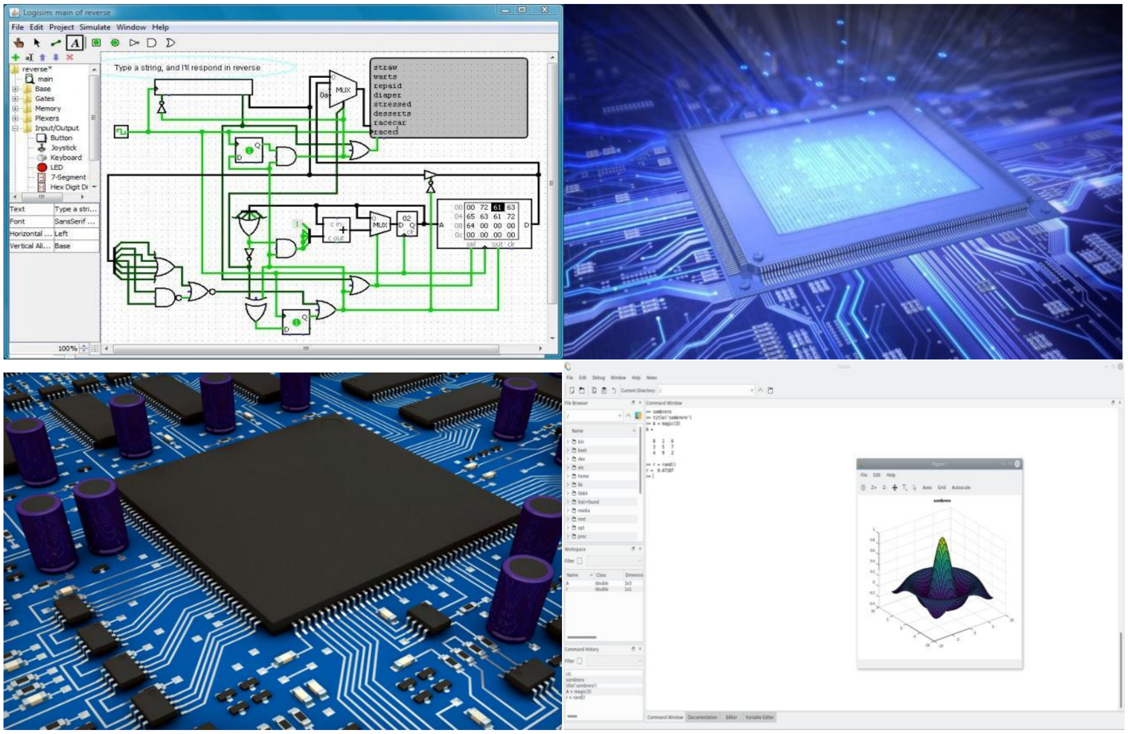
Curriculum & Contents

M. Tech.
(IC Design and Technology)



Offered by: Electrical and Electronics Engineering Department (EEE)

विश्वजीवनामृतं ज्ञानम्

ABV-Indian Institute of Information Technology & Management, Gwalior

Name of the program: M. Tech. (IC Design and Technology)
(Credits: 73)

Name of the Department: Electrical and Electronics Engineering

SEMESTER-I				
S. No.	**Subject Code**	**Title of the course**	**L-T-P**	**Credits**
1.	EE-601	Digital IC Design	3-0-0	3
2.	EE-602	System Design using HDL	3-0-0	3
3.	EE-603	Machine Learning Techniques	3-0-2	4
4.	EE-604	IC Technology	3-0-0	3
5.	EE-605	Device Modelling and Simulation	3-0-0	3
6.	EE-606	Advanced IC Design and Technology Lab-1	0-1-4	3
7.	EE-XXX	Elective 1	3-0-0	3
			Total credits	**22**

SEMESTER-II				
S. No.	**Subject code**	**Title of the course**	**L-T-P**	**Credits**
1.	EE-607	Analog IC Design	3-0-0	3
2.	EE-608	Design Verification and Testing	3-0-0	3
3.	EE-609	Engineering Research Methodology	2-1-0	3
4.	EE-610	CAD for VLSI	3-0-0	3
5.	EE-611	Advanced IC Design and Technology Lab-II	0-1-4	3
6.	EE-XXX	Elective- II	3-0-0	3
7.	EE-XXX	Elective-III	3-0-0	3
			Total credits	**21**

EXIT AFTER YEAR-1: Post Graduate Diploma in IC Design and Technology

SEMESTER-III				
S. No.	**Subject code**	**Title of the course**	**L-T-P**	**Credits**
1	XXX	Elective-IV/MOOC course	3-0-0	3
2	EE-698	Major Project Part I/Internship	-	12
			Total credits	**15**

