, impulse invariant method, Bilinear transformation; Design of linear phase FIR digital filters: Symmetry and Anti-symmetry FIR filters, FIR digital filter design using the windowing method and the frequency-sampling method.	**08L**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Understand the discrete time signals and systems.

CO2: Understand the Fourier transform and Fourier series of discrete time signals.

CO3: Analysis the discrete time signals in frequency domain using DFT and FFT.

CO4: Understand the Z-Transform and its properties.

CO5: Understand the realization structures for FIR and IIR digital filters.

CO6: Analysis the design characteristic of FIR and IIR filters.

Books and References

1. Digital Signal Processing: Principles, Algorithms and Applications by John G. Proakis & Dimitris G. Manolakis, Pearson Education.
2. Digital Signal Processing by Sanjit K. Mitra, Tata McGraw Hill Publication.

Course Name: **Antenna and Wave Propagation**
Course Code: **EC-322**
Course Type: **Core**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To impart knowledge about the Electromagnetic radiation, antenna basic parameters, antenna arrays and their patterns, special antennas, wave propagation over ground, through troposphere and ionosphere.
- To introduce the fundamental concepts relevant to electromagnetic theory and its application to antennas and wave propagation.

Unit Number	Course Content	Contact Hours
UNIT-01	**Electromagnetic radiation:** Recap of Maxwell's equations and wave equations, Retarded potentials, Vector potential A for an electric current source J, Radiation phenomenon from an oscillation dipole, Infinitesimal Dipole Antenna, Small dipole, Half wave dipole and quarter wave monopole antenna and its radiation characteristics.	**08L**
UNIT-02	**Antenna Fundamentals:** Radiation Pattern, Radiation Power Density, Radiation Intensity, Beamwidth, Directivity, Antenna Efficiency, Gain, Beam Efficiency, Bandwidth, Polarization, Input Impedance, Antenna Vector Effective Length and Equivalent Areas, Maximum Directivity and Maximum Effective Area, Friis Transmission Equation and Radar Range Equation	**08L**
UNIT-03	**Antenna Arrays:** Classification of arrays, Linear arrays of two-point sources, Linear arrays of npoint sources, Pattern multiplication, Array factor, Linear arrays of equal amplitude and spacing (Broad side and end fire arrays) of n-point sources, Directivity and beam width, Non-uniform arrays excitation using Binomial series	**09L**
UNIT-04	**Special Antennas:** Basics of Loop antennas, Folded dipole antennas, Yagi-Uda antenna, Horn antennas, Helical antennas, Microstrip Patch antennas and its feeding techniques.	**08L**
UNIT-05	**Wave Propagation:** Ground Wave Propagation: Characteristics for ground wave propagation, Reflection at the surface of a finitely conducting plane and on earth, Attenuation Calculation of field strength at a distance. Ionosphere Propagation: ionosphere structure, Effective characteristics of the various layers of ionosphere, Reflection and Refraction of waves by ionosphere, Space Wave Propagation: Space wave range, Troposphere waves-reflection, Refraction, Duct propagation, Troposphere propagation link.	**09L**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Understand the mechanism of radiation and will be able to Identify basic antenna parameters

CO2: Design and analyse wire antennas

CO3: Design and analyse antenna arrays

CO4: Analyse different antennas

CO5: To identify characteristics of radio wave propagation

Books and References

1. Antennas Theory by C.A. Balanis, Willey Publication.
2. Antennas by J. D. Kraus, McGraw Hill.
3. Antennas and Radio Propagation by R. E. Collins, McGraw-Hill.
4. Electromagnetic waves & radiating System, E. C. Jorden and B. C. Balmann, P.H.I.

Course Name: **Electronic Measurements and Instrumentation**
Course Code: **EC-323**
Course Type: **Core**

Contact Hours/Week: **2L** Course Credits: **02**

Course Objectives

- To introduce the various methods of instrumentation and parameters
- To impart knowledge about the various AC and DC measurement instruments
- To enable the students to understand the various types and transducers

Unit Number	Course Content	Contact Hours
UNIT-01	**Instrumentation Scheme & Characteristics:** Definition, Application and Methods of Measurements, Instrument Classification, Functional Elements of an instrument, Input Output Configuration of Measuring Instruments, Methods of Correction for Interfering and Modifying Inputs, Standards, Calibration, Accuracy, Precision, Loading Effects, Selection of Instruments, Measurement Systems–Static and Dynamic Characteristics, Zero Order, First Order and Second Order Systems and their Response	**07L**
UNIT-02	**Error analysis:** Types of Errors, Methods of Error Analysis, Uncertainty Analysis, Statistical Analysis, Gaussian Error Distribution, Rejection of Data, Method of Least Square, Curve Fitting, Graphical Analysis, General Consideration in Data Analysis	**07L**
UNIT-03	**DC & AC Measurement:** Analog Ammeter, Voltmeter and Ohmmeters, PMMC, Moving Iron, Electro-dynamometer, Electrostatic, Ohmmeter, Digital type voltmeter, AC Voltmeter using Rectifier, True RMS Voltmeter, Digital VOM Meter	**05L**
UNIT-04	**Transducers:** Principles, Classification, Guidelines for Selection, Requirements, Types and Application of Transducers, Resistance, Capacitance, Inductance Transducers, Potentiometer, Strain Gauges, LVDT, Piezo Electric Transducers, Resistance Thermometers, Thermocouples, Thermistors, Photosensitive Device, Capacitive Transducer, Hall Effect Transducers, Pyroelectric Sensors, Thermo Sensors using Semiconductor Devices, Thermal Radiation Sensor, Measurement of Force, Pressure, Velocity, Humidity, Moisture, Speed, Proximity and Displacement	**08L**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Describe basic principles of instrumentations and measurements associated with engineering, design and the general technology applications.

CO2: Use and calibrate common errors in instruments and their analysis.

CO3: Selecting appropriate sensors, instruments, display devices and analyzers for the task under consideration.

CO4: Understanding various transducers available, their operating principles, strengths, and weaknesses.

Books and References

1. Modern Electronic Instrumentation and Measurement Techniques by A.D. Helfrick and W.D. Cooper, Prentice Hall.
2. Instruments and Measurements by C.N. Herrick, Mc Graw Hill.
3. Electrical and Electronic Measurements and Instrumentation by A. K Sawhney, Dhanpat Rai Publishing.

Course Name: **Engineering Economics and Accountancy**
Course Code: **HS-321**
Course Type: **Core**

Contact Hours/Week: **2L** Course Credits: **02**

Course Objectives

- To impart knowledge about the Economics and its applicability to the Engineers
- To introduce the fundamental concepts of economics
- To enable the students to understand the factors that causes the changes in economic conditions of the entrepreneur

Unit Number	Course Content	Contact Hours
UNIT-01	**Introduction to Engineering Economics:** Definitions, Nature, Scope and application; Difference between Micro Economics and Macro Economics; Theory of Demand & Supply: Meaning, Determinants, Law of Demand, Elasticity of demand, Demand Forecasting, Law of Supply, Equilibrium between Demand & Supply.	**06L**
UNIT-02	**Production and Cost**: Production functions, Isoquant, Least Cost combination, Laws of Returns to Scale. Economics and Diseconomies of Scale of production, Cost and Cost curves, Revenue and Revenue curve, Break even analysis.	**06L**
UNIT-03	**Costing and Appraisal:** Cost elements, Economic cost, Accounting cost, Standard cost, Actual cost, Overhead cost, Cost control, Criteria of project appraisal, Social cost benefit analysis	**05L**
UNIT-04	**Markets**: Meaning, Types of Markets, Characteristics (Perfect Competition, Monopoly, Monopolistic Competition, Oligopoly) Price and Output Determination; Product Differentiation; Selling Costs; Excess Capacity.	**05L**
UNIT-05	**Money**: Meaning, Functions, Types; Monetary Policy- Meaning, Objectives, Tools; Fiscal Policy:- Meaning, Objectives, Tools. **Banking:** Meaning, Types, Functions, Central Bank: its Functions, concepts CRR, Bank Rate, Repo Rate, Reverse Repo Rate, SLR.	**04L**
UNIT-06	**Depreciation:** Meaning of depreciation, causes, object of providing depreciation, factors affecting depreciation, Methods of Depreciation: Straight line method, Diminishing balance method, Annuity method and Sinking Fund method	**04L**
UNIT-07	**Financial Accounting:** Double entry system (concept only), Rules of Double entry system, Journal(Sub-division of Journal) , Ledger, Trial Balance Preparation of final accounts-Trading Account. Profit and Loss account, Balance Sheet.	**06L**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Identify the challenges of the economy as entrepreneur/manufacturer as well as consumer

CO2: Describe the economic system at the micro and macro level

CO3: Apply principles of economics and accountancy in the professional, personal and societal life

CO4: Assess the role of engineering economics and accounting in attaining economic efficiency

Books and References

1. Principles of Micro Economics by Mceachern & Kaur, Cengage Publication.
2. Managerial Economics by Craig Peterson & W Cris Lewis, PHI Publication.
3. Modern Microeconomics by A. Koutsoyiannis, Macmillan.
4. Managerial Economics Theory and Applications by D. M. Mithani, Himalaya Publication House.
5. Fundamental of Managerial Economics by Mark Hirschey, South Western Educational Publishing.
6. Engineering Economics by Degramo, Prentice Hall.
7. Financial Accounting–A Managerial Perspective by R. Narayanaswamy, PHI.
8. Introduction to Accounting by J.R. Edwards and Marriot, Sage Publication.
9. Cost Accounting by Jawahar Lal, Tata McGraw Hill.
10. Project Planning Analysis, Selection, Implementation and Review by Prasanna Chandra, Tata McGraw Hill

Course Name: **Digital Signal Processing Lab**
Course Code: **EC-324**

Contact Hours/Week: 2P **Course Credits: 01**

Course Objectives

- To understand the fundamentals of digital signal processing, including discrete-time signals and systems, sampling and quantization, and digital filter design.
- To gain hands-on experience with MATLAB and other DSP tools for signal generation, analysis, and processing.
- To undertake a project on a specific DSP application and develop a prototype system using DSP hardware and software tools.
- To develop critical thinking and problem-solving skills through laboratory assignments and project work, and to enhance technical writing and presentation skills through lab reports and project presentations.

1. Demonstrate the Nyquist-Shannon sampling theorem and perform sampling and reconstruction of analog signals using different sampling rates and reconstruction filters.
2. Generate and analyze different types of fundamental signals such as sinusoidal, square wave, triangular wave, sawtooth wave, and noise signals. Perform frequency analysis using Fourier transform and windowing techniques.
3. Perform linear convolution, correlation and circular convolution of signals using MATLAB.
4. Perform Z-transform of signals using MATLAB and analyse the important properties of Z-transform.
5. Perform discrete Fourier transform (DFT) of signals using MATLAB and analyze the frequency domain characteristics of the signals.
6. Implement FFT (fast Fourier transform) algorithm to reduce the computation complexity in MATLAB.
7. Design and implement different types of digital filters such as low-pass, high-pass, band-pass, and band-stop filters using FIR (finite impulse response) and IIR (infinite impulse response) filter structures.
8. Image Processing: Perform image processing operations such as image filtering, edge detection, and image compression using MATLAB. Implement image codecs such as JPEG and MPEG.
9. DSP Hardware Implementation: Implement DSP algorithms on hardware platforms such as DSP kits (TMS320C6713 Processor Kits).
10. Project Work: Undertake a project on a specific DSP application such as digital audio processing, speech recognition, or image processing. Develop a prototype system using DSP hardware and software tools and present a report and demonstration of the project.

Note: The concerned Course Coordinator may prepare the actual list of experiments/problems at the start of semester based on above generic list.

Course Outcomes:

Upon successful completion of the course, the students will be able to

1. have a good understanding of basic DSP concepts, including sampling, filtering, frequency analysis, and time-domain analysis.
2. be proficient in using DSP tools, such as MATLAB, Simulink, or other software platforms for designing, simulating, and analyzing DSP systems.
3. be able to implement DSP algorithms in software or hardware, depending on the focus of the lab. They should be able to design, simulate, and test DSP algorithms for various applications.
4. have hands-on experience with DSP hardware, such as digital signal processors or field-programmable gate arrays (FPGAs). They should be able to program and configure DSP hardware for specific applications.

Course Name: **Antenna and Microwave Systems Lab**
Course Code: **EC-325**

Contact Hours/Week: **2P** Course Credits: **01**

Course Objectives

- To provide skills for operating microwave benches at designed X band setup
- To provide skills for usage of microwave sources
- To enable the students to practical know how the microwave measurements.

List of Experiments

1. To Study the Microwave Components, Sources and Different Types of Loads at X Band Setup.
2. To Study the Characteristics of Reflex Klystron Oscillator and Determine its Mechanical and Electronics Tuning Range.
3. To Study the V-I Characteristics of Gunn Diode and Determine its Negative Resistance.
4. To Determine the Insertion Loss Parameter and Isolation Parameter of a Ferrite Based Isolator and Circulators.
5. To Measure the Frequency in a Rectangular Waveguide and Demonstrate the Relationship among the Frequency, Free Space Wavelength and Guide Wavelength.
6. To Study the Characteristics of Various Tees, i.e., E-Plane Tee, H-Plane Tee and Magic Tees.
7. To Measure the Coupling and Directivity of a 3 dB, 10 dB and 20 dB Directional Couplers.
8. To Measure the Low, Medium, and High VSWR of DUT Using Slotted Lines Section.
9. To Measure the Unknown Impedances using Smith Chart.
10. To Measure of VSWR, Insertion Loss, Attenuation of Fixed and Variable Attenuators.
11. To Plot the Radiation Pattern of a Pyramidal Horn Antenna and determine its Gain and Beam width.
12. To Study the working of Vector Network Analyzer (VNA) and its applications.
13. To Study the *E*-and *H*- field of a Rectangular Waveguide using HFSS/ CST.

Note: The concerned Course Coordinator may prepare the actual list of experiments/problems at the start of semester based on above generic list.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Understand basic requirements of microwave components and sources in real time applications.

CO2: Identify a practical approach for testing and measurement of microwave devices in real environment.

CO3: Design any analyse microwave device and components using software.

Course Name: **Computer Architecture and Organization**
Course Code: **EC-411**
Course Type: **Core**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To conceptualize the basics of organizational and architectural issues of a digital computer
- To analyse processor performance improvement using instruction level parallelism.
- To study various data transfer techniques in digital computer.

Unit Number	Course Content	Contact Hours
UNIT-01	**Basics of Computer Architecture**: Codes, Number System, Logic gates, Flip flops, Registers, Counters, Multiplexer, Demultiplexer, Decoder, Encoder etc, Register transfer, Bus & memory transfer, Logic micro operations, and Shift micro operation.	**05L**
UNIT-02	**Basic Computer Organization:** Instruction codes, Computer instructions, Timing & control, Instruction Cycles, Memory reference instruction, Input/output and Interrupts, Complete computer description & design of basic computer	**07L**
UNIT-03	**ARM Processor Fundamentals:** AR M core data flow model, Architecture, ARM General Purpose Register set, Exceptions, Interrupts, Vector Table, ARM processors family	**08L**
UNIT-04	**Central Processing Unit:** General register organization, Stack organization, Instruction format, Data transfer & manipulation, Program control, RISC, CISC, Addition & subtraction, Multiplication Algorithms, Division algorithms, Peripheral devices, I/O interface Data transfer schemes, Program control, Interrupt, DMA transfer, I/O processor	**07L**
UNIT-05	**Memory Unit**: Memory hierarchy, Processor vs. memory speed, High-speed memories, Cache memory, Associative memory, Interleave, Virtual memory, Memory management.	**05L**
UNIT-06	**Introduction to Parallel Processing:** Pipelining, Characteristics of multiprocessors, Interconnection structures, Inter-processor arbitration, Inter-processor communication & synchronization.	**04L**

Course Outcomes

Upon successful completion of the course, the students will be able to
CO1: Identify and compare different methods for computer I/O mechanisms.
CO2: Categorize memory organization and explain the function of each element of a memory hierarchy.
CO3: Demonstrate control unit operations and conceptualize instruction level parallelism.

Books and References

1. Computer System Architecture by Morris M. Mano and Yu Dong, Prentice Hall.
2. Computer Architecture A Quantitative Approach by J. L. Hennessy, D. A. Patterson and D. Goldberg, 3 rd ARM Edition.
3. Computer Architecture and Organization by J. P. Hayes, McGraw Hill.
4. System Architecture: Software and Hardware Concepts by W. E. Leigh and D. L. Ali, South Wester Publishing.

Course Name: **Wireless Communication**
Course Code: **EC-412**
Course Type: **Core**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To understand the cellular concept of wireless communications.
- To study large-scale and small-scale propagation effects in wireless channels.
- To study different techniques that improve radio link performance in wireless communications.
- To understand general concepts of various multiple access techniques used in wireless communication.

Unit Number	Course Content	Contact Hours
UNIT-01	**INTRODUCTION** Evolution of wireless communication systems, Examples of wireless communication systems.	**02L**
UNIT-02	**THE CELLULAR CONCEPT-SYSTEM DESIGN FUNDAMENTALS** Concept of frequency reuse, Channel assignment strategies, Handoff strategies, Interference and system capacity, Trunking and grade of service, Improving coverage and capacity in cellular systems.	**09L**
UNIT-03	**PROPAGATION MODELS:** Free space propagation model, Two-ray ground reflection model, Distance power loss, Macro-cell propagation model, Micro-cell propagation model, Shadowing model, Multipath effects in mobile communication, Models for multipath reception.	**08L**
UNIT-04	**EQUALIZATION, DIVERSITY AND CHANNEL CODING:** Fundamentals of equalization, Adaptive equalizers, Linear and nonlinear equalization, Algorithms for adaptive equalization, Diversity techniques, Fundamentals of channel coding, Overview of error detection and correction codes.	**09L**
UNIT-05	**MULTIPLE ACCESS TECHNIQUES:** Introduction to multiple access, Frequency division multiple access, Time division multiple access, Spread spectrum multiple access, Space division multiple access, Packet radio, Orthogonal frequency division multiple access; Introduction to wireless systems and standards.	**09L**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Understand the operation of wireless and cellular communication systems.
CO2: Analyze various design related issues associated with improving coverage and capacity of cellular systems.
CO3: Analyze large-scale and small-scale radio propagation effects in mobile cellular systems.
CO4: Understand the concepts of equalization, diversity and channel coding in wireless communications.
CO5: Understand general concepts of various multiple access techniques for wireless communication.

Books and References

1. Wireless Communications: Principles and Practice by Theodore S. Rappaport, Pearson / PHI Publications.
2. Wireless Communications and Networks: 3G and Beyond by Iti Saha Misra, Tata McGraw Hill Publications.
3. Mobile Cellular Telecommunications: Analog and Digital Systems by William C. Y. Lee, Tata McGraw Hill Publication
4. Wireless Digital Communications by Kamilo Feher, PHI Publication.

