INDIAN INSTITUTE OF INFORMATION TECHNOLOGY BHAGALPUR

Dept. of Electronics and Communication Engineering (ECE)

M. Tech in VLSI & Embedded System

(For Regular Students)

Curriculum

Code	Course Name	L	T	P	C
1st Semester					
EC510	Embedded System Design	3	0	2	4
EC511	Modeling & Simulation of Nanoscale Device	3	0	0	3
EC512	Digital VLSI Design	3	0	2	4
EC513	VLSI DSP	3	0	0	3
EC5XX	Elective-I	3	0	0	3
EC535	Device Simulation LAB	0	0	3	2
EC583	Seminar	0	0	0	1
	Total Credits				20
2nd Semester					
EC514	Analog VLSI Design	3	0	0	3
EC515	Embedded Computing	3	0	2	4
EC516	SoC Design using Verilog	3	0	2	4
EC5XX	Elective-II	3	0	0	3
EC5XX	Elective-III	3	0	0	3
EC537	Analog IC Design LAB	0	0	3	2
EC582	Capstone Project	0	0	0	1
	Total Credits				20
3rd Semester					
EC591	Major Project-I	0	0	0	10
4th Semester					
EC592	Major Project-II	0	0	0	14
	Total Credits				64

Elective Courses

Code	Course Name	L-T-P-C
EC561	Semiconductor Microwave Devices and Applications	3-0-0-3
EC562	Semiconductor IC Technology	3-0-0-3
EC563	RF Integrated Circuit Design	3-0-0-3
EC564	Performance and Reliability of VLSI Circuits	3-0-0-3
EC565	Advanced VLSI Interconnects	3-0-0-3
EC566	VLSI Physical Design	3-0-0-3
EC567	CAD for VLSI	3-0-0-3
EC568	MEMS & NEMS	3-0-0-3
EC569	Real Time and Embedded Operating Systems	3-0-0-3
EC570	Quantum Electronics	3-0-0-3
EC553	Introduction to IoT	3-0-2-4
EC571	Hardware Security	3-0-0-3

Course Syllabus

Course Code	Course name	L	T	P	C	Semester
EC510	Embedded System Design	3	0	0	3	1st

Topic	Contents	No. of Lectures
Module-I	Embedded Systems design & modeling with unified markup language (UML). ARM processor fundamentals: Introduction to microprocessors and microcontrollers, 8-bit and 16- bit, von Neumann and Harvard architectures, CISC and RISC architectures, open-source core (LEOX), ARM versions, ARM instruction set: programming model, assembly language, Thumb instruction set, memory organization, data operations and flow control.	**06**
Module-II	CPUs: Input/output mechanisms, isolated and memory mapped IO; interrupts and real time operations, ARM interrupts vectors, priorities and latency; supervisor modes, exceptions, traps, co-processors; cache memory and memory management.	**07**
Module-III	Embedded Platforms: CPUs: bus protocols, system bus configuration, USB and SPI buses, DMA, ARM bus; memory devices: memory device configuration, ROM, RAM, DRAM; I/O devices: timers, counters, ADC & DAC, keyboards, displays and touch screens. Embedded Systems Interfacing: Serial Peripheral Interface (SPI), Inter-Integrated Circuit (I2C), RS-232, Universal Serial Bus (USB), CAN, IrDA, Bluetooth, PCI and AMBA bus protocols.	**10**
Module-IV	Processes and Embedded Operating Systems: multiple tasks and multiple processes; process abstraction; context switching: cooperative multitasking, pre-emptive multitasking, process and object-oriented design; operating systems and RTOS; scheduling polices; inter-process communication.	**08**
Module-V	Networks: distributed embedded architectures: networks abstractions, hardware and software architectures; networks for embedded systems: I2C bus, CAN bus.	**09**
	Total No. of Lectures	**40**
Text	1. E. A. Lee and S. A. Seshia, *Introduction to Embedded Systems - A Cyber-Physical Systems Approach*, 2nd edition, MIT Press, 2017. 2. Frank Vahid and Tony Givargis, *Embedded System Design: A Unified Hardware / Software Introduction*, John Wiley & Sons, 3rd edition, 2006. 3. Ramesh Gaonkar, *Microprocessor Architecture, Programming and Applications with the 8085*, Penram International Publishing, 6th edition, 2013.	
Reference	1. S. Chattopadhyan, *Embedded System Design*, PHI, 2nd edition, 2013. 2. Shibu K V, *Introduction to Embedded Systems*, Tata McGraw Hill, 2nd edition, 2017.	

