Two year Master of Technology (MTech) Degree Program
in
VLSI and Embedded System
by

Department of Electrical Engineering Department
Indian Institute of Technology Patna
Bihta, Patna-801106

Academic Program: M. Tech in VLSI and Embedded System

Program Learning Outcomes:

Program Learning Objectives:	**Program Learning Outcomes:**
Program Goal 1: Identify, formulate and solve engineering problems in the field of Embedded system and VLSI	**Program Learning Outcome 1a:** Graduates will be able to take up career in the field of design, testing and implementation of VLSI systems in any said domain in the real world. **Program Learning Outcome 1b:** Identify and apply appropriate Electronic Design Automation (EDA) to solve real world problems in VLSI and Embedded Systems domain to create innovative products and systems.
Program Goal 2: Apply knowledge, proper methodology and modern tools to analyze and solve the problems in the domain VLSI Design and Technology.	**Program Learning Outcome 2:** Acquire in-depth knowledge of VLSI and Embedded systems in wider and global perspective, with an ability to discriminate, evaluate, analyze, synthesize and integrate for enhancement of knowledge.
Program Goal 3: Acquire competency in areas of VLSI and Embedded Systems, IC Fabrication, Design, Testing, Verification and prototype development focusing on applications.	**Program Learning Outcome 3a:** Pursue career in research in VLSI Design and Embedded Systems domain through self-learning and self-directed on cutting edge technologies **Program Learning Outcome 3b:** Graduates will be able to achieve broad and in-depth knowledge of analysis and design of micro-electronic components which will support them to pursue research studies.
Program Goal 4: Acquire professional and intellectual integrity and ethics of research and recognize the need to engage in learning with a high level of enthusiasm and commitment to contribute to the community for sustainable development of society.	**Program Learning Outcome 4a:** Graduates will be able to asses, innovate, implement and serve the end users problems with cutting edge solutions to meet industry standards **Program Learning Outcome 4b:** Graduates will be able to work both as an individual and a team on multidisciplinary projects and excel in their career

Academic Program: M. Tech in VLSI and Embedded System

Sl. No.	Subject Code	**SEMESTER I**	**L**	**T**	**P**	**C**
1.	XX51PQ	Technical Writing and Soft Skill	3	0	2	4
2.	EC5151	Digital VLSI System	3	0	2	4
3.	EC5152	Embedded System	3	0	2	4
4.	EC5161	Semiconductor Device Modeling and Simulation	3	0	2	4
5.	EC51PQ/EC61PQ	**DE-1**	3	0	0	3
6.	EC51PQ/EC61PQ	**DE-2**	3	0	0	3
7.	XX61PQ	IDE	3	0	0	3
	TOTAL		**18**	**0**	**8**	**25**

Sl. No.	Subject Code	**SEMESTER II**	**L**	**T**	**P**	**C**
1.	EC5251	Analog and Mixed Signal Integrated Circuits	3	0	2	4
2.	EC5252	High Performance Embedded Computing system	3	0	2	4
3.	EC52PQ/EC62PQ	**DE-3**	3	0	0	3
4.	EC52PQ/EC62PQ	**DE-4**	3	0	0	3
5.	EC52PQ/EC62PQ	**DE-5**	3	0	0	3
6.	RM6201	Research Methodology	3	1	0	4
7.	IK6101	IKS	3	0	0	3
	TOTAL		**18**	**1**	**4**	**24**

Sl. No.	Subject Code	**SEMESTER III**	**L**	**T**	**P**	**C**
1.	EC6198	Summer Internship/ Mini Project*	0	0	12	3
2.	EC6199	Project I	0	0	30	15
	TOTAL					**18**

Sl. No.	Subject Code	**SEMESTER IV**	**L**	**T**	**P**	**C**
1.	EC6299	Project II	0	0	42	21
	TOTAL					**21**

GRAND TOTAL	**88**

Academic Program: M. Tech in VLSI and Embedded System

Elective Courses:

1. Semester-I

DE-1	**DE-2**
EC5112 Opto-Electronics Materials and Devices	EC5104 Quantum Computing
EC5113 Radio Frequency Integrated Circuits	EC5111 VLSI Architecture Design and Implementation
EC5114 Advanced Digital Image Processing	EE5111 Control Techniques in Power Electronics
EC5158 VLSI Testing and Verification	EC5166 Semiconductor Packaging Technology
EC5159 Bio Sensors and Circuits	EC6151: Computer Vision
EC6150 CMOS Phase Locked Loops	EC6157 VLSI Signal Processing

2. Semester-II

DE-3	**DE-4**	**DE-5**
EC5250 Patterns Recognition and Machine Learning	EE5213 Recent Trends in Optimization Techniques	EC5216 Silicon Photonics
EC5204 Multimedia Communication	EC5254 Low Power VLSI	EC5260 Embedded System Integration
EC5211 VLSI Technology	EC5256 CAD VLSI	EC5271 High Power Semiconductor Devices
EC5264 Sensors and Actuators	EE6215 Random Signals and Syste	EC6256 System-on-Programmable-Chip Design
EC6254 MEMS and NEMS	EC6252 Hardware Security system	EC6258 Real time Embedded Operating Systems
EC6270 Advance FPGA Platform and System	EC6257 Network on Chip	EC6271: Generative AI for Video Surveillance System

Core Courses

Course Number	**EC5151**
Course Credit	**L-T-P-C: 3-0-2-4**
Course Title	**Digital VLSI System**
Learning Mode	Lectures and Labs
Learning Objectives	Complies with Program Goals 1, 2 and 3
Course Description	The Digital VLSI Systems course covers the design, analysis, and implementation of Very-Large-Scale Integration (VLSI) circuits. It focuses on techniques for optimizing digital systems for performance, power, and area.
Course Outline	Digital Systems and its applications; Basics on manufacturing process of Digital systems; Device and Wire Model; Design and implementation strategies of digital VLSI systems: Full and Semi-custom; Static and Dynamic MOS Logic design and Characteristics: Combinational and sequential circuits and systems; Introduction to ASIC and FPGA based system Design; Digital System and HDL; Design Steps of digital systems; Digital Arithmetic circuits; Semiconductor Memory and peripheral circuits and Systems; Digital IC testing and validation methodologies.
Learning Outcomes	Complies with PLOs 1a, 1b, 2 and 3a
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Readings	**Text/References** 1. Ming-Bo Lin, "Introduction to VLSI Systems: A Logic, Circuit, and System Perspective" Indian Edition, CRC Press, 2011. 2. Seetharaman Ramachandran, "Digital VLSI Systems design", 1st Edition, Springer, 2007. 3. Michael John Sebastian Smith, "Application Specific Integrated Circuit" Addison Wesley, Reprint edition, 1997. 4. J. M. Rabaey, A. Chandrakasan, and B. Nikolic, "Digital Integrated circuits: A design perspective" 2nd Edition, Pearson Education India, 2016. 5. Sung-Mo Kang, and Yusuf Leblebici, "CMOS Digital Integrated Circuits", 3rd Edition McGraw-Hill Education, 2002. 6. Michael, D. Ciletti, "Advanced Digital Design with the Verilog HDL", PHI Learning Private Limited, 2012. 7. Samir Palnitkar, "Verilog HDL: A Guide to Digital Design and Synthesis", Second Edition, Prentice Hall PTR, 2003.

Course Number	**EC5152**
Course Credit	**L-T-P-C: 3-0-2-4**
Course Title	**Embedded System**
Learning Mode	Lectures and Labs
Learning Objectives	Complies with Program Goals 1, 2, 3 and 4
Course Description	Embedded Systems focus on the design and integration of hardware and software in specialized computing systems. The course explores real-time operating systems, microcontrollers, and applications in various domains.
Course Outline	Introduction to the Embedded systems, Basics of Microprocessors and Microcontrollers, Embedded System models and Development Cycle, Embedded system design constraints Sensors, Actuators, Embedded processor and memory architecture, Analog to Digital (A/D) convertors, D/A convertors

	Introduction to different processors, Arduino-Architecture, communication, Field Programmable Gate Array (FPGA)-configurable logic blocks, ARM Processor- Architecture, Instruction Set, Pipelining, Interfacing, Pulse Width Modulation Communication Interfaces: Serial and Parallel communication, Onboard Communication Interfaces (UART, SPI, I2C) and External Communication Interfaces (IR, Wireless-Bluetooth, Wireless LAN, USB, Ethernet etc.), Introduction to Embedded OS and RTOS, Task scheduling-clock-driven and event-driven, RMA and EDF scheduling, Voltage Scheduling, priority inversion, inheritance and ceiling protocol, Multi-tasking State Charts, Finite State Machines, Hierarchical state machines, Program State Machines, Specification and description language (SDL), Embedded system analysis and verification.
Learning Outcomes	Complies with PLOs 1a, 1b, 2 and 3a
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Readings	**Text/References** 1. P. Marwedel: Embedded System Design, Springer, ISBN978-3-319-56045-8,2018. 2. G.C.Buttazzo:HardReal-TimeComputingSystems.SpringerVerlag,ISBN978-1-4614-0676-1,2011. 3. Peter Marwedel, “Embedded System Design: Embedded Systems Foundations of Cyber-Physical Systems”, Springer, 2011. 4. Edward A.Lee and Sanjit A .Seshia: Introduction to Embedded Systems, A Cyber-Physical Systems Approach, Second Edition, MIT Press, ISBN978-0-262-53381-2,2017. 5. M.Wolf: Computers as Components–Principles of Embedded System Design. Morgan Kaufman Publishers , ISBN978-0-128-05387-4,2016. 6. Mazidi & Mazidi, “8051MicrocontrollerandEmbeddedSystems” Steve Furber,―ARM System-On-Chip Architecture, Second Edition, Pearson Publisher,2015. 7. Shibu K V, ―Introduction to Embedded Systems‖, Tata McGraw Hill Education Private Limited, 2009. 8. Steve Furber, ― ARM System-On-Chip Architecture‖, Second Edition, Pearson Publisher, 2015. 9. N. Sloss, D. Symes, and C. Wright, "ARM system developer's guide: Designing and optimizing and system software", Elsevier, 2008.