Course Name: **Optical Fiber Communication**
Course Code: **EC-413**
Course Type: **Core**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To introduce the students to various optical fiber modes, configurations and various signal degradation factors associated with optical fiber.
- To study about various optical sources and optical detectors and their use in the optical communication system

Unit Number	Course Content	Contact Hours
UNIT-01	**OVERVIEW:** The Electromagnetic Spectrum, Properties of Light, Dual Nature of Light Concept of a Photon, Wave Model, Characteristics of Light Waves. Concepts of Information, General Communication Systems, Evolution of Basic Fiber Optic Communication System, Benefits and Disadvantages of Fiber Optics. Transmission Windows. Transmission Through Optical Fiber, The Laws of Reflection and Refraction, Light Rays and Light Waves, Reflection of Light from Optical Surfaces, Refraction of Light from Optical Interfaces, The Numerical Aperture (NA), The Optical Fiber, Types of Fiber.	**07L**
UNIT-02	**LOSSES IN OPTICAL FIBER:** Attenuation, Material Absorption Losses, Linear and Non-Linear Scattering Losses, Fiber Bend Loss, Dispersion Viz. Inter Modal Dispersion and Intra Modal Dispersion, Overall Fiber Dispersion and Polarization, Dispersion Shifted and Dispersion Flattened Fibers, Attenuation and Dispersion Limits in Fibers, Kerr Nonlinearity, Self-Phase Modulation, Combined Effect of Dispersion and Self Phase Modulation	**07L**
UNIT-03	**FIBER MATERIAL, COUPLERS AND CONNECTORS:** Preparation of Optical Fiber: Liquid-Phase Techniques, Vapor Phase Deposition Techniques, Connector Principles, Fiber End Preparation, Splices, Connectors.	**06L**
UNIT-04	**OPTICAL SOURCES AND DETECTORS:** Sources: Basic Principle of Surface Emitter LED and Edge Emitter LED- Material Used Structure, Internal Quantum Efficiency and Characteristics, LASER Diode - Material Used Structure, Internal Quantum Efficiency and Characteristics, Working Principle and Characteristics of Distributed Feedback (DFB) Laser. Detectors: PIN Photodiode - Material Used, Working Principle & Characteristics, Avalanche Photodiode: - Material Used Working Principle and Characteristics.	**05L**
UNIT-05	**ADVANCED TOPICS:** Optical TDM, SCM, WDM And Hybrid Multiplexing Methods, Fiber Optic Networks, Trans receivers for Fiber-Optic Networks, Semiconductor Optical Amplifiers, Erbium Doped Fiber Amplifiers (EDFAs), Introduction to Free Space Optical and Visible Light Communications.	**05L**
UNIT-06	**OPTICAL NETWORKS:** Elements and Architecture of Fiber-Optic Network, SONET/SDH, ATM, IP, Optical Line Terminals (OLT), Optical Add-Drop Multiplexers, Optical Cross Connects.	**06L**

Course Outcomes

Upon successful completion of the course, the students will be able to
CO1: Learn the basic elements of optical fiber transmission link, fiber modes configurations and structures
CO2: Understand the different kind of losses, signal distortion in optical wave guides and other signal degradation factors.
CO3: Learn the fiber optical receivers such as PIN APD diodes, noise performance in photodetector, receiver operation and configuration
CO4: Learn the various optical source materials, LED structures, quantum efficiency, Laser diodes
CO5: Understand the optical multiplexing techniques, optical network and its architecture.

Books and References

1. Fiber Optic Communications (Fifth Ed.) by J.C. Palais, Pearson Prentice Hall, 2005
2. Optical Fiber Communications (Third Ed.) by Gerd Keiser, McGraw-Hill, 2000
3. Optical Networks: A Practical Perspective (Third Ed.) by R Ramaswamiand and K.N. Sivarajan, Morgan Kaufman Publishers

Course Name: **Optical Fiber Communication Lab**
Course Code: **EC-414**
Course Type: **Core**

Contact Hours/Week: **2P** Course Credits: **01**

Course Objectives

- To study the design and deployment of optical fiber communication links.
- To understand the characteristics of optical fiber and losses in optical fiber communication link.

List of Experiments

1. To Study Numerical Aperture of optical Fiber.
2. To Study bending Losses in Optical Fiber.
3. To set up an 850nm fiber optic analog link.
4. To set up 850nm and 650 nm digital link, and to measure the maximum bit rates supportable on these links.
5. To measure the losses in optical fiber communication link.
6. To analyze the V-I characteristics and P-I characteristics using LED module.
7. To analyze the V-I characteristics of Laser Diode.
8. To study the characteristics of Avalanche photodiode (APD)
   (a). APD at zero bias
   (b). APD at reverse bias.

Note: The concerned Course Coordinator will prepare the actual list of experiments/problems at the start of semester based on the above generic list.

Course Outcomes

Upon successful completion of the course, the students will be able to
CO1: Understand the communication using optical fiber.
CO2: Set up the analog and digital communication links.
CO3: Analyse the characteristics of LED and Avalanche photodiode.

Course Name: **Communication Systems and Network Simulation Lab**
Course Code: **EC-415**

Contact Hours/Week: 2P **Course Credits: 01**

Course Objectives

- To introduce students to the fundamental concepts of communication systems and networks, including signal processing, coding, modulation, and multiple access techniques.
- To provide students with hands-on experience in designing, implementing, and evaluating communication systems and networks using simulation and modeling techniques.
- To prepare students for further study or research in the field of communication systems and networks.

1. Introduction to the simulation platform or programming language.
2. Simulation of random variables and probability distributions for modelling of communication systems and networks.
3. Simulation of digital modulation techniques (PSK, QAM, FSK) and comparison of their performance in AWGN channel
4. Performance analysis of error-correcting codes (Reed-Solomon, convolutional, turbo codes) using BER and FER metrics
5. Simulation of channel coding schemes (block codes, convolutional codes) and their application in digital communication systems
6. Implementation of Equalization techniques (linear, decision feedback) and their performance evaluation in a noisy channel
7. Simulation of spread-spectrum techniques (DS-CDMA, FH-CDMA) and comparison of their performance in a multipath fading channel.
8. Implementation and analysis of Carrier Sense Multiple Access (CSMA) and Carrier Sense Multiple Access with Collision Detection (CSMA/CD) protocols in a network.
9. Simulation of TCP congestion control and analysis of its impact on network performance.
10. Design and analysis of routing protocols (Dijkstra, Bellman-Ford, OSPF) in a network.

Note: The concerned Course Coordinator may prepare the actual list of experiments/problems at the start of semester based on above generic list.

Course Outcomes:

Upon successful completion of the course, the students will be able to

CO1: Understand the fundamental concepts of communication systems and networks, including signal processing, coding, modulation, and multiple access techniques.

CO2: Analyse and evaluate the performance of digital communication systems using simulation and modelling techniques.

CO3: Proficiently use the simulation tools and software (such as MATLAB/Simulink, Python, Network simulators) to design, implement and evaluate communication systems and networks.

CO4: Develop the critical thinking skills, problem-solving skills, and apply theoretical concepts to practical scenarios.

CO5: Prepare for further study or research in the field of communication systems and networks.

Discipline Elective Courses

Course Name: **Electronics Device Modeling**
Course Code: **EC-241**
Course Type: **Discipline Elective-I**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To bring home knowledge of fundamentals of electronics devices and modeling.
- Build upon the theoretical, mathematical and physical models of electronic devices used in VLSI, for proper understanding of e-circuit design, simulation and working.
- To provide students with an opportunity to understand and practice on SPICE platform.

Unit Number	Course Content	Contact Hours
UNIT-01	**Introduction to Device Modeling**: Introduction, physical significance of device modeling, various devices used in device modeling. Material used in device modeling. Trends & projections in device modeling. Fundamentals of SPICE.	**05L**
UNIT-02	**Junction Diodes**: PN junction depletion region formation, Depletion-capacitance model, Storage capacitance model, DC, small signal, large signal, high frequency model of diodes. Measurement and extraction of diode model parameters.	**10L**
UNIT-03	**MOSFETs**: MOSFET fundamentals, Types of MOSFETs, Concept of threshold voltage, Large signal behavior MOSFETs, Comparison of operating regions of Bipolar and MOS Transistors, Shichman Hodges and Level-1 MOS Models, Limitations of MOS level-1. MOS level-2 model.	**10L**
UNIT-04	**Short & Narrow Channel Effects in MOSFETs**: Velocity saturation, Mobility degradation, Weak Inversion in MOS Transistors, Narrow & Short Channel Effects in MOSFETs, namely, Drain induced barrier lowering (DIBL), Subthreshold current, Impact ionization, Charge sharing, Threshold variation with transistor dimensions, etc.	**05L**
UNIT-05	**Bipolar Junction Transistors**: DC, small signal, high frequency models of bipolar junction transistors. Ebers–Moll BJT model. Gummel–Poon BJT model. Extraction of BJT model parameters.	**05L**
UNIT-06	**Modern VLSI Devices**: Principle of hetro-junction devices, High speed compound semiconductor devices, opto devices.	**05L**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Comprehend the insight of electronic devices so as to provide appropriate and economically viable solutions to electronics engineering community and society at large.

CO2: Identify the new state of art electronic device models to solve the real world research problems.

CO3: Apply principles of usage of EDA tools & techniques for effective & efficient modeling of e-devices for e-circuits.

CO4: Assess performance of electronic devices without actual fabrication so as to deal with e-designing for practical aspects and generate interest and competence in self-directed continuing professional development.

Books and References

1. CMOS Digital Integrated Circuits-Analysis & Design by S.M. Kang & Y. Leblibici, TMH.
2. Physics of Semiconductor Devices by S.M. Sze, Wiley Pub.
3. Introduction to PSPICE by H.M. Rashid, PHI.
4. Solid State Electronic Devices by B.G. Streetman & S. Baneerjee, PHI.

Course Name: **Nano Technology** Course Code: **EC-242** Course Type: **Discipline Elective-I**	
Contact Hours/Week: **3L**	Course Credits: **03**

Course Objectives

- To acquire the knowledge of the fundamentals of Nanomaterials.
- To enable the students to get familiarize with the basic concepts of Statistical and Quantum Mechanics

Unit Number	Course Content	Contact Hours
UNIT-01	**INTRODUCTION TO NANOTECHNOLOGY:** Importance of Nanotechnology-History of Nanotechnology-Opportunity at the nanoscale-length and time scale in structures-energy landscapes-Interdynamic aspects of inter molecular forces -classification based on the dimensionality- nanoparticles- nanoclusters-nanotubes-nanowires and nanodots- Semiconductor nanocrystals- carbon nanotubes- Influence of Nano structuring on Mechanical, optical, electronic, magnetic and chemical properties	**09L**
UNIT-02	**BASICS OF QUANTUM MECHANICS:** Introduction to Quantum Mechanics – Schrodinger equation – time dependent and time independent equations – Operators and observables – Commutation relations – Hermitian operators – Expectation values of observables – Solutions of the Schrodinger equation – free particle – particle in a box – one and three dimensions – particle in a finite well – Penetration through a barrier – Tunnel effect – Single step barrier.	**09L**
UNIT-03	**TYPES OF NANOMATERIALS:** Nanoclusters, Solid solutions, Thin film, Nanocomposites (Metal Oxide and Polymer based), Core Shell Nanostructure, Buckyballs, Carbon nano tubes and, Zeolites minerals, Dendrimers, Micelles, Liposomes, Block Copolymers, Porous Materials, Metal Nanocrystals, Semiconductor nanomaterials.	**06L**
UNIT-04	**STATISTICAL DESCRIPTION OF SMALL SYSTEMS:** Quantum states and phase space, the density matrix, few examples; An ideal gas in quantum mechanical ensembles; statistics of occupation numbers. Basic concepts and thermodynamic behavior of an ideal Bose gas, Bose-Einstein condensation; Discussion of a gas of phonons(The Debye field); Thermodynamics of an ideal Fermi gas, heat capacity of a free-electron gas at low temperatures.	**09L**
UNIT-05	**ELECTRON DYNAMICS IN SOLIDS:** Free electron theory of metals, band theory of solids, Bloch theorem – tight binding approximation – Kroning – Penne model, Evolution of band structure and Fermi surface- Metals and Insulators, semiconductors - Transport properties – Mobility, Resistivity, Relaxation time, Recombination centers- Hall effects – Confinement and transport in nanostructure – Electrons in quantum wires and quantum dots– Current, reservoirs, and electron channels – conductance formula for nanostructures – quantized conductance – Local density of states- Ballistic transport – Coulomb blockade – Diffusive transport – Fock space- Nanostructure Devices: Introduction, MODFETS, heterojunction bipolar transistors, Resonant-tunneling diodes, Field-effect transistors, Single electron-transfer devices, Potential-effect transistors, Carbon Nanotube transistors, Semiconductor Nanowire FETs	**12L**

Course Outcomes

Upon successful completion of the course, the students will be able to

C01: Understanding the insight of Nanoelectronics device physics so as to provide appropriate and economical viable solution to electronic engineering community and society at large.

CO2: Identifying different techniques to improve the state of art electronic device so as to solve the real world research problems.

C03: Understanding the applications of quantum physics in semiconductor devices.

C04: Identifying different devices so as to meet out the present design, health, safety and environmental challenges

Books and References

1. A textbook of Nanoscience and Nanotechnology by Pradeep.T , McGraw Hill, 2012.
2. Introduction to Nanoelectronics: Science, Nanotechnology, Engineering & Applications by Vladimir. V. Mitin, Cambridge University Press.
3. Introduction to Quantum Mechanics by David. J. Griffiths, Pearson, 2009.
4. Introductory Quantum Mechanics by Richard. L. Liboff, R, Pearson, 2003.
5. Statistical Physics by Claudine Herman, Springer, New York,2005.
6. Introduction to Solid State Physics by Kittel. C, Wiley India Pvt Ltd., 2007.
7. Nanomaterials Chemistry by Rao. C. N, Muller. A, Cheetham. A. K, Wiley-VCH, 2007.
8. Nanotechnology for Microelectronics and Optoelectronics by J.M. Martinez-Duart, R.J.Martin Palma, F. Agulle Rueda, Elsevier.

Course Name: **Digital Arithmetic**
Course Code: **EC-243**
Course Type: **Discipline Elective-I**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives:

- To impart knowledge about the computer arithmetic algorithms, including different techniques enabling enhanced throughput and low power.
- To understand algorithms techniques to hardware implementation of various arithmetic operations.

Course Content

Numbers and Arithmetic: Review of Number systems, their encoding and basic arithmetic operations, Class of Fixed-Radix Number Systems, Unconventional fixed-point number systems, Representing Signed Numbers, Negative-radix number Systems, Redundant Number Systems, Residue Number Systems. Algorithms for Fast Addition: Basic Addition and Counting, Bit-serial and ripple-carry adders, Addition of a constant: counters, Manchester carry chains and adders, Carry-Look-ahead Adders, Carry determination as prefix computation, Alternative parallel prefix networks, VLSI implementation aspects, Variations in Fast Adders, Simple carry-skip and Carry-select adders, Hybrid adder designs, Optimizations in fast adders, Multi-Operand Addition, Wallace and Dadda trees, Parallel counters, Generalized parallel counters, Adding multiple signed numbers. High-Speed Multiplication: Basic Multiplication Schemes, Shift/add multiplication algorithms, Programmed multiplication, Basic hardware multipliers, Multiplication of signed numbers, Multiplication by constants, Preview of fast multipliers, High-Radix Multipliers, Modified Booth's recoding, Tree and Array Multipliers, Variations in Multipliers, VLSI layout considerations. Fast Division and Division Through Multiplication: Basic Division Schemes, Shift/subtract division algorithms, Programmed division, Restoring hardware dividers, Non-restoring and signed division, Division by constants, Preview of fast dividers, High-Radix Dividers, Variations in Dividers, Combined multiply/divide units, Division by Convergence, Hardware implementation. Real Arithmetic: Representing the Real Numbers, Floating-point arithmetic, The ANSI/IEEE floating point standard, Exceptions and other features, Floating-point arithmetic operations, Rounding schemes, Logarithmic number systems, Floating-point adders, Barrel-shifter design, Leading-zeros/ones counting, Floating-point multipliers, Floating-point dividers, Arithmetic Errors and Error Control. Implementation Topics: Computing algorithms, Exponentiation, Approximating functions, Merged arithmetic, Arithmetic by Table Lookup, Tradeoffs in cost, speed, and accuracy. High-Throughput Arithmetic, Low-Power Arithmetic, Fault-Tolerant Arithmetic, Emerging Trends, Impact of Hardware Technology.

Course Outcomes:

Upon successful completion of the course, the students will be able to

CO1: Understand hardware implementation of various algorithms.

CO2: Learn to apply tradeoffs and multiple implementations and architectures.

CO3: Know the use cases of various algorithms and their considerations

Books and References:

1. Computer Arithmetic: Algorithms and Hardware Design by Parhami, B., Oxford University Press.
2. Computer Arithmetic Algorithms by Koren, I., CRC Press.
3. Digital Arithmetic by Ercegovac, M. and Lang, T., Elsevier.
4. Verilog Digital Computer Design Algorithms into Hardware by Mark Gordon Arnold, Prentice Hall PTR.

Course Name: **Switching and Finite Automata Theory**
Course Code: **EC-351**
Course Type: **Discipline Elective-II**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- Understand the basics of threshold logic, effect of hazards on digital circuits and techniques of fault detection
- Explain finite state model and minimization techniques
- Know structure of sequential machines, and state identification
- Understand the concept of fault detection experiments

Unit Number	Course Content	Contact Hours
UNIT-01	**Threshold Logic:** Introductory Concepts: Threshold element, capabilities and limitations of threshold logic, Elementary Properties, Synthesis of Threshold networks: Unate functions, Identification and realization of threshold functions, The map as a tool in synthesizing threshold networks.	**08L**
UNIT-02	**Reliable Design and Fault Diagnosis:** Hazards, static hazards, Design of Hazard-free Switching Circuits, Fault detection in combinational circuits, Fault detection in combinational circuits: The faults, The Fault Table, Covering the fault table, Fault location experiments: Preset experiments, Adaptive experiments, Boolean differences, Fault detection by path sensitizing.	**08L**
UNIT-03	Sequential Machines: Capabilities, Minimization and Transformation the Finite state model and definitions, capabilities and limitations of finite state machines, State equivalence and machine minimization: k-equivalence, The minimization Procedure, Machine equivalence, Simplification of incompletely specified machines.	**08L**
UNIT-04	Structure of Sequential Machines: Introductory example, State assignment using partitions: closed partitions, The lattice of closed partitions, Reduction of output dependency, Input dependence and autonomous clocks, Covers and generation of closed partitions by state splitting: Covers, The implication graph, An application of state splitting to parallel decomposition.	**08L**
UNIT-05	State–Identification and Fault Detection Experiments: Experiments, Homing experiments, Distinguishing experiments, Machine identification, Fault detection experiments, Design of diagnosable machines, Second algorithm for the design of fault detection experiments.	**08 L**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Explain the concept of threshold logic.
CO2: Understand the effect of hazards on digital circuits and fault detection and analysis.
CO3: Define the concepts of finite state model.
CO4: Analyse the structure of sequential machine.
CO5: Explain methods of state identification and fault detection experiments.