Course Code	Course name	L	T	P	C	Semester
EC511	Modeling & Simulation of Nanoscale Device	3	0	0	3	1st

Topic	Contents	No. of Lectures
Module-I	Semiconductor Fundamentals: Poisson and continuity equations, Recombination (direct, Auger, trap-assisted), Equilibrium carrier concentrations (electron statistics, density of states, effective mass, bandgap narrowing), Review of PN and MS diodes	**08**
Module-II	Quantum Mechanics Fundamentals: Basic Quantum Mechanics, Crystal symmetry and band structure, 2D/1Ddensity of states, Tunnelling; Modelling and Simulation of Carrier Transport: Carrier Scattering (impurity, phonon, carrier-carrier, remote/interface), Boltzmann Transport Equation, Monte Carlo, Hydrodynamic, Drift-diffusion	**09**

Module-III	MOS Capacitors: Modes of operation, C-V characteristics, gated diode, non-ideal effects, High fields effects, Long Channel MOSFET Devices: Review of operation, I-V characteristics, Sub threshold conduction, Threshold voltage; Short Channel MOSFET Devices: Scaling effects, Channel velocity limitations, Hot carrier effects, Quantum mechanical effects on 2DEG	**09**
Module-IV	CMOS Device Design: Scaling relationships, Threshold voltage control, On/Off currents, Channel doping profiles, Circuit and switching behavior	**07**
Module-V	Advanced Device Technology: 2D Devices, SoI, SiGe, strained Si, Alternative oxide/gate materials, Alternative geometries (raised source/drain, dual gate, vertical), Memory Devices (DRAM, Flash).	**07**
	Total No. of Lectures	**40**
Text	1. R. F. Pierret, *Advanced Semiconductor Fundamentals*, Pearson Education, 1st edition, 2006. 2. S. M. Sze, *Physics of Semiconductor Devices*, Cambridge University Press, 1st edition, 2010. 3. Ben G Streetman, S K Banerjee, *Solid State Electronic Devices*, PHI, 6th edition, 2006.	
Reference	1. S. M. Sze, M. K. Lee, *Semiconductor Devices, Physics and Technology*, Wiley & Sons, 8th edition, 2015. 2. J. Singh, *Semiconductor Devices: Basic Principles*, Wiley & Sons, 1st edition, 2007.	

Course Code	**Course Name**	**L**	**T**	**P**	**C**	**Semester**
EC512	Digital VLSI Design	3	0	0	3	1st

Topic	**Contents**	**No. of Lectures**
Module-I	A Historical Perspective of VLSI; Issues in Digital Integrated Circuit Design; Quality Metrics of a Digital Design: Cost, Functionality & Robustness, Performance, and Power & Energy Consumption; design hierarchy, layers of abstraction, VLSI design styles.	05
Module-II	MOS Device Model with Sub-micron Effects, Manufacturing CMOS Integrated Circuits, Design Rules, The Static CMOS Inverter, Properties of CMOS Inverter, Robustness of the CMOS Inverter, Switching Threshold, Noise Margins.	08
Module-III	The Dynamic behavior of Inverter, Parasitic Capacitances, Propagation Delay, Dynamic Power Consumption, Static Consumption, Sizing and optimization of Inverters, Logical Effort. Interconnect Parameters: Capacitance, Resistance, and Inductance, Electrical Wire Models, SPICE Wire Models.	09
Module-IV	Static Complimentary CMOS Design, Ratioed Logic, Pass Transistor logic, Transmission Gate Logic, DCVSL, Dynamic Logic Design and noise considerations in dynamic design, Power Dissipation in CMOS, Domino and NORA designs, Asymmetrical Gates and Skewed Gates.	10
Module-V	Sequential Circuit Design using transmission gates, Latches and Flip-flops, Race Condition, Master-slave FFs, Counter designs.	08
	Total No. of Lectures	**40**
Text	1. Jan M. Rabaey, A. Chandrakasan, B. Nikolic, "*Digital Integrated Circuits: A Design Perspective*" Pearson Education India, 2nd edition, 2016.	
Reference	1. N. Weste and D. Harris, *CMOS VLSI Design: A Circuits and Systems Perspective*, Pearson Education India, 3rd edition, 2012. 2. Wakerly, *Digital Design: Principles And Practices*, Pearson Education, 4th edition, 2008.	

Course Code	Course name	L	T	P	C	Semester
EC513	VLSI DSP	3	0	0	3	2nd

Topic	Contents	No. of Lectures
Module-I	Graphical Representation of Signals, Signal Flow Graph, Data Flow Graph, Critical Path, Dependence Graph, Retiming Theorem.	**7**
Module-II	Forward Path and Loop Retiming, Loop Bound and Iteration Bound, Cutset Retiming, Retiming IIR Filters, Adaptive Filter Basics (LMS Algorithm), Retiming LMS, Retiming Delayed LMS.	**7**
Module-III	Parallel Processing in DSP by Unfolding, Basic Unfolding Relation, Retiming for Unfolding, Loop Unfolding, Iteration bound for Loops, Bitserial, Digit serial and Word serial Structures, unfolding a Switch, Unfolding Bit Serial Systems, Folding of DFG, Folding Examples - IIR Filter, Retiming for Folding.	8
Module-IV	Introduction to Delay Optimization by Folding, Life Time Analysis of Storage Variables, Forward Backward Data Allocation, Life Time Analysis of Storage Variables in a Digital Filter, Delay Folded Realization of a Digital Filter, Polyphase Decomposition of Sequences, Hardware Efficient 2-Parallel FIR Filters.	**9**
Module-V	Hardware Efficient 3-Parallel FIR Filters, Introduction to First Level Architectures, 2's Complement Number Systems, Multiplication of Two Binary Numbers, Carry Ripple and Carry Save Array, Bit Serial Multipliers, Bit Serial Digital Filters, Baugh Wooley Multiplier, Distributed Arithmetic.	**9**
	Total No. of Lectures	40
Text	1. Keshab K. Parhi, *VLSI Digital Processing System: Design and Implementation*, Wiley, 2nd edition, 1999. 2. S. Monk, Programming FPGAs: Getting Started with Verilog, Prentice Hall, 1st edition, 2016.	
Reference	1. R. Woods, J. McAllister, G. Lightbody, Y. Yi, *FPGA-based Implementation of Signal Processing Systems*, Wiley, 2nd edition 2017.	