Course Number	**EC5153**
Course Credit	**L-T-P-C: 3-0-2-4**
Course Title	**Embedded System Lab**
Learning Mode	Lectures and Labs
Learning Objectives	Complies with Program Goals 1 and 2
Course Description	Embedded Systems focus on the design and integration of hardware and software in specialized computing systems. The course explores real-time operating systems, microcontrollers, and applications in various domains.
Course Outline	Module 1: Introduction to Embedded Systems Overview of Embedded Systems, Basics of Microcontrollers, Introduction to Arduino and Raspberry Pi, Digital I/O Programming, Analog I/O Programming, Interfacing with LEDs and Switches, PWM Control, Interfacing with LCD Display, Serial Communication Basics, Arduino IDE and Programming Module 2: Sensor Interfacing and Data Acquisition Introduction to Sensors, Interfacing Temperature Sensors, Working with Light Sensors, Motion Detection Using PIR Sensors, Interfacing with Ultrasonic Sensors, ADC Programming, Data Logging on SD Card, IoT Data Collection Basics, Real-time Data Acquisition, Introduction to Signal Processing Module 3: Communication Protocols and IoT Integration Basics of SPI Protocol, I2C Protocol Implementation, UART Communication, Introduction to MQTT Protocol, IoT Connectivity with ESP8266/ESP32, Cloud Data Integration, Working with REST APIs, IoT Dashboard Creation, Remote Monitoring and Control Module 4: Advanced Embedded System Projects Home Automation System, Environmental Monitoring System, Smart Agriculture Project, Wearable Health Monitoring, Robotics Control Basics, Introduction to Machine Learning on Embedded Systems, Voice Controlled Devices, GPS and Location Tracking, Energy Management Systems, Final Project Design and Implementation.
Learning Outcomes	Complies with PLOs 1a, 1b, 2 and 3a

Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Readings	**Text/References** 1. Monson-Haefel, R. (2019). Embedded Systems Architecture: Explore architectural concepts, pragmatic design patterns, and best practices to produce robust systems (2nd ed.). Elsevier. 2. Barr, M., & Massa, A. (2020). Programming Embedded Systems: With C and GNU Development Tools (2nd ed.). O'Reilly Media. 3. Wolf, W. (2018). Computers as Components: Principles of Embedded Computing System Design (4th ed.). Morgan Kaufmann.

Course Number	**EC5161**
Course Credit	**L-T-P-C: 3-0-2-4**
Course Title	**Semiconductor Device Modeling & Simulation**
Learning Mode	Lectures and Labs
Learning Objectives	Complies with Program Goals 1 and 2
Course Description	Semiconductor Device Modeling & Simulation covers the principles and techniques for modeling the behavior of semiconductor devices. The course includes simulation methods for analyzing device performance and the impact of physical parameters on circuit functionality.
Course Outline	Two-terminal MOS device: threshold voltage modeling (ideal case as well as considering the effects of Φms and Dit.); C-V characteristics (ideal case as well as considering the effects of Qf, Qm and Dit); MOS capacitor as a diagnostic tool (measurement of non-uniform doping profile, estimation of Qm and Dit) 4-terminal MOSFET: threshold voltage (considering the substrate bias); above threshold I-V modeling (SPICE level 1,2,3 and 4); subthreshold current model; scaling; effect of threshold tailoring implant (analytical modeling of threshold voltage using box approximation); buried channel MOSFET; short channel, DIBL and narrow width effects; small signal analysis of MOSFETs (Meyer's model) SOI MOSFET: basic structure; threshold voltage modeling Advanced topics: hot carriers in channel; EEPROMs; CCDs; high-K gate dielectrics
Learning Outcomes	Complies with PLOs 1a, 1b, 2 and 3a
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Readings	**Text/References** 1. D. G.Ong, "Modern MOS Technology: Processes, Devices and Design", McGraw Hill, 1984. 2. Y. Taur and T. H. Ning, "Fundamentals of modern VLSI Devices", Cambridge Univ. Press, 1998. 3. S.M. Sze, "Physics of Semiconductor Devices", 3rd Edition, Wiley-Interscience, 2006

Course Number	**EC5251**
Course Credit	**L-T-P-C: 3-0-2-4**
Course Title	**Analog and Mixed Signal Integrated Circuits**
Learning Mode	Lectures and Labs
Learning Objectives	Complies with Program Goals 1, 2, 3 and 4
Course Description	Analog and Mixed Signal Integrated Circuits explore the design and analysis of circuits that process both analog and digital signals. The course covers topics such as amplifiers, filters, data converters, and their applications in modern electronics.
Course Outline	CMOS Opamp: Basics of Differential amplifier with active load. Two CMOS Opamp Design, Frequency compensation of the CMOS Opamp. Three stage Opamp with output buffer. Reference circuits: Supply-insensitive biasing, Self-biased VTH-reference circuit, PTAT current generation, Temperature-insensitive biasing. Switched capacitor circuits: Switched capacitor amplifiers, integrators and filters.

	Non-Linear Analog Circuits: Basic CMOS Comparator Design, Analog Multipliers, Multiplying Quad, Level Shifting (Excluding Input Level Shifting For Multiplier). Data converter fundamentals: Analog versus Digital Discrete Time Signals, Converting Analog Signals to Data Signals, Sample and Hold Characteristics, DAC Specifications, ADC Specifications, Mixed-Signal Layout Issues. Data Converters Architectures: DAC Architectures, Digital Input Code, Resistors String, R-2R Ladder Networks, Current Steering, Charge Scaling DACs, Cyclic DAC, Pipeline DAC, ADC Architectures, Flash, 2-Step Flash ADC, Pipeline ADC, Integrating ADC, Successive Approximation ADC. Oversampling Sigma-Delta modulator and converters.
Learning Outcomes	Complies with PLOs 1a, 1b, 2, 3a and 3b
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Readings	**Text/References** 1. B. Razavi, "Design of Analog CMOS Integrated Circuits" 1st Edition, McGraw Hill, 2000. 2. P. E. Allen and D. R. Holberg, "CMOS Analog Circuit Design" 2nd Edition, Oxford University Press, 2002. 3. Paul Gray, P J Hurst, S H Lewis and R G Meyer, "Analysis and design of Analog Integrated Circuits", Wiley 4. Sergio Franco, "Analog Circuit Design Discrete and Integrated", McGrawHill 5. Walt Kester, "The Data Conversion Handbook," Elsevier 6. Franco Maloberti, "Data Converters", Springer 7. Rudy van de Plassche, "CMOS Integrated A/D and D/A Converters," Springer 8. Shanthi Pavan, Richard Schreier, "Understanding Delta-Sigma Data Converters" IEEE-Wiley 9. R. Jacaob Baker, "CMOS- Mixed Signal Circuit Design " (Vol ll of CMOS: Circuit Design, Layout and Simulation), IEEE Press and Wiley Interscience, 2002.

Course Number	**EC5252**
Course Credit	**L-T-P-C: 3-0-2-4**
Course Title	**High Performance Embedded Computing System**
Learning Mode	Lectures and Labs
Learning Objectives	Complies with Program Goals 1, 2, 3 and 4
Course Description	This course focus on the architecture and design of embedded systems that require high computational power. The course covers parallel processing, optimization techniques, and applications in areas such as signal processing and real-time computing.
Course Outline	Introduction and evolution of high-performance embedded computing system. Basics of Computer Design & Performance Evaluation: Defining Computer Architecture, Quantitative Principles of Computer Design, CPU Performance & its factors, SPEC Benchmarks. Computational model: Basic computational models, Abstract level of processor, Open Source ISA, Micro-Architecture, High performance computer arithmetic architectures, Instruction level Parallelisms: ILP concepts, Dependencies between instructions, preserving sequential consistency. Pipelining: Introduction to pipelining, Instruction pipeline design, Pipeline hazards, deep pipeline microarchitecture and micro-operation, Superscalar Processors: Introduction, Parallel decoding, Superscalar instruction issue, Shelving, Register Renaming, Memory System: Memory hierarchy, Memory system Performance, Cache Memory, Cache Coherence, Memory Consistency, Cache Performance Issues, Shared Memory Organization. High performance Bus Architecture, Parallel-Virtual-Machine Architecture and programming model. Multicore and multiprocessor architecture, VLIW processor architectures. Array and vector processors. Introduction Embedded Co-Processor: GPU and ML Accelerator
Learning Outcomes	Complies with PLOs 1a, 1b, 2 and 3a
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem

Suggested Readings	**Text/References** 1. John L. Hennessy and David A. Patterson, "Computer Architecture-A Quantitative Approach", 6th Edition, Elsevier, 2019. 2. John L. Hennessy and David A. Patterson, "Computer Organization and Design", Morgan Kaufmann Publisher, 2nd Edition, 2021. 3. S. R. Sarangi, "Advanced Computer Architecture", 1st Edition, 2021. 4. Sima, Fauntain, Kscucle, "Advanced Computer Architecture a design space approach", Pearson, 7th Edition, 2009. 5. Kai Hwang, "Advanced Computer Architecture", McGrawHill publication, 2003.

Elective Courses

Course Number	**EC5104**
Course Credit	**L-T-P-C: 3-0-0-3**
Course Title	**Quantum Computing**
Learning Mode	Lectures
Learning Objectives	Complies with Program Goals 1 and 2
Course Description	Quantum Computing explores the theory and practical applications of quantum mechanics in computing. The course covers quantum algorithms, quantum gates, qubits, and their potential impact on cryptography, optimization, and simulation problems.
Course Outline	Introduction: History, Motivation, Need of quantum bits, quantum states, quantum computations, quantum information, and quantum algorithms. Overview of complex numbers and Linear Algebra, Introduction to quantum mechanics and its postulates, Bloch sphere Quantum Circuits: Single qubits and multiple quibits operations, architecture, quantum gates; quantum teleportation, quantum Fourier Transform: phase estimation Quantum Algorithms: Deutsch's algorithm, Deutsch-Jozsa algorithm, Simon's algorithm, Grover algorithm and Shor's factoring algorithm. Quantum Information and Error Corrections: Classical vs quantum noise, quantum operations, quantum error correction, entropy and information Quantum Tools and Applications: Goal Challenges, Lights and Photon, Decoherence, Ion Trap, Linear Optics, NMR, Quantum Simulation
Learning Outcomes	Complies with PLOs 1a, 1b, 2 and 3a
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Readings	**Text/References** 1. Nielsen, Michael A., and Isaac L. Chuang. Quantum computation and quantum information. Cambridge university press, 2010. 2. Yanofsky, Noson S., and Mirco A. Mannucci. Quantum computing for computer scientists. Cambridge University Press, 2008.\ 3. Johnston, Eric R., Nic Harrigan, and Mercedes Gimeno-Segovia. Programming quantum computers: essential algorithms and code samples. O'Reilly Media, 2019.

Course Number	**EC5216**
Course Credit	**L-T-P-C: 3-0-0-3**
Course Title	**Silicon Photonics**
Learning Mode	Lectures
Learning Objectives	Complies with Program Goals 1 and 2
Course Description	Silicon Photonics involves the study and application of integrating photonic elements such as lasers, modulators, and detectors with silicon-based electronic circuits. The course covers the design, fabrication, and integration of these components for high-speed communication and sensing applications.

