CURRICULUM AND SYLLABUS OF

M. Tech.

IN

ELECTRONICS DESIGN AND TECHNOLOGY

(Applicable from 2023 admission onwards)

Department of Electronics and Communication Engineering
NATIONAL INSTITUTE OF TECHNOLOGY CALICUT
Kozhikode - 673601, KERALA, INDIA

The Programme Educational Objectives (PEOs) of M. Tech. in Electronics Design and Technology

PEO1	Graduates apply their fundamental knowledge in hardware, software and mathematics to build their chosen career in the electronics design industry
PEO2	Graduates utilize their skills in analyzing real life problems with high sensitivity to the needs of society, and provide solutions which are economically and socially feasible
PEO3	Graduates exhibit their competency and innovative skills to be an effective part of the research field of electronics design and development
PEO4	Graduates possess high level of motivation to continue in their chosen field of career and to acquire greater technical knowledge and develop higher skills as technology advances

Programme Outcomes (POs) & Programme Specific Outcomes (PSOs) of M. Tech. in Electronics Design and Technology

PO1	An ability to independently carry out research/investigation and development work to solve practical problems
PO2	An ability to write and present a substantial technical report/document
PO3	Students should be able to demonstrate a degree of mastery over the area as per the specialization of the programme. The mastery should be at a level higher than the requirements in the appropriate bachelor programme.
PSO 1	Ability to understand the steps in designing electronic systems which are in tune with current technology and adaptable for future changes
PSO 2	Develop passion for hardware and software design and capable of being a part of the electronic design industry and become leaders in indigenous product development

CURRICULUM

The minimum number of credits to be earned by a student for the award of the degree is 75. The total credits must not exceed 77

COURSE CATEGORIES AND CREDIT REQUIREMENTS:

The structure of M.Tech. programme shall have the following Course Categories:

Sl. No.	Course Category	Minimum Credits
1.	Programme Core (PC)	23
2.	Programme Electives (PE)	15
3.	Institute Elective (IE)	2
4.	Projects	35

The effort to be put in by the student is indicated in the tables below as follows:
L: Lecture (One unit is of 50-minute duration)
T: Tutorial (One unit is of 50-minute duration)
P: Practical (One unit is of one hour duration)
O: Outside the class effort / self-study (One unit is of one hour duration)

PROGRAMME STRUCTURE

Semester 1

Sl.No	Course Code	Course Title	L	T	P	O	C	Category
1	EC6101E	Design of Digital Systems	3	0	2	7	4	PC
2	EC6102E	Embedded System Design	3	0	2	7	4	PC
3	EC6103E	Applied Mathematics for Electronics Design	3	0	2	7	4	PC
4		Elective 1	3	0	0	6	3	PE
5		Elective 2	3	0	0	6	3	PE
6		Institute Elective					2	IE
		Total credits					20	

Semester 2

Sl.No	Course Code	Course Title	L	T	P	O	C	Category
1	EC6104E	Electromagnetic Compatibility	3	0	2	7	4	PC
2	EC6105E	Electronics Product Design	2	0	2	5	3	PC
3	EC6106E	Design of Cyber Physical Systems	3	0	2	7	4	PC
4		Elective 3	3	0	0	6	3	PE
5		Elective 4	3	0	0	6	3	PE
6		Elective 5	3	0	0	6	3	PE
7	EC6196E	Project Phase I	0	0	0	6	2	PC
		Total credits					22	

Semester 3

Sl. No	Course Code	Course Title	L	T	P	O	C	Category
1	EC7197E	Project Phase II	0	0	0	9	3	PC
2	EC7198E	Project Phase III	0	0	0	45	15	PC
		Total credits					18	

Semester 4

Sl. No	Course Code	Course Title	L	T	P	O	C	Category
1	EC7199E	Project Phase IV	0	0	0	45	15	PC
		Total credits					15	

List of Electives

Institute Elective Basket (Students need to credit Minimum 2 credits from this basket):

Sl. No.	Course Code	Course Title	L	T	P	O	Credits
1	IE6001E	Entrepreneurship Development	2	0	0	4	2
2	ZZ6001E	Research Methodology	2	0	0	4	2
3	MS6174E	Technical Communication and Writing	2	1	0	3	2

Elective Basket 1 (Students need to credit Minimum 3 credits from this basket):

Sl. No.	Course Code	Course Title	L	T	P	O	Credits
1	EC6121E	Control System Design	3	0	0	6	3
2	EC6122E	Electronic Packaging	3	0	0	6	3
3	EC6123E	Mechatronics	3	0	0	6	3
4	EC6124E	Data Structures and Algorithms	3	0	0	6	3
5	EC6125E	Analog and Data Conversion Systems	3	0	0	6	3
6	EC6126E	High Speed Digital Design	3	0	0	6	3
7	EC6127E	Internet of Things	3	0	0	6	3
8	EC6128E	Open-Source Processor architectures	3	0	0	6	3
9	EC6129E	Mathematical Foundations of Machine Learning	3	0	0	6	3
10	EC6130E	Machine Learning for Intelligent Systems	3	0	0	6	3
11	EC6131E	Reconfigurable System-on-Chip	2	0	2	5	3

Elective Basket 2 (Students need to credit Minimum 3 credits from this basket):

Sl. No.	Course Code	Course Title	L	T	P	O	Credits
1	EC6221E	VLSI Technology	3	0	0	6	3
2	EC6222E	MEMS Structures and Applications	3	0	0	6	3
3	EC6242E	CMOS RF IC Design	3	0	0	6	3
4	EC6245E	CMOS Image Sensors	2	0	2	5	3
5	EC6246E	Architectural Design of Digital Integrated Circuits	3	0	0	6	3
6	EC6247E	Digital VLSI Testing	3	0	0	6	3
7	EC6248E	Verification of VLSI Systems	2	0	2	5	3
8	EC6249E	VLSI Digital Signal Processing	3	0	0	6	3
9	EC6443E	Autonomous Intelligent System	2	0	2	5	3

Students can credit a maximum of two elective courses, each having minimum 3 credits, from courses offered in any M. Tech. specialization by the Institute, with the consent of the Programme Coordinator and the Course Faculty.

Syllabus for M. Tech. in Electronics Design and Technology

EC6101E DESIGN OF DIGITAL SYSTEMS

Pre-requisites: NIL

L	T	P	O	C
3	0	2	7	4

Total Sessions: 39L+26P

Course Outcomes:

CO1: Interpret the constructs of Hardware Description Language.

CO2: Design digital circuits and model them at different levels of abstraction.

CO3: Develop synthesizable RTL code targeting ASIC/FPGA.

CO4: Identify the problems with synchronous designs and address them.

Lecture Sessions

Introduction to digital design methodology using HDL - Design flow - Modeling abstraction levels, gate level model, RTL model, behavioral model - Simulation and synthesis - Modeling for ASIC/FPGA - Language concepts - Data types and operators - Structural, data flow and behavioral models - Hierarchical structure - Combinational and sequential circuit description - Continuous and procedural assignments - Blocking and non-blocking assignments - Tasks and functions - Interfaces - Delay modeling - Parameterized reusable design - System tasks - Compiler directives - Testbenches.

Datapath and controllers - Complex state machine design - Modeling FSMs - State encoding - Modeling memory - Basic pipelining concepts - Pipeline modeling - Clock domain crossing - Modeling of arithmetic functions - Impediments to synchronous design: clock skew, gating the clock, asynchronous inputs, synchronizer failure and metastability - Synchronizer design - Synchronizing high speed data transfers - Timing analysis.

Introduction to synthesis - Logic synthesis - RTL synthesis - High-level synthesis, Synthesis of combinational logic, priority structures, sequential logic with latches and flip-flops - Unintentional latches - Synthesis of state machines - Registers and counters - Clocks - Loops - Code optimizations - Design examples - Programmable LSI techniques - PLA/PAL/PLDs - CPLD and FPGAs - Xilinx/Altera series FPGAs - Programmable System on Chip - Zynq SoC design overview.

Practical Sessions

Introduction to HDL simulator, design and testbench code, backtrace and debug using waveform viewer – Model combinational/sequential logic circuits using structural, data flow and behavioral models – Model finite state machines in different styles – Synthesis and backend flow for FPGA – Implementation of digital circuits/systems on reconfigurable devices – Debug using ILA – Create custom IP and reuse.

References:

1. Stuart Sutherland, Simon Davidmann, Peter Flake, *SystemVerilog for Design: A Guide to Using SystemVerilog for Hardware Design and Modeling*, Second Edition, Springer Science & Business Media, 2006.
2. Michel D. Ciletti, *Advanced digital design with the Verilog HDL*, Second Edition, Pearson, 2010.
3. John F Wakerley, *Digital Design Principles and Practice*, Fifth Edition, Pearson education, 2018
4. J. Bhasker, *Verilog HDL Synthesis: A Practical Primer*, B. S. Publications, 2001.
5. Crockett LH, Elliot RA, Enderwitz MA, Stewart RW, *The Zynq Book: Embedded Processing with the Arm Cortex-A9 on the Xilinx Zynq-7000 All Programmable Soc*, Strathclyde Academic Media, 2014.

EC6102E EMBEDDED SYSTEM DESIGN

Pre-requisites: NIL

L	T	P	O	C
3	0	2	7	4

Total Sessions: 39L+26P

Course Outcomes:

CO1: Summarize the general architecture of an embedded system and the components involved in the design.

CO2: Illustrate the architecture of ARM processors.

CO3: Outline OS/RTOS/ its components and assess various scheduling algorithms.

CO4: Design an embedded system for a given application

Lecture Sessions

Review of general architecture of a computing system. CISC, RISC, Harvard, Von-Neumann Architectures-Overview of Embedded Systems – General architecture, Sensors and Actuators, characteristics, Real Life examples, Embedded system Design aspects – Examples of typical Components used, their selection criteria, interfacing aspects, Low power design concepts - Embedded Programming – IDE, Compiler/Assembler, Simulator/Emulator - Introduction to applications of Embedded Systems in modern era – IoT, Edge computing, Electric vehicles, Health care, Cyber physical systems etc.

