Master of Technology

in

VLSI Design

Course Structure & Syllabus

Department of Electronics and Communication Engineering

National Institute of Technology Hamirpur

Hamirpur (HP) – 177005, India

SEMESTER-I

SN	Code	Subject	L	T	P	Hours/week	Credits
1	EC-611	Device Modeling for Circuit Simulation	4	0	0	4	4
2	EC-612	VLSI Technology & Applications	4	0	0	4	4
3	EC-613	Digital Signal Processing	4	0	0	4	4
4	EC-614	Device Modeling Lab	0	0	4	4	2
5	EC-7MN	Programme Elective-I	4	0	0	4	4
6	EC-7MN	Programme Elective-II	4	0	0	4	4
	Total		20	0	4	24	22

SEMESTER-II

SN	Code	Subject	L	T	P	Hours/week	Credits
1	EC-621	Digital VLSI Design	4	0	0	4	4
2	EC-622	Analog VLSI Design	4	0	0	4	4
3	EC-623	FPGA and ASIC Design	4	0	0	4	4
4	EC-624	VLSI Design Lab	0	0	4	4	2
5	EC-7MN	Programme Elective-III	4	0	0	4	4
6	EC-70N	Open Elective	4	0	0	4	4
	Total		20	0	4	24	22

Note: List of Program Electives and Open Electives are attached as Annexure-I.

SEMESTER-III

SN	Code	Subject	Hours/ Week	Credits
1	EC-798	M Tech Dissertation	---	18
	Total			**18**

SEMESTER-IV

SN	Code	Subject	Hours/ Week	Credits
1	EC-799	M Tech Dissertation	---	18
	Total			**18**

Total Credit of the Programme = 80

ANNEXURE-I

List of Postgraduate (PG) Program Electives

PG Program Elective-I

EC-711	Characterization of Semiconductor Materials & Devices
EC-712	Nano-Electronics
EC-713	Deep Submicron VLSI Design
EC-714	Advanced Semiconductor Devices
EC-715	VLSI Test and Testability
EC-716	VLSI Interconnects
EC-717	MEMS and Micro Sensor Design
EC-718	Memory Design and Testing
EC-719	Neural Networks and Deep Learning

PG Program Elective-PG Program Elective-II

EC-720	Low Power VLSI Design
EC-721	Advanced IC Design
EC-722	IC Design for IoT Systems
EC-723	Data Converters for IC Design
EC-724	Verification of VLSI Circuits
EC-725	Reliability of VLSI Circuits
EC-726	Hardware Algorithms for VLSI
EC-727	Advanced Computer Architecture

PG Program Elective-III

EC-728	RF IC Design
EC-729	DSP Architectures
EC-730	VLSI Signal Processing
EC-731	Flexible Electronics
EC-732	Organic Electronics
EC-733	Quantum Electronics
EC-734	Magneto-electronics & Spintronics
EC-735	Numerical Optimization

List of Open Electives

EC-701	VLSI Design
EC-702	MEMS Design
EC-703	HDL Based Design
EC-704	Mobile Communication
EC-705	Communication Systems

Course Name: **Device Modeling for Circuit Simulation** Course Code: **EC-611** Course Type: **Core**	
Contact Hours/Week: **4L**	Course Credits: **04**

Course Objectives

- To impart knowledge about the basics of electronics device modeling.
- Build upon the theoretical, mathematical and physical analysis of e-devices used for e-circuit simulation
- To analyse the working of e-devices for proper understanding of VLSI design requirements.
- To enable the students to understand the parameters and factors that control the behavior of electronic devices.

Course Content

Review of semiconductor device physics, fundamentals and principles of device modeling and circuit simulation, objectives and advantages. Introduction to SPICE, AC, DC, Transient, Noise, Temperature analysis, etc. of electronic devices and their application in circuit simulation. Junction Diodes, DC, Small signal, Large signal, High frequency and noise models of diodes, junction and depletion capacitance, narrow and wide base diodes. Measurement and extraction of diode model-parameters. Modeling BJT, DC, small signal, high frequency and noise models of bipolar junction transistors. Extraction of BJT model parameters. Ebers-Moll and Gummel-poon models. MOSFETs, Types of MOSFETs, DC, small signal, high frequency and noise models of MOSFETs. MOS Capacitance model. Weak and strong inversion in MOSFETs. Threshold voltage concept. MOS Models, Level-1 and level-2 large signal MOSFET models. Introduction to BSIM models. Extraction of MOSFET model parameters. Device Scaling, Short and narrow channel MOSFETs. MOSFET channel mobility model, DIBL, charge sharing and various non-linear effects. JFET, MESFETs & HBTs, Modeling of JFET & MESFET and extraction of parameters. Principles of hetro-junction devices, HBTs, HEMT.

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 devices models to solve real world research problems.

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

CO4: Analyse the 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, S.M. Kang & Y. Leblibici, TMH, 3rd Ed.
2. Physics of Semiconductor Devices, S.M. Sze, Wiley Pub.
3. Solid State Electronic Devices, B.G. Streetman & S. Banerjee, PHI.
4. Computer Simulation of Electronic Circuits, R. Raghuram, Wiley Eastern Ltd.
5. SPICE, Sedra and Smith.
6. Introduction to PSPICE, H.M. Rashid, PHI.

Course Name:	**VLSI Technology & Applications**
Course Code:	**EC-612**
Course Type:	**Core**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To introduce the VLSI era
- 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.

Course Content

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 etching; 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; Assembly Techniques & Packaging of VLSI chip: Introduction to packaging; packaging process; package design considerations, various package types, Prototype fabrication of Monolithic Components and isolation : Prototype fabrication of Diodes, npn BJT, pnp BJT, MOSFETs (Enhancement and depletion mode), n-MOS, p-MOS, CMOS, Resistors and Capacitors. Isolation techniques in Diodes, BJT and MOSFETs (Enhancement and depletion mode.

Course Outcomes

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

CO1: Identify the various design limits material used for fabrication.
CO2: Describe the Performance 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, S.M. Sze, TMH
2. VLSI Fabrication Principles, S.K. Gandhi, John Willey& Sons
3. Micro-machined transducer, G.T.A. Kovacs, McGraw Hill
4. Principles of Microelectronics Technology, D. Nagchoudhary, PHI

Course Name: **Digital Signal Processing**
Course Code: **EC-613**
Course Type: **Core**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To study and analyze discrete-time signals and systems in time-domain
- To study and analyze discrete-time signals and systems in transform-domain
- To design and implement FIR and IIR digital filters, and to understand the basic concepts of multirate digital signal processing.

Course Content

Introduction to discrete-time signals and systems: Discrete-time signals, Operations on sequences, Sampling process, Discrete-time systems, Time-domain characterization of LTI discrete-time systems; Transform-domain representation: Discrete-time Fourier transform, Discrete Fourier transform (DFT), DFT properties, Linear convolution using DFT, Fast Fourier Transform, Z-transform, Inverse Z-transform, Properties of Z-transform; Realization structures for digital filters: Block diagram representation, Signal flow graph representation, Direct form structures, Cascade form structures, Parallel form structures, Lattice structure realization; Digital filter design: General considerations, Review of analog filter design, IIR filter design using impulse invariance method and bilinear transformation method, FIR digital filter design using windows method and frequency sampling method; Multirate digital signal processing fundamentals: Introduction to sampling rate conversion, Decimation, Interpolation, Polyphase decomposition.

Course Outcomes

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

CO1: Understand, characterize, and analyze discrete-time signals and systems in time-domain.
CO2: Analyze discrete-time signals and LTI discrete-time systems in transform-domain.
CO3: Design and implement FIR and IIR digital filters using different methods.
CO4: Understand the basic concepts of multirate digital signal processing.

Books and References

1. Digital Signal Processing: A Computer – Based Approach by S. K. Mitra, Tata McGraw Hill Publication
2. Digital Signal Processing – Principles, Algorithms, and Applications by J. G. Proakis and D. G. Manolakis, Pearson Education
3. Digital Signal Processing by A. V. Oppenheim and R. W. Schafer, PHI Publication
4. Digital Signal Processing by Monson H. Hayes, McGraw Hill Publication (Schaum's Outlines)

Course Name: **Device Modeling Lab**
Course Code: **EC-614**
Course Type: **Core**

Contact Hours/Week: **4P** Course Credits: **02**

Course Objectives

- Familiarization with EDA tools and their use for design and analysis.
- To extract various design parameters from simulation results.
- Provide students with an opportunity to practice on EDA software & tools for VLSI Design.