Course Outline	Introduction to Silicon Photonics. SOI platform. SOI, SiN, InP, and LNOI platforms. Guided modes in Silicon Photonic Waveguides. Concept of effective index. Coupled Mode theory. Coupling of light to waveguides: grating couplers, butt coupling, mode transformers, inverted tapers. Waveguides loss mechanisms: absorption scattering. Plasma dispersion effect, thermo-optic effect, and stress-optic effect. Passive silicon photonic devices: Mach Zehnder interferometer, ring resonator, directional couplers, waveguide bends, multiplexers. Active silicon photonic devices: Source, Modulators, photodetector. Fundamentals of silicon photonics device fabrication and integration. Applications of silicon photonic devices.
Learning Outcomes	Complies with PLOs 1a, 1b, 2 and 3a
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Readings	<u>**Text/References**</u> 1. G T Reed & AP Knights, "Silicon Photonics: An Introduction", Wiley 2004 2. G T Reed, "Silicon Photonics: The state of the art", Wiley 2008 3. L. Pavesi & D J Lockwoodt, "Silicon Photonics", Springer 2004 4. Lorenzo Pavesi & David J. Lockwood, "Silicon Photonics III Systems and Applications", Springer 2016 5. M J Deen & P K Basu, "Silicon Photonics: Fundamentals and Devices", Wiley 2012 6. Jameel Ahmed, Mohammed Yakoob Siyal, Freeha Adeel, Ashiq Hussain, Optical Signal Processing by Silicon Photonics, 2013, Springer 7. Amnon Yariv and Pochi Yeh, "Photonics", Sixth Edition, Oxford University Press

Course Number	**EC5111**
Course Credit	**L-T-P-C: 3-0-0-3**
Course Title	**VLSI Architecture Design and Implementation**
Learning Mode	Lectures
Learning Objectives	Complies with Program Goals 1 and 2
Course Description	VLSI Architecture Design and Implementation covers the principles of designing and implementing efficient VLSI architectures. The course includes topics such as pipeline and parallel design, data path optimization, and hardware description languages. It also covers performance analysis of various architectures. It presents case studies for the mapping of signal processing and machine learning algorithms to architectures and their performance analysis.
Course Outline	Introduction to VLSI System Design and Implementation; Architectural mapping with case studies: Data path, Control path Synthesis; Control Strategies: Hardware implementation of various control structures; Micro-program control techniques; Design issues: Timing, Area, power analysis; FSM Architecture and Synthesis, HDL design and implementation of VLSI architecture; Semiconductor Memory and Peripheral Architectures; Computer arithmetic architecture design and analysis: Introduction to integer and floating-point arithmetic, Adders, Subtractors, Sequential and Array multipliers & dividers, square root, Absolute Difference Value, CORDIC. Hardware architecture design and performance analysis: Sequential/Folding architectures; bit and word serial architecture; High performance architectures: pipelined, parallel and Systolic Array with examples; Architectural performance Analysis: Throughput and Latency; Low Power VLSI Architectures; Basic Hardware Architectures for Digital Signal processing and machine learning algorithms. Introduction to VLSI Chip testing methods and Architectures: Introduction to Chip Fault Model, DFT Architecture, BIST Architecture.
Learning Outcomes	Complies with PLOs 1a, 1b, 2 and 3a
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Readings	<u>**Text/References**</u> 1. Peter Pirsch, "Architectures for Digital Signal Processing", John Willy & sons,2nd Edition,2014.

	2. K. K. Parhi, " VLSI Digital Signal Processing Systems: Design and Implementation", A Wiley-Interscience publications,2011. 3. Behrooz Parhami, " Computer Arithmetic: Algorithm and Hardware Design", Behrooz Parhami, Oxford University Press, 2nd Edition,2009. 4. A. Bellaouar, M. I. Elmarsny, "Low Power Digital VLSI Design", A. Bellaouar, M. I. Elmarsny, Kluwe academic Publication,1995. 5. DSP Integrated Circuit, L. Wamhammer, Academic Press,1999.

Course Number	**EC5112**
Course Credit	**3-0-0-3**
Course Title	**Opto-Electronics Materials and Devices**
Learning Mode	Lectures
Learning Objectives	Complies with Program Goals 1 and 2
Course Description	Opto-Electronics Materials and Devices cover the study of materials and devices that interact with light for applications in communication, sensing, and display technologies. The course includes topics such as semiconductor optoelectronics (e.g., LEDs, lasers, photodetectors), optical materials (e.g., semiconductors, polymers), device physics, fabrication techniques, and applications in telecommunications, imaging, solar cells, and optical sensing.
Course Outline	UNIT I ELEMENTS OF LIGHT AND SOLID-STATE PHYSICS Wave nature of light, Polarization, Interference, Diffraction, Light Source, review of Quantum Mechanical concept, Review of Solid-State Physics, Review of Semiconductor Physics and Semiconductor Junction Device. UNIT II DISPLAY DEVICES AND LASERS Introduction, Photo Luminescence, Cathode Luminescence, Electro Luminescence, Injection Luminescence, Injection Luminescence, LED, Plasma Display, Liquid Crystal Displays, Numeric Displays, Laser Emission, Absorption, Radiation, Population Inversion, Optical Feedback, Threshold condition, Laser Modes, Classes of Lasers, Mode Locking, laser applications. UNIT III OPTICAL DETECTION DEVICES Photo detector, Thermal detector, Photovoltaics, Photo Conductors, Sensors, Detector Performance. UNIT IV OPTOELECTRONIC MODULATOR Introduction, Analog and Digital Modulation, Electro-optic modulators, Magneto Optic Devices, Acoustoptic devices, Optical, Switching and Logic Devices. UNIT V OPTOELECTRONIC INTEGRATED CIRCUITS Introduction, hybrid and Monolithic Integration, Application of Opto Electronic Integrated Circuits, Integrated transmitters and Receivers, Guided wave devices.
Learning Outcome	Complies with PLO 1b, 2a and 4a
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Readings	Text Books 1. Pallab Bhattacharya "Semiconductor Opto Electronic Devices", Prentice Hall of India Pvt., Ltd., New Delhi, 2006. 2. Jasprit Singh, "Opto Electronics – As Introduction to materials and devices", McGraw-Hill International Edition, 1998 Reference Books 1. S C Gupta, Opto Electronic Devices and Systems, Prentice Hal of India,2005. 2. J. Wilson and J.Haukes, "Opto Electronics – An Introduction", Prentice Hall, 1995.

Course Number	**EC5113**
Course Credit	**L-T-P-C: 3-0-0-3**
Course Title	**Radio Frequency Integrated Circuits**
Learning Mode	Lectures

Learning Objectives	Complies with Program Goals 1 and 2
Course Description	Radio Frequency Integrated Circuits (RFIC) focus on the design and implementation of circuits operating at radio frequencies. The course covers topics such as RF amplifiers, mixers, oscillators, and their applications in wireless communication systems.
Course Outline	Introduction to RF and Wireless technology; Basic concepts in RF & Wireless Integrated Circuits Design; Receiver and Transmitter Architectures. Low Noise RF Amplifiers – Electrical Noises, Two port Noise theory, LNA characteristic parameters and basic topologies, Input impedance and Noise Figure of amplifiers e.g Inductively degenerated, Differential LNA; Broadband Amplifier and amplifier Stability; Mixers – Mixer Operation and linearity, Passive and Active Mixers, Single & Double-Balanced Mixers, Conversion Gain and Port-to-Port Feedthrough (or leakage), Image Reject and Single Sideband Mixers, Noise in Mixers; Oscillators – Oscillator as a Feedback System, Negative Resistance Oscillator Model; LC Oscillators - Colpitts, Hartley, Clapp, Pierce crystal Oscillators, Quadrature Oscillators; Ring oscillators, Voltage Controlled-Oscillator, Phase Noise and Jitter in Oscillators; Frequency Synthesizers – Phase Locked Loop (PLL), Analysis of PLL Synthesizers, Phase Noise in PLL Synthesis, PLL Frequency Synthesizers, Integer-N and Fractional-N PLL Synthesizers, PLL System Frequency Response and Bandwidth; RF Power Amplifiers – Efficiency, Analysis of Basic Classes – A, AB, B, C, Class B Push-Pull Arrangements, Switch mode Classes – D, E, F Amplifiers, Doherty Power Amplifier, Linearization Techniques.
Learning Outcomes	Complies with PLOs 1a, 1b, 2 and 3a
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Readings	**Text** 1. Thomas H Lee, The Design of CMOS Radio Frequency Integrated Circuits, Cambridge University Press 2. Behzad Razavi, RF Microelectronics, 2/e, Pearson India. 3. David M Pozar, Microwave and RF Design of Wireless Systems, John Wiley and Sons 4. Steven Cripps, RF Power amplifier for wireless communications, Artech House 5. Herbert Krauss, Charles Bostian, and Frederick Raab, Solid state radio engineering, John Wiley and Sons 6. Andrei Grebennikov, Marc J. Franco Switchmode RF and Microwave Power Amplifiers, Academic Press Inc **References** 1. John W M Rogers and Calvin Plett, Radio Frequency Integrated Circuit Design, Artech House, Boston. 2. Frank Ellinger, Radio Frequency Integrated Circuits and Technologies, Springer 3. Richard C-H Li, RF Circuits Design, John Wiley 4. Les Besser and Rowan Gilmore, Practical RF Circuit Design for Modern Wireless Systems, vol. 2, Artech House, Boston

Course Number	**EC5114**
Course Credit	**L-T-P-C: 3-0-0-3**
Course Title	**Advanced Digital Image Processing**
Learning Mode	Lectures
Learning Objectives	Complies with Program Goals 1 and 2
Course Description	Advanced Digital Image Processing involves the manipulation and analysis of digital images using computational algorithms. The course covers topics such as image enhancement, restoration, segmentation, feature extraction, and compression. It also includes applications in fields such as medical imaging, remote sensing, robotics, and multimedia systems.

Course Outline	DIGITAL IMAGE FUNDAMENTALS: Elements of Visual Perception; Image Sensing and Acquisition; Image Sampling and Quantization; Basic Relationships between Pixels; Monochromatic Vision Models; Colour Vision Models; Colour Fundamentals; Colour Models; Conversion of Colour Models; Colour Transformations. ENHANCEMENT & RESTORATION : Homomorphic filtering, inverse and minimum error filtering, Noise types and related filtering. IMAGE ANALYSIS AND REPRESENATION: Introduction; Image Segmentation - Point, Line, Edge, Boundary Detection; Colour Image Segmentation; Thresholding- Basic Global Thresholding, Multiple Thresholding, Variable Thresholding; Region Based Segmentation; Representation: Chain codes, Signatures, Boundary segments, Skeletons, Description: Boundary Descriptors, Regional Descriptors. MORPHOLOGICAL PROCESSING & COMPRESSION: Morphological Image Processing – Logic Operations involving Binary Images; Dilation and Erosion; Basic Morphological Algorithms – Boundary Extraction, Region Filling, Thickening Image Compression – Compression Model, Different Coding schemes like Arithmetic Coding, LZW coding etc. Baseline jpeg, jpeg 2000, Mpeg etc. CLASSIFICATION AND APPLICATIONS of Object Recognition and Classification, Statistical classification, Structural /Syntactic Classification, 3D Image Processing, 3D Visualization: Surface rendering, Volume rendering; Applications: Motion Analysis, Image Fusion, Image super resolution
Learnng Outcome	Complies with PLOs 1a, 1b, 2 and 3a
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Readings	**<u>Text/References</u>** 1. 1. Rafael C. Gonzalez and Richard E. Woods, Digital Image Processing, Pearson 2. 2. Milan Sonka, Vaclav Hlavac and Roger Boyle, Image Processing, Analysis and Machine Vision, Springer 3. 3. Anil K. Jain, Fundamentals of Digital Image Processing, Prentice Hall