SEMESTER-IV				
S. No.	**Subject Code**	**Title of the course**	**L-T-P**	**Credits**
1	EE-699	Major Project Part II/Internship	-	15
			Total credits	**15**

SEMESTER-I	SEMESTER-II	SEMESTER-III	SEMESTER-IV	TOTAL CREDITS
22	21	15	15	**73**

S.N.	Code	Electives I,II,III, and IV Category: IC Design and Technology
1	EE-051	Device and Interconnect Modelling
2	EE-052	VLSI Signal Processing
3	EE-053	Low Power VLSI
4	EE-054	Microcontroller and Embedded Systems
5	EE-055	Memory Devices and Circuits
6	EE-056	VLSI Architecture
7	EE-057	Hardware Security
8	EE-058	FPGA-Based System Design
9	EE-059	Quantum Electronics
10	EE-060	RF Circuit Design
11	EE-061	Mixed Signal SoC Design
12	EE-062	AI-Accelerator Design
13	EE-063	System-on-Chip Design
14	EE-064	Embedded Software
15	EE-066	Special Topics in IC Design and Technology
16	EE-068	Network on Chip
17	EE-069	Digital Image Computation
18	EE-070	Audio Signal Processing
19	EE-071	Advanced Digital Signal Processing
20	EE-072	Biomedical Signal Processing
21	EE-074	Computer Vision
22	EE-076	Internet of Bio-Nano Things
23	EE-079	Cyber Security
24	EE-081	Optimization Techniques
25	EE-083	Internet of Things
26	EE-085	Software Defined Radio
27	EE-086	Quantum Communication
28	EE-087	5G and 6G standards
29	EE-088	Smart Antennas
30	EE-089	Advanced Optical Communication

31	EE-092	Data Communication Protocol
32	EE-613	Next-Generation Communication Systems
33	EE-065	High-Performance Computing Systems
34	EE-067	Sensors for Autonomous System
35	EE-073	Data Analytics
36	EE-075	Reinforcement Learning
37	EE-078	Quantum Computing
38	EE-080	Deep Learning for Autonomous Systems
39	EE-082	Advanced Control System
40	EE-093	Drone Technology and Robotics
41	EE-612	Sensors and Actuators
42	EE-615	Autonomous Systems

Course Contents

1	**Semester**	I
2	**Type of course**	Core
3	**Code of the subject**	EE-601
4	**Title of the subject**	Digital IC Design
5	**Any prerequisite**	NIL
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	To introduce the physics of MOSFETs, design rules of CMOS layout, basic theory of static and dynamic characteristics of CMOS logic circuits, power dissipation in CMOS logic circuits. On completion of this course, the students will be able to: 1. Synthesize and analyze the MOSFET based circuits. 2. Draw the layout/stick diagram of CMOS logic circuits. 3. Analyse the performance of CMOS logic circuits. 4. Design CMOS combinational and dynamic logic circuits.
8	**Brief Contents**	Basic MOSFET Characteristics – Threshold Voltage, Body Bias concept, Current-Voltage Characteristics – Square-Law Model, MOSFET Modeling – Drain-Source Resistance, MOSFET Capacitances, Geometric Scaling Theory – Full-Voltage Scaling, Constant-Voltage Scaling, Challenges of MOSFET Scaling. CMOS fabrication processing steps, Design Rules, Stick diagram, Layout of logic circuits, latch-up, CMOS Inverter, Power Dissipation in CMOS Digital Circuits, Dynamic Logic Circuit Concepts and CMOS Dynamic Logic Families
9	**Text/ Reference Books**	1. Kang, S. and Leblebici, Y., CMOS Digital Integrated Circuits – Analysis and Design, Tata McGraw Hill (2008) 3rd ed. 2. J P Uyemura, CMOS Circuit Design, Springer 3. Weste, N.H.E., Harris, D., CMOS VLSI Design: A Circuits and Systems Perspective, Pearson; 4th edition (2010). 4. Rabaey, J.M., Chandrakasen, A.P. and Nikolic, B., Digital Integrated Circuits – A Design perspective, Pearson Education (2007) 2nd ed. 5. Baker, R.J., Lee, H. W. and Boyce, D. E., CMOS Circuit Design, Layout and Simulation, Wiley - IEEE Press (2004) 2nd ed. 6. Weste, N.H.E. and Eshraghian, K., CMOS VLSI Design: A Circuits and Systems Perspective, eddision Wesley (1998) 2nd ed.