Course Code	Course Name	L	T	P	C	Semester
EC514	Analog VLSI Design	3	0	0	3	2nd

Topic	Content	No. of Lectures
Module-I	CMOS device fundamentals: Basic MOS models, device capacitances, parasitic resistances, substrate models, transconductance, output resistance, fT, frequency dependence of device parameters.	**07**
Module-II	Single stage amplifiers: Common source amplifier, source degeneration, source follower, common gate amplifier, cascade stage. Differential Amplifiers: Basic differential pair, common mode response, differential pair with MOS loads, Gilbert Cell, device mismatch effects, input offset voltage.	**09**
Module-III	Current Mirrors, Current and Voltage Reference: Basic current mirrors, cascode current mirrors, active current mirrors, low current biasing, supply insensitive biasing, temperature insensitive biasing, impact of device mismatch. Frequency Response of Amplifiers: Miller effect, CS amplifier, source follower, CG amplifier, cascade stage, differential amplifier, Multistage amplifier.	**09**

Module-IV	Operational Amplifiers: Performance parameters, One-stage and two-stage Op Amps, gain boosting, comparison, common mode feedback, input range, slew rate, power supply rejection, noise in Op Amps, VDTA.	**09**
Module-V	Stability and Frequency Compensation: Multi pole systems, phase margin, frequency compensation. High Performance CMOS Op-Amp: Buffered Op-amps, High speed/Frequency Op-amps, Differential output op-amps, low noise and low voltage op-amps	**06**
	Total	**40**
Text	1. B. Razavi, *Design of Analog CMOS Integrated Circuits*, Tata McGraw-Hill, 2nd edition, 2017. 2. R. J. Baker, H W Li, D. E. Boyce, *CMOS Circuit design, Layout and Simulation*, John Wiley & Sons, 2nd edition, 2004.	
Reference	1. P.E. Allen, Douglas R. Holberg, *CMOS Analog Circuit Design*, Oxford University Press, 2nd edition, 2002.	

Course Code	Course Name	L	T	P	C	Semester
EC515	Embedded Computing	3	0	0	3	2nd
Topic	**Contents**					**No. of Lectures**
Module-I	Embedded Systems Design Process, Formalism for System design. Preliminaries, Programming Input and Output, Supervisor mode, Exceptions, Traps, Coprocessors, Memory Systems Mechanisms, CPU Performance, CPU Power Consumption, Component Interfacing, Designing with Microprocessor, Development and Debugging, System-Level Performance Analysis.					**08**
Module-II	Components for embedded programs, Models of programs, Assembly, Linking and Loading, Basic Compilation Techniques, Program optimization, Program-Level performance analysis, Software performance optimization, Program-Level energy and power analysis, Analysis and optimization of program size, Program validation and testing.					**10**
Module-III	Introduction to processor design-architecture and organization, Abstraction in hardware design, Instruction set design, Processor design tradeoffs, RISC, Architecture inheritance, Programmer`s model, Development tools.					**07**
Module-IV	Architectural support for high level languages Architectural support for system development - ARM memory interface, AMBA, ARM reference peripheral specifications, JTAG, Embedded trace, signal processing support, ARM processor cores. Memory hierarchy Memory size and speed, On-chip memory, Caches, Memory management. Memory hierarchy Architectural support for OS-Embedded ARM applications.					**09**
Module-V	The Integrated Development Environment, Types of File generated on Cross Compilation, Dis-assembler /Decompiler, Simulators, Emulators, and Debugging, Target Hardware Debugging.					**06**
	Total No. of Lectures					**40**
Text	1. Barry, *Modern Embedded Computing*, Elsevier, 1st edition, 2012. 2. Joseph A. Fisher, P. Faraboschi, C. Young, *Embedded Computing: A VLIW Approach to Architecture, Compilers and Tools*, Morgan Kaufmann, 1st edition, 2005.					

Reference	1. Seppo J. Ovaska Phillip A. Laplante, *Real-Time Systems Design and Analysis: Tools for the Practitioner*, Wiley & Sons, 4^{th} edition, 2011.