List of Experiments:

1: Introduction to physical simulation and TCAD
2: Building a simulation mesh for diode, MOS & bipolar devices.
3: To study the current-voltage characteristics of p-n junction using TCAD.
4: Prototype fabrication of BJT and its characterization using TCAD.
5: Prototype fabrication of submicron MOS structure and its characterization using TCAD.
6: Familiarization with TANNER & Cadence Tool-Design Architectures.
7: To study NMOS and PMOS characterization in different operating regions and extraction of device parameters such as threshold voltage, channel length modulation, etc.
8: Simulation study of transient analysis of CMOS inverter. Adjustment of W/L ratio from minimum to 5 times, 10 times size of the MOSFETs and study the effect on performance parameter, using S-EDIT, L-EDIT.
9: To design two input NAND and NOR gate using CMOS logic, with minimum size transistors size using S-EDIT &L-EDIT.
10: To study CMOS AND-OR-INVERT (AOI) and OR –AND –INVERT (OAI) gates.

Note: Mini projects to be made by students based on the above experiments. *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: Develop CMOS based circuits for VLSI design
CO3: Trace and debug SPICE related program.

Course Name: **Digital VLSI Design** Course Code: **EC-621** Course Type: **Core**	
Contact Hours/Week: **4L**	Course Credits: **04**

Course Objectives

- To use modelling of the various semiconductor devices for digital VLSI circuit design.
- To comprehend static and dynamic CMOS logic circuits.
- To learn MOS Memory design.
- To build upon the theoretical, mathematical and physical analysis of digital VLSI circuits, for proper understanding of concept, working, analysis and design.
- To analyse the designed digital circuits and their verification.

Course Content

Types and principles of MOSFETs, Introduction to large signal MOS models (long channel) for digital design. MOS Inverters, Static and Dynamic characteristics, Resistive, Depletion and Enhancement load NMOS inverters, the basic CMOS inverter, voltage transfer characteristics, logic threshold, Noise margins. Dynamic behavior, transition time, Propagation Delay, Power Consumption. MOS Circuit Layout & Simulation, Stick diagrams, Layout design rules, MOS device layout, Transistor layout, Inverter layout, CMOS-circuits layout & simulation, Circuit Compaction, Euler's Rule, Circuit extraction and post-layout simulation. Combinational MOS Logic Design, Static MOS design, Complementary MOS, Ratioed logic, Pass Transistor logic, Complex logic circuits, DSL, DCVSL, and Transmission gate logic. Dynamic MOS design, Dynamic logic families and their performance. MOS Memory design, Design of ROM, SRAM and DRAM cells. Sequential MOS Logic Design, Static and dynamic latches, flip flops & registers, CMOS Schmitt trigger, Monostable sequential and Astable circuits, adders and multiplier circuits. VLSI Interconnects, Interconnect delays, Cross-talks. Introduction to low power design, Input and Output Interface circuits. BiCMOS Logic Circuits, Introduction, Basic BiCMOS Circuit behavior, Switching Delay in BiCMOS Logic circuits.

Course Outcomes

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

CO1: Classify ICs, static and dynamic VLSI design techniques.

CO2: Design any CMOS digital VLSI combinatorial and sequential circuits.

CO3: Design, analyze and verify digital logic circuits and MOS memories as well as Physical layout designing of circiuts.

CO4: Model the CMOS circuits with equivalent parameters.

CO5: Build upon the theoretical & mathematical models using design principles, for proper understanding of VLSI circuits.

Books and References

1. CMOS Digital Integrated Circuits-Analysis & Design, S.M. Kang & Y. Leblibici, TMH, 3rd Ed.
2. Digital Integrated Circuits Design by J.M. Rabaey, Pearson Education, 2003.
3. Principles of CMOS VLSI Design: A System Perspective by NHE Weste & K. Eshraghian, McGraw Hill Pub.
4. Solid State Electronic Devices, B.G. Streetman & S. Banerjee, PHI.
5. CMOS Logic Circuit Design by Uyemera, Springer India Pvt. Ltd. New Delhi, 2007.
6. Introduction to VLSI by Eshraghian & Pucknell, PHI.
7. Analysis & Design of Digital Integrated Circuits by David A. Hodges, Horace G. Jackson, R. Saleh, McGraw Hill, 2003.
8. Introduction to PSPICE, H.M. Rashid, PHI.

Course Name: **Analog VLSI Design** Course Code: **EC-622** Course Type: **Core**	
Contact Hours/Week: **4L**	Course Credits: **04**

Course Objectives

- To discuss basic transistor models for the design of analog integrated circuits and to characterize them.
- To study the most important building blocks in CMOS technologies and understand their limitations.
- To study key analog circuits for signal processing, conditioning and detection in systems
- To design analog IC circuits considering practical design parameters.

Course Content

Analog integrated circuit design, Circuit design consideration for MOS challenges in analog circuit design, Analog MOSFET Modelling: MOS transistor, Low frequency MOSFET Models, High frequency MOSFET Models, Temperature effects in MOSFET, Noise in MOSFET; Current Source, Sinks and References: MOS Diode/Active resistor, Simple current sinks and mirror, Basic current mirrors, Advance current mirror, Current and Voltage references, Bandgap references; CMOS Amplifier: Performances matrices of amplifier circuits, Common source amplifier, Common gate amplifier, Cascode amplifier, Frequency response of amplifiers and stability of amplifier; CMOS Feedback Amplifier: Feedback equation, Properties of negative feedback on amplifier design, Feedback Topology, Stability; CMOS Differential Amplifier: Differential signalling, source coupled pair, Current source load, Common mode rejection ratio, CMOS Differential amplifier with current mirror load,, Differential to single ended conversion; CMOS Operational amplifier: Block diagram of Op-amplifier, Ideal characteristics of Op-Amplifier, Design of two stage Op-Amplifier, Compensation of Op-Amplifier, Frequency response of Op-Amplifier; CMOS Comparator: Characteristic of a comparator, Two stage open loop comparator, Special purpose comparator, Regenerative comparator, High output current amplifier, High speed comparator; Introduction to Switched Capacitor Circuits: Switched capacitor circuits, Switched capacitor amplifiers, Switch capacitor integrators.

Course Outcomes

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

CO1: Identify the various design metrics of analog Design.

CO2: Describe the MOS based biasing circuits, various MOS based amplifier, Op-Amplifier, Differential amplifier

CO3: Apply principles of design to various analog blocks

CO4: Assess the results obtained by solving broadly defined engineering technology problems

Books and References

1. Design of Analog CMOS Integrated Circuits by Behzad Razavi McGraw Hill.
2. CMOS: Circuit Design, Layout and Simulation by R. Jacob Baker, Harry W. Li, and David E. Boyce, Prentice Hall of India
3. Analog Integrated circuit Design by David A. Johns and Ken Martin, John Wiley & Son

Course Name: **FPGA and ASIC Design**
Course Code: **EC-623**
Course Type: **Core**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To prepare the student to be an ASIC and FPGA based Chip design engineer
- To give the student an understanding of issues and tools related to ASIC/FPGA design and implementation.
- To give the student an understanding of High performance algorithms.

Course Content

ASIC and FPGA devices, ASIC and FPGA Design flows, Top-Down and Bottom-Up design methodologies, Hardware Description Languages, Design Automation Tools, HDL Support for Synthesis. Language concepts: Design Entity, Declaration statements, concurrent statements, sequential statements, data types, data objects, expressions, operands, if-else, for-loop, case statements, synthesis equivalents and constraints. Modelling Combinational Circuits: Control & Data partitioning, Synthesis concepts, non-synthesizable constructs, operators, expressions, conditional statements, post synthesis simulation, basic test bench, Logic and arithmetic equations, multiplexers, encoders, decoders, comparators, adders, subtractors, multipliers, ALUs, synthesis constraints. Modelling sequential circuits: Latches and Flip-flops, counters, mealy and Moore FSM, shifters, sequential adders, multipliers and dividers. Blocking and non-blocking statements, Static timing analysis, Procedures and timing control, procedural blocks, loops, Tasks and functions, Test bench modeling techniques, Path delay modeling, Timing analysis, User defined primitives, compiler directives, and system tasks, Implementation on FPGA. Unsigned integer, signed integer, fixed-point, floating-point arithmetic, Asynchronous considerations. Memory design: synchronous and asynchronous, single, dual and multi-port, Error detection and correction, compiler directives. Design Considerations: Hardware and software processor options, SoC design considerations and implementation, I/O interfacing, Bus architectures, Serial and parallel data transmission, Handling interrupts and timers, Accelerators, DSP Blocks, Area, Power and Timing constraints, Scripting languages.

Course Outcomes

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

CO1: Understand the algorithms used for ASIC construction.

CO2: Design chip using the Full Custom Design Flow and Tool.

CO3: Understand the basics of System on Chip and on chip communication architectures appreciate high performance algorithms for ASICs.

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.

Course Name: **VLSI Design Lab**	
Course Code: **EC-624**	
Course Type: **Core**	
Contact Hours/Week: **4P**	Course Credits: **02**

Course Objectives

- To learn Physical Design i.e. Layout making of VLSI circuits.
- Programming in Verilog and its use for design and analysis.
- To extract various design parameters from simulation results.
- Debug and identify the errors in codes.
- Synthesize Combinational and Sequential circuits on FPGA and test the hardware.