Course Number	**EC5158**
Course Credit	**L-T-P-C: 3-0-0-3**
Course Title	**VLSI Testing and Verification**
Learning Mode	Lectures
Learning Objectives	Complies with Program Goals 1 and 2
Course Description	VLSI Testing and Verification covers methodologies and techniques for ensuring the correctness and reliability of Very-Large-Scale Integration (VLSI) circuits. The course includes topics such as test pattern generation, fault simulation, design for testability (DFT), and verification methodologies using simulation and formal methods.
Course Outline	Testing Philosophy, Role of Testing, Digital and Analog VLSI Testing, Test Economics, Defects, Errors, and Faults Levels of Fault Models, Controllability and Observability. Algorithms and Representations: Structural vs. Functional Test, Search Space Abstractions ATPG Algebras, Redundancy Identification, Combinational ATPG Algorithms, Test Generation Systems, Simulation-Based Sequential Circuit ATPG, Complexity of Sequential ATPG. Memory Test: Memory Density and Defect Trend, Memory Test Levels, Fault Modeling, Memory Testing Delay Test, IDDQ test, Design for Testability. Built in Self-test. Design Verification: The importance of verification, Reconvergence model, Formal verification, Equivalence checking, Model checking, Functional verification. Verification Tools. Simulators: Stimulus and response, Event based simulation, cycle-based simulation, Co-simulators, verification intellectual property: hardware modelers, The verification plan: The role of verification plan: specifying the verification plan, defining the first success. Levels of verification: unit level verification, reusable

	components verification, ASIC and FPGA verification, system level verification, board level verification, verifying strategies, verifying responses.
Learning Outcomes	Complies with PLOs 1a, 1b, 2 and 3a
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Readings	**Text/References** 1. P. K. Lala, "Digital Circuit Testing and Testability", Academic Press, 1997. 2. M. L. Bushnell and V.D. Agrawal, "Essentials of Electronic Testing for Digital, Memory and Mixed-Signal VLSI Circuits", Kluwar Academic Publishers 2002. 3. M. Abramovici, M.A. Breuer and A.D. Friedman, "Digital Systems and Testable Design", Jaico Publishing House, 2002. 4. Janick Bergeron, "Writing Test benches: functional verification of HDL models", 2nd Edition, Kluwer Academic Publishers, 2003 5. Jayaram Bhasker and Rakesh Chadha, "Static Timing Analysis for Nanometer Designs" A practical approach, 1st Edition, Springer publications, 2009. 6. Prakash Rashinkar, Peter Paterson, Leena Singh "System on a Chip Verification", Kulwer Publications, 2002.

Course Number	**EC5159**
Course Credit	**L-T-P-C: 3-0-0-3**
Course Title	**Bio Sensors and Circuits**
Learning Mode	Lectures
Learning Objectives	Complies with Program Goals 1 and 2
Course Description	Bio Sensors and Circuits focus on the design and implementation of circuits and systems for biological sensing applications. The course covers topics such as sensor technologies (e.g., optical, electrochemical), signal conditioning, data acquisition, and integration with biological systems for healthcare monitoring, environmental sensing, and biomedical research.
Course Outline	Transducers Principles, Biochemical Transducers: Electrode theory, electrode impedance, metal-electrolyte interface and electrode-tissue interface, Bio-potential electrodes: microelectrodes, body surface electrodes, needle electrodes, electrodes for ECG, EEG, and EMG. Electrodes: hydrogen electrodes, Ag/AgCl electrodes, Calomel electrodes, specific ion electrodes, pH electrode, O2 and CO2 electrode, Optical Sensor and Radiation Detectors: Principles of optical sensors and types of optical sensors, Optical fibers, LASERs, Radiation detectors: Proportional counter, Gas-ionization chamber, Geiger counters, Scintillation detectors., Biological Sensors: Receptors in the human body, Ion exchange membrane electrodes, enzymatic biosensors, Basic principles of MOSFET biosensors & BIOMEMS, basic idea about Smart sensors, Biomedical Measurement
Learning Outcomes	Complies with PLOs 1a, 1b, 2 and 3a
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Readings	**Text/References** 1. Josheph J. Carr and John M. Brown, "Introduction to Biomedical Equipment Technology", 4th Edition, Pearson Education, 2001. 2. John. G. Webster, "Medical Instrumentation- Application and Design", 4th Edition, John Wiley & Sons, 2010. 3. Willis J. Tompkins, "Biomedical Digital Signal Processing" Prentice-Hall of India, 1993. 4. Rangraj M. Rangayyan, "Biomedical Signal analysis- A Case Study Approach", Wiley India Pvt. Ltd., 2009.

	5. Suresh R. Devashahayan, "Signals and Systems in Biomedical Engineering", Revised 2nd Edition, Kluwer academics/ Plenum publication, 2013. 6. Josheph J. Carr and John M. Brown, "Introduction to Biomedical Equipment Technology",4th Edition, Prentice Hall, 2000. 7. Leslie Cromwell, Fred J. Weibell, and Erich A. Pfeiffer "Biomedical Instrumentation and Measurements", 2nd Edition, Prentice-Hall of India, 2000.

Course Number	**EC5171**
Course Credit	**L-T-P-C: 3-0-0-3**
Course Title	**High Speed Semiconductor Devices**
Learning Mode	Lectures
Learning Objectives	Complies with Program Goals 1 and 2
Course Description	High-Speed Semiconductor Devices involve the study and design of semiconductor devices capable of operating at very high frequencies. The course covers topics such as transistor physics at high frequencies, device modeling, high-frequency measurement techniques, microwave and millimeter-wave devices, and applications in communication systems, radar systems, and high-speed data processing.
Course Outline	Introduction to High-Speed Semiconductor Devices: Overview of semiconductor device fundamentals, Importance and applications of high-speed devices Semiconductor Physics for High-Speed Devices: Carrier transport mechanisms, High-field effects Material Properties and Device Architectures: High-mobility materials (e.g., GaAs, InP), Heterostructures and quantum wells High speed Schottky diodes: working, characteristics, design, small signal models High-Speed Bipolar Junction Transistors (BJTs): Structure and operation of BJTs, High-speed performance characteristics High Electron Mobility Transistors (HEMTs): Design and operation principles, Application in RF and microwave circuits Metal-Semiconductor Field-Effect Transistors (MESFETs): Structure, operation, and performance Comparison with other high-speed devices Emerging High-Speed Devices: Tunnel FETs, Ballistic transistors, Nanoscale devices and their challenges Device Modeling and Simulation: Techniques for modeling high-speed devices, Introduction to CAD tools for device simulation High-Frequency Performance Analysis: S-parameters, cut-off frequency, and maximum oscillation frequency Noise analysis in high-speed devices Recent Advances and Research Trends: Breakthroughs in high-speed semiconductor devices Future directions and potential applications
Learning Outcomes	Complies with PLOs 1a, 1b, 2 and 3a
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Readings	**Text** 1. "Physics of Semiconductor Devices" by S.M. Sze and Kwok K. Ng , Edition: 3rd, Publisher: Wiley, Year: 2006 2. "High-Speed Semiconductor Devices" by S.M. Sze, Publisher: Wiley, Year: 1990 3. "Microwave Engineering" by David M. Pozar, Edition: 4th, Publisher: Wiley, Year: 2011 4. "Semiconductor Device Fundamentals" by Robert F. Pierret, Publisher: Addison-Wesley, Year: 1996 5. "Advanced Semiconductor Fundamentals" by Robert F. Pierret, Edition: 2nd, Publisher: Prentice Hall, Year: 2002 **References** 1. "Semiconductor Physics and Devices" by Donald A. Neamen, Edition: 4th, Publisher: McGraw-Hill, Year: 2011 2. "Fundamentals of Modern VLSI Devices" by Yuan Taur and Tak H. Ning, Edition: 2nd Publisher: Cambridge University Press, Year: 2009

	3. "The Physics of High-Speed Transistors" by D.J. Roulston, Publisher: Oxford University Press, Year: 1997 4. "RF Microelectronics" by Behzad Razavi, Edition: 2nd, Publisher: Prentice Hall, Year: 2011

Course Number	**EE5111**
Course Credit	**L-T-P-C: 3-0-0-3**
Course Title	**Control Techniques in Power Electronics**
Learning Mode	Lectures
Learning Objectives	Complies with Program Goals 1 and 2
Course Description	Control Techniques in Power Electronics cover methods for managing and optimizing the flow and conversion of electrical power. The course typically includes topics such as pulse-width modulation (PWM), feedback control loops, voltage and current regulation, switch-mode power supplies (SMPS), and applications in renewable energy systems, motor drives, and electronic devices.
Course Outline	State space modelling and simulation of linear systems, Discrete time models, conventional controllers using small signal models, Hysteresis controllers, Output and state feedback switching controllers. Averaged - switch modelling, modelling of dynamics of converters operating in discontinuous conduction mode, input filter design.
Learning Outcomes	Complies with PLOs 1a, 1b, 2 and 3a
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Readings	**<u>Text/References</u>** 1. Muhammad Rashid, Power Electronics Handbook, Academic Press-Elsevier, 2001. 2. B. Wu, High-Power Converters and AC Drives. Wiley-IEEE Press, New Jersey, 2006. 3. Erickson and Maksimovic, Fundamentals of Power Electronics, 2nd ed., Springer Science+Business (2000) 4. Ned Mohan, Tore M, Undelnad, William P, Robbins (3 Edition), Power Electronics: Converters, Applications and Design; Wiley 2002.