Processing elements – Microprocessor, Micro controller, System on chip (SoC), Digital Signal Processors (DSP), Application Specific IC (ASIC), Field Programmable Gate Arrays (FPGA). Basic concepts of Embedded system design using these elements - Typical architecture of a microcontroller unit by taking ARM Cortex as an example. Register architecture, Instruction set, GPIO, timer/counter, watch dog timer, Stack, Interrupts, DMA and other peripherals - Programming and Design examples of embedded system using ARM Cortex based processors - Buses& Protocols – I2C, SPI, UART, USB, CAN, AMBA. Ethernet/WLAN/Bluetooth/Zigbee.

Operating systems – Need for operating systems in Embedded application, Functions of Operating systems, The kernel, Task/Process, Thread, Inter Process Communication, Task synchronization, Semaphores, Priority inversion, Device drivers. Various Scheduling algorithms - Pre-emptive/Non-pre-emptive methods - RTOS. Types of Real time tasks. Qualities of Good RTOS. Real time scheduling algorithms

Practical Sessions

Design and implementation of Embedded systems using ARM Cortex based processors – Interfacing of input devices like switch, LDR, IR sensor, Ultra sound sensors and output devices like LED, Relay, Motor etc. ADC interfacing, Waveform generation, Timer programming, Interrupts, Installing normal operation system on Embedded board, Usage of threads, task synchronization.

References:

1. Lyla.B.Das, Embedded Systems, *An Integrated Approach*, Pearson Ed, 2013
2. Zhu, Yifeng. *Embedded systems with arm cortex-m microcontrollers in Assembly language and C*. E-Man Press Llc, 2015.
3. Jonathan W Valvano, *Embedded systems: Introduction to ARM Cortex-m microcontrollers*, Fifth edition, 6th printing- January 2019, ISBN: 978-1477508992,
4. Jonathan W Valvano, *Embedded Systems: Real-Time Operating Systems for Arm Cortex M Microcontrollers*, Eighth printing, July 2021, ISBN: 978-1463590154

EC6103E APPLIED MATHEMATICS FOR ELECTRONICS DESIGN

Pre-requisites: NIL

L	T	P	O	C
3	0	2	7	4

Total Sessions: 39L+26P

Course Outcomes:

CO1: Illustrate the knowledge of numerical methods, linear algebra and optimization theory to comprehend Electronics System Design problems

CO2: Design mathematical frameworks to address real-world problems in Electronics Engineering.

CO3: Apply mathematical skills for analysis and independent research in the area of Electronics System Design.

Lecture Sessions

Mathematical modelling, analytical and numerical methods of solutions – Errors and approximation, Truncation error and Taylor series – Linear system of equations and methods of solutions, – Errors and ill conditioned systems - Numerical methods for solving Ordinary differential equations – Euler and Runge-Kutta methods, Boundary value problems and Eigenvalue problems. Numerical techniques for finding the roots of an equation – Termination criteria and error analysis –- Curve fitting - Regression and interpolation - Case studies from electric circuits.

Optimization – One-dimensional unconstrained optimization – Golden section search - multi-dimensional unconstrained optimization – Gradient methods – Constrained optimization – Linear programming – Dual problems – Sensitivity analysis – Convex optimization – Non-linear optimization – Case studies on optimization for system design

Vector spaces, Linear Independence, Basis and Rank, Linear Mappings, Norms, Inner Products, Orthonormal Basis, Orthogonal Projections, Determinant and Trace, Eigen Value and Eigen vectors, Eigen decomposition, Singular value decomposition, Gradients of matrices, Back propagation and automatic differentiation, Application to Linear Regression and Artificial neural networks. Signals and vectors, Inner product of signals, norm - notion of length of signal and distance between signals, orthogonal signal space, Fourier series representation, Fourier transform.

Practical Sessions

The practical sessions include experiments/projects which involve Dimensionality reduction using principal component analysis, Denoising using singular value decomposition, Logistic regression, Binary linear classifier, Curve fitting, Multilayer Perceptron etc

References:

1. Steven C. Chapra, Raymond P. Canale. *Numerical Methods for Engineers*, Seventh Edition, McGrawHill Education, 2015.
2. Charu C. Aggarwal, *Linear Algebra and Optimization for Machine Learning*, Springer, 2020.
3. Gilbert Strang, *Linear Algebra and Learning from Data*, Cambridge: Wellesley-Cambridge Press, 2019.

EC6104E ELECTROMAGNETIC COMPATIBILITY

Pre-requisites: NIL

L	T	P	O	C
3	0	2	7	4

Total Sessions: 39L+26P

Course Outcomes:

CO1: Summarize the importance of electromagnetic compatibility in electronic product design

CO2: Examine different parts of an electronic product for probable EMC failures and propose methods to solve them.

CO3: Choose design techniques to develop EM compatible electronic products.

Lecture Sessions

Need for Electromagnetic Compatibility, two aspects of EMC – Emission and Susceptibility, Radiation and Conduction, EMC regulations, designing for Electromagnetic Compatibility - Noise and Interference, Typical Noise path, Methods of noise coupling - Capacitive and Inductive Coupling, Effect of Shielding on capacitive and inductive coupling, Shielding to prevent magnetic radiation, shielding a receptor against magnetic fields, Shield Transfer Impedance -shielding properties of various cable configurations, coaxial cable and shielded twisted pair, braided shields, ribbon cables, Shield Terminations - Safety grounds, signal grounds, single point, multi-point and hybrid grounds, Chassis Grounds, Common Impedance Coupling, Grounding of cable shields, Ground loops and its breaking, Common Mode Choke – Analysis at low and high frequencies, Balancing and Filtering

Digital circuit grounding, internal noise sources, Digital circuit ground noise, minimizing ground impedance and loop area, ground grid, ground plane, Ground plane current distribution, ground plane impedance. Current flow in micro-strip and strip-line routing - Digital circuit power distribution- Transient power supply currents, decoupling capacitor design, effective decoupling strategies, decoupling capacitor selection and mounting - Radiated emission - Differential mode and common mode radiation – Reasons and controlling methods - Conducted emission – Power line impedance, Line impedance stabilization network, Common mode and differential mode noise sources in SMPS. Power line filters

PCB layout and stack up - General PCB layout Considerations, PCB to chassis ground connections, return path discontinuity, PCB layer stack up, General PCB design procedure, mixed signal PCB layout, Split planes, Ground connection and power distribution, vertical isolation - Near fields and far fields, characteristic and wave impedances, shielding effectiveness, absorption and reflection loss, shielding with magnetic material, apertures, conductive gaskets, conductive windows, conductive coating, grounding of shields - Electrostatic Discharge (ESD) -Static generation, human body model, static discharge, ESD protection in equipment design, Transient and Surge Protection Devices, ESD grounding, non-grounded products, software and ESD protection, ESD versus EMC, ESD Testing

Practical Sessions

EMC analysis of electronic systems using software's like ANSYS or equivalent which include - Near/far field EMI, parasitic extraction, circuit simulation, Cable harness design with appropriate shielding to minimize cross talk, radiation and susceptibility, Analysis of antenna radiation patterns, Cable and Circuit simulation, Analysis of the performance of electronic subsystems to be examined in electrically large environments. PCB design for good EMC performance.

References:

1. Henry W.Ott, *Electromagnetic Compatibility Engineering*, John Wiley & Sons, 2009.
2. Henry W.Ott, *Noise Reduction Techniques in Electronic Systems*, Second Edition, Wiley Interscience Publication, 1988.
3. Clayton R.Paul, *Introduction to Electromagnetic Compatibility*, Second Edition , Wiley Interscience Publication, 2006.

4. V. Prasad Kodali, *Engineering Electromagnetic Compatibility: Principles, Measurements, Technologies, and Computer Models*, Second Edition, IEEE Press, 2001.
5. Ralph Morrison, *Grounding and Shielding circuits and interference*, Fifth Edition, Wiley, 2007.

EC6105E ELECTRONIC PRODUCT DESIGN

Pre-requisites: NIL

L	T	P	O	C
2	0	2	5	3

Total Sessions: 26L+26P

Course Outcomes:

CO1: Assess the requirement for a new product by conducting a market survey.

CO2: Infer working knowledge of several electronic components and integration of these components to form a final product.

CO3: Examine the various stages involved in an electronic product development.

CO4: Build prototype of an electronic product undergoing different stages of product development life cycle.

Lecture Sessions

Life cycle of electronic products, product planning - Customer need identification, feasibility study, specifications etc. Design and development process, technical drawings, circuit diagrams, computer aided design.

Reliability of electronic products: Calculation principles – Terminologies, parameters, mathematical modelling, failure of electronic components and systems, reliability analysis design for manufacturing, design for testing, design for environment.

Industrial design, aesthetics, ergonomics, thermal design – Power dissipation in electronic components, temperatures of components and systems, electrical and thermal network methods of calculations, heat transfer, methods to increase heat transfer.

Practical Sessions

The students need to implement the prototype model of an electronic product undergoing different stages of product development life cycle, which include:

- Requirements/market study/feasibility study
- Finalizing the Specifications
- Mechanical design
- Ergonomics and Aesthetics
- Hardware Design
  - Component selection
  - Schematic Entry
  - Layout Design
  - PCB manufacturing and assembly
- Mechanical Assembly
- Software Design
- Testing.

In this process students will be familiarized with different tools and machines like Shop bot, 3D printer, Laser cutter, PCB fabrication machine & soldering tools.

References:

1. Jens Lienig, Hans Bruemmer, *Fundamentals of Electronic Systems Design*, Springer, 2017.
2. Karl T. Ulrich, Steven D. Eppinger, *Product Design and Development*, Mc Graw Hill, 2016.
3. V.B. Baru R.G.Kaduskar, *Electronic Product Design*, Wiley India 2011.
4. Tony Ward and James Angus, *Electronic Product Design*, Chapman &Hall 1996.