Books and References

1. Switching and Finite Automata Theory – Zvi Kohavi, McGraw Hill, 2nd edition. (Text Book)
2. Fault Tolerant and Fault Testable Hardware Design - Parag K Lala, Prentice Hall Inc.
3. Digital Circuits and Logic Design .- Charles Roth Jr, Larry L. Kinney, Cengage Learning.

Course Name: **Data Structures and Algorithms**
Course Code: **EC-352**
Course Type: **Discipline Elective-II**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To impart knowledge about linear and non-linear data structures as the foundational base for computer solutions to problems.
- To introduce the fundamental concepts relevant to binary trees, binary tree traversals, binary search trees and perform related analysis to solve problems.
- To enable the students to understand various types of sorting algorithms.

Unit Number	Course Content	Contact Hours
UNIT-01	**Introduction:** Data types, data structures, abstract data types, the running time of a program, the running time and storage cost of algorithms, complexity, asymptotic complexity, big O notation, obtaining the complexity of an algorithm.	**07L**
UNIT-02	**Development of Algorithms:** Notations and Analysis, Storage structures for arrays – sparse matrices - structures and arrays of structures, Stacks and Queues: Representations, implementations and applications. Linked Lists: Singly linked lists, Linked stacks and queues, operations on Polynomials, Doubly Linked Lists, Circularly Linked Lists, Operations on linked lists- Insertion, deletion and traversal, dynamic storage management – Garbage collection and compaction.	**10L**
UNIT-03	**Trees:** Basic terminology, General Trees, Binary Trees, Tree Traversing: in-order, pre-order and post-order traversal, building a binary search tree, Operations on Binary Trees - Expression Manipulations - Symbol Table construction, Height Balanced Trees (AVL), B-trees, B+-trees	**07L**
UNIT-04	**Graphs:** Basic definitions, representations of directed and undirected graphs, the single-source shortest path problem, the all-pair shortest path problem, traversals of directed and undirected graphs, directed acyclic graphs, strong components, minimum cost spanning tress, articulation points and biconnected components, graph matching.	**06L**
UNIT-05	**Sorting and Searching Techniques:** Bubble sorting, Insertion sort, Selection sort, Shell sort, Merge sort, Heap and Heap sort, Quick sort, Radix sort and Bucket sort, Address calculation, Sequential searching, Binary Searching, Index searching, Hash table methods.	**06L**

Course Outcomes

Upon successful completion of the course, the students will be able to
CO1: Interpret and compute asymptotic notations of an algorithm to analyze the time complexity.
CO2: Use of linear and non-linear data structures as the foundational base for computer solutions to problems.
CO3: Demonstrate the ability to implement various types of static and dynamic lists.
CO4: Implement binary trees, binary tree traversals, and binary search trees.
CO5: Implement various types of sorting algorithms.

Books and References

1. An Introduction to Data Structures with applications by J.P. Tremblay and P.G. Sorenson, Tata McGraw Hill.
2. Data structures, Algorithms ad Applications in C++ by Sartaj Sahni, WCB/McGraw Hill.
3. Data Structures and Algorithms by Alfred V. Aho, Jeffrey D. Ullman and John E. Hopcroft, Addison Wesley.
4. Data Structures using C by Y. Langsam, M. J. Augenstein and A. M. Tenenbaum, Pearson Education.
5. Data Structures – A Pseudocode Approach with C by Richard F. Gilberg and Behrouz A. Forouzan, Thomson Brooks /Cole

Course Name: **Object Oriented Programming**
Course Code: **EC-353**
Course Type: **Discipline Elective-II**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To impart knowledge about the concept of Object Oriented programming.
- To introduce the fundamental concepts relevant to Arrays, Pointers and Functions, Classes, Objects, etc.
- To enable the students to understand the standard library, exception handling, streams and files

Unit Number	Course Content	Contact Hours
UNIT-01	**Concepts of Object-Oriented Programming:** Object Oriented Programming Paradigm, Basic concepts of OOPs, Benefits of OOPs, and Introduction to object oriented design and development, Design steps, Design example, Object oriented languages, Comparison of structured and object-oriented programming languages.	**06L**
UNIT-02	**Arrays, Pointers and Functions:** Arrays, Storage of arrays in memory, Initializing Arrays, MultiDimensional Arrays, Pointers, accessing array elements through pointers, passing pointers as function arguments, Arrays of pointers, Pointers to pointers, Functions, Arguments, Inline functions, Function Overloading Polymorphism.	**06L**
UNIT-03	**Classes and Objects:** Data types, operators, expressions, control structures, arrays, strings, Classes and objects, access specifiers, constructors, destructors, operator overloading, type conversion. Storage classes: Fixed vs. Automatic declaration, Scope, Global variables, register specifier, Dynamic memory allocation.	**07L**
UNIT-04	**Inheritance:** Inheritance, single Inheritance, Multiple Inheritance, Multi-level inheritance, hierarchical inheritance, hybrid inheritance, Virtual functions. Streams and Files: Opening and closing a file, File pointers and their manipulations, Sequential Input and output operations, multi-file programs, Random Access, command line argument, string class, Date class, Array class, List class, Queue class, User defined class, Generic Class.	**07L**
UNIT-05	**Exception Handling and Graphics:** List of exceptions, catching exception, handling exception. Text Mode, Graphics mode functions, Rectangles, and Lines, Polygons and Inheritance, Sound and Motion, Text in Graphics Mode. Standard Template Library: Standard Template Library, Overview of Standard Template Library, Containers, Algorithms, Iterators, Other STL Elements, Container Classes, General Theory of Operation, Vectors.	**10L**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Understand the concept of object oriented paradigm and programming.

CO2: Apply the concept of polymorphism and inheritance.

CO3: Implement exception handling and templates.

CO4: Handling of files and streams during programming.

Books and References

1. Object Oriented programming with C++ by E. Balagurusamy, Tata McGraw Hill.
2. The C++ programming Language by Bjarne Strustrup, Addison Wesley.
3. Object Oriented Analysis and Design with Applications by Grady Booch, Addison Wesley.
4. The Complete Reference Visual C++ by Chris H. Pappas and William H. Murray, Tata McGraw Hill.
5. C++ Primer by S. B. Lippman, Josee Lajoie and Barbara E. Moo, Pearson Education.

Course Name: **Data Communication and Computer Networks**
Course Code: **EC-341**
Course Type: **Discipline Elective-III**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To introduce basic concepts of Data communication with different models. Enumerate the physical layer, Data Link Layer, Network Layer, Transport Layer and Application Layer, explanation of the function(s) of each layer.
- Understanding of switching concept and different types of switching techniques

Unit Number	Course Content	Contact Hours
UNIT-01	**Introduction to Data Communication:** Goals and Applications of Networks, Wireless Network, Interfaces and services. Reference Models: The OSI reference model, TCP/IP reference model.	**07L**
UNIT-02	**Physical Layer:** Analog and Digital, Analog Signals, Digital Signals, Analog versus Digital, Data Rate Limit, Transmission Impairments, Line Coding, Block Coding, Sampling, Transmission Mode, Modulation of Digital Data, Telephone Modems, Modulation of Analog Signal, FDM, WDM, TDM, Guided Media, Unguided Media, Switching.	**05L**
UNIT-03	**Data Link Layer:** Data Link Layer Design Issues, Services Provided to Network Layers, Framing, Error Control, Flow Control, Error Detection and Correction, Elementary Data Link Protocols, An Unrestricted Simplex Protocol, A Simplex Stop-and-Wait Protocol, Simplex Protocol for a Noisy Channel, Sliding Window Protocols, A protocol using go-back-N, A Protocol using Selective Repeat, Example Data Link Protocol-HDLC, PPP.	**07L**
UNIT-04	**Medium Access Sublayer:** Channel Allocations, Random Access, ALOHA, Carrier Sense Multiple Access Protocols, Collision Free Protocols, Limited Contention Protocols, Controlled Access, Channelization, Wired LANs: Ethernet, Wireless LANs	**05L**
UNIT-05	**Network Layer:** Internetworks, Addressing, Routing, ARP, IP, ICMP, IPV6, Unicast Routing, Unicast Routing Protocol, Multicast Routing, Multicast Routing Protocols	**04L**
UNIT-06	**Transport Layer:** Process to Process Delivery, User Datagram Protocol (UDP), Transmission Control Protocol (TCP), Data Traffic, Congestion, Congestion Control, Quality of Service, Techniques to Improve QOS, Integrated Services, QOS in Switched Networks	**08L**
UNIT-07	**Application Layer:** Design Issues of the Layer, Domain Name Systems, File Transfer, http, Web Documents, Virtual Terminals.	**--**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Give the basic information of how a network can be designed, possible choice of various models for designing a network.

CO2: Understand the protocol layer specific communication between two trusted entities.

CO3: Analyse the possible attacks on a network to interrupt the transmission and mislead the communication between different entities.

CO4: Analyse the shortest path over which data can be transmitted, able to design a routing protocol implementing security mechanisms for secure transmission of data from sender to the receiver.

CO5: Understand the subject based on course work, assignments and through implementation on a specific platform

CO6: Design a network topology with the available networking elements and can implement a routing protocol along with secure mechanisms ensuring the error free transmission of data.

Books and References

1. Data Communications and Networking by Behrouz A Ferouzan, McGraw Hill Education.
2. Data and Computer Communication by Stallings William, Pearson Education.
3. Computer Networks by A.S. Tanenbaum, Pearson Education.
4. An Engineering Approach on Computer Networking by S. Keshav, Addison Welsey.
5. Introduction to Data Communications and Networking by Wayne Tomasi, Pearson.

Course Name: **Spread Spectrum and Wideband Communication**
Course Code: **EC-342**
Course Type: **Discipline Elective-III**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To impart knowledge about the basic spread spectrum techniques that are used in CDMA based cellular communication systems, including direct sequence spread spectrum and frequency-hopped spread spectrum.
- To introduce the fundamental mathematical concepts relevant to design aspects of the PN sequence generators.
- To enable the students to understand the factors that affect the practical implementation of IS-95, 3G,4G and 5G systems.

Unit Number	Course Content	Contact Hours
UNIT-01	**Introduction:** Concept of Multiple Access Systems, Narrowband and Broadband Systems, Advantages of Spread Spectrum Systems.	**02L**
UNIT-02	**Principles of Direct Spread Spectrum:** Direct Spectrum System: Definition and Concepts, Spreading Sequences and Waveforms, Random Binary Sequence, Shift-Register Sequences, Periodic Auto Correlations, Polynomials over The Binary Field, Systems with PSK Modulation, Power Spectral Density of DSS-CDMA, Pulsed Interference, De-Spreading with Matched Filter.	**10L**
UNIT-03	**Spreading Code Acquisition and Tracking:** Initial Code Acquisition, Acquisition Strategy: Serial Search, Parallel Search, Multi-Dwell Detection, False Alarm and Miss Probability for Matched Filter Receiver, False Alarm and Miss Probability for Radiometer, Mean Overall Acquisition Time for Serial Search.	**06L**
UNIT-04	**Performance of Spread Spectrum System:** Link Performance of Direct Sequence Spread Spectrum CDMA In (I) Additive White Noise Channel (Ii) Multipath Fading Channel. Concept of Rake Receiver, Performance of RAKE Receiver in Multipath Fading.	**06L**
UNIT-05	**Frequency Hoped Systems:** Concepts and Characteristics, Modulations, MFSK, Hybrid Systems, Frequency Synthesizers, Direct Frequency Synthesizer, Digital Frequency Synthesizer, Indirect Frequency Synthesizers.	**06L**
UNIT-06	**Spread Spectrum and Wide-band systems:** CDMA-IS-95: Forward link Channels, Reverse link Channels, Overview of 3G, 4G and 5G Systems. Ultra-wideband communication: definition, features and applications.	**06L**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Identify spread spectrum techniques that are used in CDMA based cellular communication systems, including direct sequence spread spectrum and frequency-hopped spread spectrum.

CO2: Apply the principles of linear algebra to design PN sequence generators.

CO3: Analyze the performance of CDMA systems in various wireless Channels

CO4: Assess the practical implementation of IS-95, 3G,4G and 5G systems.

Books and References

1. Principles of Spread Spectrum Communication Systems by Don Torrieri, Springer Science & Business Media, Inc.
2. CDMA: Principles of Spread Spectrum Communication by Andrew J. Viterbi, Addison- Wesley Publishing Company.
3. Introduction to CDMA Wireless Communications by Mosa Ali Abu-Rgheff, Elsevier Academic Press.
4. Code Division Multiple Access-CDMA by R. Michael Buehrer, Morgan & Claypool Publishers Series.
5. CDMA Systems Engineering Handbook by Jhong S. Lee and Leonard E. Miller, Artech House Publishers.
6. IS-95 CDMA and CDMA-2000 by Vijay K Garg, Pearson Education.
7. OFDM for Wireless Communications Systems by Ramjee Prasad, Artech House, Inc.

Course Name: **Satellite Communication and Radar**
Course Code: **EC-343**
Course Type: **Discipline Elective-III**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To impart knowledge about the Orbital Mechanism, satellites and satellite system, satellite link design.
- To introduce the basic functioning of a radar system and to make the students understand this by taking a specific example of MTI and PULSE Doppler radar.

Unit Number	Course Content	Contact Hours
UNIT-01	**Orbital Mechanics:** Overview of Satellite Communications, Satellite orbit and orbital equations, Kepler's laws of planetary motion, Locating satellite in the orbit, Locating satellite with respect to earth, Orbital Elements, Look Angle Determination, Orbital Perturbations, Orbit Determination, Space Launch Vehicles and Rockets, Placing Satellites Into Geostationary Orbit, Orbital Effects in Communications Systems Performance	**08L**
UNIT-02	**Satellites:** Satellite subsystems, Attitude and orbit control system, Telemetry tracking command and monitoring, Power system, communication subsystem, Satellite antennas	**07L**
UNIT-03	**Satellite Link Design:** Transmission Theory, System Noise Temperature and G/T Ratio, Design of Downlinks, Ku-Band GEO Satellite Systems, Uplink Design, Design for Specified CNR: Combining CNR and C/I Values in Satellite Links, System Design for Specific Performance	**08L**
UNIT-04	**Introduction to Radar System:** Introduction to Radar, Applications of Radar, Radar Frequencies, Working Principle of Radar, Radar block diagram, Simple form of Radar Equation, Minimum detectable signal, Range to a target, Pulse repetition frequency and range ambiguities. Radar System: Maximum radar range, Detection of Signals in Noise, Receiver noise and SNR, Integration of radar pulse, Radar cross section of targets, RADAR detection, Range & Doppler measurements, tracking.	**10L**
UNIT-05	**MTI and Pulse Doppler Radar:** Concept of Doppler Effect, Introduction to Doppler and MTI Radar, Doppler frequency shift, CW Doppler radar, MTI radar, Delay line cancellers, Staggered PRF, pulse Doppler radar, FM-CW radar, Tacking Radar, Sequential lobing, Conical Scan, Monopulse, Acquisition, Comparison of Track, Radar Transmitter/Receiver.	**09L**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Understand the orbital and functional principles of satellite communication systems

CO2: Architect, interpret, and select appropriate technologies for implementation of specified satellite communication sytems

CO3: Analyze and evaluate a satellite link and suggest enhancements to improve the link performance.

CO4: Understand the basic working of RADAR, Doppler shift.

CO5: Understand the working of a MTI, Pulse Doppler Radar and Tracking radar

Books and References

1. Satellite Communications by Timothy Pratt and Jeremy E., Willey.
2. Satellite Communications by Dennis Roddy, Tata McGraw Hill.
3. Digital Satellite Communications by Tri. T. Ha, Tata McGraw Hill.
4. Introduction to Radar Systems by Skolnik, Tata McGraw Hill.
5. Radar Handbook by Skolnik, McGraw-Hill
6. Radar Principles by Peyton Z. Peebles, John Wiley and Sons (2004).
7. Radar Foundation for Imaging & Advanced Concepts by R.J Sullivan, PHI, 2004

Course Name: **Digital Image Processing**
Course Code: **EC-361**
Course Type: **Discipline Elective-IV**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To understand the basics of image formation
- To understand image enhancement in spatial and frequency domain.
- To understand the concepts of image compression, image segmaentation and morphological operation on image.

Unit Number	Course Content	Contact Hours
UNIT-0 1	**Introduction:** Steps in Digital Image Processing, Components of an Image Processing system, Applications. Human Eye and Image Formation; Sampling and Quantization, Basic Relationship among pixels- neighbour, connectivity, regions, boundaries, distance measures.	06
UNIT -02	**Image Enhancement:** Spatial Domain, Gray Level transformations, Histogram, Arithmetic/Logical Operations, Spatial filtering, Smoothing & Sharpening Spatial Filters; Frequency Domain- 2-D Fourier transform, Smoothing and Sharpening Frequency Domain Filtering; Convolution and Correlation Theorems.	08
UNIT -03	**Image Restoration:** Image degradation/restoration process, noise models, restoration in the presence of noise only-spatial filtering, periodic noise reduction by frequency domain filtering, Linear, Position-Invariant Degradation, Estinating the Degradation Function, Inverse filtering, Wiener Filtering, Constrainsed Least Square Filtering, Geometric filter, Geometric Transsformation.	08
UNIT -04	**Image Compression:** Redundancies- Coding, Interpixel, Psycho visual; Fidelity, Source and Channel Encoding, Elements of Information Theory; Loss Less and Lossy Compression; Run length coding, Differential encoding, DCT, Vector quantization, entropy coding, LZW coding; Image Compression Standards-JPEG, JPEG 2000, MPEG; Video compression.	08
UNIT -05	**Image Segmentation:** Discontinuities, Edge Linking and boundary detection, Thresholding, Region Based Segmentation, Segmentation by Morphological Watersheds; binary morphology- erosion, dilation, opening and closing operations, Hit-or-Miss Transform, some basic morphological algorithms.	08

Course Outcomes

Upon successful completion of the course, the students will be able to:

CO1: Understand the basic image formation model and application of image processing.

CO2: Enhancement of image in spatial and frequency domain.

CO3: Understand the.Image Restoration

CO4: Analyse the different image compression techniques.

CO5: Understand the image segmentation and morphological operations

Books and References

1. Digital Image Processing- R. C. Gonzalez and R. E. Woods, Pearson Education
2. Fundamentals of Digital Image processing- A. K. Jain, Pearson Education
3. Digital Image Processing using MATLAB- R. C. Gonzalez , R. E. Woods and S. L Eddins, Pearson Education.
4. Digital Image Processing and Analysis- Chanda and Mazumdar, PHI
5. N.J. Fliege, “Multirate Digital Signal Processing”, John Wiley and Sons.