List of Experiments

1. Familiarity with Cadence Familiarization with Cadence EDA Tools. To study the main features and utilities of the tools for design and physical layout design. Report the same in practical file.
2. Simulate CMOS NAND, NOR and XOR circuits and validation with physical Layout using Cadence EDA Tool. Analyze and plot their power and delay variations i) with voltage scaling, (ii) For dimension, load and frequency variations.
3. Design a differential amplifier circuit for a voltage gain of 10. Design its layout.
4. Design NAND NOR, XOR circuits using Cadence EDA Tools, for delay and power centric design criteria.
5. Physical design a full adder circuit using minimum number of CMOS NAND gates.
6. Write Verilog code for SR, D, JK, and T Flip flops.
7. Write a program to implement a 3:8 decoder.
8. Write a program to implement an 8:1 multiplexer and 1:8 demultiplexer.
9. Write a program to implement 4-bit addition/subtraction.
10. Write a program to implement a 4-bit comparator.
11. Write a program to generate Mod- 10 up counter.
12. Write a program to generate the 1010 sequence detector. Overlapping patterns are allowed.
13. Write a program to design a 2-bit ALU containing 4 arithmetic & 4 logic operations.
14. Write a Verilog code to design a clock divider circuit that generates 1/2, 1/3rd and 1/4th clock from a given input clock. Port the design to FPGA and validate the functionality.

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

CO4: Identify and abstract the programming task involved for a given VLSI problem.

CO5: Design and develop programming skills for VLSI circuit design.

CO6: Trace and debug any VLSI related program.

Course Name: **Characterization of Semiconductor Materials & Devices** Course Code: **EC-711** Course Type: **Program Elective-I**	
Contact Hours/Week: **4L**	Course Credits: **04**

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

Course Content

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. 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. Resistivity, conductivity, and Band gap of Semiconductor materials. 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. Electronic properties of compound Semiconductor materials, Optoelectronic Devices; LED, PIN Photodetector, Semiconductor laser, Microwave Devices.

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 material.
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: **Nano-Electronics**
Course Code: **EC-712**
Course Type: **Program Elective-I**

Contact Hours/Week: **4L** Course Credits: **04**

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 Nano electronics and critically evaluate challenges and opportunities in scaling down devices to the nanoscale, and their potential impact on various industries.

Course Content

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. 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. 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. 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. 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.

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.
3. Introduction to Nano Science and Technology by S.M. Lindsay, World Scientific.
4. Lessons from Nanoscience: A Lecture Note Series, By Supriyo Dutta, World Scientific.
5. Quantum Transport- Atom to Transistor, By Supriyo Dutta, Cambridge University Press.
6. Nanotechnology for Microelectronics and optoelectronics, By J.M. Martinez-Duart, R. J. Martin Palma, F. Agulle Rueda, Elsevier.

Course Name: **Deep Submicron VLSI Design**
Course Code: **EC-713**
Course Type: **Program Elective-I**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To teach fundamentals of deep submicron (DSM) technologies in VLSI.
- To give an insight into the various non-ideal effects in DSM.
- To provide remedial measures for various issues in DSM VLSI design.

Course Content

Evolution of the structure of MOSFETs, the structure of deep-submicron MOSFETs (0.25-μm to 0.13-μm), compare to the structure of the conventional MOSFETs (2.0-μm to 0.5-μm), evolution of the MOSFET gate stack and contact structure, gate dielectric materials in deep-submicron MOSFETs, doping-concentration profiles of the MOSFET channel, evolution of the drain structure of MOSFETs. Deep-submicron CMOS structures, Substrate issues for deep-submicron CMOS, well formation in deep-submicron CMOS, dual-doped poly in deep-submicron CMOS, shallow trench isolation for deep-submicron CMOS, silicon-on-insulator (SOI) technology. 300-mm Silicon Wafers, 300-mm silicon crystal growth, grown-in silicon defects, formation of crystal-originated-particles (cops), the oxygen-stacking-fault ring (OSF-ring), mitigating effects of cops by use of post-crystal-growth annealing, high pull speed silicon, from ingot to finished wafer, slicing, etching, & polishing, specifications of silicon wafers for VLSI. Gate Dielectrics, Thin Gate Oxides, required characteristics of gate dielectrics for deep submicron MOSFETs, the structure of thermally grown SiO_2 and the properties of the Si/SiO_2 interface, Dielectric breakdown in silicon dioxide films trapped in SiO_2, Leakage currents in SiO_2 films (tunneling phenomena), Manufacturing thin gate oxides, High-k dielectrics and low-k dielectrics. The Structure of Deep-Submicron MOSFETs, well-formation in deep-submicron CMOS, Super-steep retrograde channel (SSR) profiles Source/drain engineering in deep-submicron CMOS, Anti-punch-through structures in deep-submicron CMOS. Advanced Lithography and Chemical Mechanical Polishing (CMP) Deep-submicron resists, Chemically-amplified deep-UV resists for optical lithography, chemically-amplified deep-UV resists for optical lithography, anti-reflective coating (arcs), photoresist processing systems. Optics and hardware, Excimer laser deep-UV light sources, exposure tools for DUV lithography, resolution enhancement technologies (RETS), mask error factor (MEF or MEEF), non-optical (or next generation) lithographic technologies (NGL) Mechanisms of CMP, CMP equipment, cleaning issues in CMP, miscellaneous issues in CMP. Shallow Trench Isolation (STI), Shallow trench isolation for CMOS, details of the process flow to form a baseline shallow-trench-isolation (STI) structure, issues and characteristics of MOSFETs fabricated with STI.

Course Outcomes: Upon successful completion of the course, the students will be able to:
CO1: Comprehend the insight of deep submicron (DSM) VLSI design.
CO2: Identify the non-ideal issues and remedial solutions for these.
CO3: Assess and analyze the performance of DSM VLSI designs.

Books and References

1. Silicon Processing for the VLSI Era: Deep-Submicron Process Technology by Stanley Wolf, Lattice Pr.
2. Deep-Submicron CMOS ICs: From Basics to ASICs by Harry Veendrick, Kluwer Academic.

Course Name:	**Advanced Semiconductor Devices**
Course Code:	**EC-714**
Course Type:	**Program Elective-I**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To teach about various advanced semiconductor devices.
- To build upon the theoretical and mathematical models for working and behavior of the advanced semiconductor devices.
- To understand and practice designing of VLSI circuits with advanced devices.

Course Content

Review of semiconductors fundamentals, semiconductor materials and their properties, band structure modification by alloys, carrier transport in semiconductors, scattering, defects, phonons, mobility, excess carriers in semiconductor, reverse recovery time. Junctions and interfaces, description of p-n junction, action, abrupt junction, example of an abrupt junction, linearly graded Junction. Ideal diode model, real diodes, temperature dependence of current-voltage (I-V) characteristics, high level injection effects, example of diodes. Description of breakdown mechanism, Zener and Avalanche breakdown in p-n junctions. Majority carrier diodes, Tunnel diode, backward diode, Schottky barrier diode, Ohmic contacts, heterojunctions. Microwave diodes, Varactor diode, p-i-n Diode, IMPATT diode, TRAPATT diode, BARITT diode, transferred electron devices. Optoelectronic devices &nano-electronics, solar cell, photo detectors, light emitting diodes, semiconductor lasers. Nano devices, material and classification, issues in scaling MOS transistors, transport in nano-MOSFET, carbon nanotubes (CNTs). Metal semiconductor field effect transistors, basic types of MESFETs, models for I-V characteristics of short channel MESFETs, high frequency performance, MESFETs structures. MOS transistors and charge coupled devices, basic structures and the operating principle, I-V characteristics, short-channel effects, charge coupled devices.

Course Outcomes

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

CO1: Identify the conventional and new state of the art semiconductor devices.

CO2: Apply the theoretical and mathematical models of advanced devices for usage in electronic design.

CO3: Assess and analyse the performance of advanced semiconductor devices and circuits.

Books and References

1. Advanced Theory of Semiconductor Devices by Karl Hess, Wiley-IEEE Press, 1999.
2. Physics of Semiconductors and Their Heterostructures by Jasprit Singh, McGraw-Hill Education, 1993.
3. Advanced Semiconductor Fundamentals by Robert F. Pierret, Prentice Hall, 2002.
4. Fundamentals of Modern VLSI Devices by Y. Taur and T. Ning, Cambridge University Press, 2013.

Course Name:	**VLSI Test and Testability**
Course Code:	**EC-715**
Course Type:	**Program Elective-I**

Contact Hours/Week: **4L** Course Credits: **04**

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.

Course Content

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. 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. Design For Testability Design for Testability: Ad-hoc design, Generic scan-based design, Classical scan-based design – System level DFT approaches, Memory test. 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. Fault Diagnosis Logic Level Diagnosis: Diagnosis by UUT reduction, Fault Diagnosis for Combinational Circuits, Self-checking design, System Level Diagnosis.