EC6106E DESIGN OF CYBER PHYSICAL SYSTEMS

Pre-requisites: NIL

L	T	P	O	C
3	0	2	7	4

Total Sessions: 39L+26P

Course Outcomes:

CO1: Identify various components of a cyber physical system

CO2: Design control system for cyber physical systems

CO3: Choose the suitable scheduling algorithm for a given application

CO4: Model digital twin for complex embedded systems

Lecture Sessions

Introduction to Cyber Physical Systems and applications – Industry standards and functional elements -Sensors, Processors and networks - Data acquisition and processing - Interfacing - Communication networks and protocols- Development of an IoT system – User requirements and specifications - Finite State Machines – Syntax, semantics, and realizability – Task scheduling in CPS -Case study for the development of CPS - Adaptive Embedded systems – Reactive components - Model based design

Dynamical Systems – Linear Systems - Continuous time models – Stability - Lyapunov Stability – Designing controllers – Open loop and closed loop control – PID Controller – Stability analysis – Timed systems - Timing-Based Distributed Coordination - Timed Automaton – Real-Time Scheduling – Periodic job model - Fixed-Priority Scheduling – Case study of design and analysis of dynamical systems

Concept of Digital twin – Integration levels - Computing and digital twin - Role of digital twins in Industrial IoT and Process Manufacturing - Digital twins for complex real time embedded systems

Practical Sessions

Modelling of physical systems, Interfacing of sensors with microprocessors/micro controllers, taking real time data, Interfacing of communication modules and communication with cloud. Implementation of control systems. Installation of RTOS on systems, Real Time scheduling, Modelling of Digital twin for simple systems, analysing of system using Digital Twin.

References:

1. Edward A. Lee and Sanjit A. Seshia, *Introduction to Embedded Systems, A Cyber-Physical Systems Approach*, Second Edition, MIT Press, 2017.
2. Rajeev Alur, *Principles of Cyber-Physical Systems*, MIT Press, 2015.
3. T. D. Lewis, *Network Science: Theory and Applications*, Wiley, 2009.
4. Twan Basten, Roelof Hamberg, Frans Reckers, Jacques Verriet., *Model Based Design of Adaptive Embedded Systems*, Springer Science & Business Media, 2013.
5. Ranjan Ganguli, Sondipon Adhikari, Souvik Chakraborty, Mrittika Ganguli, *Digital Twin: A Dynamic System and Computing Perspective*, CRC Press, 2023.

EC6196E PROJECT PHASE I

Pre-requisites: NIL

L	T	P	O	C
0	0	0	6	2

Course Outcomes:

CO1: Survey the literature on new research areas and compile findings on a particular topic

CO2: Organize and illustrate technical documentation with scientific rigor and adequate literal standards on the chosen topic strictly abiding by professional ethics while reporting results and stating claims

CO3: Develop aptitude for research and independent learning.

CO4: Demonstrate communication skills in conveying the collected data through technical reports and oral presentations using modern presentation tools.

The objective of this phase of the project is to impart training to the students in collecting materials on a specific topic in the broad domain of Engineering/Science from books, journals and other sources, compressing and organizing them in a logical sequence, and presenting the matter effectively both orally and in written format. The topic should not be a replica of what is contained in the syllabi of various courses of the M. Tech programme. The topic chosen by the student shall be approved by the project guide(s) and the evaluation committee. Based on the collected information and acquired knowledge, the student is expected to identify unresolved problems in the domain of the selected topic.

EC7197E PROJECT PHASE II

Pre-requisites: NIL

L	T	P	O	C
0	0	0	9	3

Course Outcomes:

CO1: Develop aptitude for research and independent learning

CO2: Demonstrate the ability to select unresolved problems in the domain of the selected project topic and explore suitable solutions

CO3: Illustrate the expertise to use new tools and techniques for the design and development.

CO4: Demonstrate communication skills in conveying the collected data through technical reports and oral presentations using modern presentation tools.

The work carried out in EC7102E Project Phase II is a continuation of EC6196E Project Phase I and to be continued in EC7198E and/or EC7199E. In these project phases, students get an opportunity to apply and extend knowledge acquired in the first and second semesters of their M. Tech. programme. The work will be carried out individually. The objective of the Project Phase II is to identify unresolved problems in the domain of the selected topic (if not done at the end of the second semester) and explore possible solutions. The proposed solution(s) shall be compared with the ones which are available in the literature or in practice using suitable methods along with a feasibility study. The work can be analytical, simulation, hardware design or a combination of these in the emerging areas of Electronic System Design under the supervision of a faculty from the ECE Department.

At the end of Project Phase II, students are expected to have a clear idea of the work to be done, and have learnt the analytical / software / hardware tools. Presenting preliminary designs and results are highly desirable. The students are also expected to submit an interim technical report including the project work carried out in this phase and the work plan for the forthcoming semester(s).

EC7198E PROJECT PHASE III

Pre-requisites: NIL

L	T	P	O	C
0	0	0	45	15

Course Outcomes:

CO1: Develop aptitude for research and independent learning

CO2: Apply the knowledge and awareness to carry out cost-effective and environment friendly designs.

CO3: Demonstrate the expertise to use new tools and techniques for the design and development.

CO4: Develop the ability to write good technical report, to make oral presentation of the work, and to publish the work in reputed conferences/journals.

The work carried out in EC7198E Project Phase III is a continuation of EC7197E Project Phase II and shall be continued in EC7199E or it can be an internship work carried out in an industry. In both cases, the work will be carried out individually. The objective of the Project Phase III is to design/develop the solution proposed in the Project Phase II using one or more of the following approaches: (i) Analytical models (ii) Computer simulations (iii) Hardware implementation. The project work of a student during the third semester is evaluated by a committee in two phases. The first evaluation shall be conducted in the middle of the semester. This should be followed by the end semester evaluation.

If a student plans for an internship in the fourth semester or exploring a different project topic in the fourth semester after doing the Project Phase III in the institute, the student should complete the work planned in the beginning of the third semester, attaining all the objectives and shall prepare a project report of the complete work starting from Project phase I to Project Phase III. If a student plans to continue the same work in the Project phase IV, a detailed project report should be submitted at the end of the Project Phase IV. In case of an internship, the work will be decided jointly by the guides of the student both in the institute and the internship organization. A detailed internship report shall be prepared and submitted by the student.

EC7199E PROJECT PHASE IV

Pre-requisites: NIL

L	T	P	O	C
0	0	0	45	15

Course Outcomes:

CO1: Develop aptitude for research and independent learning

CO2: Apply the knowledge and awareness to carry out cost-effective and environment friendly designs.

CO3: Demonstrate the expertise to use new tools and techniques for the design and development.

CO4: Develop the ability to write good technical report, to make oral presentation of the work, and to publish the work in reputed conferences/journals.

The work carried out in EC7199E Project Phase IV is a continuation of EC7198E Project Phase III or it can be an internship work carried out in an industry. At the end of the work, the students are expected to communicate their innovative ideas and results to reputed conferences and/or journals. The work carried out by the students in Project Phase IV will be evaluated in two phases.

IE6001E ENTREPRENEURSHIP DEVELOPMENT

Pre-requisites: NIL

L	T	P	O	C
2	0	0	4	2

Total Sessions: 26L

Course Outcomes:

CO1: Describe the various strategies and techniques used in business planning and scaling ventures.

CO2: Apply critical thinking and analytical skills to assess the feasibility and viability of business ideas.

CO3: Evaluate and select appropriate business models, financial strategies, marketing approaches, and operational plans for startup ventures.

CO4: Assess the performance and effectiveness of entrepreneurial strategies and actions through the use of relevant metrics and indicators.

Entrepreneurial Mindset and Opportunity Identification

Introduction to Entrepreneurship Development - Evolution of entrepreneurship, Entrepreneurial mindset, Economic development, Opportunity Recognition and Evaluation - Market gaps - Market potential, Feasibility analysis - Innovation and Creativity in Entrepreneurship - Innovation and entrepreneurship, Creativity techniques, Intellectual property management.

Business Planning and Execution

Business Model Development and Validation - Effective business models, Value proposition testing, Lean startup methodologies - Financial Management and Funding Strategies - Marketing and Sales Strategies - Market analysis, Marketing strategies, Sales techniques - Operations and Resource Management - Operational planning and management, Supply chain and logistics, Stream wise Case studies.

Growth and Scaling Strategies

Growth Strategies and Expansion - Sustainable growth strategies, Market expansion, Franchising and partnerships - Managing Entrepreneurial Risks and Challenges - Risk identification and mitigation, Crisis management, Ethical considerations - Leadership and Team Development - Stream wise Case studies

References:

1. Kaplan, J. M., Warren, A. C., & Murthy V. (Indian Adoption). *Patterns of entrepreneurship management*. John Wiley & Sons, 2022.
2. Kuratko, D. F. *Entrepreneurship: Theory, process, and practice*. Cengage learning, 2016.
3. Barringer, B. R. *Entrepreneurship: Successfully launching new ventures*. Pearson Education India, 2015
4. Rajiv Shah, Zhijie Gao, Harini Mittal, *Innovation, Entrepreneurship, and the Economy in the US, China, and India*, Academic Press, 2014
5. Dr. K. Sundar, *Entrepreneurship Development*, Vijaya Nichkol Imprints, Chennai, Second edition, 2022
6. E. Gordon,Dr. K. Natarajan, *Entrepreneurship Development*, 2017, Himalya Publishers,Delhi, sixth edition, 2017.
7. Debasish Biswas, Chanchal Dey,*Entrepreneurship Development in India*, Taylor & Francis, 2021

ZZ6001E RESEARCH METHODOLOGY

Pre-requisites: NIL

L	T	P	O	C
2	0	0	4	2

Total sessions: 26L

Course Outcomes:

CO1: Explain the basic concepts and types of research

CO2: Develop research design and techniques of data analysis

CO3: Develop critical thinking skills and enhanced writing skills

CO4: Apply qualitative and quantitative methods for data analysis and presentation

CO5: Implement healthy research practice, research ethics, and responsible scientific conduct

Exploring Research Inquisitiveness
Philosophy of Scientific Research, Role of Research Guide, Planning the Research Project, Research Process, Research Problem Identification and Formulation, Variables, Framework development, Research Design, Types of Research, Sampling, Measurement, Validity and Reliability, Survey, Designing Experiments, Research Proposal, Research Communication, Research Publication, Structuring a research paper, structuring thesis/ dissertation,

Research Plan and Path
Developing a Research Plan: Reviewing the literature- Referencing – Information sources – Information retrieval – Role of libraries in information retrieval – Tools for identifying literatures – Reading and understanding a research article – Critical thinking and logical reasoning; Framing the research hypotheses, Converting research Question into a Model; Data collection- Types of data-Dataset creation- Primary and Secondary data- Scales of measurement-Sources and collection of data- Processing and analysis of data-Understanding Data-statistical analysis, displaying of data-Data visualization-Data interpretation; Research design- Qualitative and Quantitative Research- Designing of experiments- Validation of experiments- Inferential statistics and result interpretation

Scientific Conduct and Ethical Practice
Plagiarism– Ethics of Research- Scientific Misconduct- Forms of Scientific Misconduct. Plagiarism, Unscientific practices in thesis work-Conduct in the workplace and interaction with peers – Intellectual property: IPR and patent registration, copyrights; Current trends – Usage and ethics of AI tools in scientific research.