1	**Semester**	I
2	**Type of course**	Core
3	**Code of the subject**	EE-602
4	**Title of the subject**	System Design using HDL
5	**Any prerequisite**	Digital Electronics in UG
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	Correctly describe the detailed behavior of the given standard and a few special application-based digital logic circuits as defined by Verilog HDL, state diagrams, or other means, including those circuits related to modern computer architecture. Translate system requirements into a practical digital design using Verilog HDL, Xilinx Vivado, and FPGA prototyping boards. Model the digital designs including FSMs to Processor architectures using the knowledge of HDL Language. Apply the knowledge of Reconfigurable architectures like FPGAs in designing and implementing digital ICs.
8	**Brief Contents**	Basic concepts of hardware description languages (VHDL, Verilog HDL), Logic and delay modeling, Structural, Data- flow and Behavioral styles of hardware description, Architecture of event driven simulators, Operators, Operands, Operator types, Blocking and non-blocking statements, Delay control, Generate statement, Event control, Sequential Logic Design, FSM, Configuration Specifications, Sub-Programs, Test Benches. Types of Reconfiguration, Details study of FPGA, Design tradeoffs, Bidirectional wires and switches, FPGA Placement: Placement Algorithms, FPGA Routing, Timing Analysis, Network Virtualization with FPGAs, On-chip Monitoring Infrastructures, Multi-FPGA System Software, Logic Emulation, Applications, High Level Compilation
9	**Text/ Reference Books**	1. Charles H. Roth, Digital System Design Using VHDL, Jr., Thomson, (2008)2nd Ed. 2. Bhaskar, J., A VHDL Primer, Pearson Education/ Prentice Hall (2006)3rd Ed. 3. Samir Palnitkar, Verilog HDL: A Guide to Digital Design and Synthesis, Prentice Hall PTR (2003) 2nd Ed. 4. Ashenden, P., The Designer's Guide To VHDL, Elsevier (2008) 3rd Ed. 5. David C. Black and Jack Donovan, SystemC: From the Ground Up, Springer, (2014) 2nd Ed. 6. Rushton, A., VHDL for Logic Synthesis, Wiley (1998) 2ed.

1	**Semester**	I
2	**Type of course**	Core
3	**Code of the subject**	EE-603
4	**Title of the subject**	Machine Learning Techniques
5	**Any prerequisite**	None
6	**L-T-P**	3-0-2
7	**Learning Objectives of the subject**	• Understand key machine learning concepts and algorithms, including supervised and unsupervised learning. • Gain practical experience in implementing machine learning models. • Learn data preprocessing techniques and model evaluation methods for accurate performance assessment. • Explore neural networks and deep learning basics, focusing on real-world applications.
8	**Brief Contents**	Supervised, unsupervised, and reinforcement learning, along with their real-world applications. It explores key algorithms like linear regression for model fitting and evaluation, and classification techniques such as Logistic Regression, K-Nearest Neighbors, and Support Vector Machines. The course also delves into decision trees and random forests, examining their use in both classification and regression tasks. Unsupervised learning methods like K-means clustering, Hierarchical Clustering, and DBSCAN are discussed. Basics of neural networks, including their architecture, backpropagation, and activation functions. Students will learn how to evaluate models using techniques like cross-validation, confusion matrices, precision, recall, and F1 scores. Dimensionality reduction techniques, including PCA etc.
9	**Lab Content**	Implementation of various machine learning algorithms, starting with supervised learning techniques like linear regression, logistic regression, K-Nearest Neighbors, and Support Vector Machines for both classification and regression tasks. They will explore unsupervised learning methods such as K-means clustering, Hierarchical Clustering, and DBSCAN to uncover patterns in data. The lab will also cover decision trees and random forests, and introduce students to the basics of neural networks, including their architecture, backpropagation, and activation functions. Additionally, students will practice model evaluation using techniques like cross-validation, confusion matrices, precision, recall, and F1 scores. The lab will conclude with experiments on dimensionality reduction using methods like PCA to simplify complex datasets.
10	**Text/ Reference Books**	1. "Pattern Recognition and Machine Learning" by Christopher M. Bishop 2. "Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow" by Aurélien Géron 3. "Machine Learning: A Probabilistic Perspective" by Kevin P. Murphy 4. "Introduction to Machine Learning with Python" by Andreas C. Müller and Sarah Guido 5. "MATLAB for Machine Learning" by Giuseppe Ciaburro