Course Number	**EC5250**
Course Credit	**L-T-P-C: 3-0-0-3**
Course Title	**Pattern Recognition and Machine Learning**
Learning Mode	Lectures
Learning Objectives	Complies with Program Goals 1 and 2
Course Description	Pattern Recognition and Machine Learning focuses on algorithms and techniques for identifying patterns and making predictions from data. The course covers topics such as supervised and unsupervised learning, classification, regression, clustering, and feature extraction using statistical and machine learning methods.
Course Outline	Introduction: Feature extraction and Pattern Representation, Concept of Supervised and Unsupervised Classification, Introduction to Application Areas. Statistical Pattern Recognition: Bayes Decision Theory, Minimum Error and Minimum Risk Classifiers, Discriminant Function and Decision Boundary, Normal Density, Discriminant Function for Discrete Features, Parameter Estimation. Dimensionality Problem: Dimensionality Reduction, Fisher Linear Discriminant and Multiple Discriminant Analysis. Nonparametric Pattern Classification: Density Estimation, Nearest Neighbour Rule, Fuzzy Classification. Linear Discriminant Functions: Separability, Two Category and Multi Category Classification, Linear Discriminators, Perceptron Criterion, Relaxation Procedure, Minimum Square Error Criterion, Widrow-Hoff Procedure, HoKashyap Procedure, Kesler's Construction. Neural Network Classifier: Single and Multilayer Perceptron, Back Propagation, Learning Hopfield, Network Fuzzy and Neural Network. Time Varying Pattern Recognition: First Order Hidden Markov, Model Evaluation, Decoding Learning. Unsupervised Classification: Clustering, Hierarchical Clustering, Graph Based Method, Sum of Squared Error Technique, Iterative Optimization.
Learning Outcomes	Complies with PLOs 1a, 1b, 2 and 3a
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Readings	<u>**Text/References**</u> 1. Richard O. Duda, Peter E. Hart and David G. Stork, Pattern Classification, John Wiley & Sons, 2001. 2. Earl Gose, Richard Johsonbaugh and Steve Jost, Pattern Recognition and Image Analysis, Prentice Hall, 1999

Course Number	**EC5204**
Course Credit	3-0-0-3
Course Title	**Multimedia Communication**
Learning Mode	Lectures
Learning Objectives	After learning this course, the students will be able 1. to understand the fundamental knowledge on multimedia system and Multimedia Communication. 2. to understand the knowledge on Multimedia Information Systems. 3. to understand the real-time constraints in Multimedia Communication. 4. to develop problem statement on Multimedia Communication for research direction

Academic Program: M. Tech in VLSI and Embedded System

Course Description	This course deals with the Multimedia Communication.
Course Outline	Introduction to Multimedia System: Architecture and components, Multimedia distributed processing model, Synchronization, Orchestration and Quality of Service (QOS) architecture. Audio and Speech: Data acquisition, Sampling and Quantization, Human Speech production mechanism, Digital model of speech production, Analysis and synthesis, Psycho-acoustics, low bit rate speech compression, MPEG audio compression. Images and Video: Image acquisition and representation, Composite video signal NTSC, PAL and SECAM video standards, Bilevel image compression standards: ITU (formerly CCITT) Group III and IV standards, JPEG image compression standards, MPEG video compression standards. Multimedia Communication: Fundamentals of data communication and networking, Bandwidth requirements of different media, Real time constraints: Audio latency, Video data rate, multimedia over LAN and WAN, Multimedia conferencing. Hypermedia presentation: Authoring and Publishing, Linear and non-linear presentation, Structuring Information, Different approaches of authoring hypermedia documents, Hyper-media data models and standards. Multimedia Information Systems: Operating system support for continuous media applications: limitations is usual OS, New OS support, Media stream protocol, file system support for continuous media, data models for multimedia and hypermedia information, content based retrieval of unstructured data.
Learning Outcome	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments, and Exams
Suggested Readings	**Text Books:** 1. J. D. Gibson, Multimedia Communications: Directions and Innovations, 2000, Elsevier. 2. A. Puri and T. Chen, Multimedia Systems, Standards, and Networks, 1st Edition, 2000, CRC Press. 5. Iain E.G. Richardson, H.264 and MPEG-4 Video Compression, 2004, John Wiley & Sons. **Reference Books:** 1. Ralf Steinmetz and Klara Nahrstedt, Multimedia Systems, 2004, Springer. 2. K. Sayood, Introduction to Data Compression, 2017, Morgan-Kaufmann. 3. Borivoje Furht, Handbook of Multimedia Computing, 1998, CRC Press

Course Number	**EC5211**
Course Credit	**L-T-P-C: 3-0-0-3**
Course Title	**VLSI Technology**
Learning Mode	Lectures
Learning Objectives	Complies with Program Goals 1 and 2
Course Description	VLSI Technology focuses on the processes and methodologies used in the fabrication of Very-Large-Scale Integration circuits. The course covers semiconductor materials, photolithography, etching, doping, and the integration of components into complex systems.
Course Outline	General Overview of current status of VLSI Technology- Interaction between Technology and Design, - Interaction between Physics and Technology, - Limits of Technology, Environment for Integrated Circuits Manufacture, - Clean Rooms and Wafer cleaning procedures., - Technology Processes in Fabrication, - Oxidation, Diffusion, Ion Implantation, Etching and Deposition, techniques., - Characterization of Processes. Lithography and Mask generation techniques - Advanced Unit-Processors for ULSI Circuit Technologies., - Use of RTP, - Plasma processes in the fabrication in the fabrication of circuits., Basic Bipolar process Technologies., NMOS Technology, Mask sequence based fabrication process for NMOS transistors, - Silicon Gate and Metal Gate Technologies. Limitations of NMOS Technology. CMOS Technology - Process Sequence for CMOS Technology, Advanced CMOS Processes, “Design – Rules” for NMOS and CMOS Technologies as “Constraints” for Layouts. Process Simulation - Use of SUPREM-IV ans STEP Simulators for process Design, - Some

	Examples of actual technologies.
Learning Outcomes	Complies with PLOs 1a, 1b, 2 and 3a
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Readings	**Text/References** 1. S.K. Gandhi, "VLSI Fabrication principles", John Wiley Inc., New York, 1983 2. S.M. Sze "VLSI Technology", 2nd Edition, McGraw Hill Co. Inc., New York, 1988 3. C. Y. Chang and S. M. Sze, "VLSI Technology", McGraw Hill Co. Inc., New York, 1996

Course Number	**EC5254**
Course Credit	**L-T-P-C: 3-0-0-3**
Course Title	**Low power VLSI**
Learning Mode	Lectures
Learning Objectives	Complies with Program Goals 1 and 2
Course Description	Low Power VLSI focuses on techniques and strategies for reducing power consumption in Very-Large-Scale Integration (VLSI) circuits. The course covers power-aware design, optimization methods, and applications in portable and energy-efficient devices.
Course Outline	Need for Low Power Circuits, Low Power Techniques at different Hierarchical levels; CMOS basics: MOS Transistors, Short Channel Effects, Spice models for MOS transistors, MOS Invertors characteristics, Delay Estimation, BICMOS logic circuits; MOS Logic Styles: Static CMOS, Dynamic CMOS and Pass transistor circuits; Sources of Power dissipation: Diode Leakage Power, Short Circuit Leakage Power, Switching Power and Switching Activity of Static and Dynamic Circuits, Parameters involved in power dissipation; Low-power Design Methodologies: Supply voltage scaling approaches at different levels of hierarchy, Multi-threshold CMOS circuit design, Dynamic Voltage Scaling, Minimizing Switched Capacitance at different levels; Adiabatic switching concepts; Low Power CMOS RAM Circuits.
Learning Outcomes	Complies with PLOs 1a, 1b, 2 and 3a
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Readings	**Text/References** 1. Ajit Pal, "Low-Power VLSI Circuits and Systems", Springer, 2015 2. J. B. Kuo and J-H. Lou, "Low-Voltage CMOS VLSI Circuits", Wiley, 1999. 3. K. Roy and S. C. Prasad, "Low-Power CMOS VLSI Circuit Design", Wiley, 2000.

Course Number	**EC5256**
Course Credit	**L-T-P-C: 3-0-0-3**
Course Title	**CAD VLSI**
Learning Mode	Lectures
Learning Objectives	Complies with Program Goals 1 and 2
Course Description	CAD VLSI (Computer-Aided Design for Very-Large-Scale Integration) involves the use of software tools and methodologies to design, simulate, and verify integrated circuits. The course covers topics such as layout design, logic synthesis, timing analysis, and physical design automation (PDA) for efficient and reliable VLSI circuit design.

Course Outline	Introduction: VLSI design flow, challenges. Verilog/VHDL: introduction and use in synthesis, modeling combinational and sequential logic, writing test benches. Logic synthesis: two-level and multilevel gate-level optimization tools, state assignment of finite state machines. Basic concepts of high-level synthesis: partitioning, scheduling, allocation and binding. Technology mapping. Testability issues: fault modeling and simulation, test generation, design for testability, built-in self-test. Testing SoC s. Basic concepts of verification. Physical design automation. Review of MOS/CMOS fabrication technology. VLSI design styles: full-custom, standard-cell, gate-array and FPGA. Physical design automation algorithms: floor-planning, placement, routing, compaction, design rule check, power and delay estimation, clock and power routing, etc. Special considerations for analog and mixed-signal designs.
Learning Outcomes	Complies with PLOs 1a, 1b, 2 and 3a
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Readings	<u>**Text/References**</u> 1. Naveed Shervani, "Algorithms for VLSI physical design Automation", 2nd Edition, Kluwer Academic Publisher, 1999. Christophan Meinel and Thorsten Theobold, "Algorithm and Data Structures for VLSI Design", KAP, 2002. 2. Rolf Drechsheler, "Evolutionary Algorithm for VLSI", 2nd Edition 3. Trim burger, "Introduction to CAD for VLSI", Kluwer Academic publisher, 2002. 4. Randal L and Schwartz Tom Phoenix, "Learning PERL", Oreilly Publications, 3rd Edition, 2000. 5. Samir Palnitkar, "Verilog HDL: A Guide to Digital Design and Synthesis", Second Edition, Prentice Hall PTR, 2003.

Course Number	**EC5260**
Course Credit	**L-T-P-C: 3-0-0-3**
Course Title	**Embedded System Integration**
Learning Mode	Lectures
Learning Objectives	Complies with Program Goals 1 and 2
Course Description	The course involves the process of combining hardware and software components into a cohesive embedded system. The course covers topics such as system architecture design, interfacing peripherals, real-time operating systems (RTOS), communication protocols, and testing methodologies to ensure the reliability and functionality of the integrated system in various applications.
Course Outline	General system design: Embedded Computing: Introduction, Complex Systems and Microprocessor, Embedded System Design Process, Formalisms for System Design, Design Examples. ARM Introduction: Introduction to processor design-architecture and organization, Abstraction in hardware design, Instruction set design, Processor design tradeoffs, RISC. Overview of ARM architecture – Architecture inheritance, Programmer`s model, Development tools. ARM Instruction Set. 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
Learning Outcomes	Complies with PLOs 1a, 1b, 2 and 3a
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Readings	<u>**Text/References**</u> 1. David E. Simon, "An Embedded Software Primer", Pearson Education Asia, 2005 2. Wayne Wolf "Computers as Components: Principles of Embedded Computing System Design", 3rd Editions, Morgan Kaufman Publishers, 2012. 3. Rajkamal, "Embedded Systems Architecture, Programming and Design", 3rd Edition, TATA McGraw Hill, 2008.