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 integrated circuits at earlier design levels to significantly reduce the testing costs.

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

Books and References:

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

Course Name: **VLSI Interconnects**
Course Code: **EC-716**
Course Type: **Program Elective-I**

Contact Hours/Week: **4L** Course Credits: **04**

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

Course Content

Interconnect Parameters, resistance, inductance, and capacitance, RC Delays, lumped RC Model, distributed RC Model, transmission line model, SPICE wire models, gate and interconnect delay, CMOS repeater: static and dynamic behavior, switching threshold, noise margins, computing the capacitances, propagation delay, first order analysis, propagation delay from a design perspective. 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. Advanced interconnect techniques**:** reduced-swing circuits, current mode transmission techniques. 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.

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:	**MEMS and Micro Sensor Design**
Course Code:	**EC-717**
Course Type:	**Program Elective-I**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To impart knowledge about the need and applications of microsystem 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 design issues and explore design tradeoff in various sensing and actuation mechanisms.

Course Content

Introduction to MEMS and Microsystems, Structural and Sacrificial Materials, Properties of Materials, Basic Modeling of Elements in Electrical and Mechanical systems, Sensors/transducers, Sensors Characterization and Classifications, Microactuators, Applications of MEMS, Silicon Growth, Additive Techniques: Oxidation, Physical Vapor Deposition, Chemical Vapor Deposition, Thin Film Deposition, Photolithography, Wet and Dry Etching, Bulk and Surface Micromachining, Etch Stop Technique and Microstructure, Microsterolithography LIGA, Wafer Bonding, Capacitive Sensors, Modeling of Capacitive Sensor, Capacitive Accelerometer, Parallel-Plate Actuator, Comb Drive Actuator, Piezoresistance Effect, Modeling of Piezoresistive Transducers, Piezoresistive Pressure Sensor, Piezoelectricity, Piezoactuators, Inertial Sensors, Microaccelerometer, Gyroscope, Temperature Coefficient of Resistance, Thermo-Electricity, Thermocouples, Thermal and Temperature Sensors, Heat Pump, Micromachined Thermocouple Probe, Thermal Flow Sensors, Shape Memory Alloy, Hot Arm Actuators, Properties of Light, Light Modulators, Beam Splitter, Microlens, Micromirrors, Digital Micromirror Devices, Light Detectors, Grating Light Valve, Optical Switch, Magnetic Sensing and Detection, Magnetoresistive Sensor, Magneto diodes, Magneto transistor, Pressure Sensor, and Bidirectional Microactuators.

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 of various MEMS & Sensors parts.

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

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

Books and References:

1. Introductory MEMS Fabrication and Applications by T. M. Adams and R. A. Layton, Springer Publications.
2. Sensors and Transducers by M. J. Usher, McMillian Hampshire.
3. MEMS by N. P. Mahalik, Tata McGraw Hill.
4. Microsensors by R. S. Muller, Howe, Senturia and Smith, IEEE Press.
5. Analysis and Design Principles of MEMS Devices by Minhang Bao, Elsevier.

Course Name:	**Memory Design and Testing**
Course Code:	**EC-718**
Course Type:	**Program Elective-I**
Contact Hours/Week: **4L**	Course Credits: **04**

Course Objectives

- To use modelling of the various semiconductor devices for digital VLSI circuit design.
- To comprehend static and dynamic CMOS logic circuits.
- To learn MOS Memory design.
- To build upon the theoretical, mathematical and physical analysis of digital VLSI circuits, for proper understanding of concept, working, analysis and design.
- To analyze the designed digital circuits and their verification.

Course Content

Types and principles of MOSFETs, Introduction to large signal MOS models (long channel) for digital design. MOS Inverters, Static and Dynamic characteristics, Resistive, Depletion and Enhancement load NMOS inverters, the basic CMOS inverter, voltage transfer characteristics, logic threshold, Noise margins. Dynamic behavior, transition time, Propagation Delay, Power Consumption. MOS Circuit Layout & Simulation, Stick diagrams, Layout design rules, MOS device layout, Transistor layout, Inverter layout, CMOS-circuits layout & simulation, Circuit Compaction, Euler's Rule, Circuit extraction and post-layout simulation. Combinational MOS Logic Design, Static MOS design, Complementary MOS, Ratioed logic, Pass Transistor logic, Complex logic circuits, DSL, DCVSL, Transmission gate logic. Dynamic MOS design, Dynamic logic families and their performance. MOS Memory design, Design of ROM, SRAM and DRAM cells. Sequential MOS Logic Design, Static and dynamic latches, flip flops & registers, CMOS Schmitt trigger, Monostable sequential and Astable circuits, adders and multiplier circuits. VLSI Interconnects, Interconnect delays, Cross-talks. Introduction to low power design, Input and Output Interface circuits. BiCMOS Logic Circuits, Introduction, Basic BiCMOS Circuit behavior, Switching Delay in BiCMOS Logic circuits.

Course Outcomes

Upon successful completion of the course, the students will be able to:
CO1: Classify ICs, static and dynamic VLSI design techniques.
CO2: Design any CMOS digital VLSI combinatorial and sequential circuits.
CO3: Design, analyze and verify digital logic circuits and MOS memories as well as Physical layout designing of circiuts.
CO4: Model the CMOS circuits with equivalent parameters.
CO5: Build upon the theoretical & mathematical models using design principles, for proper understanding of VLSI circuits.

Books and References

1. CMOS Digital Integrated Circuits-Analysis & Design by S.M. Kang & Y. Leblibici, TMH.
2. Digital Integrated Circuits Design by J.M. Rabey, Pearson Education.
3. Principles of CMOS VLSI Design: A System Perspective by NHE Weste & K. Eshraghian, McGraw Hill Pub.
4. Solid State Electronic Devices by B.G. Streetman & S. Baneerjee, PHI.
5. CMOS Logic Circuit Design by Uyemera, Springer India Pvt. Ltd. New Delhi.
6. Introduction to VLSI by Eshraghian & Pucknell, PHI.
7. Analysis & Design of Digital Integrated Circuits by David A. Hodges, Horace G. Jackson, R. Saleh, McGraw Hill.
8. Introduction to PSPICE by H.M. Rashid, PHI.

Course Name: **Neural Networks and Deep Learning**

Course Code: **EC-719**

Course Type: **Program Elective-I**

Contact Hours/Week: 4L **Course Credits: 04**

Course Objectives: The objective of this course is to develop neural networks and deep learning models for solving various real-life problems.

Course Content

Models of a Neuron, Multilayer Perceptron (MLP), Backpropagation: Computing Gradients w.r.t. the Output Units, Backpropagation: Computing Gradients w.r.t. Hidden Units, Role of Loss Functions and Optimization, Gradient Descent, MLP for Classification and Regression. Unsupervised Learning with Deep Network, Autoencoders, Link between PCA and Autoencoders, Regularization in autoencoders, Denoising Autoencoders, Sparse Autoencoders, Variational Autoencoder, Convolutional Neural Network (CNN), Building blocks of CNN, Transfer Learning, Recurrent Neural Networks (RNN), LSTM Networks. Effective training in Deep Network- early stopping, Dropout, Batch Normalization, Instance Normalization, Group Normalization. Revisiting Momentum Optimizer, RMSProp, Adam. Recent Trends in Deep Learning Architectures, Residual Network, Skip Connection Network, Fully Connected CNN etc. Generative Modeling with DL, 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.

Course Outcomes:

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

CO1: Understand the concepts of neural network learning.

CO2: Understand the concepts of autoencoders.

CO3: Understand the concepts of CNN and RNN.

CO4: Understand the concepts of generative adversarial networks.

Books and References:

1. Ian Goodfellow, Yoshua Bengio, and Aaron Courville, “Deep Learning”, MIT Press Ltd, Illustrated edition.
2. Richard O. Duda, Peter E. Hart, David G. Stork, “Pattern Classification”, John Wiley & Sons Inc.

Course Name: **Low Power VLSI Design** Course Code: **EC-720** Course Type: **Program Elective-II**	
Contact Hours/Week: **4L**	Course Credits: **04**

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.

Course Content

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

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

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

Low Power Logic Level Design: Gate Reorganization, Multistage Logic Design, Signal Gating, Logic Encoding, State Machine Encoding, and Pre-Computation Logic

Low Power Architecture and System Level Design: Power and Performance Management, Switching Activity Reduction, Parallel Architecture with Voltage Reduction, and Flow Graph Transformation.

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.

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: **Advanced IC Design**	
Course Code: **EC-721**	
Course Type: **Program Elective-II**	
Contact Hours/Week: **4L**	Course Credits: **04**

Course Objectives

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

Course Content

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. Design of Super Buffer Circuits for driving large capacitive loads. Design and analysis of CMOS Schmitt trigger circuit. Comparators and their characteristics zero crossing detector, voltage limiters, and absolute value detectors, sample and hold circuit. Biomedical applications of instrumentation amplifier. Design and analysis of multi-vibrator circuits using transistors, Op-Amps and 555 Timer. 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. Differential and Feedback Amplifiers

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 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: **IC Design for IoT Systems**

Course Code: **EC-722**

Course Type: **Program Elective-II**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To provide students with good depth of knowledge of Designing IC based IOT Systems for various application.