Course Code	**Course name**	**L**	**T**	**P**	**C**	**Semester**
EC516	SoC Design using Verilog	3	0	2	4	1^{st}
Topic	**Contents**					**No. of Lectures**
Module-I	VLSI Design Flow, Gajski-Y chart, Basic concepts of hardware description languages. Design flow for Verilog based RTL/logic synthesis. Hierarchy, Concurrency, Logic, and Delay modelling, Structural, Data-flow and Behavioral styles of hardware description.					6
Module-II	Syntax and Semantics of Verilog. Variable, signal types, arrays, attributes and tables. Data types, Operators, expressions and signal assignments. Entities, architecture specification and configurations. Component instantiation. Use of Procedures, Tasks and functions, Memory Modelling, Examples of design using Verilog.					8
Module-III	Combinational Circuit Design, Sequential Circuit Design, Design of controller and Data, path units, Finite State Machines, SRAM, DRAM					7
Module-IV	Functional Verification Concepts, Simulators, Coverage and Metrics, Introduction to Verification Methodologies, testing strategy – Directed and random Testing, Test Cases Vs Test Benches, Verification Components, Functional Verification, Assertion based verification, Coverage Driven Verification.					9
Module-V	Introduction to Programmable, Logic and FPGAs, Popular CPLD & FPGA, Families, Architecture of popular Xilinx ISE, FPGA Design Flow Xilinx ISE, Implementation Details, Advanced FPGA Design Tips Logic Synthesis for FPGA, Static Timing Analysis, Design problems using Xilinx Platforms.					10
	Total No. of Lectures					40
Text	1. S. Palnitkar, *Verilog HDL: A Guide to Digital Design and Synthesis*, PHI, 2^{nd} edition, 2003.					
Reference	1. Michael D. Ciletti, *Advanced Digital Design with the Verilog HDL*, PHI, 2^{nd} edition, 2005. 2. John M. Williams, *Digital VLSI Design with Verilog*, Springer, 2^{nd} edition, 2014.					

ELECTIVES (I, II, III) Syllabus

Course Code	**Course name**	**L**	**T**	**P**	**C**	**Semester**
EC561	Semiconductor Microwave Devices and Applications	3	0	0	3	
Topic	**Contents**					**No. of Lectures**
Module-I	Introduction to radio frequency engineering; advantages; various frequency bands; propagation; transmission lines; microwave waveguides and components; their characterizations; s-parameters and their use					**08**
Module-II	Microwave transistor; FETs, Gunn diode, IMPATT diodes; microwave tubes; Klystron; two cavity Klystron amplifier analysis; reflex Klystron; TWTs; high power tubes; cross field tubes; micro-strip lines; MMICs					**08**

Module-III	Microwave measurements; microwave antennas and microwave communication system; microwave applications; ISM applications	**08**
Module-IV	Introduction to EMI and EMC; microwave hazards., refraction and diffraction; transmission lines and resonators	**08**
Module-V	Antennas and radiation; half-wave dipole antenna; loop antenna; helical antenna; directive arrays; frequency independent antennas; reflector and lens antennas; horn antennas; antenna arrays; Friis formula; antenna practices and antenna measurements	**08**
	Total No. of Lectures	**40**
Text	1. Samuel Y. Liao, *Microwave Devices and Circuits*, Pearson education, 3rd edition, 2017.	
Reference	1. D. M. Pozar, *Microwave Engineering*, John Wiley & Sons, 2nd edition, 1998.	

Course Code	**Course name**	**L**	**T**	**P**	**C**	**Semester**
EC562	Semiconductor IC Technology	3	0	0	3	
Topic	**Contents**					**No. of Lectures**
Module-I	Introduction to Semiconductor Manufacturing and fabrication. Physics of the Crystal growth, wafer fabrication and basic properties of silicon wafers.					**06**
Module-II	Lithography, Thermal Oxidation of Silicon: The Photolithographic Process, Etching Techniques, Photomask Fabrication, Exposure Systems, Exposure sources, The Oxidation Process, Modelling Oxidation, Masking Properties of Silicon Dioxide, Technology of Oxidation, Si-SiO2 Interface					**08**
Module-III	Diffusion, Ion Implantation, Film Deposition: The Diffusion Process, Mathematical Model for Diffusion, Constant, The Diffusion Coefficient, Successive Diffusions, Diffusion Systems, Implantation Technology, Mathematical Model for Ion Implantation, Selective Implantation, Channelling, Lattice Damage and Annealing, Shallow Implantations, Chemical Vapour Deposition, Physical Vapour Deposition, Epitaxy.					**09**
Module-IV	Interconnections and Contacts, Packaging and Yield: Metal Interconnection sand Contact Technology, Diffused Interconnections, Polysilicon Interconnections and Buried Contacts, Silicides and Multilayer-Contact Technology, Copper Interconnects and Damascene Processes, Wafer Thinning and Die Separation, Die Attachment, Wire Bonding, Packages, Yield					**08**
Module-V	MOS Process Integration, Bipolar Process Integration: Basic MOS Device Considerations, MOS Transistor Layout and Design Rules, Complementary MOS (CMOS) Technology, The Junction-Isolated Structure, Current Gain, Transit Time, Base width, Breakdown Voltages, Other Elements in SBC Technology, Advanced Bipolar Structures, Other Bipolar Isolation Techniques. Deep Submicron Processes, Low-Voltage/Low-Power CMOS/BiCMOS Processes. Future Trends and Directions of CMOS/BiCMOS Processes					**09**
	Total No. of Lectures					40
Text	1. J. Plummer, Michael D. Deal and Peter B. Griffin, *Silicon VLSI Technology, Fundamentals, Practice and Modelling*, Pearson Education, 1st edition, 2009.					
Text	1. S.K. Gandhi, *VLSI Fabrication Principles*, Wiley, 2nd edition 1994.					