Course Name: **Speech Processing**
Course Code: **EC-362**
Course Type: **Discipline Elective-IV**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives:

- To introduce speech production and related parameters of speech.
- To show the computation and use of techniques such as short time Fourier transform, linear predictive coefficients and other coefficients in the analysis of speech.
- To understand different speech modeling procedures such as Markov and their implementation issues.

Unit Number	Course Content	Contact Hours
UNIT-01	**BASIC CONCEPTS:** Speech Fundamentals: Articulatory Phonetics Production and Classification of Speech Sounds; Acoustic Phonetics Acoustics of speech production; Review of Digital Signal Processing concepts; Short-Time Fourier Transform, Filter-Bank and LPC Methods.	**07L**
UNIT-02	**SPEECH ANALYSIS**: Features, Feature Extraction and Pattern Comparison Techniques: Speech distortion measures– mathematical and perceptual – Log–Spectral Distance, Cepstral Distances, Weighted Cepstral Distances and Filtering, Likelihood Distortions, Spectral Distortion using a Warped Frequency Scale, LPC, PLP and MFCC Coefficients, Time Alignment and Normalization – Dynamic Time Warping, Multiple Time – Alignment Paths.	**07L**
UNIT-03	**SPEECH MODELING:** Hidden Markov Models: Markov Processes, HMMs – Evaluation, Optimal State Sequence – Viterbi Search, Baum-Welch Parameter Re-estimation, Implementation issues.	**09L**
UNIT-04	**SPEECH RECOGNITION:** Large Vocabulary Continuous Speech Recognition: Architecture of a large vocabulary continuous speech recognition system – acoustics and language models – n-grams, context dependent sub-word units; Applications and present status.	**09L**
UNIT-05	**SPEECH SYNTHESIS:** Text-to-Speech Synthesis: Concatenative and waveform synthesis methods, sub-word units for TTS, intelligibility and naturalness – role of prosody, Applications and present status.	**08L**

Course Outcomes

Upon completion of the course, students will be able to:

CO1: Model speech production system and describe the fundamentals of speech.

CO2: Extract and compare different speech parameters.

CO3: Choose an appropriate statistical speech model for a given application.

CO4: Design a speech recognition system.

CO5: Use different speech synthesis techniques.

Books and References

1. Lawrence Rabiner and Biing-Hwang Juang, "Fundamentals of Speech Recognition", Pearson Education, 2003.
2. Daniel Jurafsky and James H Martin, "Speech and Language Processing – An Introduction to Natural Language Processing, Computational Linguistics, and Speech Recognition", Pearson Education, 2002.
3. Frederick Jelinek, "Statistical Methods of Speech Recognition", MIT Press, 1997.

Course Name: **Estimation and Detection Theory**
Course Code: **EC-363**
Course Type: **Discipline Elective-IV**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To enable the students to acquire the fundamental concepts of Signal Detection and Estimation.
- To get familiarize with different hypotheses in detection and estimation problems.
- To introduce the methods of detection and estimation of signals in white and non-white Gaussian noise.
- To familiarize with the detection of random signals.

Unit Number	Course Content	Contact Hours
UNIT-01	Review of Probability, Random variables, random processes, filtered random processes, Ensemble averages, correlation, covariance, power spectrum, cross power spectrum, Ergodicity, time averages, biased & unbiased estimators, consistent estimators. Problem Formulation and Objective of Signal Detection and Signal Parameter Estimation in Discrete-Time Domain.	07L
UNIT-02	Statistical Decision Theory: Bayesian, Min- Max, and Neyman-Pearson Decision Rules, Likelihood Ratio, Receiver Operating Characteristics, Composite Hypothesis Testing, Locally Optimum Tests, Detector Comparison Techniques, Asymptotic Relative Efficiency.	07L
UNIT-03	Detection of Deterministic Signals: Matched Filter Detector and its Performance; Generalized Matched Filter; Detection of Sinusoid with Unknown Amplitude, Phase, Frequency and Arrival Time, Linear Model.	07L
UNIT-04	Random Signals: Estimator-Correlator, Linear Model, General Gaussian Detection, Detection of Gaussian Random Signal with Unknown Parameters, Weak Signal Detection. Estimation of Signal Parameters: Minimum Variance Unbiased Estimation.	07L
UNIT-05	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.	07L
UNIT-06	Bayesian Estimation: Philosophy, Nuisance Parameters, Risk Functions, Minimum Mean Square Error Estimation, Maximum aposteriori estimation	07L

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Understand the basic concepts of signal detection and estimation.
CO2: Understand the different hypotheses in detection and estimation problems.
CO3: Understand the conceptual basics of detection and estimation of signals in white Gaussian noise.
CO4: Understand the detection of random signals.
CO5: Understand the time varying waveform detection and its estimation

Books and References

1. Fundamentals of Statistical Signal Processing: Estimation Theory, Vol. I, by S. M. Kay, Prentice Hall PTR.
2. Fundamentals of Statistical Signal Processing: Detection Theory, Vol. II by S. M. Kay, Prentice Hall PTR.
3. Detection, Estimation and Modulation Theory: Part I, II, and III by H. L. Van Trees, John Wiley, NY.
4. An Introduction to Signal Detection and Estimation by H. V. Poor, Springer.

Course Name: **FPGA SoC Design**
Course Code: **EC-431**
Course Type: **Discipline Elective-V**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To give the student an understanding of basics of system on chip and platform-based design
- To enable the student to understand issues related to FPGA and tools related to design and implementation.
- Analyse the functional and nonfunctionally performance of the system early in the design process to support design decisions.
- To impart knowledge about the system-level and SoC design methodologies and tools.
- Describe examples of applications and systems developed using a co-design approach.

Unit Number	Course Content	Contact Hours
UNIT-01	**INTRODUCTION TO DESIGN FLOW** ASICs: Types of ASICs, VLSI Design flow, Programmable ASICs, Antifuse, SRAM, EPROM, EEPROM based ASICs. Programmable ASIC logic cells and I/O cells. Programmable interconnects. Latest Version, FPGAs and CPLDs and Soft-core processors. Design Specification and Resource Scoping: Trade off issues at System Level: Optimization with regard to speed, area and power, asynchronous and low power system design. ASIC physical design issues, System Partitioning, Power Dissipation, Partitioning Methods.	**08L**
UNIT-02	**SYSTEM-ON-CHIP DESIGN:** SoC Block-Based Design: System-On-Chip Design, SoC Design Flow, Platform-based and IP based SoC Designs, Basic Concepts of Bus-Based Communication Architectures, On-Chip Communication Architecture Standards, Low-Power SoC Design, Performance Evaluation Methods for Multiprocessor System-on-Chip Design.	**07L**
UNIT-03	**FPGA DESIGN:** FPGA Design Environment: Introduction, Scripting Environment, Interaction with Version Control Software, A Regression Test System, Common Tools in the FPGA Design Environment, Challenges that FPGAs Create for Board Design, Engineering Roles and Responsibilities, FPGA Engineers, Design Flows for Creating the FPGA Pinout, Board Design Check List for a Successful FPGA Pin-Out.	**08L**
UNIT-04	**RTL DESIGN:** Power Analysis and RTL Design: Introduction, Power Basic, Key Factors in Accurate Power Estimation, Power Estimation Early in the Design Cycle, Simulation Based Power Estimation, Best Practices for Power Estimation, Recommendations for Engineers with an ASIC Design Background, Writing Effective HDL, Analyzing the RTL Design.	**07L**
UNIT-05	**THE HARDWARE/SOFTWARE CONSIDERATIONS:** Introduction, Software Interface, Definition of Register Address Map, Use of the Register Address Map, Hardware/Software Co-Design and Verification, High performance algorithms for ASICS/ SoCs as case studies – Canonic Signed Digit Arithmetic, Distributed Arithmetic.	**07L**

Course Outcomes

Upon successful completion of the course, the students will be able to
CO1: Demonstrate VLSI tool-flow and appreciate FPGA architecture.
CO2: Understand the basics of system on chip and on chip communication architectures.
CO3: Understand the issues involved in ASIC design, including technology choice, design management, tool flow.

Books and References

1. Embedded System Design: Modeling, Synthesis and Verification by D. Gajski, S. Abdi, A. Gerstlauer, G. Schirner, Springer.
2. Synthesis and Optimization of Digital Circuits by G. De Micheli, McGraw-Hill.
3. EDA for IC System Design, Verification, and Testing by Louis Scheffer, Luciano Lavagno, and Grant Martin.
4. Verilog Digital Computer Design by Mark Gordon Arnold.

Course Name: **Neural Network and Deep Learning**
Course Code: **EC-432**
Course Type: **Discipline Elective-V**

Contact Hours/Week: 3L **Course Credits: 03**

Course Objectives

The objective of this course is to develop artificial intelligence and machine learning techniques for solving various real-life problems.

Unit Number	Course Content	Lectures
UNIT-01	**NEURAL NETWORK LEARNING** Models of a Neuron, Multilayer Perceptron (MLP), Back Propagation Learning, Role of Loss Functions and Optimization, Gradient Descent, MLP for Classification and Regression	**06L**
UNIT-02	**DEEP LEARNING** Unsupervised Learning with Deep Network, Autoencoders, Convolutional Neural Network (CNN), Building blocks of CNN, Transfer Learning, Recurrent Neural Networks (RNN), Effective training in Deep Network-early stopping, Dropout, Batch Normalization, Instance Normalization, Group Normalization	**07L**
UNIT-03	Effective training in Deep Net- early stopping, Dropout, Batch Normalization, Instance Normalization, Group Normalization	**07L**
UNIT-04	**RECENT TRENDS IN DEEP NETWORK ARCHITECTURES** Generative Adversarial Networks (GAN) - Fundamentals and Applications, Classical Supervised Tasks with Deep Networks, CNN and RNN for Signal Classification, Convolutional Networks for Image Segmentation, Networks for Image Denoising, Object Detection	**08L**
UNIT-05	Classical Supervised Tasks with Deep Learning, Image Denoising, Semantic Segmentation, Object Detection etc., LSTM Networks, Generative Modeling with DL, Variational Autoencoder, Generative Adversarial Network	**08L**

Course Outcomes:

Upon successful completion of the course, the students will be able to

CO1: Understand the fundamentals of artificial intelligence and machine learning.

CO2: Understand the concepts of selected machine learning algorithms.

CO3: Understand the concepts of neural network learning.

CO4: Understand the concepts of deep neural networks.

Books and References:

1. Marc Peter Deisenroth, A. Aldo Faisal, Cheng Soon Ong, “Mathematics for Machine Learning”, Cambridge University Press.
2. Ian Goodfellow, Yoshua Bengio, and Aaron Courville, “Deep Learning”, MIT Press Ltd, Illustrated edition.
3. Richard O. Duda, Peter E. Hart, David G. Stork, “Pattern Classification”, John Wiley & Sons Inc.

Course Name: **VLSI Testing**
Course Code: **EC-433**
Course Type: **Discipline Elective-V**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To impart knowledge about the basics of testing techniques for VLSI circuits and Test Economics
- To introduce the fundamental concepts of Design for Testability.
- To enable the students to generate the test patterns.

Unit Number	Course Content	Contact Hours
UNIT-01	**Basics of Testing And Fault Modeling:** Introduction to Testing, Test process and ATE, Faults in digital circuits, Modeling of faults, Logical Fault Models, Fault detection, Fault location, Fault dominance, Logic Simulation, Types of simulation, Delay models, Gate level Event-driven simulation.	**02L**
UNIT-02	**Test Generation for Combinational and Sequential Circuits:** Logic simulation and fault simulation, Testability measures, Test generation for combinational logic circuits, Testable combinational logic circuit design, Test generation for sequential circuits, Design of testable sequential circuits.	**8L**
UNIT-03	**Design For Testability:** Ad-hoc design, Generic scan based design, Classical scan based design – System level DFT approaches, Memory test.	**9L**
UNIT-04	**Self-Test and Test Algorithms Built-In Self-Test:** Test pattern generation for BIST, Circular BIST, BIST Architectures, Testable Memory Design, Test algorithms, Test generation for Embedded RAMs, Logic BIST and EDT, Boundary Scan, System test and core test.	**12L**
UNIT-05	**Fault Diagnosis Logic Level Diagnosis:** Diagnosis by UUT reduction, Fault Diagnosis for Combinational Circuits, Self-checking design, System Level Diagnosis.	**03L**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Apply the concepts in testing which can help them design a better yield in IC design.

CO2: Tackle the problems associated with testing of semiconductor circuits at earlier design levels so as to significantly reduce the testing costs.

CO3: Identify the design for testability methods for combinational & sequential CMOS circuits

Books and References

1. M. Abramovici, M.A. Breuer and A.D. Friedman, “Digital Systems and Testable Design”, Jaico Publishing House.
2. M.L. Bushnell and V.D. Agrawal, “Essentials of Electronic Testing for Digital, Memory and Mixed-Signal VLSI Circuits”, Kluwer Academic Publishers.
3. P.K. Lala, “Digital Circuit Testing and Testability”, Academic Press, 2002.
4. A.L. Crouch, “Design Test for Digital IC's and Embedded Core Systems”, Prentice Hall International.

Open Elective Courses

Course Name: **Microcontroller and Embedded System**
Course Code: **EC-301**
Course Type: **Open Elective**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To discuss the microcontroller architecture, programming techniques, interrupts timers and assembly language.
- The concepts of ARM architecture and real-time operating system.
- To provide theoretical knowledge enabling integration of hardware and software in microcontroller-based applications.
- To impart ability to put together processor, peripherals and memory and build a real time system

Unit Number	Course Content	Contact Hours
UNIT-01	**MICROCONTROLLER** Introduction and Characteristics of Embedded Systems, Hardware and Software Co-Design, RISC Vs CISC, MCS-51 Family Overview, Architecture, Pin Diagram, Addressing Modes, Instruction Set, Instruction Types and applications of 8051 in ASIC and FPGA designs.	**05L**
UNIT-02	**PROGRAMMING** Assembly Programming, Timer Registers, Timer Modes, Overflow Flags, System clock, Timer, Counter, Interrupts, Baud Rate Generation, Serial Port Register, Modes of Operation, Processing Interrupts, Interrupt Service Routines, Look-up Tables.	**10L**
UNIT-03	**EMBEDDED SOFTWARE DEVELOPMENT** Software development flow, Polling, Multitasking systems, Architecture of an RTOS, Important features of RTOS, Embedded Systems Programming, Locks and Semaphores, Operating System Timers and Interrupts, Exceptions, Tasks, Task states and scheduling, Task structures, Synchronization, Communication and concurrency, Semaphores, Real-time clock	**08L**
UNIT-04	**32-BIT CORTEX-M ARCHITECTURE** Introduction to CPU Architecture, Memory model, Registers, Modes, Exceptions, Interrupts, Exception handlers, interrupt controllers, Power modes, Hardware features and optimizations, Advanced bus standards like AMBA, The NVIC on ARM Cortex-M.	**07L**
UNIT-05	**INTRODUCTION TO ARM ARCHITECTURE** Introduction to ARM architecture family**,** Syntax, Addressing modes and operands, Memory access instructions. Logical, Shift and Arithmetic operations, Stack, Functions and control flow, Macros and Directives, Thumb and arm instruction differences, Development with Keil and Mbed, Applications like IoT and machine learning with cortex-M.	**04L**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Develop the assembly codes for the microcontrollers.

CO2: Understand the functional role of embedded systems in real time.

CO3: Understand the design concept of embedded systems.

Books and References

1. The 8051 Microcontroller and Embedded Systems (2nd Ed.) by Mazidi Muhammad Ali, Pearson publications.
2. The Definitive Guide to ARM Cortex-M3 processors (3rd Ed.) by Joseph Yiu, Newnes publication.
3. Introduction to ARM Cortex-M Microcontrollers, Vol. 1 (5th Ed.) by Jonathan W. Valvano, Create Space.
4. Real-Time Interfacing to ARM Cortex-M Microcontrollers, Vol. 2 (4th Ed.) by Jonathan W. Valvano, Create Space.
5. Real-Time Operating Systems for ARM Cortex-M Microcontrollers, Vol. 3 (2nd Ed.) by Jonathan W. Valvano, Create Space.

Course Name: **MEMS and Sensor Design**
Course Code: **EC-302**
Course Type: **Open Elective**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To impart knowledge about the need and applications of microsystems in engineering.
- To introduce the fundamental concepts relevant to fabrication and machining process of MEMS sensors and actuators.
- To enable the students to understand the various sensing and actuation mechanisms.
- To enable the students to design and analysis MEMS technology-based devices

Unit Number	Course Content	Contact Hours
UNIT-01	**Introduction:** Introduction to MEMS and Microsystems, MEMS Classification, MEMS versus Microelectronics, Applications of MEMS in Various Industries, Some Examples of Microsensors, Microactuators, and Microsystems, Classification of Sensors, Scaling Laws in miniaturization, Materials for MEMS	**05L**
UNIT-02	**MEMS Fabrication:** Structure of Silicon, Single Crystal Growth Techniques, Photolithography, Oxidation, Diffusion, Ion Implantation, Physical Vapor Deposition, Chemical Vapor Deposition, Surface Micromachining, Bulk Micromachining, Overview of Etching, Isotropic and Anisotropic Etching, Wet Etchants, Etch Stop Techniques, Dry Etching, Micro- stereolithography, LIGA, SLIGA, Wafer Bonding	**12L**
UNIT-03	**Mechanical microsensors and microactuators**: Basic Modeling Elements in Mechanical, Electrical and Thermal Systems, Types of Beams: Fixed-Free (Cantilevers), Fixed-Fixed (Bridges), Fixed-Guided beams, Electrostatic sensing and Actuation: Parallel plate capacitor, Applications of parallel plate capacitors: Inertial sensor, Pressure sensor, Flow sensor, Parallel plate Actuators, Piezoresistive Sensors: Origin and Expressions of Piezoresisitivity, Piezoresisitive Materials and design of Piezoresisitive Sensors, Piezoelectric effect, Piezoelectric materials, Design of Piezoelectric Principle based Sensors and Actuators	**12L**
UNIT-04	Thermal and Magnetic microsensors: Thermal Sensing and Actuation: Sensors and Actuators based on Thermal Expansion, Thermocouples, Thermoresistors, Shape Memory Alloy, Applications: Interial sensors, Flow sensors, Infrared sensors, Magnetic material for MEMS, magnetic sensing, and detection, mannetoresistive sensors, hall effect, magnetodiode, megnetotransitors, MEMS magnetic sensors	**05L**
UNIT-05	**RF-MEMS:** MEMS devices for RF Applications: High-Q Capacitors, Inductors, Switching devices and their Applications in RF Circuits, Mechanical, Electromechanical and Electromagnetic modelling	**06L**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Identify structural and sacrificial materials for MEMS.

CO2: Describe the fabrication steps in designing various MEMS devices.

CO3: Apply principles for the design of Sensor and actuators.

CO4: Apply MEMS for different applications in various fields of engineering.