1	**Semester**	I
2	**Type of course**	Core
3	**Code of the subject**	EE-604
4	**Title of the subject**	IC Technology
5	**Any prerequisite**	Nil
6	**L.T.P.**	3-0-0
7	**Learning Objectives of the subject**	Students will be able to learn the flow of IC Design, which includes the fundamentals of the fabrication of chips, input-output packaging, and interconnection networks. To demonstrate a clear understanding of CMOS fabrication flow, input/output circuits, and chip packaging. Get an idea of data flow in interconnection network, routing, and topology basics.
8	**Brief Contents**	Introduction to semiconductor manufacturing, wafer production, wafer Identification, wafer handling, and wafer cleaning. Introduction to the cleanroom, Cleanroom protocols, safety, and precautions. Introduction/Recap to various instruments. photolithography: photoresist, spin-coating, masking, annealing - hands-on/demonstration for the same inside the cleanroom. Cleanroom processes such as patterning, oxygen-plasma etching, dry-etching, lift-off, structural characterization of the pattern/actuator: optical characterization, surface profilometer. Metallization of devices using negative photoresist, pattern formation. Device characterization (I-V curve in dark and with illumination), statistical analysis of the devices. Introduction to the packaging of the devices.
9	**Text/ Reference Books**	1. Ghandhi S K, VLSI Fabrication Principles: Silicon and Gallium Arsenide 2nd Edition, Wiley Blackwell (1994) 2. Plummer J D, Deal M D and Griffin P B, Silicon VLSI Technology: Fundamentals, Practice, and Modeling,1st 3. Edition, Pearson Education (2009) 4. Sze S M, VLSI Technology, 2nd Edition, McGraw Hill Education (2017) 5. Stanley A. Wolf and Richard N. Tauber, Silicon Processing for the VLSI Era Volume 1-Process Technology Lattice Press, 1999 Peter Van Zant, Microchip Fabrication. McGrawHill, 2004

1	**Semester**	I
2	**Type of course**	Core
3	**Code of the subject**	EE-605
4	**Title of the subject**	Device Modeling and Simulation
5	**Any prerequisite**	Electronics Devices and Circuits
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	The objective of the course is to provide the fundamental knowledge for understanding the basic concepts of semiconductor devices. Upon successful completion of the course, students will be able to grasp fundamental knowledge of semiconductor devices for integrated circuit design and be able to model the devices and circuits using SPICE.
8	**Brief Contents**	Device Level Modelling: PN junction, MOSFET, limitations of long-channel analysis, short-channel effects, technology nodes and ITRS, physical and technological challenges to scaling, nonconventional MOSFETs (FDSOI, SOI, Multi-gate MOSFETs), compact modeling, Verilog-A model. Interconnect Modelling: Introduction to VLSI interconnects, distributed RC interconnect model, Elmore delay, equivalent Elmore model for RLC interconnects (distributed model), two-pole model of RLC interconnects from ABCD parameters. Circuit Modelling: Circuit simulation using available device models, netlist, and System Modelling.
9	**Text/ Reference Books**	1. G. Massobrio, P. Antognetti, Semiconductor Device Modeling with SPICE 2nd edition, McGraw-Hill, New York,1993. 2. M Rudolph, Introduction to Modeling HBTs, Artech House, Boston, 2006 3. S M Sze, K K Ng, Physics of Semiconductor Devices 3rd edition, John Wiley, New Jersey, 2007 4. G. A. Armstrong, C.K.Maiti, Technology Computer Aided Design for Si, SiGe and GaAs Integrated Circuits IET Series, London, 2007 5. Nandita Das Gupta, Amitava Das Gupta, "Semiconductor devices, modeling and Technology", Prentice Hall of India, 2004. 6. Philip.E.Allen Douglas, R. Hoberg, "CMOS Analog circuit Design" Second edition, Oxford Press, 2002.

1	**Semester**	I
2	**Type of course**	Core
3	**Code of the subject**	EE-606
4	**Title of the subject**	Advanced IC Design and Technology Lab-I
5	**Any prerequisite**	NIL
6	**L-T-P**	0-1-4
7	**Learning Objectives of the subject**	The lab experiments of this course will provide exposure to how the fundamental and advanced theories, design concepts, and principles of the core courses studied in the 1st semester can be applied in practice. The objective of the course is to provide the fundamental knowledge for understanding the flow of IC design using EDA tools and better approaches/solutions for more effective design. The course will cover the fundamentals of HDL language, concepts to design systems using HDL, and the implementation of the design on FPGA boards.
8	**Brief Contents**	The complete IC layout design and its implementation using EDA tool. Provide the in-depth concept and flow for implementation of IC Design, CMOS logic, Circuit analysis with change in the device parameters, Impact of parasitic on circuit performance. Fundamentals of Verilog HDL, different levels of abstraction, tasks and directives, Concept to design the FSM and microarchitecture, Timing and delay simulations, Fundamentals of Physical Design during RTL to GDS flow, Physical Synthesis.
9	**Contents for lab**	Schematic and Layout analysis of inverter, AND gate, OR gate, NAND gate, NOR gate, XOR gate and XNOR gate (pre layout simulation and post layout simulation), IC fabrication process. Implementation of all the basic and universal gates using HDL, combinational circuits, sequential circuits, FSM implementation, memory design, Micro-architecture implementation. Automation of FPGAs. Physical Design, Partitioning, Floor plan, Placement and Routing, Timing analysis
10	**Text/ Reference Books**	1. S. M. Kang and Y. Leblebici, `CMOS Digital Integrated Circuits' Tata McGraw-Hill