References:

1. Leedy, P D, "*Practical Research: Planning and Design",* USA: Pearson, Twelfth ed., 2018.
2. Krishnaswamy, K. N., Sivakumar, A. I., and Mathirajan, M., "*Management Research Methodology"*, Pearson Education, 2006.
3. Tony Greenfield and Sue Greener., *Research Methods for Postgraduates*, USA: John Wiley & Sons Ltd., third edition, 2016.
4. John W. Creswell and J. David Creswell, "*Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*", USA: Sage Publications, Sixth edition., 2022

MS6174E TECHNICAL COMMUNICATION AND WRITING

Pre-requisites: NIL

L	T	P	O	C
2	1	0	3	2

Total Sessions: 26L

Course Outcomes:

CO1: Apply effective communication strategies for different professional and industry needs.

CO2: Collaborate on various writing projects for academic and technical purposes.

CO3: Combine attributes of critical thinking for improving technical documentation.

CO4: Adapt technical writing styles to different platforms.

Technical Communication

Process(es) and Types of Speaking and Writing for Professional Purposes - Technical Writing: Introduction, Definition, Scope and Characteristics - Audience Analysis - Conciseness and Coherences - Critical Thinking - Accuracy and Reliability - Ethical Consideration in Writing - Presentation Skills - Professional Grooming - Poster Presentations

Grammar, Punctuation and Stylistics

Constituent Structure of Sentences - Functional Roles of Elements in a Sentence - Thematic Structures and Interpretations - Clarity - Verb Tense and Mood - Active and Passive Structures - Reporting Verbs and Reported Tense - Formatting of Technical Documents - Incorporating Visuals Elements - Proofreading

Technical Documentation

Types of Technical Documents: Reports, Proposals, Cover Letters - Manuals and Instructions - Online Documentation - Product Documentation - Collaborative Writing: Tools and Software - Version Control Document Management - Self Editing, Peer Review and Feedback Processes

References:

1. Foley, M., & Hall, D. *Longman advanced learner's grammar, a self-study reference & practice book with answers*. Pearson Education Limited, 2018.
2. Gerson, S. J., & Gerson, S. M. *Technical writing: Process and product*. Pearson, 2009
3. Kirkwood, H. M. A., & M., M. C. M. I. *Hallidays introduction to functional grammar, fourth edition*. Hodder Education, 2013.
4. Markel, M. T*echnical Communication*, tenth edition. Palgrave Macmillan, 2012.
5. Tuhovsky, I. *Communication skills training: A practical guide to improving your social intelligence, presentation, Persuasion and public speaking skills.* Rupa Publications India, 2019.
6. Williams, R. *The Non-designer's Design Boo*k. Peachpit Press, 2014

EC6121E CONTROL SYSTEM DESIGN

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Sessions: 39L

Course Outcomes:

CO1: Outline the classical analog control technique and its design.

CO2: Design of digital control system

CO3: Analysis of multi-input multi output control systems

Classical control system and State Space model
Review of basic elements of control systems: classical control techniques, transfer function approach, PID controller design - State-Space Models: Controllability and state transfer, observability and state estimation – Pole placement – State feedback approach.

Design of Digital control system
Digital control systems: Sampling and reconstruction of signals, z transforms - pulse transfer function and analysis of digital control systems, discretization methods, cascade and feedback compensation from continuous data controllers - Dead beat controller design - Digital controllers: Root locus, Bode plot, Nyquist plot methods - Design of digital PID controller – State space analysis of digital control systems - Control design based on optimization.

Analysis of MIMO control systems
Controller realization structures: Canonical forms, effects of finite word length on controllability and closed loop pole placement - MIMO Control: Models for multivariable systems, the basic MIMO control loop, closed loop stability, steady state response for step inputs, frequency domain analysis, robustness issues, exploiting SISO control techniques in MIMO control.

References:

1. Dorf, Richard C. and Robert H. Bishop. *Modern Control Systems*, Fourteenth edition., Pearson Education, 2022.
2. Benjamin C Kuo and Colnaraghi Farid, *Automatic Control Systems*, Nineth edition, John Wiley & Sons, 2009.
3. Ogata, Katsuhiko, *Discrete-time control systems*, Second edition, Pearson Education India, 2015.
4. Graham C. Goodwin, Stefan F. Graebe, and Mario E. Salgado, *Control system design*, First edition, Pearson Education, 2000.
5. Nise, Norman S. *Control systems engineering*, Eighth edition, John Wiley & Sons, 2020.

EC6122E ELECTRONIC PACKAGING

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Sessions: 39L

Course Outcomes:

CO1: Understand the relevance of packaging for electronic systems

CO2: Elaborate various materials and techniques used in electronic packaging

CO3: Inspect electronic package for reliability, thermal management and testability.

Basics of electronic packaging

Fundamentals: Functions of an electronic package, packaging hierarchy, driving forces on packaging technology - Materials for microelectronic packaging: Packaging material properties, ceramics, polymers and metals in packaging - Electrical anatomy of systems packaging: signal distribution, power distribution, electromagnetic interference.

Packaging techniques

IC Assembly: Purpose, requirements, technologies, wire bonding, tape automated bonding, flip chip, wafer level packaging - Different types of IC packages: Dual-in-line Package (DIP), Quad Flat Package (QFP) etc.- Systems packaging: MCM /SoC/SiP/SoP - Discrete, integrated and embedded passives - Printed Circuit Board: Anatomy, CAD tools for PCB design, standard fabrication, microvia boards - Board assembly: Surface mount technology, through-hole technology, process control and design challenges.

Reliability of packaging

Design for reliability: Fundamentals, induced failures - Thermal management for IC and PWBs: Cooling requirements, electronic cooling methods - Electrical testing: System level electrical testing, interconnection tests, active circuit testing - Design for testability - Trends in packaging.

References:

1. Rao R. Tummala, *Fundamentals of Microsystem Packaging*, First edition, McGraw Hill, 2001.
2. Richard K. Ulrich &William D. Brown *Advanced Electronic* Packaging, Second edition, IEEE Press, 2006
3. Rao R. Tummala, MadhavanSwaminathan, *Introduction to System-on-Package (SOP)*, First edition, McGraw Hill, 2008.

EC6123E MECHATRONICS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Sessions: 39L

Course Outcomes:

CO1: Identify key elements of mechatronics system and its functioning.

CO2: Choose suitable sensors and actuators based on product requirements.

CO3: Design mechatronic systems by integrating suitable components for a given application.

Introduction - definition of mechatronics, mechatronics in manufacturing, products, and design. comparison between traditional and mechatronics approach - Sensors and Transducers - performance terminology, displacement, position and proximity, torque, velocity, motion and temperature, force, fluid pressure, liquid flow, liquid level, temperature, light sensors, selection of sensors, inputting data by switches - Actuators - pneumatic and hydraulic systems, directional control valves, pressure control valves, cylinders, servo and proportional control valves, process control valves, Mechanical systems - types of motion, kinematic chains, cams, gears, ratchet and pawl, belt and chain drives, bearings, Electromechanical linear actuators - mechanical switches, solid state switches, solenoids, direct current motors, alternating current motors, stepper motors, direct current servomotors, motor selection.

Signal conditioning - the operational amplifier, protection, filtering, wheatstone bridge, pulse modulation, problems with signals, power transfer, digital signals, analogue and digital signals, digital-to-analogue and analogue-to-digital converters, data conversion devices, signal processing devices, relays, contactors and timers - Programmable logic controller - PID controllers and PLCs, microprocessor systems, microcontrollers, applications, programming embedded system.

System models - mathematical models, mechanical system building blocks, electrical system building blocks, fluid system building blocks, thermal system building blocks, engineering systems, rotational–translational systems, electromechanical systems, linearity, hydraulic–mechanical systems, dynamic responses of systems, performance measures for second-order systems, mechatronic designs, robotic system.

References:

1. De Silva, Clarence W. *Mechatronics: a foundation course*. CRC press, 2010.
2. Samanta, Biswanath. *Basic Control Systems. In Introduction to Mechatronics: An Integrated Approach*, pp. 295-331. Cham: Springer International Publishing, 2023.
3. Onwubolu, Godfrey. *Mechatronics: principles and applications*. Elsevier, 2005.
4. Bolton, William. *Mechatronics: electronic control systems in mechanical and electrical engineerin*g. Pearson Education, 2003.
5. Bishop, Robert H. *Mechatronic Systems. Sensors and Actuators: Fundamentals and Modelin*g, CRC Press. Boca Raton, 2008.
6. Kamm, Lawrence J. *Understanding electro-mechanical engineering: an introduction to mechatronics*. John Wiley & Sons, 1995.