Course Content

Introduction to Embedded and IOT Systems: Definition, Examples and components of embedded Systems, Classification of an Embedded system. Architecture of Embedded system. General purpose computers vs embedded system, Embedded System Design Process, Various Embedded cores controller. Embedded system with IOT connectivity.

Hardware/Software Co-design for Embedded Systems: Microcontrollers for embedded systems, 32-bit RISC Architectures for embedded Design, ARM architectural details, The ARM programmer's model, ARM development tools, ARM microcontroller programming in C, Peripheral Interfacing with ARM, Basic Wire and Wireless Protocols like, UART, I2C, SPI, PLCC, Bluetooth, WiFi, Zig-Bee and LoRa for IoT applications. Embedded Operating Systems: Operating system requirements for Embedded systems, Fundamentals of Real Time Operating System (RTOS), Operating system services, Process, Task and Thread, System calls, Timer and Event Function, Memory management, File and I/O subsystem management, Device Management, Device drivers and It's Programming for Embedded platform. OS based Software development: Programming in higher level languages on embedded OS platform, Communication protocols and it's applications , Embedded Systems with Internet of Things (IoT) and Cloud support.

Introduction to IOT based Embedded Systems: Basic architecture of an IoT based Embedded Systems., Embedded Hardware for IoT applications, like Raspberry Pi, Arduino, and ARM development board, IoT Cloud Platform and IoT client applications on mobile phones. Case Studies of Embedded Systems: Embedded application development through ARM based development boards, Development of mini-Project on new version of Operating systems and development board.

Course Outcomes

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

CO1: Acquire the knowledge of theory and practice related to IC Design of IoT System.

CO2: Identify, formulate and solve engineering problems by using Embedded Systems with IoT.

CO3: Implement real field problem by gained knowledge of Embedded Systems with IoT capability

Books and References

1. Muhammad Ali Mazidi, Shujen Chen, Sepehr Naimi, Sarmad Naimi, "Embedded Programming Using C Language", 1st Edition, Freescale ARM Cortex-M.
2. Rajkamal, "Embedded System: Architecture, Programming and Design", TMH3.
3. Dr. Ovidiu Vermesan, Peter Friess, "Internet of Things: Converging Technologies for Smart Environments and Integrated Ecosystems", River Publisher.

Course Name: **Data Converters for IC Design** Course Code: **EC-723** Course Type: **Program Elective-II**	
Contact Hours/Week: **4L**	Course Credits: **04**

Course Objectives

- Introduce students to the fundamentals of VLSI signal processing and expose them to examples of applications.
- Design and optimize VLSI architectures.

Course Content

The functions and applications of D/A and A/D converters. Ideal DACs and ADCs: operation, specifications, metrics. Converter non-idealities: offset and gain error, DNL, INL, non-monotonicity, missing codes, SNR, DR, SFDR, etc. DAC architectures: decoder-type, binary, thermometer, hybrid DACs. DAC circuit structures: R-string and R-ladder circuits, current-steering, charger distribution, hybrid, segmented DACs. ADC architectures: integrating, successive approximation and algorithmic, pipelined, time-interleaved, sub ranging and two-step, interpolating, folding and flash ADCs. ADC circuits: resistor-string, charge-redistribution, current steering, hybrid, folding/interpolating circuits. Operational principles of delta-sigma (D-S) DACs and ADCs. Main architectures for the realization of D-S DACs and ADCs. Circuit realization and non-idealities of D-S data converters.

Course Outcomes

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

1. Understand the fundamentals of sampling and the translation of signals from digital to analog and analog to digital domains.
2. Know the basic circuits unique to data converters and how they impact design.
3. Have designed your own digital-to-analog converter as well as ADCs.

Books and References

Analog Integrated Circuit Design, by D. Johns and K. Martin, Wiley, 1997 or second ed. by T. Carusone, D. Johns and K. Martin, Wiley, 2012.

2. Data Conversion System Design, by B. Razavi, IEEE Press, 1995.
3. Understanding Delta-Sigma Data Converters, by R. Schreier and G.C. Temes, IEEE Press/Wiley, 2004.
4. Data Converters, F. Maloberti, Springer 2007.
5. Analog-to-Digital Conversion, M. Pelgrom, second ed., Springer, 2013.

Course Name: **Verification of VLSI Circuits**

Course Code: **EC-724**

Course Type: **Program Elective-II**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To impart knowledge about the verification of VLSI circuits.
- To introduce the concepts of Verification techniques, UML and considerations
- To demonstrate the hardware acceleration and emulation techniques

Course Content

Design and Verification Languages Stephen A. Edwards: Introduction, History, Design Languages, Verification Languages. Digital Simulation: Introduction, Event-vs Process-Oriented Simulation, Logic Simulation Methods and Algorithms, Impact of Languages on Logic simulation, Logic Simulation Techniques, Impact of HVLs on simulation, Summary. Using Transactional-Level Models in a SoC Design Flow: Introduction, Overview of the System-to-RTL Design Flow, TLM —View for the Design Flow, TLM Modeling Application Programming Interface, Example of a Multimedia Platform, Design Flow Automation, Conclusion. Hardware Acceleration and Emulation: Introduction, Emulator Architecture Overview, Design Modeling, Debugging, Use Models, The Value of In-Circuit Emulation, Considerations for Successful Emulation, Summary. Formal Property Verification: Introduction, Formal Property Verification Methods and Technologies, Software Formal Verification, Summary.

Course Outcomes

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

CO1: Able to verify digital circuits for design errors.

CO2: Understand the constraints and corner cases.

CO3: Utilize techniques and technology for efficient circuit verification.

Books and References

1. EDA for IC System Design, Verification, and Testing by Louis Scheffer, Luciano Lavagno, and Grant Martin.
2. Verification Techniques for System-Level Design by M. Fujita, I. Ghosh, and M. Prasad, , Morgan Kaufmann.
3. Formal Verification: An Essential Toolkit for Modern VLSI Design by Erik Seligman, Morgan Kaufmann.

Course Name: **Reliability of VLSI Circuits** Course Code: **EC-725** Course Type: **Program Elective-II**	
Contact Hours/Week: **4L**	Course Credits: **04**

Course Objectives

To acquaint the students with state-of-the-art circuit performance and reliability models of VLSI circuits.

Course Content

Nanoscale MOSFET Characteristics: Quasi-ballistic I-V characteristics, terminal capacitances of transistors considering quantum effects, parasitic resistances in nanoscale MOSFETs.

Delay and Timing Models: Classical delay models of logic gates, logic gate delay models for nano-regime CMOS technologies, timing parameters of sequential circuit elements, access-time of CMOS memories, impact of process/temperature/supply-voltage variations on timing parameters.

Power Consumption: Models for dynamic power, short circuit power and leakage power of CMOS circuits, full-chip power estimation techniques, impact of process/temperature variations on power consumption.

Reliability of CMOS Circuits: Circuit performance considering NBTI/PBTI, oxide breakdown, random telegraph noise, radiation damage.

Analog Circuit Performance Parameters: Impact of parasitic effects, process/temperature variation, device reliability effects.

Course Outcomes

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

CO1: Understand the Nanoscale MOSFET Characteristics.

CO2: Apply the concepts of Delay and Timing Models.

CO3: Understand the concepts of power consumption and Reliability of CMOS Circuits.

CO4: Familiarize with the Analog Circuit Performance Parameters.

Books and References

1. Yuan Taur and T. Ning, “Fundamentals of Modern VLSI Devices,” Cambridge University Press.

2. Jan M. Rabaey, Anantha Chandrakasan, Borivoje Nikolic, “Digital Integrated Circuits: A Design Perspective,” Prentice Hall

3. Behzad Razavi, “Design of Analog CMOS Integrated Circuits”, Tata McGraw-Hill.

Course Name: **Hardware Algorithms for VLSI** Course Code: **EC-726** Course Type: **Programme Elective-II**	
Contact Hours/Week: **4L**	Course Credits: **04**

Course Objectives

- To impart knowledge about 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. Parhami, B., Computer Arithmetic: Algorithms and Hardware Design, Oxford University Press (2000).
2. Koren, I., Computer Arithmetic Algorithms, 2nd Edition, Uni Press (2005) 2nd ed.
3. Ercegovac, M. and Lang, T., Digital Arithmetic, Elsevier (2005).
4. Mark Gordon Arnold, Verilog Digital Computer Design Algorithms into Hardware

Course Name: **Advanced Computer Architecture**
Course Code: **EC-727**
Course Type: **Program Elective-II**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To impart knowledge about the quantitative principles of computer architecture.
- To introduce the fundamental concepts relevant to analyze the ILP and associated hazards.
- To enable the students to understand superscalar, vector and VLIW styles of computing for various applications.