Course Number	**EC5264**

Course Credit	**L-T-P-C: 3-0-0-3**
Course Title	**Sensors and Actuators**
Learning Mode	Lectures
Learning Objectives	Complies with Program Goals 1 and 2
Course Description	Sensors and Actuators involve the study and application of devices that sense physical quantities (sensors) and act upon them (actuators). The course covers principles of transduction, sensor types (e.g., optical, pressure, temperature), actuator mechanisms (e.g., motors, valves), interfacing with electronics, and applications in various fields such as automotive, healthcare, and industrial automation.
Course Outline	Brief overview of measurement systems, classification, characteristics and calibration of different sensors. Measurement of displacement, position, motion, force, torque, strain gauge, pressure flow, temperature sensor sensors, smart sensor. Optical encoder, tactile and proximity, ultrasonic transducers, opto-electrical sensor, gyroscope. Principles and structures of modern micro sensors, micro-fabrication technologies: bulk micromachining, surface micromachining, LIGA, assembly and packaging. Pneumatic and hydraulic systems: actuators, definition, example, types, selection. Pneumatic actuator. Electro-pneumatic actuator. Hydraulic actuator, control valves, valve sizing valve selection. Electrical actuating systems: solid-state switches, solenoids, voice coil; electric motors; DC motors, AC motors, single phase motor; 3-phase motor; induction motor; synchronous motor; stepper motors. Piezoelectric actuator: characterization, operation, and fabrication; shape memory alloys.
Learning Outcomes	Complies with PLOs 1a, 1b, 2 and 3a
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Readings	**<u>Text/References</u>** 1. John G. Webster, Editor-in-chief, "Measurement, Instrumentation, and Sensors Handbook", CRC Press (2014). 2. Jacob Fraden, "Handbook of modern Sensors", AIP Press, Woodbury (2016). 3. Nadim Maluf, "An Introduction to Microelectromechanical Systems Engineering", Artech House Publishers, Boston (2004). 4. Marc Madou, "Fundamentals of Microfabrication", CRC Press, Boca Raton (2002). 5. Gregory Kovacs, "Micromachined Transducers Sourcebook", McGraw-Hill, New York (1998). 6. E. O. Deobelin and D. Manik, "Measurement Systems – Application and Design", Tata McGraw-Hill (2004). 7. D. Patranabis, "Principles of Industrial Instrumentation", Tata McGraw-Hill, eleventh reprint (2004). 8. B. G. Liptak, "Instrument Engineers' Handbook: Process Measurement and Analysis", CRC (2003).

Course Number	**EC5166**
Course Credit	**L-T-P-C: 3-0-0-3**
Course Title	**Semiconductor Packaging Technology**
Learning Mode	Lectures
Learning Objectives	Complies with Program Goals 1 and 2
Course Description	Semiconductor Packaging Technology focuses on the methods and materials used to protect, connect, and enhance the reliability of semiconductor devices. The course covers topics such as packaging types (e.g., flip-chip, wire-bonding), thermal management, and reliability testing for various electronic applications.
Course Outline	Introduction to IC Packaging • Definition of packaging and its significance in various industries. • Introduction to packaging and its importance in Modern Electronics. Traditional Packaging Technologies • Exploring different packaging technologies, such as leaded and leadless packages, surface mount technology (SMT), and ball grid array (BGA). Discussion on the purpose and characteristics of each technology. • Explanation of the factors influencing technology selection. Introduction to Advanced Packaging • Definition of advanced packaging and its importance in meeting evolving technology requirements. Explaining the benefits and challenges associated with advanced packaging. • Exploring different integrated technology of advanced packaging technologies, such as 2.5D, 3D packaging,

	Advanced Packaging Interconnects: Discussion on interconnect technologies used in advanced packaging, such as flip chip bumping, solder balls, and through-silicon vias (TSVs), photonic integration. Testing and Reliability in Advanced Packaging: The testing methodologies and reliability considerations specific to advanced packaging. • Discussion on package-level testing, interconnect testing, and reliability testing. Explanation of various failure analysis techniques and strategies for ensuring package reliability.
Learning Outcomes	Complies with PLOs 1a, 1b, 2 and 3a
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Readings	**Textbooks** 1. Yoshio Nishi and Robert Doering, "Handbook of Semiconductor Manufacturing Technology" 2nd Edition, CRC Press, 2017. 2. Simon M. Sze, Ming-Kwei Lee , "Semiconductor Devices: Physics and Technology" Wiley, 2012. 3. John H. Lau " Semiconductor Advanced Packaging", Springer, 2021. **References** 1. Christopher Bower, Peter Ramm, Philip Garrou , "Handbook of 3D Integration: Technology and Applications of 3D Integrated Circuits", Wiley, 2011. 2. Behzad Razavi, "Fundamentals of Microelectronics", Wiley, 2014.

Course Number	**EC5271**
Course Credit	**L-T-P-C: 3-0-0-3**
Course Title	**High-Power Semiconductor Devices**
Learning Mode	Lectures
Learning Objectives	Complies with Program Goals 1 and 2
Course Description	High-Power Semiconductor Devices focus on components capable of handling high electrical currents or voltages efficiently. The course typically covers topics such as power semiconductor materials (e.g., silicon, gallium nitride), device structures (e.g., MOSFETs, IGBTs), switching characteristics, thermal management, and applications in power electronics, renewable energy systems, electric vehicles, and industrial automation.

Course Outline	Introduction to High-Power Semiconductor Devices: Overview of high-power devices, Applications in power electronics Semiconductor Physics for High-Power Devices: Charge carrier dynamics, Breakdown mechanisms Power Diodes: Structure, operation, and types (e.g., Schottky, PiN), Performance characteristics and applications Power Bipolar Junction Transistors (BJTs): Structure and operation principles, High-power performance characteristics Insulated Gate Bipolar Transistors (IGBTs): Design and operation principles, Power MOSFETs: Structure, operation, and characteristics, Comparison with other high-power devices Thyristors and Related Devices: Structure and types (e.g., SCR, GTO), Switching characteristics and applications Thermal Management in High-Power Devices: Heat generation and dissipation, Thermal modeling and packaging techniques Reliability and Failure Mechanisms: Degradation and failure modes, Reliability testing and improvement strategies Advanced Materials for High-Power Devices: Wide bandgap materials (e.g., SiC, GaN), Advantages and challenges Integration and Application of High-Power Devices: Power modules and converters, Applications in renewable energy and electric vehicles Recent Advances and Research Trends: Innovations in high-power device technology,
Learnng Outcome	Complies with PLOs 1a, 1b, 2 and 3a
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Readings	**<u>Text/References</u>** 1. "Power Semiconductor Devices" by B. Jayant Baliga, Edition: 1st , Publisher: PWS Publishing Company, Year: 1995 2. "Fundamentals of Power Semiconductor Devices" by B. Jayant Baliga, Edition: 2nd, Publisher: Springer, Year: 2010 3. "Semiconductor Power Devices: Physics, Characteristics, Reliability" by Josef Lutz, Heinrich Schlangenotto, Uwe Scheuermann, Rik De Doncker, Edition: 2nd, Publisher: Springer 4. "Power Electronics: Converters, Applications, and Design" by Ned Mohan, Tore M. Undeland, William P. Robbins, Edition: 3rd, Publisher: Wiley, Year: 2002 5. "Wide Bandgap Semiconductor Power Devices: Materials, Physics, Design, and Applications" by B. Jayant Baliga, Publisher: Woodhead Publishing, Year: 2018

Course Number	**EE5213**
Course Credit	**L-T-P-C: 3-0-0-3**
Course Title	**Recent Trends in Optimization Techniques**
Learning Mode	Lectures
Learning Objectives	Complies with Program goals 1 and 2
Course Description	The course is designed to meet the requirements of Ph.D. and M. Tech students to get sufficient knowledge on optimization and its application to different fields of engineering.
Course Outline	Motivation. mathematical review , matrix factorizations, sets and sequences, convex sets and functions. Linear programming and simplex method, Weierstrass' theorem, Karush Kuhn Tucker optimality conditions, algorithms, convergence, unconstrained optimization, Line search methods, method of multidimensional search, steepest descent methods, Newton's method, modifications to Newton's method , trust region methods, conjugate gradient methods, quasi-Newton's methods.

	Constrained optimization, penalty and barrier function methods, augmented Lagrangian methods, polynomial time algorithm for linear programming, successive linear programming, successive quadratic programming.
Learning Outcomes	Complies with PLO 1a, 2a, and 3a
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Readings	**Text/References** 1. R. Fletcher Practical Optimization (2nd Edition) John Wiley & Sons, New York, 1987. 2. M.S.Bazaraa , H.D.Sherali and C.Shetty , Nonlinear Programming, Theory and Algorithms, John Wiley and Sons, New York, 1993.

Course Number	**EC6150**
Course Credit	**L-T-P-C: 3-0-0-3**
Course Title	**CMOS Phase-Locked Loops**
Learning Mode	Lectures
Learning Objectives	Complies with Program Goals 1 and 2
Course Description	CMOS Phase-Locked Loops (PLLs) involve the design and implementation of frequency synthesis circuits using Complementary Metal-Oxide-Semiconductor (CMOS) technology. The course covers topics such as PLL architecture, phase detection and comparison, loop filter design, voltage-controlled oscillator (VCO) characteristics, and applications in clock generation, frequency synthesis, and communication systems.
Course Outline	Introduction to PLL, Various types of PLL PLL building blocks: Phase detectors, Phase/Frequency detectors, Ring and LC Voltage-controlled Oscillators (VCO), Frequency Dividers Analysis of PLL: Type-I and Type-II 2nd order PLL; Higher-order loop filters and PLL; PLL Stability Designing PLL: a 2nd order PLL Jitter and Phase noise in Oscillators and PLLs, PLL-based frequency synthesizer: Integer-N and Fractional-N synthesizers, $\Delta\sum$ Fractional-N synthesizers All-Digital PLL: Time-to-Digital Conversion, Digital Filters, Digitally Controlled Oscillators, Delay-locked Loops Low jitter frequency synthesizer: Subsampling PLL Architecture and it components
Learning Outcomes	Complies with PLOs 1a, 1b, 2 and 3a
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Readings	**Text/References** 1. B. Razavi, “Design of CMOS Phase-Locked Loops” Cambridge Univ Press, 2020. 2. William F Egan, “Phase-lock Basics,” IEEE-Wiley 3. Floyd M. Gardner, “Phase Lock Techniques” 3rd Edition, Wiley-inter-science 4. Ronald E Best, “Phase-locked Loop, Design, Simulation and Applications”, 6th edition, McGrawHill 5. Venceslav F Kroupa, “Phase Lock Loops and Frequency Synthesis,” Wiley 6. Shanthi Pavan, Richard Schreier, “Understanding Delta-Sigma Data Converters” IEEE-Wiley

Course Number	**EC6151**
Course Credit	**L-T-P-C: 3-0-0-3**
Course Title	**Computer Vision**
Learning Mode	Lectures

Academic Program: M. Tech in VLSI and Embedded System

Learning Objectives	Complies with Program Goals 1 and 2
Course Description	Computer Vision involves the development of algorithms and systems that enable computers to interpret visual information from the real world. The course covers topics such as image processing, object detection and recognition, image segmentation, feature extraction, 3D reconstruction, and deep learning techniques applied to visual data. Applications include autonomous vehicles, medical imaging, surveillance, augmented reality, and robotics.
Course Outline	Computer vision introduction, image formation, perspective projection, camera response & HDR imaging, nature of image sensors, image filtering, template matching, Fourier transform, convolution and deconvolution, edge and corner detection, canny edge detection, Active contours, Hough transform, SIFT detector and descriptor, Image homography, Image warping and image blending, Face detection, nearest neighbor classifier, support vector machine, Radiometry and reflectance property, Photometric stereo, reflectance map, shape from normal, shape from shading, stereographic projection, shading illusion, dept from focus and depth from defocus, photometric stereo systems, camera calibration, simple stereo, uncalibrated stereo, epipolar geometry, stereo vision in nature, optical flow, Lucas Kanade method, structure from motion, object tracking, gaussian mixture model, feature detection for tracking, image segmentation by k-means, mean-shift and graph cut based methods. PCA and SVD and shape verses appearance. Neural network, Gradient descent, back propagation algorithm.
Learning Outcomes	Complies with PLOs 1a, 1b, 2 and 3a
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Readings	**Text** 1. Computer Vision - A modern approach, by D. Forsyth and J. Ponce, Prentice Hall Robot Vision, by B. K. P. Horn, McGraw-Hill. **References** 1. Computer Vision: Algorithms and Applications: Richard Szeliski 2. Foundations of Computer Vision Antonio Torralba (Author), Phillip Isola (Author), William T. Freeman (Author)