1	**Semester**	II
2	**Type of course**	Core
3	**Code of the subject**	EE-607
4	**Title of the subject**	Analog IC Design
5	**Any prerequisite**	Digital IC Design
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	This course builds the basic concepts and the design of advanced CMOS analog Integrated Circuit. This course focuses on the concepts of MOSFETs and design of amplifiers including non-linear effects. The course will give the practical aspects of CMOS analog IC design. The course aims to teach basic concepts along with advanced design techniques for CMOS amplifiers. The objective of the course is to design and implement the product-level opamps and buffers for VLSI applications.
8	**Brief Contents**	Small signal Models, Amplifiers and Current sources: Large Signal and Small-Signal analysis of common source stage, Source Follower, Common Gate Stage, Cascode, Folded Cascode, Differential amplifier, current Sources, Basic Current Mirrors, Cascode Current Mirrors and current mirror based differential amplifier, Frequency Response of Amplifiers, Feedback, Operational Amplifier, Noise, Determination of dominants poles; Compensation and relocation of poles and zeros, Basic concepts to design PLL and ADC
9	**Text/ Reference Books**	1. Behzad Razavi, Design of Analog CMOS Integrated Circuits, McGraw-Hill Education, Second Edition (2017). 2. Tony Chan Carusone David A. Johns Kenneth W. Martin, Analog Integrated Circuit Design, Wiley, Second Edition (2011) 3. CMOS Analog Circuit Design” by Phillip Allen and Douglas R. Holberg, OUP USA; Third Edition edition (1 September 2011) 4. Operation and Modeling of the MOS Transistor” by Yannis Tsividis, Oxford University, Press; 2 edition, June 26, 2003 5. “Microelectronic Circuits-Theory & Applications” by A.S. Sedra and K.C. Smith, Adapted by A.N. Chandorkar, 6th Edition, Oxford, 2013.

1	**Semester**	II
2	**Type of course**	Core
3	**Code of the subject**	EE-608
4	**Title of the subject**	Design Verification and Testing
5	**Any prerequisite**	CAD for VLSI
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	The main objective of this course is to provide in-depth understanding of the problems encountered in testing large circuits, approaches to detect and diagnose the faults and methods to improve the design to make it testable. The students will be able to develop algorithms and tools for VLSI testing, designing of testable and trustworthy circuits. The scope of this course is to particularly address the challenges in the VLSI testing domain and get motivated towards research in this field.
8	**Brief Contents**	Introduction and Fault Modeling, Testing Techniques, Time frame expansion methods, Boolean Satisfiability, Transitive-closure based and Neural Network based approaches, Fault Simulation, Design for Testability and Built-in-self-test, Controllability and observability measures, TEMEAS, SCOAP, Ad-hoc design built-in-logic-block-observer (BILBO), Linear feedback shift register (LFSR), Theory of LFSRs, Design for Trust Techniques: Different Types of Attacks, Counter Measures for different types of attacks, Prevention based Approaches, Importance of verification, Verification plan, Verification flow, Levels of verification, Verification methods and languages, Introduction to Hardware Verification methodologies, Verifications based on simulation, Analytical and formal approaches. Functional verification, Timing verification, Formal verification. Basics of equivalence checking and model checking
9	**Text/ Reference Books**	1. M.L. Bushnell and V.D. Agrawal, “Essentials of Electronic Testing”, Kluwer Academic Publishers, 2000 2. N.K. Jha and S. Gupta, “Testing of Digital Systems”, Cambridge University Press 2004 3. M. Abramovici, M.A. Breuer and A.D. Friedman, “Digital Systems Testing and Testable Design”, Wiley-IEEE Press,1993 4. P.H. Bardell, W.H. McAnney and J. Savir, “Built-in Test for VLSI: Pseudorandom Techniques”, Wiley Interscience, 1987 5. L-T. Wang, C-W. Wu and X. Wen, “VLSI Test Principles and Architectures”, Morgan Kaufman Publishers, 2006 6. P.K. Lala, “Fault Tolerant and Fault Testable Hardware Design”, Prentice-Hall Intl 1985