Books and References

1. MEMS and Microsystems design and manufacture by Tai-Ran Hsu, Tata McGraw Hill.
2. MEMS by N. P. Mahalik, Tata McGraw Hill.
3. Foundations of MEMS by Chang Liu, Pearson Prentice Hall.
4. Sensors and Transducers by M. J. Usher,McMillian Hampshire.
5. Analysis and Design Principles of MEMS Devices by MinhangBao, Elesvier.
6. Fundamentals of Microfabrication by M. Madou, CRC Press
7. Microsensors by R.S. Muller, Howe, Senturia and Smith, IEEE Press.
8. Semiconductor Sensors by S. M. Sze, Willy –Interscience Publications.

Course Name: **Communication Systems**
Course Code: **EC-303**
Course Type: **Open Elective**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To introduce students to the principles and applications of communication systems
- To provide students with an understanding of analog, digital and pulse communication techniques
- To familiarize students with modulation and demodulation techniques
- To introduce students to multiplexing and error correction codes
- To provide students with an understanding of the basic concepts of information theory, noise, and channel capacity

Unit Number	Course Content	Contact Hours
UNIT-01	**Introduction to Communication Systems** Definition and scope of communication systems, Communication channels and media, Basic block diagram of communication systems, Signal Representation and Analysis, Time and frequency domain representation of signals, Analog and digital signals, Fourier series and Fourier transform.	**05L**
UNIT-02	**Modulation and multiplexing techniques** Amplitude modulation (AM), Frequency modulation (FM), Phase modulation (PM) Digital modulation techniques (ASK, FSK, PSK, QAM), Pulse modulation schemes: pulse amplitude modulation (PAM), pulse position modulation (PPM), pulse width modulation (PWM), pulse code modulation (PCM), delta modulation (DM), and adaptive delta modulation (ADM). Frequency division multiplexing (FDM), Time division multiplexing (TDM), Code division multiplexing (CDM).	**08L**
UNIT-03	**Analog and Digital radio receivers** Types of analog radio receivers: Superheterodyne, TRF (Tuned Radio Frequency), and Regenerative, Demodulation Techniques: Amplitude Modulation (AM) and Frequency Modulation (FM), Sensitivity and Selectivity of Radio Receivers, Noise in Radio Receivers Automatic Gain Control (AGC) in Radio Receivers, Applications of analog radio receivers, Types of digital radio receivers: Direct Conversion, Superheterodyne, and Software Defined Radio (SDR), Demodulation Techniques: Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK), Phase Shift Keying (PSK), and Quadrature Amplitude Modulation (QAM).	**08L**
UNIT-04	**Channel Capacity and Coding** Introduction to information theory, Entropy and information content, Source coding, Channel capacity, introduction to error correction codes, Linear block codes, Convolutional codes, Shannon's channel capacity theorem.	**05L**
UNIT-05	**Recent Communication Systems** 5G Communication Systems, Satellite Communication Systems, Cognitive Radio Systems, Internet of Things (IoT) Communication Systems.	**05L**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: understand the basic building blocks of communication systems, including modulation techniques and transmission media.

CO2: understand the principles of digital signal processing and its application to communication systems, including techniques for signal filtering, modulation, and demodulation.

CO3: Understand the source and channel encoding principles used in the communication systems.

CO4: Understand the emerging communication technologies, including 5G, Internet of Things (IoT), and Cognitive radio systems.

Books and References

1. "Communication Systems Engineering" by John G. Proakis and Masoud Salehi.
2. “Communication Systems, 3rd edition” by Simon Haykin.

Course Name: **VLSI Design and Techniques**
Course Code: **EC-304**
Course Type: **Open Elective**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To impart knowledge about the Hardware Description Language based design approach.
- To Understand different modeling techniques used in HDL.
- The ability to code and simulate any digital function in HDL.

Unit Number	Course Content	Contact Hours
UNIT-01	**Introduction:** Introduction and levels of abstraction, Modeling and Hierarchical design concepts, Languages, Compilation & Simulation, concurrency, Logic value system, Role of CAD Tools in the VLSI design process.	**05L**
UNIT-02	**Language concepts:** Lexical conventions, Data types, modules and ports, Behavioral modeling, Dataflow modeling, Structural modelling.	**08L**
UNIT-03	**RTL Design:** Control & Data partitioning, Synthesis concepts, Non-synthesizable constructs, Operators, Expressions, Conditional statements, Post synthesis simulation.	**07L**
UNIT-04	**Advanced language concepts:** Procedures and timing control, Procedural blocks, Loops, Tasks and functions, Test bench modeling techniques, Path delay modeling, Timing analysis, User defined premitives, Compiler directives, and System tasks.	**08L**
UNIT-05	**Hardware modules:** Boolean equations, Encoders, Decoders, Multiplexers, Cascaded multiplexers, Adders, Serial adders, Comparators, Multipliers, Divider, Sorters, Shifters, Static and dynamic memories, Mealy & Moore finite state machine, Vending machines.	**05L**
UNIT-06	**Advanced design concepts:** FPGA architecture, Static timing analysis, Synchronization, Metastability, Verification methods, Implementation on FPGA, PLA based design.	**06L**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Design digital circuits in HDL.

CO2: Verify behavioral and RTL models.

CO3: Synthesize and simulate RTL design to standard cell libraries and FPGAs.

Books and References

1. Peter J. Ashenden, “The Designer's Guide to VHDL”, 2nd Edition, Morgan Kaufmann Publishers, 2001
2. J. Bhasker, “A Verilog HDL Primer”, Star Galaxy Press, 1996.
3. Samir Palnitkar, “Verilog HDL: A Guide to Digital Design and Synthesis”, Prentice Hall, 1996.
4. Vivek Sagdeo, “The Complete Verilog Book”, Kluwer Academic Publishers.
5. Douglas J. Smith, “HDL Chip Design : A Practical guide for Designing, Synthesizing and Simulating ASICs and FPGAs using VHDL or Verilog”, Doone Pubns, 1996.
6. Ben Cohen, “VHDL Coding Styles and Methodologies”, Kluwer Academic Publishers, 1999.
7. J. Bhasker, “A VHDL Primer”, Third Edition, Prentice Hall, 1998.

Stream Core Courses

Course Name: **Hardware Description Language**
Course Code: **EC-381**
Course Type: **Stream Core-I**

Contact Hours/Week: **2L** Course Credits: **02**

Course Objectives

- To impart knowledge about the Hardware Description Language based design approach.
- To Understand different modeling techniques used in HDL
- The ability to code and simulate any digital function in HDL.

Unit Number	Course Content	Contact Hours
UNIT-01	**Language concepts:** Lexical conventions, Data types, modules and ports, Behavioral modeling, Dataflow modeling, Structural modelling.	**08L**
UNIT-02	**RTL Design:** Control & Data partitioning, Synthesis concepts, Non-synthesizable constructs, Operators, Expressions, Conditional statements, Post synthesis simulation.	**07L**
UNIT-03	**Advanced language concepts:** Procedures and timing control, Procedural blocks, Loops, Tasks and functions, Test bench modeling techniques, Path delay modeling, Timing analysis, User defined premitives, Compiler directives, and System tasks.	**08L**
UNIT-04	**Hardware modules:** Boolean equations, Encoders, Decoders, Multiplexers, Cascaded multiplexers, Adders, Serial adders, Comparators, Multipliers, Divider, Sorters, Shifters, Static and dynamic memories, Mealy & Moore finite state machine, Vending machines.	**05L**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Design digital circuits in HDL.

CO2: Verify behavioral and RTL models.

CO3: Synthesize and simulate RTL design to standard cell libraries.

Books and References

1. Peter J. Ashenden, “The Designer's Guide to VHDL”, 2nd Edition, Morgan Kaufmann Publishers, 2001
2. J. Bhasker, “A Verilog HDL Primer”, Star Galaxy Press, 1996.
3. Samir Palnitkar, “Verilog HDL: A Guide to Digital Design and Synthesis”, Prentice Hall, 1996.
4. Vivek Sagdeo, “The Complete Verilog Book”, Kluwer Academic Publishers.
5. Douglas J. Smith, “HDL Chip Design : A Practical guide for Designing, Synthesizing and Simulating ASICs and FPGAs using VHDL or Verilog”, Doone Pubns, 1996.
6. Ben Cohen, “VHDL Coding Styles and Methodologies”, Kluwer Academic Publishers, 1999.
7. J. Bhasker, “A VHDL Primer”, Third Edition, Prentice Hall, 1998.

Course Name: **Simulation of Communication Systems**
Course Code: **EC-382**
Course Type: **Stream Core-I**

Contact Hours/Week: **2L** Course Credits: **02**

Course Objectives

- This course provides an introduction to simulating communication systems using MATLAB and Python.
- Understand the basics of communication systems, including signal modulation, demodulation, channel impairments, and error correction techniques.
- Develop skills in MATLAB and Python programming for numerical computation and data analysis.
- Learn how to model and simulate various communication systems, including analog and digital modulation, synchronization, channel coding, and demodulation.
- Analyze the performance of simulated systems under different channel conditions and noise levels.
- Gain experience in presenting and interpreting simulation results.

Unit Number	Course Content	Contact Hours
UNIT-01	Introduction to Communication Systems and Programming Essentials: Overview of communication systems, Signal representation and analysis, Analog modulation and demodulation techniques, Digital modulation and demodulation techniques, Channel impairments and noise Introduction to MATLAB and Python Data types, variables, operators, and control flow Functions, modules, and packages Numerical computations and data analysis, Plotting and visualization.	**08L**
UNIT-02	Communication System Modeling and simulation in MATLAB: Modeling of signal sources and modulators Channel modeling and noise generation, simulating analog modulation schemes (AM, FM, PM), Simulating digital modulation schemes (PSK, QAM), Performance analysis of simulated systems.	**08L**
UNIT-03	Communication System Modeling in Python: Implementing similar simulations using Python libraries (NumPy, SciPy, Matplotlib), Object-oriented programming for complex system modeling, Advanced signal processing techniques in Python.	**08L**
UNIT-04	Advanced Topics: Channel coding and decoding techniques, Synchronization methods, MIMO systems, Introduction to software-defined radio (SDR)	**06L**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Explain the basic concepts of modeling and simulation and their role in communication system engineering.
CO2: Simulate communication systems including modulators, filters, demodulators, channels, equalizers, and encoders and decoders.
CO3: Apply simulation and modeling methodologies to solve real-world communication system problems.
CO4: Interpret simulation results and use them to make informed decisions about communication system design and implementation

Books and References

1. "Simulation of Communication Systems" by Michel C. Jeruchim, Philip Balaban, Sam Shanmugan.
2. "Communication Systems" by Simon Haykin, Wiley.

Course Name: **Information Theory and Coding**
Course Code: **EC-451**
Course Type: **Stream Core-II**

Contact Hours/Week: **02L** Course Credits: **02**

Course Objectives

- To impart knowledge about measuring the amount of information, capacities calculation of different channels in communication systems
- To understand the theorems and inequalities used in information and coding theory field.
- To enable the students to design the source coding algorithms for improving transmission efficiency.
- To enable the students to design the block-based error control coding algorithms for improving error performance of communication systems.

Unit Number	Course Content	Lectures
UNIT-01	**Measures of Information and Channel Capacity:** Entropy, Relative Entropy and Mutual Information, Chain rule for entropy functions, Basic Inequalities: Jensen Inequality and its Physical Application), Log–Sum Inequality and its Physical Application. Definition of Capacity and its Computation of Discrete Memory Less Channels (BNC, BSC, BEC, Cascaded Channels, Noiseless Channels, Noisy Typewriter),	**06L**
UNIT-02	**Data Compression:** Unique Decodability and the Prefix Condition, Kraft's Inequality, Relationship of Average Codeword Length to Source Entropy, Examples of Coding Techniques: Huffman, Shannon–Fano–Elias, Lempel–Ziv and Universal.	**06L**
UNIT-03	**Design of Linear Block Codes:** Introduction of Linear Block Codes, Syndrome and Error Detection, Minimum Distance of a Block Code, Error Detecting and Error Correcting Capability of a Block Code, Design of Encoder and Syndrome Decoder for Linear Block Codes.	**06L**
UNIT-04	**Convolutional Codes**: Encoding of Convolutional Codes, Structural Properties of Convolutional Codes, Distance Properties of Convolutional Codes, Design of Encoder and Decoder for Convolutional Codes.	**06L**

Course Outcomes:

Upon successful completion of the course, the students will be able to

CO1: Understand the various terminologies to estimate information content in the communication system.

CO2: Apply various inequalities and quantities to evaluate the information content of a discrete memory-less source.

CO3: Design lossless source codes for discrete memory-less source to improve the efficiency of information transmission.

CO4: Design block-based error control codes for improving the error performance of information transmission systems.

Books and References:

1. Elements of Information Theory by T. M. Cover and J. A. Thomas, John Wiley, 1991.
2. Error Control Coding by S. Lin and D. J. Costello, Pearson Education, 2010.
3. Information Theory and Reliable Communication by R. G. Gallager, John Wiley & Sons, 1969.
4. Information Theory, Coding & Cryptography by Ranjan Bose, Mc Graw Hill, 2016.

Course Name: **Analog IC Design**

Course Code: **EC-452**

Course Type: **Stream Core-II**

Contact Hours/Week: **2L** Course Credits: **02**

Course Objectives

- To give the student an understanding of basics of Analog IC Design.
- To enable the student to understand issues related to MOSFET and its small signal model design.
- The course aims to teach basic concepts along with advanced design techniques for CMOS amplifiers.
- The objective of the course is to design and implement the product level op amps and buffers for VLSI applications.

Unit Number	Course Content	Contact Hours
UNIT-01	**MOS DEVICE MODELS AND SHORT CHANNEL EFFECTS:** MOSFET level 1 and level 2 models, threshold voltage model, capacitance model, mobility model, MOSFET basics, small-signal model derivation for a single transistor amplifier Process	**06L**
UNIT-02	**CMOS CURRENT MIRRORS:** Scheme and implementation: basic current mirrors, cascode current mirrors and active current mirrors with large and small signal analysis Understanding of common-mode properties Analog layout making techniques for current mirrors	**06L**
UNIT-03	**CMOS AMPLIFIERS:** Basic concept, Common source stage: with resistive load, with diode connected load, with current-source load, with triode load,Single ended differential operation, basic differential pair (qualitative and quantitative analysis, Miller effect, common source (CS), common gate (CG), common drain (CD) stages and cascode stage Analog layout techniques for MIM, MOM and fringe capacitor Noise analysis of the CMOS amplifier circuits	**08L**
UNIT-04	**DESIGN OF THE CMOS OPERATIONAL AMPLIFIERS:** One-stage op amps and two stage op-amps, Gain boosting techniques, folded cascode, telescopic amplifier and common mode feedback (CMFB) amplifier Three stage op amp architectures, op amp specifications analysis, Design of high speed and high gain amplifiers,Feedback topologies	**08L**

Course Outcomes:

Upon successful completion of the course, the students will be able to

CO1: Understand the operation of MOSFET and its small signal model.

CO2: Analyze and design amplifiers, current mirrors and differential amplifiers.

CO3: Understand the significance of different biasing techniques and apply them aptly to different circuits.

CO4: Comparatively evaluate the frequency response different single stage amplifiers.

CO5: Analyze & design the compensation different single stage amplifiers.

Books and References:

1. Design of Analog CMOS Integrated Circuits by Behzad Razavi, McGraw Hill Education (1 September 2000)
2. CMOS Analog Circuit Design by Phillip Allen and Douglas R. Holberg, OUP USA; Third Edition edition (1 September 2011).
3. Operation and Modeling of the MOS Transistor by Yannis Tsividis, Oxford University Press; 2 edition, June 26, 2003
4. Microelectronic Circuits-Theory & Applications by A.S. Sedra and K.C. Smith, Adapted by A.N. Chandorkar, 6th Edition, Oxford, 2013.

Course Name: **Artificial Intelligence and Machine Learning**
Course Code: **EC-471**
Course Type: **Stream Core-III**

Contact Hours/Week: 2L **Course Credits: 02**

Course Objectives

The objective of this course is to develop artificial intelligence and machine learning techniques for solving various real-life problems.

Unit Number	Course Content	Lectures
UNIT-01	**INTELLIGENT AGENTS AND PROBLEM-SOLVING** The Foundations of Artificial Intelligence. The History of Artificial Intelligence, Risks and Benefits of AI, Agents and Environments, The Concept of Rationality, The Nature of Environments, The Structure of Agents, Problem-Solving Agents, Search Algorithms, Uninformed Search Strategies, Informed (Heuristic) Search Strategies, Heuristic Functions	**06L**
UNIT-02	**INTRODUCTION TO MACHINE LEARNING** Performance Measures of Classification, Bayesian Decision Theory, Bayesian Belief Networks, Parameter Estimation and Maximum Likelihood Estimation, Dimensionality Problem and Principal Component Analysis (PCA), Linear Discriminant Analysis	**06L**
UNIT-03	**SELECTED MACHINE LEARNING ALGORITHMS** Linear Regression, Decision Tree Classifiers, Overfitting, Notion of Training, Validation and Testing, Support Vector Machine (SVM), Logistic Regression, Kernels (with SVM), Hidden Markov Model (HMM)	**06L**
UNIT-04	**ENSEMBLE LEARNING AND CLUSTERING** Ensemble Learning, Boosting, Classifier Evaluation, Unsupervised Learning, K-means clustering, Fuzzy K-means clustering, Hierarchical Agglomerative Clustering and Mean-shift Clustering	**06L**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Understand the basics of artificial intelligence and intelligent agents.

CO2: Understand the fundamentals of machine learning.

CO3: Understand the concepts of selected machine learning algorithms.

CO4: Understand the concepts of ensemble learning and clustering.

Books and References

1. S. Russel and P. Norvig, “Artificial Intelligence – A Modern Approach”, Second Edition, Pearson Education
2. Marc Peter Deisenroth, A. Aldo Faisal, Cheng Soon Ong, “Mathematics for Machine Learning”, Cambridge University Press

Course Name: **Embedded Systems**
Course Code: **EC-472**
Course Type: **Stream Core-III**

Contact Hours/Week: **2L** Course Credits: **02**

Course Objectives

- To impart knowledge about the microcontrollers, its programming, interrupts, timers and assembly language.
- The concepts of ARM architecture and realtime operating system.
- To provide experience to integrate hardware and software for microcontroller application system.
- To impart ability to put together processor, peripherals and memory and build a real time system.