Course Content

Introduction: review of basic computer architecture, quantitative techniques in computer design, measuring and reporting performance. CISC and RISC processors. Pipelining: Basic concepts, instruction and arithmetic pipeline, data hazards, control hazards, and structural. Hazards, techniques for handling hazards. Exception handling: Pipeline optimization techniques. Compiler techniques for improving. Performance. Hierarchical memory technology: Inclusion, Coherence, and locality properties. Cache memory organizations: Techniques for reducing cache misses; Virtual memory organization, mapping and management techniques, memory replacement policies. Instruction-level parallelism: basic concepts, techniques for increasing ILP, superscalar, super pipelined and VLIW processor architectures. Array and vector processors. Multiprocessor architecture: taxonomy of parallel architectures. Centralized shared-memory architecture: synchronization, memory consistency, interconnection networks. Distributed shared-memory architecture. Cluster computers. Non von Neumann architectures: data flow computers, reduction computer architectures, systolic architectures.

Course Outcomes

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

CO1: Understand quantitative principles of computer architecture.

CO2: Understand and analyse the ILP and associated hazards.

CO3: Design memory hierarchies for better performance.

CO4: Identify superscalar, vector and VLIW styles of computing for various applications.

Books and References

1. Computer Organization and Design: A Hardware/Software Interface by John L. Hennessy and David A. Patterson, Morgan Kaufmann.
2. Computer Architecture: A Quantitative Approach by John L. Hennessy and David A. Patterson, Morgan Kaufmann.
3. Advanced Computer Architecture: Parallelism, Scalability, Programmability by Kai Hwang, McGraw-Hill.

Course Name: **RF IC Design** Course Code: **EC-728** Course Type: **Program Elective-III**	
Contact Hours/Week: **4L**	Course Credits: **04**

Course Objectives

- To develop the foundation for IC design for radio frequency applications, specific to MOS integrated circuits.
- To impart knowledge about Characteristics of Passive and Active IC Components at RF Frequencies such as Low Noise Amplifier Design, Mixers, and Oscillators.

Course Content

Overview of RF and Wireless Technology, Units in RF design, Time variance, Nonlinearity, Effect of nonlinearity, Noise, Sensitivity and Dynamic Range, Passive RLC Networks**:** Parallel and Series RLC Networks, Other resonant RLC Networks, RLC Networks as Impedance Transformers, Interconnects, Resistors, Capacitors, Inductors, Transformers, Transmission lines, General Considerations, Nonlinear systems as Mixers, Multiplier-based Mixers, Single-Balanced and Double-Balanced Mixers, Passive Mixers, Active Mixers General Considerations for LNA, LNA Topologies: Common-Source Stage with Inductive load, Common-Source Stage with Resistive Feedback, Common-Gate Stage, Basic topologies, VCO, Describing functions, Resonators, Negative resistance oscillators, Heterodyne Receivers, Direct-Conversion Receivers, Image Reject Receivers, Transmitter Architectures MEMS devices for RF Applications: SPST, SPDT devices, High-Q Capacitors, Inductors and their Applications in RF Circuits.

Course Outcomes

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

CO1: Understand the Characteristics of Passive IC Components at RF Frequencies.

CO2: Design LNA for RF IC Circuits.

CO3: Design Mixers for RF IC Circuits

CO4: Understand the transceiver architectures.

CO5: Design oscillators as a part of the RF IC circuit.

CO6: Understanding the MEMS Devices for RF Applications

Books and References

1. RF Microelectronics by Behzad Razavi, Pearson Education India.
2. The Design of CMOS Radio-Frequency Integrated Circuits by Thomas H. Lee, Cambridge University Press.
3. Integrated Circuits for Wireless Communications by A.A. Abidi, P.R. Gray and R.G. Meyer, IEEE Press.
4. RF Circuit Design, Theory and Applications by R. Ludwig and P. Bretchko, Pearson.
5. RF MEMS: Theory, Design, and Technology by G.M. Rebeiz, Wiley.

Course Name: **DSP Architectures** Course Code: **EC-729** Course Type: **Program Elective-III**	
Contact Hours/Week: **4L**	Course Credits: **04**

Course Objectives

- To give an exposure to the various fixed point & a floating point DSP architectures and to develop applications using these processors.

Course Content

Difference between DSP and other microprocessor architectures. An overview of Motorola and Analog Device DSPs. TMS320C54X fixed point and TMS320C3X floating point DSP architectures, CPU, memory, buses, and peripherals. Addressing modes, instruction sets, control operations, interrupts. Repeat operations. Pipeline operation. Pipeline conflicts and programming concepts. Interfacing, serial interface, parallel interface, DMA operations, A/D and D/A converter interfaces. DSP tools. DSP applications. MAC, filter design, implementation of DFT, echo cancellation, spectrum analyzer. Speech and video processing. Architecture of other DSPs.

Course Outcomes

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

CO1: Recognize the fundamentals of fixed- and floating-point architectures of various DSPs.

CO2: Learn the architecture details and instruction sets of fixed- and floating-point DSPs.

CO3: Infer about the control instructions, interrupts, and pipeline operations.

CO4: Illustrate the features of on-chip peripheral devices and their interfacing along with its programming details.

CO5: Analyze and learn to implement the signal processing algorithms in DSPs.

CO6: Learn the DSP programming tools and use them for applications.

CO7: Design and implement signal processing modules in DSPs.

Books and References

1. B. Venkataramani & M. Bhaskar, Digital Signal Processor, Architecture, Programming and Applications (2/e), McGraw-Hill, 2010.
2. S. Srinivasan & Avtar Singh, Digital Signal Processing, Implementations using DSP Microprocessors with Examples from TMS320C54X, Brooks/Cole, 2004.

Course Name: **VLSI Signal Processing** Course Code: **EC-730** Course Type: **Programme Elective-III**	
Contact Hours/Week: **4L**	Course Credits: **04**

Course Objectives

- Introduce students to the fundamentals of VLSI signal processing and expose them to examples of applications.
- Design and optimize VLSI architectures for basic DSP algorithms.
- Design and optimize VLSI architectures for basic DSP algorithms.

Course Content

Pipelining and Parallel Processing: Introduction, Pipelining of FIR Digital Filters, Parallel Processing. Pipelining and Parallel Processing for Low Power. Retiming: Introduction, Definition and Properties, Solving System of Inequalities, Retiming Techniques. Algorithms for Unfolding, Properties of Unfolding, Critical Path, Unfolding and Retiming Application of Unfolding. Introduction to Folding Transformation, Register Minimization Techniques, Register Minimization in Folded Architectures, Folding in Multirate Systems. Systolic Architecture Design: Introduction, Systolic Array Design Methodology, FIR Systolic Arrays, Selection of Scheduling Vector, Matrix Multiplication and 2D Systolic Array Design, Systolic Design for Space Representations Containing Delays. Fast Convolution: Introduction, Cook, Toom Algorithm, Winogard Algorithm, Iterated Convolution, Cyclic Convolution, Design of Fast Convolution Algorithm by Inspection.

Course Outcomes

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

CO1: Understand VLSI design methodology for signal processing systems.

CO2: Familiarization with VLSI algorithms and architectures for DSP.

CO3: Be able to implement basic architectures for DSP using CAD tools.

Books and References

1. Keshab K. Parhi. VLSI Digital Signal Processing Systems, Wiley-Inter Sciences,1999

2. Mohammed Ismail, Terri, Fiez, Analog VLSI Signal and Information Processing, McGraw Hill, 1994.

3. Kung. S.Y., H.J. While house T. Kailath, VLSI and Modern Signal processing, Prentice Hall, 1985.

4. Jose E. France, Yannis Tsividis, Design of Analog Digital VLSI Circuits for Telecommunications and Signal Processing' Prentice Hall, 1994.

Course Name:	**Flexible Electronics**
Course Code:	**EC-731**
Course Type:	**Programme Elective-III**
Contact Hours/Week: **4L**	Course Credits: **04**

Course Objectives

- To give exposure to the various organic semiconductor devices.
- To give an exposure to the various flexible electronic devices.

Course Content

Organic Semiconductors, Electronic Transitions, Excitons, and Energy transfer; Charge generation and recombination mechanisms; Polaron and Disorder models for charge transport; Space charge and Trap limited currents; Charge injection at metal/organic interface. Inorganics, Nanomaterials, Active Materials, Barrier films, Stretchable and twistable interconnects. Modeling and Reliability, Lamination and molding, Ink-Jet printing, Flexible Display, Actuators, Medical Applications.

Course Outcomes

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

CO1: Understand the fundamental aspects of the field of flexible electronics and analyze its wide range of applications and impact on society.

CO2: Apply knowledge from interdisciplinary areas of math and science into the FE systems, integrating various disciplines such as biology, chemistry, physics, and engineering.