Course Code	Course name	L	T	P	C	Year	Semester
EC563	RF Integrated Circuit Design	3	0	0	3		

Topic	Contents	No. of Lectures
Module-I	Introduction & Passive RLC Networks: RF systems – basic architectures Transmission media and reflections Maximum power transfer, Parallel RLC tank, Series RLC networks, matching, Pi match, T match, Review of MOS Device Physics	**07**
Module-II	Distributed Systems: Transmission lines, reflection coefficient, the wave equation, examples, Lossy transmission lines, Smith charts – plotting gamma, Bandwidth estimation using open-circuit & short-circuit time constants, Zeros to enhance bandwidth, Shunt-series amplifiers, tuned amplifiers, Cascaded amplifiers	**09**
Module-III	LNA Design: Intrinsic MOS noise parameters, Power match versus noise match, large signal performance, design examples & Multiplier based mixers, Mixer Design, Subsampling mixers	**08**
Module-IV	RF Power Amplifiers: Class A, AB, B, C, D, E, F amplifiers, Voltage controlled oscillators, Resonators, Negative resistance oscillators, Phase locked loops, Linearized PLL models, Phase detectors, charge pumps, Loop filters, PLL design examples	**08**
Module-V	Frequency synthesis and oscillators: Frequency division, integer-N synthesis, Fractional frequency synthesis, Phase noise General considerations, Radio architectures, GSM radio architectures, CDMA, UMTS radio architectures	**08**
	Total No. of Lectures	**42**
Text	1. T. H. Lee, *The Design of CMOS Radio-Frequency Integrated Circuits*, Cambridge University Press; 2nd edition, 2004. 2. C. Coleman, *An Introduction to Radio Frequency Engineering*, Cambridge University Press, Reissue edition, 2004.	
Reference	1. Kiat S. Yeo, *Design Of CMOS RF Integrated Circuits And Systems*, World Scientific, 1st edition, 2010.	

Course Code	Course name	L	T	P	C	Semester
EC564	Performance and Reliability of VLSI Circuits	3	0	0	3	

Topic	Contents	No. of Lectures
Module-I	Nanoscale MOSFET Characteristics: Quasi-ballistic I-V characteristics, terminal capacitances of transistors considering quantum effects, parasitic resistances in nanoscale MOSFETs.	**05**
Module-II	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.	**12**
Module-III	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.	**06**
Module-IV	Reliability of CMOS Circuits: Circuit performance considering NBTI/PBTI, oxide breakdown, random telegraph noise, radiation damage.	**11**
Module-V	Analog Circuit Performance Parameters: Impact of parasitic effects, process/temperature variation, device reliability effects.	**06**
	Total No. of Lectures	**42**

Text	1. M Stanisavljević, A Schmid, Y Leblebici, "*Reliability of Nanoscale Circuits and Systems: Methodologies and Circuit Architectures*" Springer, 11th edition, 2014.
Reference	1. Behzad Razavi, "*Design of Analog CMOS Integrated Circuits*", Tata McGraw-Hill, 2nd edition, 2017.

Course Code	**Course name**	**L**	**T**	**P**	**C**	**Semester**
EC565	Advanced VLSI Interconnects	3	0	0	3	
Topic	**Contents**					**No. of Lectures**
Module-I	Interconnects for VLSI applications, metallic interconnects, optical interconnects, superconducting interconnects, advantages of copper interconnect, challenges posed by copper interconnects, fabrication process, even and odd mode capacitances, miller theorem, transmission line equations, resistive interconnection as ladder network, propagation modes in microstrip interconnection, slow wave mode propagation, propagation delays.					06
Module-II	Parasitic resistance, effect of surface/interface scattering and diffusion barrier on resistance, Capacitance: parallel-plate capacitance, fringing capacitance, coupling capacitance, methods of capacitance extraction, Inductance: self-inductance, mutual inductance, methods of inductance extraction, high frequency losses, frequency dependent parasitics, skin effect, dispersion effect.					08
Module-III	Elmore model, Transfer function model, even and odd mode model, Time domain analysis of multiconductor lines, Finite Difference Time Domain (FDTD) method, performance analysis using linear driver (Resistive) and nonlinear driver (CMOS), advanced interconnect techniques to avoid crosstalk.					07
Module-IV	Optical interconnects, Superconducting interconnects, Nanotechnology interconnects, Silicon nanowires, Carbon nanotubes, Graphene nanoribbons: system issues and challenges, material processing issues and challenges, design issues and challenges.					09
Module-V	Quantum electrical properties: quantum conductance, quantum capacitance, kinetic inductance, Carbon nanotube (CNT) and Graphene nanoribbon (GNR) interconnects, electron scattering and lattice vibrations, electron mean free path, single-wall CNT and single layer GNR resistance model, multi-wall CNT and multi-layer GNR resistance model, transmission line interconnect models, performance comparison of CNTs, GNRs and copper interconnects.					09
	Total No. of Lectures					42
Text	1. Michel S. Nakhla, Q.J. Zhang, "*Modeling and Simulation of High-Speed VLSI Interconnects*", Springer, 2nd edition, 2012. 2. Y. S. Diamand, T. Osaka, M. Datta, T. Ohba, "*Advanced Nanoscale ULSI Interconnects: Fundamentals and Applications*", Springer, 9th edition, 2009.					
Reference	1. M. Baklanov, Paul S. Ho, E. Zschech, "*Advanced Nanoscale ULSI Interconnects: Fundamentals and Applications*", Wiley, 1st edition, 2012.					