EC6124E DATA STRUCTURES AND ALGORITHMS

Pre-requisite: NIL

L	T	P	O	C
3	0	0	6	3

Total Sessions: 39L

Course Outcomes:

CO1: Analyze different algorithms in terms of their space and time complexity.

CO2: Model systems as classes to enable ease of problem solving.

CO3: Identify problems and model them as trees and graphs.

CO4: Assess and compare different sorting algorithms.

General concepts of object oriented programming C++ - Class overview : Class definition, access Control, class Scope, constructors and destructors, inheritance, polymorphism, overloading, encapsulation, friend functions - Dynamic memory allocation and deallocation - Complexity analysis - Asymptotic notation - Recursion - Sorting algorithms : Selection sort, quick sort, merge Sort - Abstract data types : Linked lists, stack and queue - Searching : Linear and binary search implementation - Implementation of sorting, searching, linked lists, stack and queues using C++.

Binary tree: in-order, pre-order and post-order traversals - Representation and evaluation of arithmetic expressions using binary trees - Binary Search trees: Insertion, deletion and search - Prefix, Infix and postfix representation and conversions - Heaps and heap sort - Implementation of tree algorithms using C++.

Graph representation: Adjacency matrix, adjacency list - Graph Search Algorithms: Depth First Search (DFS), breadth First Search (BFS) - Minimum spanning tree problem: Kruskal's algorithm, Prim's algorithm - Shortest path problem: Dijkstra's algorithm - Implementation of graph algorithms using C++ and the standard template library - Hashing: Chaining, linear probing, double hashing.

References:

1. D.Ravichandran, *Programming with C++*,Third Edition, Mc Graw Hill Education, 2011.
2. Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest, and Clifford Stein, *Introduction to Algorithms*, Fourth Edition, MIT, 2022.
3. Yedidyah Langsam, MosheJ.Augenstein, AaronM.Tanenbaum, *Data Structures using C++*, Pearson Education, 2016.
5. Larry Nyhoff , *ADTs, Data Structures and Problem Solving with C++*, Second Edition, Pearson Education 2012.
6. Sahni S., *Data Structures, Algorithms, and Applications in C++*, Fourth Edition, Mc Graw Hill, Singapore, 2004.

EC6125E ANALOG AND DATA CONVERSION SYSTEMS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Sessions: 39L

Course Outcomes:

CO1: Interpret static and dynamic specifications of data conversion systems

CO2: Develop testing setup to characterize ADCs and DACs

CO3: identify error sources and minimize the error in data converters

CO4: Improve the accuracy of data conversion systems with proper design choices for the support circuits

Sampling, Nyquist criteria, need for sample and hold circuit, sample and hold/track and hold circuits, quantization, noise in data converters, input referred noise, static non-linearity, harmonic distortion, signal-to-noise-distortion ratio, spurious free dynamic range, timing issues, aperture time and jitter, DAC architectures, binary weighted, R-2R and segmented DACs, ADC architectures, data conversion principles of flash, subranging, SAR, slope ADCs, oversampling and noise shaping ADCs

Testing of DAC, end point and linearity errors, measurement of DAC INL and DNL, oscilloscope measurements, static ADC testing using histograms (code density) with ramp input and computer-based servo loops, dynamic ADC testing using sine wave input, FFT measurements and bit error rate test, driving ADC analog inputs, gain amplifiers and level shifters using op-amps, non-ideal effects of gain amplifiers, noise in op-amps, error budget analysis of gain amplifiers, input and output errors of amplifiers, signal conditioners with auto-zero/choppers/isolation amplifiers, amplifier selection, data converter digital interfaces, driving external loads

Data converter support circuits, voltage references, low dropout voltage regulators, power supply noise reduction and filtering, analog switches and multiplexers, error sources in switches, latch up effect in CMOS switches and multiplexers, non-ideal behavior of passive resistors, capacitors and inductors, over voltage protection, ESD models and testing, Thermal design considerations for data converters, heat sink, PCB design, skin effect, transmission line, ground isolation, stray capacitance, return currents and power planes, grounding and decoupling in mixed signal systems.

References:

1. P. Horowitz, and W. Hill, *The art of electronics*, third edition, Cambridge university press, 2015.
2. S Franco, *Design with Operational Amplifiers and Analog Integrated Circuits*, McGraw Hill, fourth edition, 2016.
3. R. J. Baker, *CMOS- Circuit Design, Layout & Simulation*, third edition, Wiley–Blackwell, 2010.
4. Application notes of ICs.

EC6126E HIGH SPEED DIGITAL DESIGN

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Sessions: 39L

Course Outcomes:

CO1: Differentiate between high-speed design and a normal design

CO2: Model the interconnects in the high-speed digital system

CO3: Design transmitter and receiver circuits for effective transmission through a given interconnect

CO4: Identify noise sources in high-speed system and perform the noise budgeting

CO5: Design power and clock distribution networks for a high-speed digital system

Frequency, Time and Distance, Lumped vs Distributed Systems, 3-dB and RMS frequencies, Capacitance, Inductance, Mutual Capacitance, Mutual Inductance. Measurement of high-speed signals - Modelling of interconnects - electrical models of wires, lumped single-element models, lumped multi-element models, transmission line model, thumb rules for the applicability of models - Transmission line behaviour of interconnects, termination, Cross talk, Signal Integrity

Power supply Distribution – Providing stable voltage reference, distributing uniform voltages, IR drop, bypass capacitors, regulators, power supply isolation - Noise sources in digital system – Noise budgeting and SNR - Transmitter and receiver circuits –voltage mode drivers, current mode drivers, rise-time control, time domain performance specifications, eye diagram

Timing properties of clocked systems, open loop timing, closed loop timing, pipeline timing, Off-chip and on-chip clock distribution, PLL and DLL based clock aligners - Synchronisation failure and metastability, probability of synchronization failure, Hierarchy of synchronizer design – delay line, 2-register and FIFO mesochronous synchronizers

References:

1. William J Dally, John W Poulton, *Digital Systems Engineering*, Cambridge University Press, 2008
2. Stephen H. Hall, Garrett W. Hall, James A. McCall, *High-Speed Digital System Design - A Handbook of Interconnect Theory and Design Practices*, John Wiley & Sons, 2014
3. Stephen H. Hall, Howard L. Heck, *Advanced Signal Integrity for High-Speed Digital Designs*, John Wiley and Sons, 2009
4. H W Johnson, Martin Graham, *High Speed Digital Design – A handbook of black magic*, Pearson India, 2003

EC6127E INTERNET OF THINGS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Sessions: 39L

Course Outcomes:

CO1: Understand the importance of market perspective and architectural features of internet-of-things (IoT) based systems.

CO2: Explore and employ the concepts on sensing, actuation, embedded system, networking, and data analysis related to IoT systems.

CO3: Analyse various IoT based systems for Smart City, Smart Transportation, Smart Manufacturing, and Smart Healthcare.

CO4: Apply acquired skills to design and implement IoT systems based on given requirements.

Introduction to internet-of-things (IoT), impact of IoT, IoT challenges - Market perspective of IoT based systems – machine-to-machine (M2M) value chains, IoT value chains, an emerging industrial structure for IoT - An Architectural overview IoT systems – Building an architecture, main design principles – an IoT architecture outline, standards considerations – Basics of networking, data management, business processes in IoT, everything as a service(XaaS), M2M and IoT Analytics, knowledge management.

IoT system design: Functional View, information view, deployment and operational view, other relevant architectural views - Components of an IoT system: Sensors, actuators, smart objects, sensor networks and communicating with smart objects - communication criteria, basics of IoT access technologies - Wireless Hart mZ-Wave, Bluetooth Low Energy, Zigbee Smart Energy, NB-IoT – basics of network layer and transport layer design aspects - Security in IoT protocols - Application Layer - Data and Analytics for IoT: IoT Middleware, Data analytics for IoT, Big Data analytics tools and technology.

Some example IoT hardware platforms: Basic architecture, interfacing sensors and actuators, programming aspects, interfacing to external devices, design of simple IoT systems - Real-world design constraints: technical design constraints, hardware data representation and visualization, interaction and remote control - Introduction to software defined networking (SDN), SDN for IoT - Basics of cloud computing – Sensor cloud - Fog computing - IoT application case study: Smart City, Smart Transportation, Smart Manufacturing, and Smart Healthcare.

References:

1. M. Jan Holler, et al., *From Machine-to-Machine to the Internet of Things: Introduction to a New Age of Intelligence*, first edition, Academic Press, 2014.
2. A. Bagha, V. Madisetti, *Internet of Things, A hands on approach*, Universities Press 2015
3. D. Hanes, G. Salgueiro, P. Grossetete, R. Barton, J. Henry*; IoT Fundamentals: Networking Technologies, Protocols, and Use Cases for the Internet of Things*, first edition, Pearson India Pvt. Ltd., 2018.
4. P. Raj, A. C. Raman, *The Internet of Things: Enabling Technologies, Platforms, and Use Cases*, CRC press, 2017
5. Y. Kanetkar, S. Korde; *21 Internet of Things (IOT) Experiments: Learn IoT, the programmer's way*, first edition, BPB Publications, 2018.
6. Relevant research articles

EC6128E OPEN-SOURCE PROCESSOR ARCHITECTURES

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Sessions: 39L

Course Outcomes:

CO1: Understand the open-source processor architecture and their relevance in modern computing systems.

CO2: Apply RISC-V ISA and assembly language programming for efficient code development.

CO3: Design RISC-V processors with performance optimization and hazard avoidance techniques.

CO4: Utilize RISC-V system architecture for developing robust and secure computing systems.

Introduction to open-source processor architecture – Traditional classes of computing applications and their characteristics, the growth of embedded computing, eight great ideas in computer architecture, from a high level language to the language of hardware, technologies for building processors and memory, performance, the power wall, communication between processors, single core and multi-core processors, parallelism.