CO3: Identify the terminology, equipment, and design methodology used in the fabrication, and characterization of FE systems.

CO4: Recognize and discuss the societal and economical significance of FE systems applications, including benefits and potential risks.

Books and References

1. Suganuma Katsuaki, Introduction to Printed Electronics, Springer, 2014
2. Stergios Logothetidis, Handbook of Flexible Organic Electronics - Materials, Manufacturing, and Applications, 1st Ed., Woodhead Publishing, 2014.
3. Eugenio Cantatore, Applications of Organic and Printed Electronics: A Technology Enabled Revolution, Springer, 2012.

Course Name:	**Organic Electronics**
Course Code:	**EC-732**
Course Type:	**Program Elective-III**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To give exposure to the various organic semiconductor devices.
- To give exposure about organic deposition techniques.

Course Content

Introduction to organic semiconductor devices; Electronic Transitions, Excitons, and Energy transfer; Charge generation and recombination mechanisms; Polaron and Disorder models for charge transport; Space charge and Trap limited currents; Charge injection at metal/organic interface; Organic light emitting diodes (OLEDs); Bilayer, Bulk-heterojunction, Inverted, and Tandem organic photovoltaic (OPV) devices; Carrier loss mechanisms in OPVs; Nanomorphology; Hybrid Perovskite solar cells and LEDs; Top and bottom contact organic thin film transistors (OTFTs); Display driver circuits; Operating principles of organic lasers and memory devices; Device degradation mechanisms and Stability testing methods; Organic thin film deposition techniques and Overview of various printing technologies.

Course Outcomes:

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

CO1: Recognize the fundamentals of organic semiconductor devices.

CO2: Learn the charge generation and recombination mechanisms.

CO3: Infer about the organic light emitting diodes (OLEDs).

CO4: Learn about organic thin film deposition techniques and overview of various printing technologies.

Books and References

1. Suganuma Katsuaki, Introduction to Printed Electronics, Springer, 2014.
2. Stergios Logothetidis, Handbook of Flexible Organic Electronics - Materials, Manufacturing, and Applications, 1st Ed., Woodhead Publishing, 2014.
3. Eugenio Cantatore, Applications of Organic and Printed Electronics: A Technology Enabled Revolution, Springer, 2012.
4. Wolfgang Brütting and Chihaya Adachi, Physics of Organic Semiconductors, 2nd Ed., Wiley-VCH, 2012.
5. Anna Köhler and Heinz Bässler, Electronics Processes in Organic Semiconductors - An Introduction, 1st Ed., Wiley- VCH, 2015.

Course Name: **Quantum Electronics**

Course Code: **EC-733**

Course Type: **Program Elective-III**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives:

- The goal of this course is to introduce the quantum mechanical concept.
- To understand the operation of current nanoelectronics and nanophotonics as well as next generation quantum information processing technologies.
- To learn the fundamentals of quantum cryptography.

Course Content

Maxwell's Equations of Isotropic Media, Electromagnetic Waves and Interfaces, Mirrors, Interferometers and Thin-Film Structures, Gaussian Beams and Paraxial Wave Equation, Ray Optics and Optical Systems, Optical Resonators

Integrated Optics: Waveguides, Coupled Mode Theory, Optical Fibers, Anisotropic, Media: Crystal Optics and Polarization

Quantum Nature of Light and Matter, Schrödinger Equation and Stationary States, Harmonic Oscillator and Hydrogen Atom, Wave Mechanics. Dirac Formalism and Matrix Mechanics, Harmonic Oscillator Revisited, Coherent States,

Interaction of Light and Mater the Two-Level Atom: Rabi-Oscillations, Density Matrix, Energy and Phase Relaxation, Rate Equations, Dispersion, Absorption and Gain. Optical Amplifiers and Lasers, Homogenous and inhomogeneous Broadening and Related Effects, Q-Switching and Mode Locking, Electro- and Acousto-Optic Modulation

Course Outcomes:

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

CO1: Students will understand new physical effects.

CO2: Understand the operation of current Nano electronics and Nano photonics.

CO3: Learn quantum teleportation for processing quantum information.

CO4: Understand basic principles of quantum cryptography.

Books and References:

1. Quantum Electronics by A. Yariv, John-Willey.
2. Optical Electronics by A. K. Ghatak, Cambridge University Press.
3. Laser Fundamentals by T. Silfvast William, Cambridge University Press.

Course Name: **Magneto-electronics & Spintronics**
Course Code: **EC-734**
Course Type: **Program Elective-III**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To provide students with the necessary knowledge, skills and tools to contribute to the development of Magneto-electronics & Spintronics

Course Content

Fundamentals of magnetism, Fundamentals of Semiconductor, Basic Principles of Electrical and Magnetic transport, Magnetic-Nonmagnetic multilayer-structures, Ferromagnetic Semiconductors, Half-metallic Ferromagnets. Anisotropic Magnetoresistance (AMR), Giant Magnetoresistance (GMR), Colossal Magnetoresistance (CMR). Spin-valve, Spin-diode, Spin-LED, Spin-transistor, Spin-FET, Magnetic Random Access Memory (MRAM). Magneto-logic Gates (magnetic AND, OR, NAND, NOR), Read-head of Computer Hard Disk.

Course Outcomes

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

CO1: Demonstrate knowledge of the fundamentals of magnetism.
CO2: Demonstrate knowledge of the AMR, GMR, and CMR.
CO3: Demonstrate knowledge of the magnetic random-access memory (MRAM).
CO5: Demonstrate knowledge of the magneto-logic gates.

Books and References

1. Fundamentals of Magnetism and Spintronics, by Atowar Rahman, Zobra Books, 2022.
2. Spintronics, Fundamentals and Applications, by Puja Dey, Jitendra Nath Roy, Springer, 2021

Course Name:	**Numerical Optimization**
Course Code:	**EC-735**
Course Type:	**Program Elective-III**

Contact Hours/Week: **4L** — Course Credits: **04**

Course Objectives

- To impart knowledge about the principles of optimization techniques.
- To introduce the fundamental concepts relevant to classical optimization methods, linear programming, nonlinear programming and dynamic programming.
- To enable the students to understand the factors that causes the different optimization methods to provide different solutions for the same mathematical problem.

Course Content

Introduction: Historical Development; Engineering applications of Optimization; Art of Modeling; Objective function; Constraints and Constraint surface; Formulation of design problems as mathematical programming problems; Classification of optimization problems based on nature of constraints, structure of the problem, deterministic nature of variables, separability of functions and number of objective functions.

Linear Programming: Standard form of linear programming (LP) problem; Canonical form of LP problem; Assumptions in LP Models; Elementary operations; Graphical method for two variable optimization problem; Examples; Motivation of simplex method, Simplex algorithm and construction of simplex tableau; Simplex criterion; Minimization versus maximization problems; simplex method with artificial variables.

Optimization using Calculus: Stationary points - maxima, minima and saddle points; Functions of single and two variables; Global Optimum; Convexity and concavity of functions of one and two variables; Optimization of function of one variable and multiple variables; Gradient vectors; Examples; Optimization of function of multiple variables subject to equality constraints; Lagrangian function; Optimization of function of multiple variables subject to inequality constraints; Hessian matrix formulation; Eigen values; Kuhn-Tucker Conditions; Examples.

Nonlinear programming: One dimensional minimization method, elimination, sequential and descent methods, unconstrained optimization techniques, Direct search methods, Descent methods, 2nd order methods, quasi-newton method, Constrained optimization, Indirect methods, exterior penalty function, interior penalty function, geometric viewpoint, augmented Lagrange multiplier. Dynamic Programming: Sequential optimization; Representation of multistage decision process; Types of multistage decision problems; Concept of sub optimization and the principle of optimality; Recursive equations – Forward and backward recursions; Computational procedure in dynamic programming (DP); Discrete versus continuous dynamic programming; Multiple state variables; curse of dimensionality in DP, application example.

Course Outcomes

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

CO1: Identify different types of optimization techniques and problems.

CO2: Describe techniques like calculus based classical optimization, linear programming, nonlinear programming, dynamic Programming.

CO3: Apply principles and techniques described in CO2 to solve sample mathematical and practical optimization problems.

CO4: Assess the results obtained by applying optimization techniques to solve mathematical programming problems.

Books and References

1. Introduction to optimization by Pablo Pedregal, Publisher, Springer.
2. Numerical optimization with applications by Suresh Chandera, Jaydeva, Aparna Mehta, Narosa.
3. An Introduction to optimization by Edvin K.P. Chong, and Stanislaw H. Zak Publisher, John Wiley.
4. Engineering optimization Theory and Practice by Singiresu S. Rao, New Age International Publisher.