Course Code	Course name	L	T	P	C	Semester
EC566	VLSI Physical Design	3	0	0	3	

Topic	Contents	No. of Lectures
Module-I	Layout and design rules, materials for VLSI fabrication, basic algorithmic concepts for physical design, physical design processes and complexities. Partition: Kernigham-Lin's algorithm, Fiduccia Mattheyes algorithm, Krishnamurty extension, hMETIS algorithm, multilevel partition techniques.	07
Module-II	Floor-Planning: Hierarchical design, wirelength estimation, slicing and nonslicing floorplan, polar graph representation, operator concept, Stockmeyer algorithm for floor planning, mixed integer linear program.	07
Module-III	Placement: Design types: ASICs, SoC, microprocessor RLM; Placement techniques: Simulated annealing, partition-based, analytical, and Hall's quadratic; Timing and congestion considerations.	08
Module-IV	Routing: Detailed, global and specialized routing, channel ordering, channel routing problems and constraint graphs, routing algorithms, Yoshimura and Kuh's method, zone scanning and net merging, boundary terminal problem, minimum density spanning forest problem, topological routing, cluster graph representation.	09
Module-V	Sequential Logic Optimization and Cell Binding: State based optimization, state minimization, algorithms; Library binding and its algorithms, concurrent binding	09
	Total No. of Lectures	40
Text	1. M. Sarrafzadeh, and C.K. Wong, "*An Introduction to VLSI Physical Design*", McGraw-Hill. 4th edition, 2009. 2. W. Wolf, "*Modern VLSI Design System on Silicon*", Prentice Hall, 2nd Education., 2008.	
Reference	1. Naveed A. Sherwani, "*Algorithm for VLSI Physical Design Automation*", Springer, 3rd edition, 2013. 2. Alan Hastings, "*Art of Analog Layout*", Pearson, 2nd edition, 2005.	

Course Code	Course name	L	T	P	C	Semester
EC567	CAD for VLSI	3	0	0	3	

Topic	Contents	No. of Lectures
Module-I	Matrices: Linear dependence of vectors, solution of linear equations, bases of vector spaces. orthogonality, complementary orthogonal spaces and solution spaces of linear equations.	07
Module-II	Graphs: representation of graphs using matrices; paths, connectedness; circuits, cutsets, trees; fundamentals circuit and cutset matrices; voltage and current spaces of a directed graph and their complementary orthogonality.	07
Module-III	Algorithms and data structures: efficient representation of graphs; elementary graph algorithms involving BFS and DFS trees, such as finding connected and 2-connected components of a graph, the minimum spanning tree, shortest path between a pair of vertices in a graph.	09
Module-IV	Algorithms for VLSI Physical Design, Synthesis, Circuit Simulation and Digital Design Automation.	09
Module-V	Algorithms for Design Automation using FPGA/CPLD, Fault Tolerant Systems, VLSI Testing.	08
	Total No. of Lectures	40

Text	1. B. Muthuswamy, S. Banerjee, *Introduction to Nonlinear Circuits and Networks*, Matrix Springer, 1st edition, 2019. 2. W. J. McCalla, *Fundamentals of Computer-Aided Circuit Simulation*, Springer, 1st edition, 1987. 3. L. Pillage, Ronald A. Rohrer, C. Visweswariah, *Electronic Circuit and System Simulation Methods*, McGraw-Hill Inc, 1st edition, 1995.
Reference	1. Naveed A. Sherwani, *Algorithms for VLSI Design Automation*, Springer, 3rd edition, 2013. 2. H. Narayanan, *Submodular Functions and Electrical Networks*, Elsevier, 2nd edition, 1997. 3. David S. Watkins, *Fundamentals of Matrix Computations*, Wiley, 3rd edition, 2010. 4. Narsingh Deo, *Graph Theory with Applications to Engineering and Computer Science*, PHI, 1st edition, 1979.