Introduction to RISC-V - History and motivation, RISC-V instruction set architecture (ISA), execution model and basic concepts, Assembly Language Programming, assembly language syntax and conventions, Basic instructions and addressing modes, Control flow instructions, Data transfer and manipulation instructions. RISC-V Pipeline Architecture - Introduction to pipeline processing, Five-stage pipeline architecture in RISC-V, Hazards and techniques for hazard avoidance, Instruction-level parallelism and performance optimization. RISC-V Memory Hierarchy - Memory organization and hierarchy in computer systems, Cache memory: organization, mapping, and replacement policies, Virtual memory and memory management techniques, TLB (Translation Look aside Buffer).

RISC-V System Architecture - Interrupts and exceptions handling in RISC-V, Privilege levels and protection mechanisms, System calls and operating system interface interrupt controllers and device drivers. RISC-V Design and Implementation - design principles and methodologies for RISC-V processors, RTL (Register Transfer Level) design and verification, Pipelined processor design using RISC-V ISA, performance analysis and evaluation. RISC-V Tools and Ecosystem - assemblers, compilers, and linkers, simulation and debugging tools, development boards and platforms, software development and debugging. RISC-V extensions: integer and floating-point extensions - Vector processing extensions (RVV), Security and trusted execution environments, Custom instructions and accelerators.

References:

1. David A. Patterson, John L. Hennessy. *Computer Organization and Design RISC-V Edition: The Hardware Software Interface*, Morgan Kaufmann; first edition, 2018
2. Jim Ledin, *Modern Computer Architecture and Organization: Learn x86, ARM, and RISC-V architectures and the design of smartphones, PCs, and cloud servers*, Packt Publishing; first edition, 2020
3. RISC-V international, https://riscv.org/
4. Shakthi Processors, https://shakti.org.in/
5. Vega Processors, https://vegaprocessors.in/

EC6129E MATHEMATICAL FOUNDATIONS OF MACHINE LEARNING

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Sessions: 39L

Course Outcomes:

CO1: Illustrate the knowledge of linear systems, vector calculus and optimization theory to comprehend machine learning problems.

CO2: Design mathematical frameworks to formulate machine learning solutions for real-world problems.

CO3: Apply mathematical skills for analysis and independent research in the area of machine learning.

Matrix Theory: Review of linear algebra - Eigenvalue decomposition - Symmetric positive definite matrices - Matrix norms - Cholesky factorization: Symmetric LU decomposition - Machine learning and optimization applications: Fast matrix operations, examples of diagonalizable matrices, symmetric matrices in quadratic optimization - Numerical algorithms for finding eigenvectors: QR method via Schur decomposition, Power method for finding dominant eigenvectors.

Machine learning problems - Linear models: regression and classification models - Training a model - Loss function - Minimum problems - Optimization basics for machine learning: Univariate optimization, multivariate optimization, convex optimization - Gradient Descent (GD) algorithm - Typical objective functions and additive separability in machine learning - Stochastic gradient descent - Tuning hyperparameters - Feature preprocessing - Useful matrix calculus identities - Chain rule of calculus for vectored derivatives - Challenges in gradient based optimization: Local optima and flat regions, differential curvature, vanishing and exploding gradients - Adjusting derivatives for descent: Momentum based learning, AdaGrad, RMSProp, Adam - Constrained optimization: Lagrangian method, Kuhn-Tucker optimality conditions - Optimization models for binary targets: Least-Squares classification, Support Vector Machine (SVM), Logistic regression.

Singular Value Decomposition (SVD): Principal Components and low rank matrix - Truncated SVD - Principal Component Analysis (PCA) - Applications of SVD - Linear algebra of similarity: Equivalence of data and similarity matrices - Efficient data recovery from similarity matrices - Energy of similarity matrix and unit ball normalization - Norm of the mean and variance - Centering a similarity matrix in kernel PCA - Feature engineering from similarity matrix: Kernel clustering, kernel outlier detection, kernel classification, kernel k-means, kernel SVM - Similarity matrices and linear separability.

References:

1. Charu C. Aggarwal, *Linear Algebra and Optimization for Machine Learning*, Springer, 2020.
2. Gilbert Strang, *Linear Algebra and Learning from Data*, Cambridge: Wellesley-Cambridge Press, 2019.
3. Deisenroth, Marc Peter, A. Aldo Faisal, and Cheng Soon Ong. *Mathematics for Machine Learning*, Cambridge University Press, 2020.

EC6130E MACHINE LEARNING FOR INTELLIGENT SYSTEMS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Sessions: 39L

Course Outcomes:

CO1: Illustrate the knowledge machine learning to comprehend the problems in intelligent systems.

CO2: Design mathematical frameworks to address real-world data engineering problems.

CO3: Apply mathematical skills for analysis and independent research in the area of intelligent systems.

Introduction

Introduction to Artificial Intelligence, Data Science, Machine Learning and Applications, The Self Driving Car as an Intelligent System. The Machine Learning Process: Supervised, Unsupervised and Reinforcement Learning. Supervised Learning: Classification and Regression, Training, Testing and Validation. Overfitting and Underfitting - The Bias-Variance Tradeoff, Performance Measurement Metrics - Confusion Matrix.

.

Classical Machine Learning Algorithms: Part - I

Linear Regression: General Model, Mathematical Representation, Gradient Descent, Univariate and Multivariate regression. Logistic Regression: Binary Classification, Intuitive and Mathematical Formulation of Logistic Regression, Decision Boundaries. Frequently used Terms: Regularization, Standardization, Normalization, Outliers. Support Vector Machines (SVM): Maximum Margin Classifier, Non-linear Separable Data, Implementation of algorithms using Python.

Classical Machine Learning Algorithms: Part – II

The k-Nearest Neighbor Algorithm, Naïve Bayes Classification Algorithm - Mathematical Formulation and Numerical Calculations. Decision Tress-Node Purity, Decision Tree Constructions using Entropy and Gini Index. Ensemble Methods - Adaboost, Bagging and Random Forest algorithms. Unsupervised Learning: k-Means Clustering Algorithm. Implementation of Algorithms using Python.

Deep Learning Algorithms

Artificial Neural Networks: Perceptron, the Sigmoid Function, Linear Separability, Multi-layer Perceptron, The Feed Forward and Backpropagation Algorithms, Objective Functions, Batch, Stochastic and Mini Batch Gradient Descent Techniques. Exploding and Vanishing Gradients, Non-linear Activation Functions, Advanced Optimization Techniques. Popular Deep Learning Networks: Convolutional Neural Networks (CNN) - Image Processing Basics, Convolutional, Pooling and Fully Connected Layers. Standard CNNs, Transfer Learning. Introduction to Recurrent Neural Networks (RNN) and its applications. Implementation of Deep Learning Networks using Python. Implementation of Machine Learning Algorithms in Embedded Hardware.

References:

1. Lyla B. Das, Sudhish N. George, Anup Aprem *Artificial Intelligence and Machine Learning: Theory and Practice*, IK International Publishing House, 2023.
2. Aggarwal, Charu C., *Neural Networks and Deep Learning*, Springer 10.978, 2020.
3. C.M. Bishop, *Pattern Recognition and Machine Learning*, Springer, 2006.
4. Aggarwal, Charu C., Machine learning for text: An introduction. Springer, 2018

EC6131E RECONFIGURABLE SYSTEM-ON-CHIP

Pre-requisites: C and a hardware description language

L	T	P	O	C
2	0	2	5	3

Total Sessions: 26L + 26P

Course Outcomes:

CO1: Interpret the SoC architecture and the integration of essential components.

CO2: Illustrate the architecture of a reconfigurable SoC and its application.

CO3: Utilize HW/SW co-design methodology and develop applications on reconfigurable SoC.

Lecture Sessions

Introduction to SoC architecture – CPU, Accelerators, IPs, Memory and Peripherals - On-chip interconnects, system and peripheral buses, bus arbitration – Arm multi-processor SoC architecture – On-chip protocol classes – Bus structures - AMBA AHB, APB, AXI bus protocols.

Reconfigurable SoC - ZYNQ SoC design overview – Processing system – Programmable logic – PS-PL AXI interfacing – Interrupt controller – DMA - IP creation, reuse and integration – AXI interfacing – HW/SW partitioning, codesign – High level synthesis concepts – HLS design flow - Operating System and system integration.

Practical Sessions

Introduction to SDK tools – HW/SW co-simulation – IP Blocks creation and integration – Debug using ILA cores – DMA transfers using Polling and Interrupt mode - Implement algorithms in SW using PS– Implement algorithms in HW using PL – PS-PL AXI interfacing - Partition the algorithm and implement it in HW/SW – OS boot on SOC – Improve performance utilizing multiple cores.

References:

1. Crockett LH, Elliot RA, Enderwitz MA, Stewart RW, *The Zynq Book: Embedded Processing with the Arm Cortex-A9 on the Xilinx Zynq-7000 All Programmable Soc*, Strathclyde Academic Media, 2014.
2. Veena S. Chakravarthi, *A Practical Approach to VLSI System on Chip (SoC) Design, A Comprehensive Guide,* Second Edition, Spring International Publishing, 2022.
3. David Greaves, Modern System-on-Chip Design on Arm, ARM Education Media, 2021.
4. Ahmed Jerraya, Wayne Wolf, Multiprocessor System-on-Chips, Elsevier Science, 2005

EC6221E VLSI TECHNOLOGY

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Sessions: 39L

Course Outcomes:

CO1: Analyze the basics of crystal growth, wafer preparation and wafer cleaning

CO2: Model the oxidation growth and diffusion mechanism in semiconductors

CO3: Analyze the lithography, etching and deposition process

CO4: Verify processes and device characteristics via simulations

Semiconductor Crystal Growth and Wafer Engineering
Historical perspective, semiconductor manufacturing, processing overview, Crystal growth- Electronic grade silicon, Czochralski growth, Bridgman growth, Float zone growth, Si wafer characterization and properties of Silicon wafers, clean rooms, gettering and wafer cleaning.