Unit Number	Course Content	Contact Hours
UNIT-01	**Programming:** Introduction to Embedded System Architecture, The Embedded Systems Model, Embedded Hardware, Assembly Programming, Timer Registers, Timer Modes, Overflow Flags, Clocking Sources, Timer Counter Interrupts, Baud Rate Generation, Serial Port Register, Modes of Operation, Processing Interrupts, Interrupt Service Routines, Look-up Tables.	**10L**
UNIT-02	**Embedded software development:** Software development flow, Polling, Interrupt driven, Multi-tasking systems, Architecture of an RTOS, Important features of RTOS, Embedded Systems Programming, Locks and Semaphores, Operating System Timers and Interrupts, Exceptions, Tasks, Task states and scheduling, Task structures, Synchronization, Communication and concurrency, Semaphores, Mutexes, Real-time clock, Memory management. Scheduling algorithms like Round Robin, Rate monotonic, Earliest Deadline First.	**08L**
UNIT-03	**32-Bit Cortex-M Architecture:** CPU architecture, Memory model, Registers, Modes, Exceptions, Interrupts, Exception handlers, interrupt controllers, Power modes, Hardware features and optimizations, Advanced bus standards like AMBA, The NVIC on ARM Cortex-M.	**07L**
UNIT-04	**Instruction set of ARM:** Syntax, Addressing modes and operands, Memory access instructions, Logical operations, Shift operations, Arithmetic operations, Stack, Functions and control flow, Assembler directives, Thumb and arm instruction differences, Development with Keil and mbed, Applications like IoT and machine learning with cortex-M.	**06L**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Write the programs for microcontrollers.

CO2: Understand the role of embedded systems in industry.

CO3: Understand the design concept of embedded systems.

Books and References

1. Mazidi Muhammad Ali, "The 8051 Microcontroller and Embedded Systems", 2nd Edition, Pearson publications.
2. Joseph Yiu, "The Definitive Guide to ARM Cortex-M3 processors", 3rd Edition, Newnes publication.
3. Jonathan W. Valvano, "Volume 1, Introduction to ARM Cortex-M Microcontrollers", 5th Edition, CreateSpace.
4. Jonathan W. Valvano, "Volume 2, Real-Time Interfacing to ARM Cortex-M Microcontrollers", 4th Edition, CreateSpace.
5. Jonathan W. Valvano, "Volume 3, Real-Time Operating Systems for ARM Cortex-M Microcontrollers", 2nd Edition, CreateSpace.

Stream Elective Courses

Course Name: **Applied Linear Algebra for Signal Processing, Data Analytics and Machine Learning**
Course Code: **EC-461**
Course Type: **Stream Elective-I**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To introduce all the basic and advanced concepts in Linear Algebra with a strong focus on applications. Linear Algebra is one of the fundamental tools that has.
- To introduce applications of Linear Algebra in diverse fields such as Machine Learning, Data Analytics, Signal Processing, Wireless Communication, Operations Research, Control and Finance.
- To learn about the novel cutting edge applications of linear algebra in various fields such as Machine Learning, Data Analytics, Signal Processing, Wireless Communication.

Unit Number	Course Content	Contact Hours
UNIT-01	Introduction to vectors, properties and applications, Introduction to matrices and Applications Circuits, Graphs, Social Networks, Traffic flow, Eigenvalue decomposition, properties and Applications Principal component analysis (PCA), Eigen faces for facial recognition	**08L**
UNIT-02	Singular value decomposition (SVD) and Applications Beamforming in MIMO, Dimensionality reduction, Rate maximization in wireless, MUSIC algorithm, Linear regression and Least Squares. Applications: System identification, linear regression, Support vector machines (SVM), kernel SVMs, Optimal linear MMSE estimation. Applications MMSE Receiver, Market prediction and forecasting, ARMA models	**08L**
UNIT-03	Data analytics: Recommender systems, user rating prediction, Structure of FFT/ IFFT matrices, properties, System model for OFDM/ SC-FDMA, Signal processing in OFDM systems	**08L**
UNIT-04	Modeling of Dynamical systems Examples, Solution of autonomous linear dynamical systems (LDS), solution of with inputs and outputs, Unsupervised learning: Centroid based clustering, probabilistic model-based clustering and EM algorithm, Linear perceptron. Training a perceptron stochastic gradient. Compressive sensing, orthogonal matching pursuit for sparse signal estimation	**08L**
UNIT-05	Discrete time Markov chains Applications: supply chain management, forecasting, Operations research resource and inventory management.	**04L**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Understand the basic of Linear Algebra

CO2: Understand applications of Linear Algebra in diverse fields such as Machine Learning, Data Analytics, Signal Processing, Wireless Communication, Operations Research, Control and Finance

Books and References

1. Introduction to Linear Algebra: Gilbert Strang
2. Fundamentals of Wireless Communication. David Tse, Pramod Viswanath
3. Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow: Concepts, Tools, and Techniques to Build Intelligent Systems, Third Edition by Aurélien Géron Shroff/O'Reilly Publisher

Course Name: **RF and Microwave Circuit Design**
Course Code: **EC-462**
Course Type: **Stream Elective-I**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To impart knowledge about the transmission lines theory, network analysis, smith chart, microwave filter circuits, power divider, coupler and their characterization.

Unit Number	Course Content	Contact Hours
UNIT-01	**REVIEW OF TRANSMISSION LINES THEORY** Propagation of voltage and current in transmission lines, Parameters, transmission line equation, reflection and transmission coefficient, lossy transmission line, standing waves, input impedance, Generator and load mismatches, transient analysis of transmission lines.	**09 L**
UNIT-02	**SMITH CHART AND MATCHING NETWORKS** Smith chart, Matching with lumped element, single stub matching, double stub matching, quarter wave transformers.	**06 L**
UNIT-03	**NETWORK ANALYSIS** Scattering Parameter, Z Parameter, Y parameter, ABCD parameter, conversion from S-parameter in terms of Z parameter, conversion from Z-parameter in terms of S- parameter, S-parameter in terms of Y-parameter, conversion from Y-parameter in terms of S- parameter, S-parameter in terms of ABCD parameter, conversion from ABCD parameter in terms of S- parameter.	**05 L**
UNIT-04	**MICROWAVE RESONATOR AND FILTERS** Series and parallel resonant circuits, Transmission Line Resonators, Dielectric Resonators, Filter Parameters, Filter design by Image Parameter method, Filter design by Insertion Loss method, Filter Transformation, Filter Implementation, Impedance and Admittance inverters.	**09 L**
UNIT-05	**MICROWAVE POWER DIVIDER AND COUPLERS** Directional couplers, Bethe-hole couplers, coupled line directional coupler, Wilkinson Power Divider.	**06 L**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Describe and apply transmission line theory, matching networks in different microwave devices.
CO2: Describe and utilize different network analysis parameters for solving two or multiport networks.
CO3: Design and characterize different microwave filter, coupler and power divider.

Books and References

1. Microwave Engineering by D. M. Pozar, Wiley
2. Foundations of Microstrip Circuit Design by T. C. Edwards and M. B. Steer, Wiley-IEEE Press.
3. Elements of Electromagnetics by M. N. O. Sadiku, Oxford University Press, New York.
4. Microwave Engineering, by Sushrut Das, Oxford University Press

Course Name: **Low Power VLSI Design Techniques**
Course Code: **EC-463**
Course Type: **Stream Elective-I**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To impart knowledge about the dominant sources of power dissipation in VLSI circuits.
- To introduce the fundamental concepts for optimization of power at all design levels: technology, circuit, logic, and architectural level.
- To enable the students to aware of power estimation by various means.

Unit Number	Course Content	Contact Hours
UNIT-01	**Introduction:** Need for Low Power VLSI Chips, Sources of Power Dissipation in Digital Integrated Circuits, Physics of Power Dissipation in CMOS Devices, Dynamic Dissipation in CMOS, Leakage Power Dissipation, Low Power Figure of Merits, Impact of Technology Scaling, Device Innovation and Channel Engineering	**06L**
UNIT-02	**Power Estimation:** Simulation Power Analysis: SPICE Circuit Simulators, Gate Level Logic Simulation, Capacitive Power Estimation, Static State Power, Gate Level Capacitance Estimation, Data Correlation Analysis in DSP Systems, Monte Carlo Simulation, Probabilistic Power Analysis: Random Logic Signals, Probability and Frequency, and Probabilistic Power Analysis Techniques	**09L**
UNIT-03	**Low Power Circuit Level Design:** Circuit Level Transistor and Gate Sizing, Circuit Techniques for Leakage Power Reduction, Transistor Stacking, Supply Voltage Scaling Techniques, DTCMOS, MTCMOS, Network Restructure and Reorganization, Flip Flops and Latches Design, and Low Power Digital Cell Library	**07L**
UNIT-04	**Low Power Logic Level Design:** Gate Reorganization, Multistage Logic Design, Signal Gating, Logic Encoding, State Machine Encoding, and Pre-Computation Logic	**07L**
UNIT-05	**Low Power Architecture and System Level Design**: Power and Performance Management, Switching Activity Reduction, Parallel Architecture with Voltage Reduction, and Flow Graph Transformation.	**05L**
UNIT-06	**Special Techniques:** Low Power Clock Distribution, Single Driver vs Distributed Buffers, Various Clock Distribution Networks, Power Reduction in Clock Networks, Low Power Bus, CMOS Floating Nodes, and Adiabatic Logic.	**05L**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Identify sources of power dissipation in VLSI systems.

CO2: Analyze various circuit and logic design techniques for dynamic and leakage power reduction.

CO3: Design arithmetic circuits, latches and flip flops with different logic styles.

CO4: Understand the concepts of probability and random logic signals for estimation of capacitance and power dissipation.

CO5: Understand power management through architectural level techniques.

Books and References

1. Practical Low Power Digital VLSI Design by Gary K. Yeap, Kluwer Academic Press.
2. Low-Power CMOS VLSI Circuit Design by Kaushik Roy, and Sharat Prasad, Wiley.
3. Low Power VLSI CMOS Circuit Design by A. Bellamour, and M. I. Elmasri, Kluwer Academic Press.
4. Low Power Design Methodologies by J. M. Rabaey and M. Pedram, Kluwer Academic Press.
5. Low-Voltage Low-Power VLSI subsystems by Kait-Seng Yeo and Kaushik Roy, Tata McGraw-Hill.
6. Low Power Digital CMOS Design by Anantha P. Chandrakasan and Robert W. Brodersen, Kluwer Academic Press.

Course Name: **VLSI Interconnects and Packaging**
Course Code: **EC-464**
Course Type: **Stream Elective-I**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To impart knowledge about the importance of electrical on-chip interconnects in modern VLSI circuits
- To introduce the various equivalent circuit models of interconnects and their comparison
- To understand the short-channel model of CMOS repeater driving interconnect and its analysis
- To enable the students to understand the advanced interconnect techniques

Unit Number	Course Content	Contact Hours
UNIT-01	**Interconnects:** *Interconnect Parameters*: Resistance, Inductance, and Capacitance, *Interconnect RC Delays*: Elmore Delay Calculation. *Interconnect Models*: Lumped RC Model, Distributed RC Model, Transmission Line Model. *SPICE Wire Models*: Distributed RC Lines in SPICE, Transmission Line Models in SPICE, Gate and Interconnect Delay	**07L**
UNIT-02	**CMOS Repeater:** *Static Behavior*: Switching Threshold, Noise Margins. Dynamic Behavior-Computing Capacitances. *Propagation Delay*: First order analysis, Propagation Delay from a Design Perspective. *Power, Energy and Energy-Delay*: Dynamic Power Consumption, Static Consumption, Analyzing Power Consumption using SPICE	**06L**
UNIT-03	**Driving Interconnects for Optimum Speed and Power:** *Short Channel Model of CMOS Repeater*: Transient Analysis of an RC Loaded CMOS Repeater, Delay Analysis. *Analytical Power Expressions*: Dynamic Power, Short Circuit Power, Resistive Power Dissipation. *CMOS Repeater Insertion*: Analytical Expressions for Delay and Power of a Repeater Chain Driving an RC Load	**05L**
UNIT-04	**Advanced Interconnect Techniques:** Reduced-swing Circuits, Current Mode Transmission Techniques	**05L**
UNIT-05	**Crosstalk:** Theoretical Basis and Circuit Level Modeling of Crosstalk, *Energy Dissipation due to Crosstalk*: Model for Energy Calculation of two Coupled Lines. Contribution of Driver and Interconnect to Dissipated Energy. *Crosstalk effects in logic VLSI circuits*: Static Circuits, Dynamic Circuits and Various Remedies	**07L**
UNIT-06	**IC Packaging:** Package Types, Packaging Design Considerations, VLSI Assembly Technology, Package Fabrication Technology	**06L**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Develop the ability to analyze and design electrical interconnect using equivalent circuit models.

CO2: Understand the use of CMOS repeater to predict delay and power in interconnects.

CO3: Describe the design trade-offs in driver-interconnect-load system.

CO4: Design crosstalk and delay aware repeater driven interconnect system using advanced signaling techniques

Books and References

1. Analysis and Design of Digital Integrated Circuits – A Design Perspective by Jan M. Rabaey, Tata Mc-Graw Hill.
2. Interconnection Noise in VLSI Circuits by F. Moll and M. Roca, Kluwer Academic Publishers.
3. Introduction to VLSI Circuits and Systems by J. P. Uymera, Wiley Student Edition.
4. CMOS Digital Integrated Circuits – Analysis and Design by S. M. Kang and L. Yusuf, Tata Mc-Graw Hill.

Course Name: **Internet of Things and Applications**
Course Code: **EC-465**
Course Type: **Stream Elective-I**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To understand the basics of Internet of Things (IoT) in different aspects of research, implementation, and business with IoT.
- To understand different application domain verticals ranging from civilian to defence sectors including agriculture, space, healthcare, manufacturing, construction, water, and mining.
- To envision pervasive connectivity, storage, and computation, which, in turn, gives rise to building different IoT solutions.
- To understand implementation of IoT with Arduino, Raspberry Pi

Unit Number	Course Content	Contact Hours
UNIT-01	Introduction to IoT: Sensing, Actuation, Basics of IoT Networking, Connectivity Technologies, Communication Protocols, Sensor Networks, UAV Networks, Machine-to-Machine Communications	**07L**
UNIT-02	Interoperability in IoT, Introduction to Arduino Programming, Integration of Sensors and Actuators with Arduino, Introduction to Python programming, Introduction to Raspberry Pi	**07L**
UNIT-03	Implementation of IoT with Raspberry Pi, Introduction to Software Defined Networking (SDN), SDN for IoT, Data Handling and Analytics	**07L**
UNIT-04	Cloud Computing, Cloud Computing-Fundamental, Cloud Computing-Service Model, Cloud Computing-Service Management and Security, Cloud Computing- Case Studies, Sensor-Cloud, Fog Computing,	**07L**
UNIT-05	Applications: Smart Cities and Smart Homes, Connected Vehicles, Smart Grid, Industrial Internet of Things, Data Handling and Analytics, Case Study: Agriculture, Healthcare, Activity Monitoring	**08L**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Give the basic of Internet of Things

CO2: Understand basics of Networking, Sensor Networks and Communication Protocols.

CO3: To understand Implementation of IoT with Raspberry Pi.

CO4: To understand and implement different applications of IoT

Books and References

1. S. Misra, A. Mukherjee, and A. Roy, 2020. Introduction to IoT. Cambridge University Press.
2. S. Misra, C. Roy, and A. Mukherjee, 2020. Introduction to Industrial Internet of Things and Industry 4.0. CRC Press.
3. Internet of Things, An Indian Adaptation: : Concepts And Applications Paperback – 1 May 2021 by Wiley Editorial
4. Designing the Internet of Things, by Adrian McEwen (Author), Hakim Cassimally Wiley Publisher
5. The Silent Intelligence: The Internet of Things by Daniel Kellmereit, Daniel Obodovski, Lightning Source Inc

Course Name: **Wavelet Transform and Applications** Course Code: **EC-466** Course Type: **Stream Elective-I**	
Contact Hours/Week: **3L**	Course Credits: **03**

Course Objectives

- To introduce Time-frequency analysis
- To introduce Frames, orthonormal bases of wavelets, multiresolution analysis
- To introduce Wavelet packets, Approximation theory of wavelet thresholding
- To introduce Statistical estimation with wavelets, and Coding theory

Unit Number	Course Content	Contact Hours
UNIT-01	Introduction Stationary and non-stationary signals, Signal representation using basis and frames, Brief introduction to Fourier transform and short time Fourier transform, Instantaneous Frequency, Analytic Signals, Multicomponent Signals, Time-frequency analysis, Bases of time frequency: orthogonal, Filter banks, Multi resolution formulation: Wavelets from filters, Classes of wavelets: Haar, Daubechies, bi-orthogonal.	**07L**
UNIT-02	Continuous Wavelet Transform Continuous wavelet transform (CWT), Time and frequency resolution of the continuous wavelet transform, Construction of continuous wavelets: Spline, orthonormal, bi-orthonormal, Inverse continuous wavelet transform, Redundancy of CWT, zoom property of the continuous wavelet transform, Filtering in continuous wavelet transform domain, Bases, Orthogonal Bases, Biorthogonal Bases, Frames, Tight Frames, and unconditional Bases	**07L**
UNIT-03	Discrete Wavelet Transform and Filterbanks, Orthogonal and biorthogonal two-channel filter banks, Design of two-channel filter banks, Tree-structured filter banks, Discrete wavelet transform, Non-linear approximation in the Wavelet domain, multi resolution analysis, Construction and Computation of the discrete wavelet transform, the redundant discrete wavelet transform, Regularity, Moments, and Wavelet System Design	**07L**
UNIT-04	Multi Resolution Analysis Multirate discrete time systems, Parameterization of discrete wavelets, Bi-orthogonal wavelet bases, Two dimensional, wavelet transforms and Extensions to higher dimensions, Wavelet packet and local cosine bases	**07L**
UNIT-05	Signal and Image compression, Detection of signal changes, analysis and classification of audio signals using CWT, Wavelet based signal de-noising and energy compaction	**07L**
UNIT-06	Transform coding, Wavelets in adaptive filtering, Adaptive wavelet techniques in signal acquisition, coding and lossy transmission, Image fusion, Edge Detection and object isolation.	**07L**

Course Outcomes:

Upon successful completion of the course, the students will be able to

CO1: Understand the Continuous wavelet transform.

CO2: Understand the discrete wavelet transform.

CO3: Understand the multiresolution analysis.

CO4: Understand the Wavelet packets.

CO5: Understand the Applications of wavelet transform.

CO6: Analyse the Transform coding.

Books and References:

1. A Wavelet Tour of Signal Processing, 2nd edition, S. Mallat, Academic Press, 1999.
2. Wavelets and Sub band Coding, M. Vetterli and J. Kovacevic, Prentice Hall, 1995.
3. Wavelets and Wavelet Transforms, C. Sidney Burrus, Ramesh Gopinath, Haitao Guo, 2013

Course Name: **RF Microelectronics**
Course Code: **EC-467**
Course Type: **Stream Elective-I**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To give the student an understanding of the fundamental concepts of RF microelectronics, including electromagnetic waves and design challenges.
- To enable the student to understand and develop the skills needed to design and analyse RF amplifiers and mixers.
- Develop skills to design and analyse RF amplifiers, mixers, filters, and oscillators.
- Learn about RF transceiver architectures and power amplifiers.
- Gain an understanding of RF system design and trade-offs.