Course Code	**Course name**	**L**	**T**	**P**	**C**	**Year**	**Semester**
EC568	MEMS and NEMS	3	0	0	3		

Topic	**Contents**	**No. of Lectures**
Module-I	Overview and Introduction: New trends in Engineering and Science: Micro and Nano scale systems Introduction to Design of MEMS and NEMS, Overview of Nano and Micro electromechanical Systems, Applications of Micro and Nano electromechanical systems, Micro electromechanical systems, devices and structures Definitions, Materials for MEMS: Silicon, silicon compounds, polymers, metals	**09**
Module-II	MEMS Fabrication Technologies: Microsystems fabrication processes: Photolithography, Ion Implantation, Diffusion, Oxidation. Thin film depositions: LPCVD, Sputtering, Evaporation, Electroplating; Etching techniques: Dry and wet etching, electrochemical etching; Micromachining: Bulk Micromachining, Surface Micromachining, High Aspect-Ratio (LIGA and LIGA-like) Technology; Packaging: Microsystems packaging, Essential packaging technologies, Selection of packaging materials	**09**
Module-III	Micro Sensors: MEMS Sensors: Design of Acoustic wave sensors, resonant sensor, Vibratory gyroscope, Capacitive and Piezo Resistive Pressure sensors-engineering mechanics behind these Micro sensors. Case study: Piezo-resistive pressure sensor	**08**
Module-IV	Micro Actuators: Design of Actuators: Actuation using thermal forces, Actuation using shape memory Alloys, Actuation using piezoelectric crystals, Actuation using Electrostatic forces (Parallel plate, Torsion bar, Comb drive actuators), Micromechanical Motors and pumps. Case study: Comb drive actuators	**08**
Module-V	Nano-systems And Quantum Mechanics: Atomic Structures and Quantum Mechanics, Molecular and Nanostructure Dynamics: Schrödinger Equation and Wave function Theory, Density Functional Theory, Nanostructures and Molecular Dynamics, Electromagnetic Fields and their quantization, Molecular Wires and Molecular Circuits	**08**
	Total No. of Lectures	40
Text	1. Tai Ran Hsu, *MEMS and Microsystems Design and Manufacture*, Tata McGraw Hill, 1st edition, 2017. 2. Chang Liu, *Foundations of MEMS*, Pearson Education, 1st edition, 2011.	
Reference	1. S. E. Lyshevski, *MEMS and NEMS: Systems, Devices, and Structures*, CRC Press, 1st edition, 2002.	

Course Code	Course name	L	T	P	C	Semester
EC569	Real time and Embedded Operating Systems	3	0	0	3	2nd
Topic	**Contents**					**No. of Lectures**
Module-I	Introduction to real time system, embedded systems, and reactive systems.					06
Module-II	Hard and soft real time systems; Handling real time; specification and modeling; design methods.					08
Module-III	Real time operating systems; validation and verification; real time process and applications; distributed real time systems.					09
Module-IV	Secure coding practices, memory management, timeline design and analysis using metrics and schedulability tests, hardware interfacing, device driver programming.					08
Module-V	Memory maps and boot kernels, firmware, and ROM- resident system code, communications and networking, and debugging live systems. These concepts will be reinforced through C programming assignments using the Linux operating system.					09
	Total No. of Lectures					**40**
Text	1. Sam Siewert, "Real-Time Embedded Systems and Components", Cengage Learning India Edition, 2007. 2. Dreamtech Software Team, "Programming for Embedded Systems", Jhon Wiley India Pvt. Ltd., 2008.					
Reference	1. Tanenbaum A S, "Modern Operating Systems", 3rd Edition, PHI learning private limited, 2009.					

Course Code	Course Name	L	T	P	C	Semester
EC570	Quantum Electronics	3	0	0	3	
Topic	**Contents**					**No. of Lectures**
Module-I	Basic Quantum Mechanics: Wave-particle duality; basic postulates of Wave Mechanics; Schrödinger equation; Wave function and its interpretation; Time independent Schrödinger equation; Wave packet and uncertainty principle. Operators and their role in QM; Eigen values and Eigen functions; Hermitian operators; Potential wells; parabolic potential well; harmonic oscillators; creation and annihilation operators. Hydrogen atom problem. Time dependent perturbation theory. Maxwell-Boltzmann, Bose and Fermi distributions.					**09**
Module-II	Quantum Theory of Solids: Motion of electrons in a periodic potential; Kronig-Penney model; E-k diagram; Brillouin zone; Concept of effective mass and of hole; Density-of-states function; Distinction between metals, insulators and semiconductors. Transport in solids; Boltzmann equation; Conductivity; Mobility; Diffusion constant; Thermal properties of electron gas. Thermal properties; lattice vibrations; phonons; heat capacity; thermal conductivity					**09**
Module-III	Light Propagation: Maxwell and Helmholtz equations; Light propagation in a dielectric and a conducting media; Susceptibility; Absorption. Interaction of light and a two-level atomic system; Absorption, spontaneous and stimulated emission; Einstein's A and B coefficients; Population inversion and amplification of light waves.					**07**
Module-IV	Light-matter Interaction: Condition for laser oscillation. Different types of Lasers: Gas, Solid, Semiconductor and Dye lasers. Properties of Semiconductor Lasers.					**08**