1	**Semester**	II
2	**Type of course**	Core
3	**Code of the subject**	EE-609
4	**Title of the subject**	Engineering Research Methodology
5	**Any prerequisite**	None
6	**L-T-P**	2-1-0
7	**Learning Objectives of the subject**	• Equip students with the ability to formulate research problems, design experiments, and employ appropriate research methodologies in engineering. • Teach students to collect, analyse, and interpret data using various statistical and computational tools. • Install a strong understanding of ethical considerations in research, including data integrity, plagiarism, and responsible reporting. • Develop students' skills in technical writing and presentation, enabling them to effectively communicate research findings. • Foster critical thinking and problem-solving abilities, preparing students to tackle complex engineering challenges through rigorous research.
8	**Brief Contents**	This course provides an in-depth understanding of research techniques and methodologies essential for engineering research. Topics include the formulation of research problems, literature review, research design, and experimental methods. Students will learn quantitative and qualitative research methods, data collection and analysis techniques, and the use of statistical tools. The course covers ethical considerations, technical writing, and presentation skills, emphasizing the importance of reproducibility and peer review. Practical sessions will involve developing research proposals, designing experiments, and analysing real-world data, equipping students with the skills to conduct rigorous and impactful engineering research.
9	**Text/ Reference Books**	1. "Research Methodology: A Step-by-Step Guide for Beginners" by Ranjit Kumar 2. "Research Methods for Engineers" by David V. Thiel 3. "Engineering Research: Design, Methods, and Analysis" by Herman Tang 4. "The Craft of Research" by Wayne C. Booth, Gregory G. Colomb, and Joseph M. Williams

1	**Semester**	II
2	**Type of course**	Core
3	**Code of the subject**	EE-610
4	**Title of the subject**	CAD for VLSI
5	**Any prerequisite**	Digital Design
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	1. Understand the general design process of modern VLSI chips. 2. Be able to identify and formulate design problems within a sound methodology. 3. Build capability to analysis a problem, and design efficient algorithms to solve it. 4. Become familiar with most algorithms and methods used in VLSI CAD. 5. Be able to implement algorithms in CAD tools.
8	**Brief Contents**	Introduction to VLSI-CAD, module generation, PLAs and FPGAs, digital hardware modelling, benchmark circuits (ISCAS’85, ISCAS’89, etc.), simulation algorithms, design verification, graph data structure and algorithms for VLSI-CAD, high-level synthesis, algorithms for physical design automation, slicing and non-slicing floorplans, polar graphs and adjacency graphs for floorplans, Placement: objective functions; partitioning based placement. Global routing: geometric spanning trees; Steiner trees; net ordering. Detailed Routing: shortest paths and maze search, Channel routing, introducing NoC as a future SoC paradigm, timing analysis, SDC, set-up and hold time concepts, timing exceptions, set-up and hold calculations, and noise analysis.
9	**Text/ Reference Books**	1. Sherwani, N., Algorithms for VLSI Physicsl Design Automation, Springer (2005) 3rd ed. 2. Gerez S.H., Algorithms for VLSI Design Automation, John Wiley (1998) 3. Sarrafzadeh, M. and Wong, C. K., An Introduction to VLSI Physical Design, McGraw Hill (1996). 4. Trimberger, S. M., An Introduction to CAD for VLSI, Kluwer (1987). 5. Sait, S. M. and Youssef, Habib, VLSI Physical Design Automation – Theory and Practice, World Scientific, 2004.

1	**Semester**	II
2	**Type of course**	Core
3	**Code of the subject**	EE-611
4	**Title of the subject**	Advanced IC Design and Technology Lab-II
5	**Any prerequisite**	NILL
6	**L-T-P**	0-1-4
7	**Learning Objectives of the subject**	• The lab experiments of this course will provide exposure to how the fundamental and advanced theories, design concepts, and principles of the core/elective courses studied in the 2nd semester can be applied in practice. • The objective of the course is to provide the fundamental knowledge for understanding the flow of IC design using EDA tools and better approaches/solutions for more effective design. • The objective of the course is to provide the fundamental knowledge of analog IC design using the Cadence EDA tool. In-depth introduction to System Verilog and efficient verification using System Verilog.
8	**Brief Contents**	Design steps to implement the Analog circuits using EDA tools, Provide the in-depth concept and flow for implementation of IC Design, Circuit analysis with change in the device parameters, Impact of parasitic on circuit performance. Improvements for RTL design and synthesis; Verification enhancements such as object-oriented design; Assertions and randomization.
9	**Contents for lab**	Introduction to digital circuit simulators– NGSPICE and Cadence tools for circuit and layout simulations; SPICE models of CMOS devices; Static and dynamic characterization of CMOS inverters, gate delay and interconnect delay in CMOS; Analog Circuits Simulations, Combinational and sequential static CMOS circuits including pass transistors; Dynamic CMOS logic circuits; Introduction to hardware description languages (VHDL/Verilog)- - analysis, elaboration, and synthesis of HDLs and implementation on FPGAs.
10	**Text/ Reference Books**	1. S. M. Kang and Y. Leblebici, `CMOS Digital Integrated Circuits' Tata McGraw-Hill