Course Name: **VLSI Design**
Course Code: **EC-701**
Course Type: **Open Elective**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

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

Course Content

Introduction to VLSI Design, 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 and MOSFET parasitic, Trends & Projections in VLSI Design & Technology, Flow of VLSI Circuit Design, Scaling in MOS devices. NMOS, CMOS Process flow, Noise Margin, Inverter Threshold Voltage, NMOS Inverter design and characteristics, CMOS Inverter Design and Properties, Delay and Power Dissipation, Parallel & Series Equivalent circuits, Static CMOS Circuit Design. Stick Diagrams, Physical Design Rules, Layout Designing, Euler's Rule for Physical Design, Reliability issues in CMOS VLSI, Latching. Static CMOS design Dynamic CMOS logic circuits. Transmission gate logic. MOS memories: ROM design, SRAM design and DRAMs.

Course Outcomes

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

CO1: Understanding of conventional Semiconductor device MOSFET used in VLSI design.

CO2: Design of static and dynamic CMOS VLSI logic circuits for practical applications and memory design.

CO3: Use of VLSI design in designing various applications required in different engineering branches

CO4: 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. Solid State Electronic Devices by B.G. Streetman and S. Banerjee, PHI.
3. Principles of CMOS VLSI Design- A Systems Perspective by Neil H E Weste and K. Eshraghian.
4. Introduction to VLSI by K. Eshraghian and Pucknell, PHI.

Course Name: **MEMS Design**
Course Code: **EC-702**
Course Type: **Open Elective**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To impart knowledge about the need and applications of microsystem 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.

Course Content

Introduction to MEMS and Microsystems, MEMS Materials, Structural and Sacrificial Materials, Properties of Silicon, Polymers, Ceramics, and Composites, Basic Modeling of Elements in Electrical and Mechanical Systems, Sensors/Transducers, Sensors Characterization and Classifications, Microactuators, Application of MEMS. Silicon Growth, Additive Techniques: Oxidation, Physical Vapor Deposition, Chemical Vapor Deposition, Thin Film Deposition, Photolithography, Etching, Bulk and Surface Micromachining, Etch Stop Technique and Microstructure, Microstereolithography LIGA, and Wafer Bonding. Beam and Cantilever, Capacitive Sensors, Modeling a Capacitive Sensor, Capacitive Accelerometer, Pressure Sensors, Piezoresistance Effect and Its Modeling, Piezoresistive Sensor, Flow Measurement, Piezoelectricity, Piezoactuators, Inertial Sensors, Micro accelerometer, MEMS Gyroscope, and Parallel-Plate Actuator. Need and Classification, Temperature Coefficient of Resistance, Thermo-Electricity, Thermocouples, Thermal and Temperature Sensors, Heat Pump, Gas sensors, Micromachined Thermocouple Probe, Thermo-resistive Sensor, Thermal Flow Sensors, Pyroelectricity, Shape Memory Alloy, and Thermal Actuators. Properties of Light, Light Modulators, Beam Splitter, Microlens, Micromirrors, Digital Micromirror Devices, Light Detectors, Grating Light Valve, and Optical Switch.

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 of various MEMS parts.
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. Introductory MEMS Fabrication and Applications by T. M. Adams and R. A. Layton, Springer Publications.
2. Sensors and Transducers by M. J. Usher, McMillian Hampshire.
3. MEMS by N. P. Mahalik, Tata McGraw Hill.
4. Microsensors by R.S. Muller, Howe, Senturia and Smith, IEEE Press.
5. Analysis and Design Principles of MEMS Devices by Minhang Bao, Elsevier.
6. Semiconductor Sensors by S. M. Sze, Willy –Inderscience Publications.

Course Name:	**HDL Based Design**
Course Code:	**EC-703**
Course Type:	**Open Elective**
Contact Hours/Week: **4L**	Course Credits: **04**

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.

Course Content

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. Lexical conventions, Data types, modules and ports, Behavioral modeling, Dataflow modeling, Structural modelling. Control & Data partitioning, Synthesis concepts, Non-synthesizable constructs, Operators, Expressions, Conditional statements, Post synthesis simulation. Procedures and timing control, Procedural blocks, Loops, Tasks and functions, Test bench modeling techniques, Path delay modeling, Timing analysis, User defined primitives, Compiler directives, and System tasks. 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. FPGA architecture, Static timing analysis, Synchronization, Metastability, Verification methods, Implementation on FPGA, PLA based design.

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

Course Name: **Mobile Communication**
Course Code: **EC-704**
Course Type: **Open Elective**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To understand the basic cellular system concepts.
- To have an insight into the interference, frequency management and handoff management in cellular mobile system.
- To go in depth for understanding the popular GSM cellular mobile standard and wireless standards.

Course Content

Wireless Communication Systems, Applications of Wireless Communication Systems, Types of Wireless Communication Systems, Trends in Mobile Communication Systems. Basic Cellular Systems, Performance Criteria, Uniqueness of Mobile Radio Environment, Operation of Cellular Systems, Analog& Digital Cellular Systems. Concept of Frequency Reuse Channels, Co-channel Interference Reduction Factor, Desired C/I From a Normal Case in an Omnidirectional Antenna System, Handoff Mechanism, Cell Splitting. Co-channel Interference, Design of an Omnidirectional Antenna System in the Worst Case, Design of a Directional Antenna System, Lowering the Antenna Height, Power Control, Reduction in C/I by Tilting Antenna, Umbrella Pattern Effect Adjacent-Channel Interference, Near-end, Far-end Interference, Effect on Near-end Mobile Units. Frequency Management, Frequency-Spectrum Utilization, Set-up Channels, Fixed Channel Assignment Schemes, Non-Fixed Channel Assignment Schemes, Concept of Handoff, Initiation of a Hard Handoff, Delaying a Handoff, Forced Handoffs, Queuing of Handoffs, Power Difference Handoffs, Mobile Assisted Handoff, Soft Handoffs, Cell-site Handoff, Intersystem Handoff, Dropout Calls. GSM System Architecture, GSM Radio Subsystem, GSM Channel Types, Frame Structure for GSM, Signal Processing in GSM, GPRS and EDGE. Overview of Wi-Fi, WiMAX and Bluetooth Technology: Basic Features and Physical Specifications.

Course Outcomes

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

CO1: Discuss cellular radio concepts.

CO2: To have knowledge of the mobile system specifications.

CO3: Classify frequency and handoff management techniques in mobile communication.

CO4: Outline cellular mobile communication standards.

CO5: Analyze various methodologies to improve the cellular capacity.

Books and References

1. Mobile Cellular Telecommunications: Analog and Digital Systems by W. C. Y. Lee; Tata McGraw Hill Publication.
2. Wi-Fi, Bluetooth, Zigbee and WiMax by H. Labiod, H. Afifiand, C. D. Santis, Springer.
3. Wireless Communications: Principles and Practice by T. S. Rappaport; Pearson Publication.
4. Wireless Communications and Networks: 3G and Beyond by Iti S. Misra; Tata McGraw Hill Publication.
5. Wireless and Digital Communications by K. Feher; PHI Publication.

Course Name: **Communication Systems** Course Code: **EC-705** Course Type: **Open Elective**	
Contact Hours/Week: 4**L**	Course Credits: **04**

Course Objectives

- To understand the building blocks of analog, pulse and digital communication systems.
- To prepare mathematical background for communication signal analysis.
- To understand and analyze the signal flow in a analog, pulse and digital communication systems.

Course Content

Communication process, sources of information, communication channels, base band and pass band signals, representation of signals and systems, classification and characterization of signals and systems. Amplitude modulation (AM), frequency spectrum of the AM wave, representation of AM, power relations in the AM wave, AM detector, vestigial side-band modulation.
Frequency spectrum of Frequency Modulation (FM) and Phase Modulation, generation of FM (direct and indirect method), demodulation of FM signal. Tuned Radio-Frequency (TRF) receiver, Super heterodyne receiver. Sampling process, Modulation and demodulation principles of : Pulse Amplitude Modulation (PAM), Time Division Multiplexing (TDM), Frequency Division Multiplexing (FDM), Pulse Width Modulation (PWM), Pulse Position Modulation (PPM). **:** Quantization process, Pulse Code Modulation (PCM), Differential Pulse Code Modulation (DPCM), Delta Modulation (DM), Adaptive Delta Modulation, Amplitude – Shift Keying (ASK), Frequency-Shift Keying (FSK), Phase-Shift Keying (PSK), QPSK.

Course Outcomes

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

CO1: Analyze the signals and systems used in communication systems in time domain and frequency domain.
CO2: Select and identify the functions of the blocks in the design of analog communication system.
CO3: Select and identify the functions of the blocks in the design of digital communication system.
CO4: Select and identify the functions of the blocks in the design of pulse modulation system.
CO5: Compare and analyze performance of communication systems in terms of bandwidth requirement, error performance and complexity in design.

Books and References

1. Electronic Communication Systems by George Kennedy
2. Communication Systems by Simon Haykin
3. An Introduction to Analog and Digital Communications by Haykin
4. Principles of Communication Systems by H. Taub and D.L. Schilling