Course Number	**EC6157**
Course Credit	**L-T-P-C: 3-0-0-3**
Course Title	**VLSI Signal Processing**
Learning Mode	Lectures
Learning Objectives	Complies with Program Goals 1 and 2
Course Description	VLSI Signal Processing involves the design and implementation of signal processing algorithms and systems using Very-Large-Scale Integration (VLSI) technology. The course covers topics such as digital signal processing (DSP) algorithms, efficient hardware implementations, optimization techniques, and applications in areas such as telecommunications, audio processing, image processing, and biomedical signal processing.
Course Outline	Introduction to DSP systems: Representation of DSP algorithms; Iteration Bound: Definition, Examples, Algorithms for computing Iteration bound; Pipelining and Parallel Processing: Definitions, Pipelining and parallel processing of FIR filters, Pipelining and parallel processing for low power; Retiming: Definitions and Properties, Solving system of Inequalities, Retiming techniques; Unfolding: Definition, An algorithm for unfolding, Applications of unfolding; Folding: Definition, Folding transformations, Register minimization techniques, Register minimization in folded architectures; Systolic Architecture Design: Introduction, Systolic array design methodology, FIR systolic arrays, Selection of scheduling vector, Matrix-Matrix multiplication and 2D systolic array design; CORDIC based Implementations: Architecture, Implementation of FIR filter and FFT algorithm; Bit-Level arithmetic architectures: Parallel multipliers, Bit-serial multipliers, Bit-Serial FIR filter design and Implementation; Redundant arithmetic: Redundant number representation, Carry-free radix-2 addition and subtraction, radix-2 hybrid redundant multiplication architectures; Low-power design: Theoretical background, Scaling versus power consumption, Power analysis, Power reduction techniques, Power estimation approaches.

Learning Outcomes	Complies with PLOs 1a, 1b, 2 and 3a
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Readings	**Text/References** 1. U. Meyer-Baese, “DSP with FPGA”, Springer,4th Edition, 2014. 2. K. K. Parhi, “VLSI DSP Systems”, Wiley, 2003. 3. R.G. Lyons, “Understanding Digital Signal Processing”, Pearson Education,3rd Edition, 2011.

Course Number	**EE6215**
Course Credit	**L-T-P-C: 3-0-0-3**
Course Title	**Random Signals and Systems**
Learning Mode	Lectures
Learning Objectives	Complies with Program Objectives 1 and 2.
Course Description	The course is designed to meet the requirements of Ph.D. and M. Tech students to get sufficient knowledge on random processes and its effects on linear systems.
Course Outline	Probability and statistics of multivariable (a quick revision): Bayes theorem, multiple random variable, discrete random variable, probability mass function and probability density function, a few well known distributions, moments. Random process: Concept of random process, ensemble, mathematical tools for studying random process, correlation function, stationarity, ergodicity, a few known stochastic processes: random walk, Poisson process, Gaussian random process, Markov chains, Brownian motion etc., pseudorandom process, nonlinear transformation of random process. Random process in frequency domain: Peridogram and power sprectral density, Weiner-Khintchine-Einstein Theorem, concept of bandwidth, spectral estimation. Linear system: Discrete time and continuous time LTI system, concept of convolution, system described in frequency domain, state space description of the system. Linear systems with random inputs: Linear system fundamentals, response of a linear system, convolution, mean, autocorrelation and cross correlation function in LTI system, power spectral density in LTI, cross power spectral density in LTI. Processing of random signals: Noise in systems, noise bandwidth, SNR, bandlimited random process, noise reduction, matched filter, Wiener filter. The Kalman filter: Mean square estimation, discrete Kalman filter, innovation, Kalman filter vs Wiener filter,properties of Kalman filter, Kalman Bucy filter, engineering examples.
Learning Outcomes	Complies with PLOs 1a, 2a, and 3a.
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem

Suggested Readings	**Text** 4. Miller, Scott, and Donald Childers, “probability and random processes: with applications to signal processing and communications”, Academic Press, 2012. 5. Wim C. van Etten, “Introduction to random signals and Noise”, Chichester, England: Wiley, 2005. 6. Peyton Z. Peebles, “Probability, random variables, and random signal principles”. McGraw Hill Book Company, 1987. **References** 1. Geoffrey R. Grimmett, and David Stirzaker, “Probability and random processes”, Oxford university press, 2001. 2. Alberto Leon-Garcia, “Probability, statistics, and random processes for Electrical engineering”, Upper Saddle River, NJ: Pearson/Prentice Hall, 2008. 3. Grewal, Mohinder, and Angus P. Andrews, “Kalman filtering: theory and practice with MATLAB”, John Wiley & Sons, 2014. 4. Alberto Leon-Garcia, “Probability, statistics, and random processes for Electrical engineering”, Upper Saddle River, NJ: Pearson/Prentice Hall, 2008. 5. Kay, Steven M, “Fundamentals of statistical signal processing”, Prentice Hall PTR, 1993. 6. H.L. Van Trees, “Detection, estimation, and modulation theory, part I”, New York, NY: John Wiley & Sons, Inc., 1971. 7. Brown, Robert Grover, and Patrick YC Hwang., “Introduction to random signals and applied Kalman filtering”, New York: Wiley, 1992. 8. Shovan Bhaumik, and Paresh Date, “Nonlinear estimation: methods and applications with deterministic Sample Points”, CRC Press, 2019. 9. Steven Key, “Intuitive probability and random processes using MATLAB®”, Springer Science & Business Media, 2006. 10. D. J. Gordana, “Random signals and processes primer with MATLAB”, Springer Science & Business Media, 2012

Course Number	**EC6252**
Course Credit	**L-T-P-C: 3-0-0-3**
Course Title	**Hardware Security System**
Learning Mode	Lectures
Learning Objectives	Complies with Program Goals 1 and 2
Course Description	A Hardware Security System focuses on protecting electronic hardware from various threats, including unauthorized access, tampering, and exploitation. The course typically covers topics such as secure hardware design principles, cryptographic algorithms, side-channel attacks, physical unclonable functions (PUFs), and hardware/software co-design for secure systems in applications ranging from IoT devices to critical infrastructure.
Course Outline	Review of modular arithmetic, Groups, rights and Fields, Polynomial fields, Galois Field arithmetic. Mapping between Binary and Composite Fields. Overview of Modern Cryptography: Stream ciphers, Block Ciphers, DES, AES, Rijndael in Composite Field, Elliptic Curves, Montgomery’s Algorithm for Scalar Multiplication. Modern Hardware Design: FPGA architecture, Mapping an Algorithm to Hardware, Hardware Design of Cryptographic Algorithms. Overview of Different Issues of Hardware Security, Useful hardware Security Primitives, Side-channel Attacks on Cryptographic Hardware, Testability and Verification of Cryptographic Hardware, Modern IC Design and Manufacturing Practices and Their Implications, Hardware Trojans. Differential Fault Analysis of Ciphers
Learning Outcomes	Complies with PLOs 1a, 1b, 2 and 3a
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Readings	**Text/References** 1. Christof Paar, Jan Pelzl, "Introduction to Cryptography" Springer 2010, ISBN: 978-3-642-44649-8 (Print) 978-3-642-04101-3 (Online) 2. Ingrid Verbauwhede (Eds), "Secure Integrated Circuits and Systems" Springer 2010, ISBN: 978-0-387-71827-9 (Print) 978-0-387-71829-3 (Online) Stefan Mangard, Elisabeth Oswald, Thomas Popp, "Power Analysis Attacks," Springer 2007, ISBN: 978-0-387-30857-9 (Print) 978-0-387-38162-6 (Online) 3. Debdeep Mukhopadhyay, Rajat Subhra Chakraborty, "Hardware Security: Design, Threats, and Safeguards," CRC Press 2015, ISBN 9781439895832

	4. Marc Joye, Michael Tunstall, "Fault Analysis in Cryptography," Springer 2012, ISBN: 978-3-642-29655-0 (Print) 978-3-642-29656-7 (Online)

Course Number	**EC6254**
Course Credit	**L-T-P-C: 3-0-0-3**
Course Title	**MEMS and NEMS**
Learning Mode	Lectures
Learning Objectives	Complies with Program Goals 1 and 2
Course Description	MEMS (Microelectromechanical Systems) involve the integration of mechanical elements, sensors, actuators, and electronics on a single semiconductor substrate at a microscale level. The course covers fabrication techniques, design principles, and applications in fields such as automotive, biomedical devices, and consumer electronics.
Course Outline	MEMS and Microsystems, Miniaturization, Typical products, Micro sensors, Micro actuation, MEMS with micro actuators, Micro-accelerometer's and Micro fluidics, MEMS materials, Micro fabrication , Elasticity, Stress, strain and material properties, Bending of thin plates, Spring configurations, torsional deflection, Mechanical vibration, Resonance, Thermo mechanics – actuators, force and response time, Fracture and thin film mechanics. Electrostatics: basic theory, electro static instability. Surface tension, gap and finger pull up, Electro static actuators, Comb generators, gap closers, rotary motors, inch worms, Electromagnetic actuators. bistable actuators. Electronic Interfaces, Feedback systems, Noise , Circuit and system issues, Case studies – Capacitive accelerometer, Peizo electric pressure sensor, Modelling of MEMS systems, CAD for MEMS. Optical MEMS, - System design basics – Gaussian optics, matrix operations, resolution. Case studies, MEMS scanners and retinal scanning display, Digital Micro mirror devices. RF Memes – design basics, case study – Capacitive RF MEMS switch, performance issues
Learning Outcomes	Complies with PLOs 1a, 1b, 2 and 3a
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Readings	<u>**Text**</u> 1. Stephen Santuria, "Microsystems Design", Kluwer publishers, 2000. References <u>**References**</u> 1. Nadim Maluf, "An introduction to Micro electro mechanical system design", Artech House, 2000 2. Mohamed Gad-el-Hak, editor," The MEMS Handbook", CRC press Baco Raton, 2000. 3. Tai Ran Hsu, "MEMS & Micro systems Design and Manufacture", Tata McGraw Hill, New Delhi, 2002.