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-051
4	**Title of the subject**	Device and Interconnect Modelling
5	**Any prerequisite**	NIL
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	By studying this course, students will gain a comprehensive understanding of technology trends and scaling in the semiconductor industry. They will learn about Moore's Law, technology nodes, and the physical and technological limitations that impact semiconductor miniaturization. The course will provide in-depth knowledge of interconnect modeling and analysis, covering RC, RLC, and transmission line models while exploring the effects of capacitive and inductive coupling on signal integrity. Students will also understand key factors such as power dissipation, reliability concerns, and performance trade-offs in interconnects.
8	**Brief Contents**	Technology trends, Device and interconnect scaling, Interconnect Models: RC model and RLC model, Effect of capacitive coupling, Effect of inductive coupling, Transmission line model, Power dissipation, Interconnect reliability, Driver and Load Device Models, Interconnect Analysis, Time domain analysis, RLC network analysis, RC network analysis and responses in time domain, S domain analysis, Circuit reduction via matrix approximation, Analysis using moment matching, Crosstalk Analysis, Advanced Interconnect Materials. Moore law, Technology nodes and ITRS, Physical & Technological Challenges to scaling, Two terminal MOS Device threshold voltage modelling, C-V Characteristics, Four terminal MOSFET threshold voltage I-V modelling, short channel effect (SCE), High-K gate dielectric, Nonconventional MOSFET – (FDSOI, SOI, Multi-gate MOSFETs). Nonconventional MOSFET – (FDSOI, SOI, Multi-gate MOSFETs) and advanced VLSI devices and interconnects
9	**Lab Content**	NA
10	**Text/ Reference Books**	**1.** Nano Interconnects: Device Physics, Modeling and Simulation by Afreen Khursheed and, Kavita Khare (CRC Press, 2024) **2.** Fundamentals of Device and Systems Packaging: Technologies and Applications, Second Edition by Rao Tummala

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-052
4	**Title of the subject**	VLSI Signal Processing
5	**Any prerequisite**	Digital Circuit, and Signals & Systems
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Provides comprehensive coverage of techniques for designing efficient VLSI architectures specifically for Digital Signal Processing (DSP) systems. • Addresses real-world challenges in implementing DSP systems, such as high throughput data processing, real-time operation, and resource constraints. • Focuses on optimizing power consumption and minimizing chip area while maintaining performance in DSP applications. • Equips students with the skills to design VLSI architectures that meet the demands of modern DSP systems in terms of efficiency and scalability.
8	**Brief Contents**	Discusses Signal Flow Graph (SFG), Data Flow Graph (DFG), and Dependence Graph (DG) for DSP algorithms. Critical path minimization, retiming of DFG, loop retiming, and iteration bounds. Pipelined DSP architectures and parallel realization of DSP algorithms for optimization. Explores parallel realizations of FIR filters, including 2-parallel and 3-parallel architectures, and hardware minimization. Introduces unfolding theorem and polyphase decomposition for efficient DSP realization.
9	**Reference Book**	1. VLSI Digital Signal Processing Systems: Design and Implementation, Keshab K. Parhi,: Wiley-Interscience. 2. VLSI for Signal Processing, Umesh H. Patil, Prentice Hall 3. Digital Signal Processing: A VLSI Implementation Perspective, Keshab K. Parhi, Wiley-Interscience.

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-053
4	**Title of the subject**	Low Power VLSI
5	**Any prerequisite**	Digital Electronics
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Understand the Need for Low Power VLSI Design. • Analyze Power Dissipation Mechanisms in CMOS Circuits. • Apply Low Power Design Techniques at device, circuit, and architecture level. • Perform Power Estimation and Analysis. • Understand clock gating and low-power clocking strategies. • Reduce power consumption in clock distribution networks.
8	**Brief Contents**	Need for low-power VLSI chips, Sources of Power Dissipation on Digital Integrated Circuits, Dynamic Dissipation, Static Dissipation, Technology & Device Innovation, Emerging Low power Approaches, Low Power Design Techniques at Architecture and System Levels, Power Consumption of Dedicated Hardware vs. Software Implementations of Systems, Low Power Architecture, RTL design Techniques for Low Power, Low Power Random Access Memory Circuits, Power Analysis and Design at System level and state-of-the-art Low Power Applications.
9	**Lab Content**	NA
10	**Text/ Reference Books**	1. "Low-Power CMOS VLSI Circuit Design" by Kaushik Roy and Sharat C. Prasad 2. "Low-Power Digital VLSI Design: Circuits and Systems" by Abdellatif Bellaouar and Mohamed I. Elmasry 2. "Low Power Digital CMOS Design" by Anantha P. Chandrakasan and Robert W. Brodersen