Fabrication Processes-I
Deposition- Thin films deposition, evaporation, E-beam and resistive heating evaporation, Sputtering, PLD and chemical vapor deposition. Epitaxy- molecular beam epitaxy, vapor phase epitaxy, liquid phase epitaxy, ALD, evaluation of epitaxial layers. silicon oxidation- Thermal oxidation process, kinetics of growth, Deal-Grove model, properties of Silicon dioxide, oxide quality, high κ and low κ dielectrics –Lithography - photo-reactive materials, pattern generation and mask making, pattern transfer, photolithography, electron beam, Ion beam and X-ray lithography- Etching- Wet and dry etching, reactive ion etching, plasma and ion beam techniques

Fabrication Processes-II
Diffusion- Diffusion process, modeling of diffusion, diffusion in a concentration gradient, impurity behaviour, diffusion systems, problems in diffusion, evaluation of diffused layers - Ion Implantation- Types Ion Implantation, modeling of Ion implantation, penetration range, Ion implantation systems, process considerations, implantation damage and rapid thermal annealing

Process Integration
Device Isolation - Junction and oxide isolation, LOCOS, shallow trench isolation, contacts and Metallization-Schottky contacts, ohmic contacts, planarization techniques - Integration of processes for bipolar - N well, P-well and Twin tub CMOS, BiCMOS fabrication processes -Defining system rules for IC layout - Packaging - Die-bonding, wire-bonding, flip-chip technology - Future trends and challenges- Challenges for integration, system on chip

References:

1. S.K. Ghandhi, *VLSI Fabrication principles*, John Wiley Inc., 2008
2. S.M. Sze, *VLSI Technology*, fourth Edition, McGraw Hill Co. Inc., 1999
3. James Plummer, M. Deal and P.Griffin, *Silicon VLSI Technology*, Prentice Hall Electronics, 2010
4. R.C. Jaeger, *Introduction to microelectronic fabrication*, Prentice Hall, Second Edition, 2013

EC6222E MEMS STRUCTURES AND APPLICATIONS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Sessions: 39L

Course Outcomes:

CO1: Gain knowledge of basic approaches for various MEMS sensors and actuators design.

CO2: Capability to critically analyze microsystems technology for technical feasibility as well as practicality.

CO3: Develop efficient MEMS design for improving device performance in terms of speed, sensitivity Selectivity and accuracy

CO4: Design and analysis of efficient MEMS sensors and actuators

MEMS Materials and Micromachining Technology
Overview of Nano and Microelectromechanical Systems and Applications-Review of Electrical and Mechanical concepts in MEMS- Stress and strain analysis, Mechanics including elasticity, beam bending theory, cantilevers, Membranes, and plates. Materials for MEMS and NEMS-Silicon, silicon compounds, polymers, and metals. MEMS fabrication technologies- Micromachining- Bulk Micromachining, Surface Micromachining, Silicon Etching, LIGA Process - Assembly of 3D MEMS – Foundry process.

Sensors and Actuators I
Piezoresistive sensors – Piezoresistive sensor materials, Stress analysis of mechanical elements, Design of cantilevers and Membranes Piezoresistive sensor, Applications to Inertia, Pressure, Tactile and Flow sensors. Electrostatic Sensing and Actuation- Design parallel plate Capacitive and Comb drive actuators, Pull-in Effect, Applications to Inertia, Pressure, Tactile and Flow sensors, Micro-motor, MEMS RF switches, Thermal actuators- Fundamentals of thermal transfer, Thermal bimorph principle, Thermal couples, resistors and their applications

Sensors and Actuators II
Piezoelectric sensors and actuators – piezoelectric effects – piezoelectric materials – Applications to Inertia, Acoustic, Tactile and Flow sensors, Microphone, Micro speaker, Nanogenerator, RF resonator, Acoustic wave sensors, SAW filter- Magnetic Actuation- Fabrication of Micro Magnetic Components, Case Studies of MEMS Magnetic Actuators. Bio-MEMS- Chemoresistors, Chemocapacitors, Chemotransistors, Electronic nose (E-nose)

Calibration and Packaging Techniques
Basic Fluid Mechanics Concepts, Micro Fluidics Applications. Case Studies- Gyros. MEMS device Calibration and packaging techniques- Device Design Considerations, Types of packaging, Hermetic or Nonhermetic Packaging, Wafer Dicing, Wafer Bonding, Reliability Market Uncertainties, Investment, and Competition. MEMS software: COMSOL & Intellisuite.

References:

1. Chang Liu, *Foundations of MEMS*, Prentice Hall, 2006.
2. Tai Ran Hsu, *MEMS and Microsystems Design and Manufacture*, Tata Mcraw Hill, 2002.
3. Albert Folch, *Introduction to BioMEMS*, CRC, 2012.
4. Edward Lyshevski, *MEMS and NEMS: Systems, Devices, and Structures*, CRC Press, 2002

EC6242D CMOS RF IC DESIGN

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Sessions: 39L

Course Outcomes:

CO1: Demonstrate an understanding of the language, basic operation of basic RF modules.

CO2: Relate to the inventory of RF device models.

CO3: Design of RF modules to meet the given specifications.

CO4: Apply the understanding to the design of wireless systems and other allied fields appreciating the trade-offs between noise, linearity, spectral cost etc.

Basics of RF Circuit Design
Linearity and distortion: Third-order intercept point, second-order intercept point, 1-dB compression point, broadband measures of linearity - Modelling of active & passive components at high frequencies - Noise: Available noise power, noise figure- Impedance matching: broadband matching, power matching & noise matching - High frequency amplifiers: Bandwidth estimation using open-circuit & short-circuit time constants - using zeros to enhance bandwidth - shunt-series amplifiers, tuned amplifiers & cascaded amplifiers

RF Amplifiers and Mixers
RF power amplifiers: Design of class A, AB, B, C, D, E, F, G & H amplifiers - Low-noise amplifier (LNA), CS, CG & cascode amplifiers, Feedback amplifiers - Noise & linearity of amplifiers - Amplifiers using differential configurations - Low voltage topologies for LNA, DC bias networks for LNA, design of broadband LNA, Case studies of RF power amplifiers and LNAs

Mixers and Oscillators
Mixers: Mixing operation, Mixing with nonlinearity, Mixer noise and linearity, Mixer with local oscillator switching, popular mixer configurations like the Moore mixer, mixer with simultaneous noise and power match, mixer employing current reuse for low power applications - Oscillators: Negative resistance-based LC resonator, Colpitts oscillator, Differential topologies, Phase noise in oscillators - Tunable oscillators -Phase-locked loops (PLL), PLL components, in-band and out-of-band phase noise, Frequency synthesizers

References:

1. John W M Rogers & Calvin Plett, *Radio Frequency Integrated Circuit Design*, 2nd Edition, Artech House, 2010
2. Richard Chi-Hsi Li, *RF Circuit Design*, John Wiley & Sons, 2009
3. Hooman Darabi, *Radio Frequency Integrated Circuits & Systems*, Cambridge University Press, 2015
4. Behzad Razavi, *RF Microelectronics*, 2nd Edition, Prentice Hall, 2012
5. Thomas H Lee, *The Design of CMOS Radio-Frequency Integrated Circuits*, 2nd Edition, Cambridge University Press, 2004.

EC6245E CMOS IMAGE SENSORS

Pre-requisites: NIL

L	T	P	O	C
2	0	2	5	3

Total Sessions: 26L+26P

Course Outcomes:

CO1: Compare the performance of various pixels and choose suitable architecture for an application

CO2: Distinguish various noise sources in image sensors and apply suitable noise reduction techniques for the readout under consideration

CO3: Design building blocks of an image sensor readout

CO4: Develop architecture/application -dependent design optimizations in the readout of an image sensor

Pixel circuits

Review of MOS capacitor and MOSFET, charge transfer and charge coupled systems, limitation of CCDs - Photodiodes in a standard CMOS technology, photo-generated charges, photo current – Pixel circuits: Passive pixel and its limitation, 3-T active pixels, fill factor, full well capacity, sensitivity, signal dependent non-idealities, reset, temporal and photon shot noise, dark current, signal-to-noise ratio, dynamic range, fixed pattern noise, double sampling techniques, correlated double sampling, pinned-photodiode, 4-T active pixel

Readout circuits

Readout architectures, pixel, column and chip level readouts, column amplifier and sensitivity, adaptive gain column amplifiers, column-level ADCs, slope, cyclic and SAR ADCs, column-shared architectures, low noise readouts, high dynamic range imagers – Applications of image sensors: Event-driven pixels, time-of-flight pixels - Characterization of an image sensor

Practical

Photodiode model, active pixel circuits, temporal and fixed-pattern noise minimization, double sampling technique, – Column readout: Multiple sampling, amplifiers, analog-to-digital converters – High dynamic range pixel circuits and readouts - Layout design techniques for pixel, column and chip level blocks - Application specific pixel circuits

References:

1. J. Nakamura, *Image Sensors and Signal Processing for Digital Still Cameras*, CRC Press, 2005
2. A. Theuwissen, *Solid-State Imaging with Charge-Coupled Devices*, Kluwer academic publishers, 1995.
3. M. Sarkar and A. Theuwissen, *A Biologically Inspired CMOS Image Sensor*, Springer Verlag, 2013.
4. J. R. Janesick, *Photon Transfer DN*, SPIE press, 2007.
5. T. Kuroda, *Essential Principles of Image Sensors*, CRC Press, 2014.
6. Research articles and technical reports in the area of CMOS image sensors

EC6246E ARCHITECTURAL DESIGN OF DIGITAL INTEGRATED CIRCUITS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Sessions: 39L

Course Outcomes:

CO1: Compare the various methodologies of architectural design of digitals ICs

CO2: Optimize an algorithm and map it into an efficient architecture

CO3: Design of low-area and low-power architectures for data paths

Introduction to VLSI Design Flow; Digital design using static CMOS, transmission gates, etc- Area, power and delay considerations in digital design, optimizations in digital design - Number representation and formats.