Unit Number	Course Content	Contact Hours
UNIT-01	**INTRODUCTION TO RF MICROELECTRONICS:** Overview of RF systems and applications, Frequency bands and spectrum allocation, RF circuit design challenges, Transmission Lines and Impedance Matching, Transmission line theory, Smith chart analysis, Impedance matching techniques	**06L**
UNIT-02	**RF AMPLIFIERS AND MIXERS:** Basic amplifier concepts, Analysis and design of common-source and common-emitter amplifiers, Noise and stability analysis, Frequency mixing fundamentals, Analysis and design of passive and active mixers, Conversion gain and noise figure analysis,	**07L**
UNIT-03	**RF FILTERS AND OSCILLATORS:** Filter types and specifications, Filter design techniques, SAW and BAW filters, Oscillator basics and types, Phase noise and jitter analysis, Analysis and design of LC and crystal oscillators	**07L**
UNIT-04	**RF TRANSCEIVER ARCHITECTURES AND POWER AMPLIFIERS:** Transceiver architecture overview, Single- and double-conversion architectures, Superheterodyne and direct-conversion architectures, Power amplifier basics and classes, Power amplifier design techniques, Efficiency and linearity analysis	**07L**
UNIT-05	**RF SYSTEM DESIGN AND TESTING:** RF system requirements and specifications, Link budget analysis, RF system design trade-offs RF testing and measurement techniques	**07L**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Understand and analyse the basic concepts of RF Microelectronics.

CO2: Design, simulate, and optimize RF circuits using software tools.

CO3: Apply knowledge to the design and implementation of wireless communication systems.

CO4: Apply advanced topics in RF Microelectronics.

CO5: Evaluate performance of RF systems and components and communicate findings effectively.

Books and References

1. Behzad Razavi, "RF Microelectronics," 2nd edition, Prentice Hall, 2012.
2. Thomas H.Lee, The Design of CMOS Radio-Frequency Integrated Circuits, Cambridge University Press, 2nd edition, 2004.

Course Name: **Embedded Networking and Device Driver Programming**

Course Code: **EC-468**

Course Type: **Stream Elective-I**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

The objective of this course is to explore embedded networking and programming, which are the tools used to investigate and create reliable communication protocols. This course is primarily aimed for designers who want to employ networking ideas like Ethernet, CAN Protocols, USB, and others.

Unit Number	Course Content	Contact Hours
UNIT-01	**BASICS OF EMBEDDED COMMUNICATION** Embedded Networking Overview: Serial/Parallel Communication, Serial communication protocols - RS232 standard, Synchronous and Asynchronous Communication - Serial Peripheral Interface (SPI) - Inter Integrated Circuits (I2C) - PC Parallel port Interface -ISA/PCI Bus protocols.	**08L**
UNIT-02	**USB BUS, CAN BUS AND FRAMING** Introduction to the USB bus, USB States, USB bus communication: Packets-Data flow types-Descriptors-Enumeration, Speed Identification on the bus, Introduction to the CAN Bus, the CAN Identifier, Data Transmissions on the CAN, Framing, Error Control Coding, Baseband Transmissions, RZ and NRZ techniques.	**08L**
UNIT-03	**ETHERNET** Network elements, Bus and Star Topologies, protocol CSMA/CD, IEEE802.3 and its different versions, Ethernet Addressing, Cables, Connections, Hubs, switches, and Bridges. Ethernet Addressing and network speed.	**06L**
UNIT-04	**PROTOCOLS FOR NETWORK LAYER** Internetworks, Addressing, Routing, ARP, IP, ICMP, IPV6, Unicast Routing, Unicast Routing Protocol, Multicast Routing, Multicast Routing Protocols, Distance Vector Routing, Link State Routing, Network Address Translator (NAT), Firewall.	**05L**
UNIT-05	**PROTOCOLS FOR TRANSPORT AND APPLICATION LAYER** User Datagram Protocol (UDP), Transmission Control Protocol (TCP), Data Traffic, Congestion, Congestion Control, Quality of Service, Techniques to Improve QOS, Integrated Services, QOS in Switched Networks. Concepts of Cryptography, Symmetric cryptography, and public key cryptography.	**05L**
UNIT-06	**EMBEDDED PROGRAMMING** Overview of Embedded C programming, Object-oriented programming fundamentals, pointers, functions, dynamic memory allocation and de-allocation, Tools for developing embedded software, Embedded system development fundamentals.	**04L**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Understand the Basics of Embedded Communication.

CO2: Understand the USB BUS, CAN BUS concepts.

CO3: Understand the concept of ETHERNET.

CO4: Understand the different layer protocols for embedded networking.

CO5: Understand the basics of embedded programming.

Books and References

1. Frank Vahid, Tony D. Givargis, “Embedded Systems Design: A Unified Hardware Software Introduction”, Wiley Publications 2007.
2. Pont Michael J, “Embedded C”, Pearson Education ,2007

Course Name: **VLSI Verification**
Course Code: **EC-469**
Course Type: **Stream Elective-I**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To impart knowledge about the basics of verification techniques for VLSI circuits
- To introduce the fundamental concepts of Logic checking and design validation
- To enable the students to get accustomed to the verification methodologies.

Unit Number	Course Content	Contact Hours
UNIT-01	**Basics of UVM:** Introduction to UVM, UVM Basics, Advanced UVM, UVM Connect, UVM Debug, UVMF - One Bite at a Time	**02L**
UNIT-02	**Verification standards:** Introduction to ISO 26262, Introduction to DO-254, Clock-Domain Crossing Verification, Portable Stimulus Basics, Power Aware CDC Verification Power Aware Verification, System Verilog OOP for UVM Verification	**8L**
UNIT-03	**System Verilog:** System Verilog Testbenches, Co-Emulation, functional verification, Assertion-Based Verification, Evolving FPGA Verification Capabilities	**9L**
UNIT-04	**Formal-based techniques:** Formal Assertion-Based Verification, Formal-Based Technology: Automatic Formal Solutions, Formal Coverage, Getting Started with Formal-Based Technology, Handling Inconclusive Assertions in Formal Verification, Sequential Logic Equivalence Checking	**12L**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Apply the concepts in verification which can help them design a better yield in IC design.

CO2: Tackle the problems associated with verification of semiconductor circuit design including several critical cases.

CO3: Identify the methodologies and design guidelines suitable for better circuit design

Books and References

1. System Verilog for Verification: A Guide to Learning the Testbench Language Features by Chris Spear & Greg Tumbush (3rd Edition)
2. A Practical Guide to Adopting Universal Verification Methodology (UVM) by Sharon Rosenberg & Kathleen A Meade (2nd Edition)
3. The UVM Primer: A Step-by-Step Introduction to the Universal Verification Methodology by Ray Salemi
4. Getting Started with UVM: A Beginner's Guide by Vanessa R. Copper
5. A Practical Guide for System Verilog Assertions by Srikanth Vijayaraghavan & Meyyappan Ramanathan

Course Name: **Compound Semiconductors: Properties & Applications**
Course Code: **EC-480**
Course Type: **Stream Elective-II**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- Understand parameters governing high-speed and high-power performance in compound semiconductor devices.
- Explore materials properties and processing techniques of compound semiconductors compared to silicon-based devices.
- Analyze metal semiconductor contacts and compound semiconductor device characteristics.
- Examine advanced compound semiconductor devices for high-speed applications and understand their operational principles.

Unit Number	Course Content	Contact Hours
UNIT-01	Important parameters governing the high-speed performance of devices and circuits: Transit time of charge carriers, junction capacitances, ON-resistances and their dependence on the device geometry and size, carrier mobility, doping concentration and temperature; important parameters governing the high-power performance of devices and circuits: Break down voltage, resistances, device geometries, doping concentration and temperature.	**06L**
UNIT-02	Materials properties: Merits of III –V binary and ternary compound semiconductors (GaAs, InP, InGaAs, AlGaAs, SiC, GaN etc.), different SiC structures, silicon-germanium alloys and silicon carbide for high speed devices, as compared to silicon based devices, outline of the crystal structure, dopants and electrical properties such as carrier mobility, velocity versus electric field characteristics of these materials, electric field characteristics of materials and device processing techniques, Band diagrams, homo and hetro junctions, electrostatic calculations, Band gap engineering, doping, Material and device process technique with these III-V and IV – IV semiconductors.	**16L**
UNIT-03	Metal semiconductor contacts and Metal Insulator Semiconductor and MOS devices: Native oxides of Compound semiconductors for MOS devices and the interface state density related issues. Metal semiconductor contacts, Schottky barrier diode, Metal semiconductor Field Effect Transistors (MESFETs): Pinch off voltage and threshold voltage of MESFETs. D.C. characteristics and analysis of drain current. Velocity overshoot effects and the related advantages of GaAs, InP and GaN based devices for high-speed operation. Sub threshold characteristics, short channel effects and the performance of scaled down devices.	**08L**
UNIT-04	High Electron Mobility Transistors (HEMT): Hetero-junction devices. The generic Modulation Doped FET(MODFET) structure for high electron mobility realization. Principle of operation and the unique features of HEMT, InGaAs/InP HEMT structures: Hetero junction Bipolar transistors (HBTs): Principle of operation and the benefits of hetero junction BJT for high-speed applications. GaAs and InP based HBT device structure and the surface passivation for stable high gain high frequency performance. SiGe HBTs and the concept of strained layer devices; High Frequency resonant –tunneling devices, Resonant-tunneling hot electron transistors	**12L**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Demonstrate comprehension of parameters impacting compound semiconductor device performance.

CO2: Evaluate suitability of compound semiconductor materials for specific applications.

CO3: Apply knowledge to analyze metal semiconductor contacts and compound semiconductor device characteristics.

CO4: Synthesize understanding to design solutions using advanced compound semiconductor devices for high-speed applications.

Books and References

1. C.Y. Chang, F. Kai, GaAs High-Speed Devices: Physics, Technology and Circuit Applications, Wiley & Sons.
2. Cheng T. Wang, Ed., Introduction to Semiconductor Technology: GaAs and Related Compounds, John Wiley & Sons.
3. David K. Ferry, Ed., Gallium Arsenide Technology, Howard W. Sams & Co., 1985
4. Avishay Katz, Indium Phosphide and Related materials: Processing, Technology and Devices, Artech House, 1992.
5. S.M. Sze, High Speed Semiconductor Devices, Wiley (1990) ISBN 0-471-62307-5
6. Ralph E. Williams, Modern GaAs Processing Methods, Artech (1990), ISBN 0-89006-343-5,
7. Sandip Tiwari, Compound Semiconductor Device Physics, Academic Press (1991), ISBN 0-12-691740-X.

Course Name: **Adaptive Signal Processing**
Course Code: **EC-481**
Course Type: **Stream Elective-II**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To introduce signal processing techniques for adaptive systems.
- To understand the applications of adaptive systems in the fields of communications, radar, sonar, seismology, navigation systems and biomedical engineering.
- To study the basic principles of adaptation, various adaptive signal processing algorithms for applications like adaptive noise cancellation, interference cancelling, system identification, etc.

Unit Number	Course Content	Contact Hours
UNIT-01	Review of Probability, Random variables, random processes, filtered random processes, Ensemble averages, correlation, covariance, power spectrum, cross power spectrum, Ergodicity, time averages, biased & unbiased estimators, consistent estimators.	**07L**
UNIT-02	Linear Optimum Filtering and Adaptive Filtering, Linear Filter Structures, Adaptive Equalization, Active Noise Cancellation, and Beam Forming, Optimum Linear Combiner and Wiener-Hopf Equations	**07L**
UNIT-03	Orthogonality Principle, Minimum Mean Square Error and Error Performance Surface, Steepest – Descent Algorithm and its Stability. LMS Algorithm and its Applications, Learning Characteristics and Convergence Behaviour	**07L**
UNIT-04	Mis- Adjustment, Normalized LMS and Affine Projection Adaptive Filters, Frequency Domain Block LMS Algorithm. Least Squares Estimation Problem and Normal Equations, Projection Operator	**07L**
UNIT-05	Exponentially Weighted RLS Algorithm, Convergence Properties of RLS Algorithm, Kalman Filter as the Basis for RLS Filter, Square-Root Adaptive Filtering and QR- RLS Algorithm, Systolic-Array Implementation of QR – RLS Algorithm	**07L**
UNIT-06	Forward and Backward Linear Prediction, Levinson-Durbin Algorithm, Lattice Predictors, Gradient-Adaptive Lattice Filtering, Least-Squares Lattice Predictor, QR-Decomposition Based Least-Squares Lattice Filters. Neural networks and multi-layer perceptrons, Adaptive IIR filtering, the constant modulus algorithm	**07L**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Comprehend design criteria and modeling of adaptive systems and theoretical performance evaluation.

CO2: Design a linear adaptive processor.

CO3: Apply mathematical models for error performance and stability.

CO4: Comprehend the estimation theory for linear systems and modeling algorithms.

Books and References

1. Adaptive Filter Theory by Haykin, S., Pearson Education.
2. Adaptive Signal Processing by Widrow, B. and Stearns, S.D., Pearson Education.
3. Statistical and Adaptive Signal Processing by Manolakis, D.G., Ingle, V.K. and Kogon, M.S., Artech House.
4. Statistical Signal Processing: Detection, Estimation, and Time Series Analysis by Scharf, L.L., Pearson.

Course Name: **Advanced Antenna and Electromagnetic Metamaterials: Concept and Applications**
Course Code: **EC-482**
Course Type: **Stream Elective-II**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To impart knowledge about the advanced concepts of antenna engineering.
- To introduce the design principle relevant to Advanced Antennas for different applications.
- To enable the students to understand concept of Electromagnetic Metamaterials.
- To introduce the design principle relevant to Metamaterials for various applications.

Unit Number	Course Content	Contact Hours
UNIT-01	**Definitions & Preliminary Information:** Application areas of Antennas, Maxwell's Equations and Boundary conditions, Wave Equations, Infinitesimal (Hertzian) Dipoles, Monopoles, Inverted-F Antennas	**06L**
UNIT-02	**Aperture-type and Microstrip Antennas:** Radiation from apertures, aperture distribution, Transmission line and Cavity model for patch antennas, circularly polarized microstrip antenna, Microstrip patch and printed dipole arrays	**8L**
UNIT-03	**Advanced Antennas:** Travelling wave and Broadband Antennas, Frequency Independent Antennas, Antenna Miniaturization, and Fractal Antennas, Smart Antennas: Concept and Benefits of Smart Antennas, MIMO Antenna configurations, Pattern and polarization diversity, Mutual coupling reduction techniques, correlation coefficients, Massive MIMO system design.	**8L**
UNIT-04	**Metamaterials Background and Spatial Metamaterials**: General Historical perspective and idea of Metamaterials (MTMs), Plane-wave propagation in simple medium, Dispersive model for the dielectric permittivity, Phase velocity and group velocity. Spatial Metamaterials: Metamaterials and homogenization procedure, Split-ring resonator media, Media with negative permittivity and permeability: theory and properties, Origins of negative refraction and other properties.	**10L**
UNIT-05	**Different Metamaterials and applications:** Transmission Line Metamaterials: Ideal Homogeneous CRLH TLs (Composite Right-Left Handed Transmission Lines), LC Network Implementation and distributed 1D CRLH Structures, Conversion from Transmission Line to constitutive Parameters, Negative and Zeroth-Order Resonators. Meta-surface concepts: Artificial High-Impedance Surface design, EBG (Electromagnetic Bandgap Structures), Gain-enhancement in antennas using MTM, Miniaturization using MTM, Design of FSS Radomes for EMI Shielding and Absorbers, Beam-steering using Intelligent Reflecting Surfaces (IRS).	**10L**

Pre-requisites: Basic Electromagnetic theory and transmission line, Basic Antennas Theory

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Describe the antenna design principle for advanced antennas.

CO3: Apply principles of radiation from the conducting surfaces and aperture surfaces at RF frequencies and assess the numerical techniques for the analysis of the antennas.

CO4: Describe the need for metamaterials and their design principle.

CO5: Apply and design different metamaterials for specific applications.

Books and References

1. Field and Wave Electromagnetics, D. K. Cheng, Pearson Education Asia Ltd, Second Edition, 2006.
2. Antenna Theory: Analysis and Design, C. A. Balanis, John Wiley, Fourth Edition, 2016.
3. Antenna Theory and Design, W. L. Stutzman and G. A. Thiele, John Wiley & Sons Inc, 1981.
4. Antennas, J. D. Karus, McGraw Hill, 1988
5. Microstrip antennas, I. J. Bahl and P. Bhartia, Artech house, 1980.
6. Electromagnetic Metamaterials: Transmission Line Theory and Microwave Applications, The Engineering Approach, C. Caloz and T. Itoh, John Wiley & Sons, Inc., Hoboken, New Jersey, 2006.
7. Physics and Applications of Negative Refractive Index Materials, S. A. Ramakrishna and T. M. Grzegorczyk, CRC Press, Taylor & Francis Group and SPIE Press, 2009.
8. Negative Refraction Metamaterials: Fundamental Principles and Applications, G. V. Eleftheriades and K. G. Balmain Copyright: IEEE, John Wiley & Sons, Inc., Hoboken, New Jersey, 2005.