Course Number	**EC6256**
Course Credit	**L-T-P-C: 3-0-0-3**
Course Title	**System-on-Programmable-Chip Design**
Learning Mode	Lectures
Learning Objectives	Complies with Program Goals 1 and 2
Course Description	System-on-Programmable-Chip (SoPC) Design involves integrating multiple hardware components, such as processors, memory, peripherals, and custom logic, onto a programmable platform like a Field-Programmable Gate Array (FPGA). The course covers topics such as hardware/software co-design, system architecture, IP core integration, and high-level synthesis tools for implementing complex functionalities efficiently on programmable devices.

Academic Program: M. Tech in VLSI and Embedded System

Course Outline	Introduction: Driving Forces for SoC - Components of SoC - Design flow of SoC - Hardware/Software nature of SoC - Design Trade-offs - SoC Applications System-level Design: Processor Selection-Concepts in Processor Architecture: Instruction set architecture (ISA), elements in Instruction Handing-Robust processors: Vector processor, VLIW, Superscalar, CISC, RISC—Processor evolution: Soft and Firm processors, Custom-Designed processors- on-chip memory. Interconnection: On-chip Buses: basic architecture, topologies, arbitration and protocols, Bus standards: AMBA, Core Connect, Wishbone, Avalon - Network-on-chip: Architecture-topologies-switching strategies - routing algorithms - flow control, Quality-of-Service- Reconfigurability in communication architectures. IP based system design: Introduction to IP Based design, Types of IP, IP across design hierarchy, IP life cycle, Creating and using IP - Technical concerns on IP reuse – IP integration - IP evaluation on FPGA prototypes. SOC implementation: Study of processor IP, Memory IP, wrapper Design - Real-time operating system (RTOS), Peripheral interface and components, High-density FPGAs - EDA tools used for SOC design. SOC testing: Manufacturing test of SoC: Core layer, system layer, application layer- P1500 Wrapper Standardization-SoC Test Automation (STAT).
Learning Outcomes	Complies with PLOs 1a, 1b, 2 and 3a
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Readings	**Text/References** 1. Michael J.Flynn, Wayne Luk, “Computer system Design: System on-Chip”, Wiley-India, 2012. 2. Sudeep Pasricha, Nikil Dutt, “On Chip Communication Architectures : System on Chip Interconnect”, Morgan Kaufmann Publishers, 2008. 3. W.H.Wolf, “Computers as Components: Principles of Embedded Computing System Design”, Elsevier, 2008.

Course Number	**EC6257**
Course Credit	**L-T-P-C: 3-0-0-3**
Course Title	**Network on Chip**
Learning Mode	Lectures
Learning Objectives	Complies with Program Goals 1 and 2
Course Description	Network on Chip (NoC) refers to a scalable and efficient communication architecture for integrating multiple processing elements (PEs) or IP cores on a single semiconductor chip. The course typically covers topics such as NoC design principles, routing algorithms, arbitration mechanisms, and performance analysis for complex system-on-chip (SoC) designs.
Course Outline	Introduction to Network layers and Network Architecture; Network on Chip: System-on-Chip Integration and Its Challenges; SoC to Network-on-Chip: A Paradigm Shift; NOC: Interconnection Networks, Architecture Design, Evaluation of Network-on-Chip Architectures, Application Mapping, Low-Power Techniques, Signal Integrity and Reliability, Testing, On-Chip multiprocessors: Integration and applications; Network Protocols on Chip: Case Studies of design, development and testing; Selective Communication Networks and protocols on Chip: Design and development methods; SoCs based NoCs: Examples; Neural Network on Chip: Design and implementation and their performance analysis and challenges with case studies.
Learning Outcomes	Complies with PLOs 1a, 1b, 2 and 3a
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Readings	**Text/References** 1. Santanu Kundu, Santanu Chattopadhyay, “Network-on-Chip: The Next Generation of System-on-Chip Integration”, CRC press, 2014. 2. Jose Flich, Davide Bertozzi, “Designing Network On-Chip Architectures in the Nanoscale Era”, CRC press, 2010. 3. De Micheli & Benini, “Networks on Chips”, Elsevier, 2006

Academic Program: M. Tech in VLSI and Embedded System

Course Number	**EC6258**
Course Credit	**L-T-P-C: 3-0-0-3**
Course Title	**Real Time Embedded Operating System**
Learning Mode	Lectures
Learning Objectives	Complies with Program Goals 1 and 2
Course Description	The Real-Time Embedded Operating Systems course focuses on the design and implementation of operating systems for embedded applications. It covers real-time scheduling, resource management, and system-level integration for efficient and reliable operation.
Course Outline	Introduction and evolution of high-performance embedded computing system. Basics of Computer Design & Performance Evaluation: Defining Computer Architecture, Quantitative Principles of Computer Design, CPU Performance & its factors, SPEC Benchmarks. Computational model: Basic computational models, Abstract level of processor, Open Source ISA, Micro-Architecture, High performance computer arithmetic architectures, Instruction level Parallelisms: ILP concepts, Dependencies between instructions, preserving sequential consistency. Pipelining: Introduction to pipelining, Instruction pipeline design, Pipeline hazards, deep pipeline microarchitecture and micro-operation, Superscalar Processors: Introduction, Parallel decoding, Superscalar instruction issue, Shelving, Register Renaming, Memory System: Memory hierarchy, Memory system Performance, Cache Memory, Cache Coherence, Memory Consistency, Cache Performance Issues, Shared Memory Organization. High performance Bus Architecture, Parallel Virtual Machine Architecture and programming model. Multicore and multiprocessor architecture, VLIW processor architectures. Array and vector processors. Introduction Embedded Co-Processor: GPU and ML Accelerator
Learning Outcomes	Complies with PLOs 1a, 1b, 2 and 3a
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Readings	<u>**Text/References**</u> 1. John L. Hennessy and David A. Patterson, "Computer Architecture-A Quantitative Approach", 6th Edition, Elsevier, 2019. 2. John L. Hennessy and David A. Patterson, "Computer Organization and Design", Morgan Kaufmann Publisher, 2nd Edition, 2021. 3. S. R. Sarangi, "Advanced Computer Architecture", 1st Edition, 2021. 4. Sima, Fauntain, Kscucle, "Advanced Computer Architecture a design space approach", Pearson, 7th Edition, 2009. 5. Kai Hwang, "Advanced Computer Architecture", McGrawHill publication, 2003.

Course Number	**EC6270**
Course Credit	**L-T-P-C: 3-0-0-3**
Course Title	Advance FPGA Platform and System
Learning Mode	Lectures
Learning Objectives	Complies with Program Goals 1 and 2
Course Description	Advance FPGA platform and system focuses on the methods of design, development and implementation of complex digital systems using advanced Field-Programmable Gate Arrays (FPGAs) fabrics platform. The course covers topics such as advance FPGA architecture, design methodologies, IP core integration, and implementation of Digital signal processing, control and communication Systems. It also highlights the methods and tools for implementation of Machine learning algorithms.
Course Outline	Introduction to reconfigurable and FPGA based system Design; Basic and Advanced FPGA Fabrics; Combinational and Sequential logic realization on FPGA; Issues on FPGA based system Design: Area, Timing and Power; Design; Behavioral /high level Design and implementation methodologies: HDL, IP Core, System Generator; Processor and memory cores; Timing analysis; Clock distribution and

	management systems; Large scale System Design: Platform FPGA, Multi-FPGA System; Busses and I/O communication system; DSP system Design and Implementation using FPGA; FPGA based Embedded system platform: Design and implementation methods. Introduction to Implementation methods and tools for machine learning algorithms. Advance FPGA for real time application: A Case Studies on signal processing, Communication and control systems.
Learning Outcomes	Complies with PLOs 1a, 1b, 2 and 3a
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Readings	**Text/References** 1. Steve Kilts, "Advanced FPGA design – Architecture, Implementation and Optimization", Wiley publications,2007.7. Samir Palnitkar, "Verilog HDL: A Guide to Digital Design and Synthesis", Second Edition, Prentice Hall PTR, 2003. 2. Wayne Wolf, "FPGA-Based System Design", Prentice Hall Modern Semiconductor Design Series, 2004. 3. Ron Sass and Andrew G. Schmidt, Morgan Kaufmann (MK), "Embedded System design with Platform FPGAs", Elsevier,2010.

Course Number	**EC6271**
Course Credit	**L-T-P-C: 3-0-0-3**
Course Title	Generative AI for Video Surveillance System
Learning Mode	Lectures
Learning Objectives	Complies with Program Goals 6 and 7
Course Description	This course introduces students to the theoretical foundations and practical applications of generative artificial intelligence (AI) in video surveillance systems. Students will learn about various generative models and their applications in video synthesis, anomaly detection, and activity recognition within surveillance scenarios.
Course Outline	**Module 1: Image and Video Processing** • Basics of Image Processing • Basics of Video Compression and Motion Analysis • Background Modelling • Object detection and classification • Human Activity Recognition • Video Object Tracking **Module 2: Video Surveillance Systems** • Foreground and Background Detection • Segmentation and Tracking • Behaviour analysis of individuals and groups • Static and Dynamic analysis of crowds **Module 3: Introduction to Generative AI** • Overview of generative AI and its applications • Introduction to generative models • Key concepts: generative models vs. discriminative models, probability distributions

	Module 4: Fundamentals of Deep Learning • Introduction to deep learning and neural networks • Training neural networks: backpropagation, optimization algorithms • Regularization techniques: dropout, L1/L2 regularization • Convolutional Neural Networks (CNNs), Recurrent Neural Networks (RNNs) and Long and Short Term Memory (LSTM) for generative tasks **Module 5: Variational Autoencoders (VAEs)** • Introduction to autoencoders • Understanding VAEs: encoder, decoder, and latent space • Variational inference and the reparameterization trick • Applications of VAEs: image generation, data compression **Module 6: Generative Adversarial Networks (GANs)** • Introduction to GANs and their components (generator, discriminator) • GAN training process: minimax game, adversarial loss • Architectural variations: DCGAN, WGAN, Conditional GAN, SR GAN, Cycle GAN • GAN applications: image synthesis, style transfer, super resolution **Module 7: Transformers** • Introduction and Evolution: Explore Transformer evolution and key components. • Transformer Architecture: Study encoder-decoder stacks and attention mechanisms. • Training Strategies: Compare pre-training, fine-tuning, and optimization techniques. • Applications: Examine text, image, and video generation tasks. • Recent Trends: Review Vision Transformers, Video Vision Transformers, GPT, DALL-E and BERT. **Module 8: Hands-on Projects and Case Studies** • Practical implementation of generative AI models using popular frameworks (e.g., TensorFlow, PyTorch) • Guided projects and assignments to reinforce concepts learned • Case studies showcasing real-world applications of generative AI
Learning Outcomes	Complies with PLOs 6a, 6b, 7 and 8a
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Readings	**<u>Text and References</u>** 1. M. H. Kolekar, “Intelligent video surveillance systems: an algorithmic approach”, Chapman and Hall/CRC; 2018 Jun 27. 2. F. Chollet, “Deep learning with Python”, Simon and Schuster; 2021 Dec 7. 3. J. Babcock, R. Bali, “Generative AI with Python and TensorFlow 2: Create images, text, and music with VAEs, GANs, LSTMs, Transformer models”, Packt Publishing Ltd; 2021 Apr 30.