Mapping an Algorithm into Architecture: Concept of hierarchical system design, algorithms and their architectures (minimum/maximum, GCD, running average, summation of N numbers, etc.) - Control structure design, critical path and worst-case timing analysis - Data path optimization and worst-case timing analysis: Efficient adder architectures, sign and unsigned multiplier architectures, Braun's multiplier, Baugh-Wolley multiplier, divider and square root design- Application specific combinational and sequential circuit design.

Advance architecture design: CORDIC, extension of CORDIC to cover the full range of angles - FFT Architecture; Parallel and pipeline processing, array architecture - Systolic architecture design: Introduction, systolic array design methodology, applications to signal processing problems.

References:

1. Frank Vahid, *Digital Design with RTL Design, VHDL, and Verilog*, Wiley, 2011.
2. Behrooz Parhami, *Computer Arithmetic: Algorithms and Hardware Designs*, Oxford University Press, 2010.
3. Sung-Mo Kang, Yusuf Leblebici, Chul Woo Kim, *CMOS Digital Integrated Circuits Analysis & Design*, Forth Edition, McGraw-Hill, 2014.
4. Research articles and technical reports in the area of architectural design of digital integrated circuits

EC6247E DIGITAL VLSI TESTING

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Sessions: 39L

Course Outcomes:

CO1: Develop test patterns required to detect faults in a circuit

CO2: Determine the testability of a circuit

CO3: Design methods/techniques to improve the testability of digital circuits.

CO4: Design Logic BIST circuits based on LFSRs

Faults and Test pattern generation

Introduction to VLSI Testing process - need and challenges, Faults in Digital Circuits - Controllability, and Observability, Fault models - stuck-at faults, Bridging faults, intermittent faults, Fault equivalence, Fault collapsing and Fault dominance, Logic Simulation and Fault simulation - Serial, Parallel, Deductive and Concurrent Fault Simulation, Combinational and Sequential SCOAP testability Measures - Combinational Circuit Test Pattern Generation - Fault table, Boolean Difference, Path Sensitization Methods, D-Algorithm, PODEM, FAN algorithm, ATPG for Single-Clock Synchronous Circuits – Nine Valued Logic and Time-Frame Expansion Methods - Delay fault testing, IDDQ Testing, Test optimization and fault coverage

Design for testability

Design for testability (DFT) - Testability analysis, Scan design-scan design rules, tests for scan circuits, Scan architectures, DFT based Sequential Circuit Testing - Adhoc design for testability - Test Point Insertion, Scan chains, Partial Scan Design, Random Access Scan, Boundary scan standard – Boundary scan cell, TAP controller, modes of operation, EXTEST, INTEST, BYPASS instructions, Fault models for PLAs, Bridging and delay faults and their tests.

Built in Self-Test

Built in Self-Test (BIST) - Design rules, Test pattern generation for BIST - Exhaustive testing, Pseudo-random testing, Pseudo-exhaustive testing, LFSR for pattern generation and Output response analysis, SISR, MISR, Test compression: Test stimulus compression, Test response compaction, Architectures for test compression - Memory BIST – Type of memory faults, Fault modeling, Fault detection by MARCH tests, Issues in test and verification of complex chips, embedded cores and SOCs, System testing and test for SOCs

References:

1. Bushnell Michael and Vishwani Agrawal, *Essentials of electronic testing for digital, memory and mixed-signal VLSI circuits*, Vol. 17, Springer Science & Business Media, 2004.
2. Wang Laung-Terng, Cheng-Wen Wu, and Xiaoqing Wen, *VLSI test principles and architectures: design for testability*, Academic Press, 2006.
3. Abramovici Miron, M. A. Breuer and A. D. Friedman, *Digital Systems testing and testable design*, Computer Science Press, 1990.
4. Roth Jr, Charles H. and Lizy K. John, *Digital systems design using VHDL*, Nelson Education, 2016.

EC6248E VERIFICATION OF VLSI SYSTEMS

Pre-requisites: A hardware description language

L	T	P	O	C
2	0	2	5	3

Total Sessions: 26L+26P

Course Outcomes:

CO1: Understand verification approaches and formulate a verification plan.

CO2: Develop HVL based deterministic and random self-checking test benches.

CO3: Design and develop reusable layered test benches.

CO4: Apply techniques to assess the verification progress using coverage concepts.

Lecture

Introduction to functional verification - HDL and HVL languages - Functional verification approaches, requirements specification and the verification plan – levels of verification – self checking test benches, deterministic and random test bench, layered test bench - code coverage, functional coverage, coverage driven random based approach - Introduction to System Verilog - data types, arrays, structures – procedural statements and routines – design hierarchy – interfaces.

High level modelling, data abstraction, OOPS – inter process communication – randomization, constrained random verification - Functional coverage, Cover group, Cover point bins, cross coverage – System Verilog assertions - System on chip verification – system level and block level verification - OVM/UVM basics.

Practical

Self-checking testbenches - Deterministic and random testbenches – Constructs of HVL, data types, arrays, structures, procedural statements, routines, interfaces – Inter process communication – Constrained randomization – Code coverage - Functional coverage, cover group, cover point bins – Automated regression runs – Layered testbenches.

References:

1. Sutherland, Stuart, Davidmann, Simon, Flake, Peter, *System Verilog for Design: A Guide to Using SystemVerilog for Hardware Design and Modeling*", Second Edition, Springer Science & Business Media, 2006.
2. Chris Spear, Greg Tumbush, *System Verilog for Verification: A Guide to Learning the Test bench Language Features*, Third Edition, Springer Science & Business Media, 2012.
3. Bergeron, J., *Writing Test benches using System Verilog*, Springer, USA, 2006.
4. Rashinkar P, Paterson P, Singh L., *System-on-a-chip verification: methodology and techniques*, Springer Science & Business Media; 2007

EC6249E VLSI DIGITAL SIGNAL PROCESSING

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Sessions: 39L

Course Outcomes:

CO1: Identify different representations of DSP Algorithms.

CO2: Distinguish between different parameters related to hardware implementation of DSP systems.

CO3: Apply different techniques for changes in speed, area and power consumption of the systems.

CO4: Design a DSP system with the given constraints and implement using Hardware Description Language (HDL).

CO5: Appraise different hardware architectures of digital filters.

Introduction to DSP Systems - Representation of DSP Algorithms - Critical path - Loop bound - Iteration bound - Algorithms for computation of iteration bound - Pipelining and parallel processing: Pipelining and parallel processing for low power, pipelining and parallel processing of FIR Filters - Retiming: Definitions and properties, solving system of inequalities, retiming technique - Unfolding: Definition, algorithm for performing unfolding, applications of unfolding - Folding: Definition, folding transformations, register minimization techniques

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 - Distributed arithmetic and its variants - Canonic sign-digit arithmetic - Subexpression elimination - Multiple constant multiplication

Fast convolution: Cook-Toom algorithm, Winograd algorithm - Low-power design: Theoretical background, scaling versus power consumption, power analysis, power reduction techniques, power estimation approaches - Scaling and roundoff noise: State variable description of digital filters, roundoff noise in digital filters - Architectures for Digital Filters - Implementation of a digital system using Field Programmable Gate Array (FPGA) - Case study on hardware implementation of a DSP system

References:

1. Keshab K. Parhi, *VLSI Signal Processing Systems, Design and Implementation*, John Wiley & Sons, 2008.
2. Lars Wanhammar, *DSP Integrated Circuits*, Academic Press, 1999.
3. Roger Woods, John McAllister, Ying Yi, and Gaye Lightbody, *FPGA-based implementation of signal processing systems, John Wiley & Sons, 2008*
4. R.G. Lyons, *Understanding Digital Signal Processing*, Pearson Education, 2004.
5. Bhattacharyya, S.S., Deprettere, E.F., Leupers, R., Takala, J. (Eds.), *Handbook of Signal Processing Systems*, Second Edition, 2013.

EC6443E: AUTONOMOUS INTELLIGENT SYSTEM

Pre-requisites: Fundamentals of Linear Algebra, Probability and Computer Programming in Python, Exposure to basic concepts in signal processing and machine learning.

L	T	P	O	C
2	0	2	5	3

Total Sessions: 26L +26P

Course Outcomes:

CO1: Understand essential subsystems for autonomous intelligent systems.

CO2: Model autonomous decision-making tasks using the estimation, planning and control architecture.

CO3: Apply reinforcement learning approaches for autonomous decision making for complex environments.

Introduction to Autonomous Systems
Introduction to autonomous systems – Levels of autonomy. Example of autonomous systems: Self driving cars, autonomous drones – Architecture of autonomous systems: Sensorimotor architecture, Stateful architectures, Logical and physical architectures – Modelling and control for autonomous systems: Representations and models, PID control

Vision for Autonomous Systems
Vision: Introduction to projective geometry, Camera modeling and calibration, Image processing techniques for object detection – Machine learning techniques for object detection: Introduction to neural networks, Convolutional neural networks, One and two-stage object detection

State Estimation, Localization, and Planning
State estimation and localization: Bayes filtering framework, Parameterized methods (Kalman filter), Sampling-based methods (particle and histogram filter) - Planning: Formalization of the planning problem, Graphs, Graph search algorithms

Reinforcement Learning
Reinforcement Learning: Markov decision processes, Value functions, Q-learning, Exploration and Exploitation techniques.

Practical Sessions

Lab experiments using simulator and AI enabled hardware. Lab experiments will include simulation of an autonomous driving environment and would involve designing a PID controller for control, developing image processing and machine learning algorithms for navigation, state estimation, and path planning.

References:

1. Ulrich Nehmzow, *Mobile robotics: a practical introduction*, second edition, Springer Science & Business Media, 2012.
2. Roland Siegwart, Illah Reza Nourbakhsh, Davide Scaramuzza, *Introduction to Autonomous Mobile Robots*, second edition,2011
3. Luc Jaulin, *Mobile robotics*. John Wiley & Sons, 2019.
4. R. Sutton and A. Barto, *Reinforcement Learning: An Introduction*, second edition., MIT Press, 2018.
5. Stuart Jonathan Russell, Peter Norvig, *Artificial intelligence a modern approach*, fourth edition, Pearson Education, Inc,2016