	Guided Light; Waveguides; Examples of planar and rectangular guides; Cylindrical guides: optical fibres; Introduction to Photonic Crystals. Introduction to non-linear optics.	
Module-V	Quantum Electronic Devices: Review of Quantum Nanostructures: Quantum Wells, Wires and Dots; Tunnelling phenomena; Resonant Tunnelling; Electron Devices: HEMTs, Resonant Tunnelling Diodes; Single Electron Transistors; Various forms of Lasers; Quantum Cascade Lasers; Photo detectors; QW and QD Infrared Photo detectors.	**07**
	Total No. of Lectures	**40**
Text	1. A. Yariv, *Quantum Electronics*, John Wiley & Sons, 1st edition, 2012. 2. Edward L. Wolf, *Quantum Nanoelectronics: An Introduction to Electronic Nanotechnology and Quantum Computing*, John Wiley & Sons, 1st edition, 2009.	
Reference	1. A. Yariv, *An Introduction to the Theory and Applications of Quantum Mechanics*, Dover Publications Inc., Reprint edition, 2013. 2. M. A, Nielson, *Quantum Computation and Quantum Information*, Cambridge University Press, 1st edition, 2013.	

Course Code	**Course name**	**L**	**T**	**P**	**C**	**Semester**
EC553	Introduction to IoT and its Applications	3	0	2	4	
Topic	**Contents**					**No. of Lectures**
Module-I	An Introduction to Internet-of-Things, architectural overview, main design principles and needed capabilities, An IoT architecture outline, standards considerations, M2M and IoT Technology fundamentals.					06
Module-II	State of art, reference model and architecture, IoT reference architecture, functional view, Deployment and Operational view, other relevant architectural views.					08
Module-III	Sensing, transducers classification, Actuation, Smart sensors, Basics of Networking; Communication Protocols, Sensor Networks, Machine to-Machine Communications, Wireless medium access issues, MAC protocol survey, Survey routing protocols, Sensor deployment & Node discovery, Data aggregation & dissemination.					09
Module-IV	Sensor Technology, RFID Technology, WPAN Technologies for IoT/ M2M, Cellular and mobile network technologies for IoT/ M2M CoAP, REST, Zigbee, Bluetooth, transport and session layer protocols – TCP, MPTCP, UDP, DCCP, HTTP, CoAP, XMPP, AMQP, MQTT					08
Module-V	Developing IoTs, Introduction to Python, Introduction to different IoT tools, developing applications through IoT tools, developing sensor-based application through embedded system platform, Integration of Sensors and Actuators with Arduino, Implementing IoT concepts with python; Domain specific applications of IoT: Home automation, Industry applications, Surveillance applications, other IoT applications.					09
	Total No. of Lectures					**40**
Text	1. J. Holler, V. Tsiatsis, C. Mulligan, S. Avesand, S. Karnouskos, D. Boyle, *From Machine-to-Machine to the Internet of Things: Introduction to a New Age of Intelligence*, Academic Press, 1st edition, 2014. 2. Bahga, V. Madisetti, *Internet of Things: A Hands-on Approach*, Universities Press, 1st edition, 2015. 3. P. Raj, Anupama C. Raman, *The Internet of Things: Enabling Technologies, Platforms, and Use Cases*, CRC Press, 1st edition, 2017.					
Reference	1. O. Hersent, D. Boswarthick, O. Elloumi, *The Internet of Things: Key Applications and Protocols*, Wiley Press, 2nd edition, 2012.					

	2. D. Uckelmann, M. Harrison, F. Michahelles, *Architecting the Internet of Things*, Springer, 1^{st} edition, 2011.

Course Code	**Course name**	**L**	**T**	**P**	**C**	**Semester**
EC571	Hardware Security	3	0	0	3	
Topic	**Contents**					**No. of Lectures**
Module-I	Review of modular arithmetic, Groups, rights and Fields, Polynomial fields, Galois Field arithmetic. Mapping between Binary and Composite Fields.					06
Module-II	Overview of Modern Cryptography: Stream ciphers, Block Ciphers, DES, AES, Rijndael in Composite Field, Elliptic Curves, Montgomery's Algorithm for Scalar Multiplication					08
Module-III	Modern Hardware Design: FPGA architecture, Mapping an Algorithm to Hardware, Hardware Design of Cryptographic Algorithms					00
Module-IV	Overview of Different Issues of Hardware Security, Useful hardware Security Primitives, Side-channel Attacks on Cryptographic Hardware, Testability and Verification of Cryptographic Hardware.					08
Module-V	Modern IC Design and Manufacturing Practices and Their Implications, Hardware Trojans. Differential Fault Analysis of Ciphers.					00
	Total No. of Lectures					**40**
Text	1. Christof Paar, Jan Pelzl, *Introduction to Cryptography*, Springer, 2^{nd} edition, 2010 2. D. Mukhopadhyay, R S Chakraborty, *Hardware Security: Design, Threats, and Safeguards*, CRC Press, 1^{st} edition, 2015					
Reference	1. M Joye, M. Tunstall, *Fault Analysis in Cryptography*, Springer, 1^{st} edition, 2012.					