Course Name: **Nano Electronics: Devices and Materials**
Course Code: **EC-483**
Course Type: **Stream Elective-II**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- Understand nanotechnology and its impact on the electronics industry and different types of nanomaterials and their properties.
- Learn principles of quantum mechanics and design quantum dot-based devices.
- Gain knowledge of carbon-based nanomaterials and design carbon-based nanoelectronic devices.
- Gain knowledge of semiconductor nanomaterials and design semiconductor nanoelectronic devices.
- Understand emerging trends in nanoelectronics and critically evaluate challenges and opportunities in scaling down devices to the nanoscale, and their potential impact on various industries

Unit Number	Course Content	Contact Hours
UNIT-01	**INTRODUCTION TO NANOELECTRONICS:** Physical and Technological Limitations of Microelectronics, Transitioning from Microelectronics to Nanoelectronics, MOS Scaling Theory- Issues in Scaling MOS Transistors, Short Channel Effects; Free Electron Theory & The New Ohm's Law: Why Electrons flow, Classical free electron theory, Sommerfeld's theory, The quantum of conductance, Coulomb blockade, Towards Ohm's law.	**07L**
UNIT-02	**EFFECT OF TEMPERATURE:** The Elastic Resistor: Conductance of an Elastic Resistor, Elastic Resistor- Semiconductor heterostructures, Lattice-matched and pseudomorphic heterostructures, Inorganic nanowires, Organic semiconductors, Carbon nanomaterials: nanotubes and fullerenes, Graphene	**07L**
UNIT-03	**MATERIALS FOR NANOELECTRONICS:** Semiconductors, Crystal lattices: bonding in crystals, Electron energy bands, Semiconductor heterostructures, Lattice-matched and pseudomorphic heterostructures, Inorganic nanowires, Organic semiconductors , Carbon nanomaterials: nanotubes and fullerenes fabrication of nanostructures Crystal growth, Nanolithography, Clusters and nanocrystals, Nanotube growth,- Characterization of nanostructures	**07L**
UNIT-04	**BALLISTIC AND DIFFUSIVE TRANSPORT:** Ballistic and Diffusive Transfer Times, Channels for Conduction Conductivity, Conductivity: E(p) or E(k) Relations, Counting States, Drude Formula, Quantized Conductance, Electron Density –Conductivity; Electron transport in semiconductors and nanostructures: Time and length scales of the electrons in solids, Statistics of the electrons in solids and nanostructures, Fermi statistics for electrons, the density of states of electrons in nanostructures, Electron transport in nanostructures.	**07L**
UNIT-05	**ELECTRONS IN TRADITIONAL LOW-DIMENSIONAL STRUCTURES:** Electrons in quantum wells: Single modulation-doped heterojunctions, Numerical analysis of a single heterojunction, Control of charge transfer, Electrons in quantum wires, Electron transport in quantum wires, Electrons in quantum dots; Nanostructure devices: Introduction, MODFETS, heterojunction bipolar transistors, Resonant-tunneling diodes, Field-effect transistors, Single-electron-transfer devices, Potential-effect transistors, Carbon Nanotube Transistors, Semiconductor Nanowire FETs etc.	**07L**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Demonstrate knowledge of nanotechnology and its impact on the electronics industry and different types of nanomaterials and their properties.
CO2: Design semiconductor nanoelectronic devices using knowledge of semiconductor nanomaterials and fabrication technique.
CO3: Understanding the applications of quantum physics in Semiconductor Devices.
CO4: Identifying different devices so as to meet out the present design, health, safety and environmental challenges

Books and References

1. Fundamentals of Nanoelectronics by George W. Hanson, Pearson Education.
2. Nanoelectronics and Nanosystems: From Transistors to Molecular and Quantum Devices by Karl Goser, Springer
3. Introduction to Nanoelectronics: Science, Nanotechnology, Engineering & Applications by Vladimir. V. Mitin, Cambridge University Press.
4. Introduction to Nano Science and Technology by S.M. Lindsay, World Scientific.
5. Lessons from Nanoscience: A Lecture Note Series, By Supriyo Dutta, World Scientific.
6. Quantum Transport- Atom to Transistor, By Supriyo Dutta, Cambridge University Press.
7. Nanotechnology for Microelectronics and optoelectronics, By J.M. Martinez-Duart, R. J. Martin Palma, F. Agulle Rueda, Elsevier.

Course Name: **Characterization of Semiconductor Materials & Devices** Course Code: **EC-484** Course Type: **Stream Elective-II**	
Contact Hours/Week: **3L**	Course Credits: **03**

Course Objectives

- To impart knowledge about properties of various semiconductor materials
- To introduce the semiconductor physics behind the materials
- To enable the students to understand the design of semiconductor devices using electronic materials
- To understand how various semiconductor devices behave and how to optimize them

Unit Number	Course Content	Contact Hours
UNIT-01	**INTRODUCTION AND PROPERTIES OF SEMICONDUCTOR MATERIALS** Various Semiconductor materials and their advantages & disadvantages applied to VLSI and Nano-electronics Crystal structure, Band theory, Carrier concentration at thermal equilibrium, Density of states, Fermi energy, Ionization of impurity in semiconductor, Quantum aspect of semiconductors.	**07 L**
UNIT-02	**SEMICONDUCTOR CARRIER DYNAMICS** Scattering of carrier in semiconductors, Low field effect in semiconductor, Very high field effect in semiconductor, Carrier transport phenomena, Charge injection and quasi equilibrium, Generation and recombination of electron and holes and Basic equation for semiconductor device operation.	**07 L**
UNIT-03	**MEASUREMENT OF SEMICONDUCTOR PROPERTIES** Resistivity, conductivity, and Band gap of Semiconductor materials.	**03 L**
UNIT-04	**SEMICONDUCTOR JUNCTION WITH METALS, INSULATORS AND SEMICONDUCTORS** Procedure for analyzing semiconductor devices, Basic equations and approximations, Characteristics, and energy band diagrams of PN Junction diodes-step and graded junction, Schottky barrier diode, Ohmic contact, Insulator-semiconductor junction.	**09 L**
UNIT-05	**COMPOUND SEMICONDUCTOR DEVICES** Electronic properties of compound Semiconductor materials, Optoelectronic Devices; LED, PIN Photodetector, Semiconductor laser, Microwave Devices.	**08 L**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Identify various Materials useful in designing Semiconductor Devices

CO2: Understand the semiconductor physics of the materials

CO3: Apply different material characteristics for designing of Semiconductor devices

CO4: Understand the theoretical concepts of various semiconductor devices and their applications

Books and References

1. Physics of Semiconductor Devices by S. M. Sze, Wiley Publication
2. Semiconductor Materials and Devices by M. S. Tyagi, Wiley Publication
3. Solid State Electronics Devices by B. G. Streetman, Prentice Hall
4. Semiconductor Devices by Kanaan Kano, Prentice Hall

Course Name: **Embedded Hardware Design**
Course Code: **EC-485**
Course Type: **Stream Elective-II**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To study the role of microcontrollers in embedded systems using the basic programming and interfacing techniques.

Unit Number	Course Content	Contact Hours
UNIT-01	**FUNDAMENTALS OF EMBEDDED SYSTEM** Introduction to the embedded system, Memory, Sensors and Actuator types, Communication Interface, Embedded firmware (RTOS, Drivers, Application programs), Power-supply (Battery technology, Solar), PCB and Passive components, Safety and reliability, environmental issues. Ethical practice. Characteristics and quality attributes (Design Metric) of embedded system. Real time system's requirements, real time issues, interrupt latency. Embedded Product development life cycle, Program modelling concepts: DFG, FSM, Petri-net, and UML.	**07L**
UNIT-02	**EMBEDDED HARDWARE, DESIGN AND SERIAL COMMUNICATION** Familiarization with ARM-v7-M (Cortex-M3), ARM-v7-R (CortexR4) architectures, basic communication protocols like SPI, SCI (RS232, RS485), I2C, 10 CAN, Fieldbus (Profibus), USB (v2.0), Bluetooth, Zig-Bee, Wireless sensor network	**06L**
UNIT-03	**EMBEDDED SOFTWARE, FIRMWARE CONCEPTS AND DESIGN** Introduction to embedded C-programming: Optimizing for Speed/Memory needs, Interrupt service routines, macros, functions, modifiers, data types, device drivers, Multithreading programming. (Laboratory work on J2ME Java mobile application). Basic embedded C programs/applications for ARM-v7, using ARM-GCC-toolchain, Emulation of ARM-v7 (e.g., using QEMU), and Linux porting on ARM-v7 (emulation) board. A case study on "Medical monitoring systems" "Process control system (temp, pressure)" & "Communication: Wireless (sensor) networks.	**07L**
UNIT-04	**REAL TIME OPERATING SYSTEM:** Need of POSIX Compliance, Role of RTOS in Embedded system software, Foreground/Background systems, multitasking, context switching, IPC, Scheduler policies, Architecture of kernel, task scheduler, ISR, Semaphores, mailbox, message queues, pipes, events, timers, memory management, RTOS services in contrast with traditional OS.	**07L**
UNIT-05	**INTRODUCTION TO MCOS-II RTOS Basics** of kernel structure of µCOS-II, Synchronization in µCOS-II, Inter-task communication in µCOS-II, Memory management in µCOS-II, porting of RTOS on ARM-v7 (emulation) board, Application developments using µCOS-II, basic device (drivers) usage.	**05L**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Acquire knowledge and understand fundamental embedded systems design paradigms, architectures, possibilities and challenges, both with respect to software and hardware

CO2: Analyse a system both as whole and in the included parts, to understand how these parts interact in the functionality and properties of the system.

CO3: Practically apply gained theoretical knowledge in order to design, analyze and implement embedded systems, e.g. integrating embedded subsystems and applications

CO4: Apply formal method, testing, verification, validation and simulation techniques and tools in order to engineer reliable and safe embedded systems.

CO5: Demonstrate a deeper understanding of the electronics and physical principles used for embedded biomedical measuring systems

Books and References

1. Introduction to Embedded Systems by Shibu K. V. (TMH)
2. Embedded System Design – A unified hardware and software introduction: by F. Vahid (John Wiley)
3. Embedded Systems by Rajkamal (TMH)
4. Embedded Systems by L. B. Das (Pearson)
5. Embedded System design by S. Heath (Elsevier)
6. Embedded microcontroller and processor design: by G. Osborn (Pearson)
7. Embedded Systems by Frank Vahid, Wiley India, 2002
8. Embedded Microcomputer Systems – Real Time Interfacing by Jonathan W. Valvano; Cengage Learning; Third or later edition.

Course Name: **Electromagnetic Interference and Compatibility**
Course Code: **EC-486**
Course Type: **Stream Elective-II**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

To introduce the basic concepts of Electromagnetic Interference, teach the importance of Electromagnetic Compatible designs and explain the existing standards for Electromagnetic Compatibility and Measurement Techniques.
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Unit Number	Course Content	Contact Hours
UNIT-01	**EMI/EMC CONCEPTS** EMI-EMC definitions, Sources and Victims of EMI; Conducted and Radiated EMI Emission and Susceptibility; Case Histories; Radiation Hazards to humans. EMC regulations	**06L**
UNIT-02	**EMI COUPLING PRINCIPLES** Conducted, radiated and transient coupling; Common ground impedance coupling; Common mode and ground loop coupling; Differential mode coupling; Near field cable to cable coupling; Field to cable coupling; Power mains and Power supply coupling; Transient EMI, ESD	**08L**
UNIT-03	**EMI CONTROL** Shielding; EMI Filters; Grounding; Bonding; Isolation transformer; Transient suppressors; EMI Suppression Cables.	**08L**
UNIT-04	**EMC DESIGN FOR CIRCUITS AND PCBS** Noise from Relays and Switches; Nonlinearities in Circuits; Cross talk in transmission line and cross talk control; Component selection and mounting; PCB trace impedance; Routing; Power distribution decoupling; Zoning; Grounding; VIAs; Terminations	**10L**
UNIT-05	**EMI MEASUREMENTS AND STANDARDS** Open area test site; TEM cell; EMI test shielded chamber and shielded ferrite lined anechoic chamber; Line impedance stabilization networks; EMI Rx and spectrum analyzer; Civilian standards - CISPR, FCC, IEC, EN; Military standards-MIL461E/462.	**10L**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Understand EMI/EMC and its hazardous effect.

CO2: Identify the various types and mechanisms of Electromagnetic Interference

CO3: Propose a suitable EMI mitigation technique.

CO4: design EMI mitigated Circuits and PCBs

CO5: Describe the various EMC Standards and methods to measure them

Books and References

1. Electromagnetic Compatibility Engineering by Henry Ott., John Wiley & Sons Inc; 1st edition 2009
2. Introduction to Electromagnetic Compatibility by C.R.Paul , John Wiley and Sons, Inc, 2nd edition 2010

Course Name: **Nanophotonics and Plasmonics: Concept and Applications**
Course Code: **EC-487**
Course Type: **Stream Elective-II**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

This course explains the concepts and applications of Nanophotonic and plasmonics for future communication devices. It focuses on the Photonic Crystals, Nanophotonics in metals, Transmission through apertures and films, Simulation and Design of different photonic and plasmonics components.

Unit Number	Course Content	Contact Hours
UNIT-01	**Introduction to Photonics:** Electromagnetic waves; light; Maxwell equations; Wave equation; Modes, laser sources, semiconductor quantum wells, photo detectors, quantum dots, nanowires, Dielectric optical waveguides, directional coupler, Machzehnder interferometer, Optical microresonators etc.	**07L**
UNIT-02	**Photonic Crystals:** Photonic bandgap (PGB). PBG structures, wave propagation, Construction methods, Applications: wave guides and photonic crystals fibres, optical microcavities, Photonic VLSI	**8L**
UNIT-03	**Nanophotonics in metals:** Electromagnetics of Metals, Electromagnetic Wave Propagation, Dielectric function and dispersion, Surface Plasmon polaritons, Single and multilayer systems, Exaction of surface Plasmon, plasmonic waveguides and resonators, localized surface plasmons, Nanoantennas. Metamaterials and Negative Index at Optical Frequencies.	**8L**
UNIT-04	**Transmission through apertures and films:** Theory of Diffraction by Sub-Wavelength Aperture, Extraordinary Transmission, Directional Emission via Exit Surface Patterning, Localized Surface Plasmons and Light Transmission Through Single Apertures, Emerging Applications of Extraordinary Transmission, Transmission of Light Through a Film Without Apertures.	**9L**
UNIT-05	**Simulation and Design:** Optical microresonators, guiding bending and splitting of light through photonic crystals, microcavity based MUX and DEMUX, photonic crystal fiber, plasmonic waveguides and resonators, Nanoantennas, Extraordinary transmission, Bull's eye structures, Metamaterials.	**10L**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Understand the basic of photonics.

CO2: Understand the photonic crystals and their application.

CO3: Understand the interaction of light with metal.

CO4: Understand and analyse the transmission through apertures and films.

CO5: Design and analyse the different photonics and plasmonic components for different applications.

Books and References

1. Fundamentals and Applications, Stefen A. Maer, Springer 2007.
2. Nanophotonics with Surface Plasmon, Vladimir M. Salaev,Part II, 2006, Photonic Spectra.
3. Photonic crystals: Molding the flow of light, J.D. Joannopoulos, 2nd Edition, 2008 Princeton University Press
4. Integrated Photonics: fundamentals, G. Lifante, Wiley.

Course Name: **Advanced IC Design**
Course Code: **EC-488**
Course Type: **Stream Elective-II**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To impart a strong foundation of IC based design.
- To introduce the various applications of operational amplifiers and its integration with other devices.
- To learn biomedical application of op-amp design and other related applications.

Unit Number	Course Content	Contact Hours
UNIT-01	**Operational Amplifier Design** using CMOS as well as Bipolar technologies. Linear and non-linear applications of operational amplifiers. Active filters, response characteristics of Butter worth, Chebyshev and causal filters. Design and analysis of higher order filters of all types.	**07L**
UNIT-02	**Design of Super Buffer Circuits** for driving large capacitive loads. Design and analysis of CMOS Schmitt trigger circuit.	**06L**
UNIT-03	**Comparators** and their characteristics zero crossing detector, voltage limiters, absolute value detectors, sample and hold circuit.	**07L**
UNIT-04	**Biomedical applications** of instrumentation amplifier. Design and analysis of multi-vibrator circuits using transistors, Op-Amps and 555 Timer.	**05L**
UNIT-05	**Design and analysis of oscillator circuits** using transistors and Op-Amps. Phase shift, Wien Bridge and quadrature oscillators. Square wave, triangular wave, saw tooth wave generators and voltage-controlled oscillator.	**06L**
UNIT-06	**Differential and Feedback Amplifiers**	**05L**

Course Outcomes

Upon successful completion of this course students will be able to:

CO1: Understand and design the advanced ICs using op-amp and perform operations and their troubleshooting.

CO2: To learn how to detect, amplify, store, create and manipulate signals using operational amplifiers.

CO3: To design and analyze the responses of IC based designed circuits in the area of power management, signal conditioning, analog and digital communication.

CO4: To develop IC based projects in the above areas.

Books and References

1. CMOS Analog Circuit Design by P. E. Allen and D. R. Holberg
2. CMOS Digital Integrated Circuits-Analysis & Design by S. M. Kang & Y. Leblebici. TMH 2004
3. Design of Analog CMOS Integrated Circuits by B. Razavi. Tata McGraw Hill, 2005.

Course Name: **Electronic Packaging**
Course Code: **EC-489**
Course Type: **Stream Elective-II**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To introduce and discuss various issues related to the system packaging.
- To enable the students to understand the various issues in packaging.

Unit Number	Course Content	Contact Hours
UNIT-01	**OVERVIEW OF ELECTRONIC SYSTEMS PACKAGING:** Functions of an Electronic Package, Packaging Hierarchy, IC packaging: MEMS packaging, consumer electronics packaging, medical electronics packaging, Trends, Challenges, Driving Forces on Packaging Technology, Materials for Microelectronic packaging, Packaging Material Properties, Ceramics, Polymers, and Metals in Packaging, Material for high density interconnect substrates	**09L**
UNIT-02	**ELECTRICAL ISSUES IN PACKAGING:** Electrical Issues of Systems Packaging, Signal Distribution, Power Distribution, Electromagnetic Interference, Transmission Lines, Clock Distribution, Noise Sources, Digital and RF Issues. Design Process Electrical Design: Interconnect Capacitance, Resistance and Inductance fundamentals; Packaging roadmaps – Hybrid circuits – Resistive, Capacitive and Inductive parasitic	**09L**
UNIT-03	**CHIP PACKAGES:** IC Assembly – Purpose, Requirements, Technologies, Wire bonding, Tape Automated Bonding, Flip Chip, Wafer Level Packaging, reliability, wafer level burn – in and test. Single chip packaging: functions, types, materials processes, properties, characteristics, trends. Multi-chip packaging: types, design, comparison, trends. System – in - package (SIP); Passives: discrete, integrated, and embedded	**09L**
UNIT-04	**PCB, SURFACE MOUNT TECHNOLOGY AND THERMAL CONSIDERATIONS:** Printed Circuit Board: Anatomy, CAD tools for PCB design, Standard fabrication, Micro via Boards. Board Assembly: Surface Mount Technology, Through Hole Technology, Process Control and Design challenges. Thermal Management, Heat transfer fundamentals, Thermal conductivity and resistance, Conduction, convection and radiation – Cooling requirements	**09L**
UNIT-05	**TESTING:** Reliability, Basic concepts, Environmental interactions. Thermal mismatch and fatigue – failures – thermo mechanically induced –electrically induced – chemically induced. Electrical Testing: System level electrical testing, Interconnection tests, Active Circuit Testing, Design for Testability	**09L**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Give a comprehensive introduction to the various packaging types used along with the associated thermal, speed, signal and integrity power issues.

CO2: Enable design of packages which can withstand higher temperature, vibrations and shock.

CO3: Design of PCBs which minimize the EMI and operate at higher frequency.

CO4: Analyze the concepts of Testing and testing methods.

Books and References

1. Fundamentals of Microsystems Packaging by Tummala, Rao R., McGraw Hill, 2001
2. The electronic packaging handbook by Blackwell (Ed), CRC Press, 2000.
3. Microelectronics packaging handbook by Tummala, Rao R,McGraw Hill, 2008.
4. Printed Circuit Boards Design and Technology by Bosshart, TataMcGraw Hill, 1988.
5. Electronic Product design by R.G. Kaduskar and V.B.Baru, Wiley India, 2011
6. Printed Circuit Board by R.S.Khandpur, Tata McGraw Hill, 2005
7. Recent literature in Electronic Packaging
8. Essentials of Electronic Testing for Digital, memory & Mixed signal VLSI Circuits by Michael L. Bushnell &Vishwani D. Agarwal, Kluwer Academic Publishers.2000.
9. Digital System Testing and Testable Design by M. Abramovici, M. A. Breuer, and A.D. Friedman, Computer Science Press,1990