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-054
4	**Title of the subject**	Microcontroller and Embedded System
5	**Any prerequisite**	Nil
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	This course aims to convey knowledge of basic concepts of embedded system design required for every state-of-the-art electrical/electronic system in the form of autonomous and real–time computing machine embodied within them. Emphasis is on the features and characteristics of embedded system, design metrics, embedded system design flow, processor, memory and input output interfacing and input output devices, assembly language, hardware description language, I/O interface design and programming, real-time operating system, hardware-software co- design and co-simulation. Special attention will be devoted to the most important challenges facing embedded system designers today and in the coming decade.
8	**Brief Contents**	Introduction to Embedded System, Major components, Design issues, Microprocessor, DSP, Microcontroller architecture, Memory, FPGA, ASIC, ARM architecture fundamentals, Interfacing and Communication Protocols
9	**Text/ Reference Books**	1. "The Art of Designing Embedded Systems" by Jack Ganssle 2. "Embedded Systems: Real-Time Interfacing to ARM Cortex-M Microcontrollers" by Jonathan W. Valvano **3.** “Architecting High-Performance Embedded Systems”, Jim Ledin

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-055
4	**Title of the subject**	Memory Devices and Circuits
5	**Any prerequisite**	Microelectronic Devices/Digital Electronics
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Understand the Fundamentals of Memory Systems. • Analyze SRAM and DRAM Architectures. • Evaluate Non-Volatile Memory Technologies. • Design and Optimize Memory Peripheral Circuits. • Explore Advanced and Emerging Memory Technologies.
8	**Brief Contents**	Introduction to Memory Systems, Memory Arrays, Memory Market, 6T/8T SRAM Design, 3T/1T-1C DRAM Design, Charge Pump Circuits, Open and Folded Bit Line Architecture, Arrays organizations, Sense Amplifiers & Peripheral Circuits, Introduction to Flash memory, NAND/NOR Flash memory, Organization of NAND Flash Memory, Advance 3D NAND Flash Configuration, Next Generation Memory (PCM, MRAM, RRAM), Emerging Memory Devices for Neuromorphic Applications.
9	**Lab Content**	NA
10	**Text/ Reference Books**	1. "Digital Integrated Circuits: A Design Perspective" by Jan M. Rabaey, Anantha Chandrakasan, and Borivoje Nikolić. 2. "CMOS Digital Integrated Circuits: Analysis and Design" by Sung-Mo Kang and Yusuf Leblebici. 3. "Advanced Memory Technology" by Ye Zhou and Guoxing Wang.

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-056
4	**Title of the subject**	VLSI Architecture
5	**Any prerequisite**	None
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• The course objective is to cover the architecture design of VLSI systems and subsystems with the notion of optimization for area, speed, dissipation, cost and reliability. • Different aspects of VLSI system design and its applications in various fields. • The course also discusses traditional, and state of the art analog and digital VLSI architectures optimized techniques.
8	**Brief Contents**	**Module 1:** ISA, Datapath and Control Path Design, Single Cycle MIPS, 5-Stage Pipeline MIPS, CISC Architecture. **Module 2:** RISC Architecture, Arithmetic Unit Design, Fixed Point and Floating Point, Memory Units, Optimization. **Module 3:** Instruction Level Parallelism, Superscalar Processor, Multi-Core and Multi-Thread Architecture. **Module 4:** Network on Chip, Dynamically Reconfigurable Gate Array, Static vs. Dynamic Reconfiguration. **Module 5:** Single Context vs. Multi-Context Dynamic Reconfiguration, Full Spatial Run-Time Reconfiguration.
9	**Text/ Reference Books**	1. “VLSI Architecture” Prentice Hall publisher by B. Randell and P.C. Treleaven 2. “Physical Architecture of VLSI Systems” Wiley publisher by Robert J. Hannemann, Allan D. Kraus, and Michael Pecht 3. “Advanced VLSI Architectures: From Concept to Silicon” I I P Iterative International Publishers by Mr. Somnath Maity and Mr. Rakesh Kumar

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-057
4	**Title of the subject**	Hardware Security
5	**Any prerequisite**	None
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Learning the state-of-the-art security methods and devices. • Better understanding of attacks and providing counter measures against them • CMOS implementation of hardware security primitives, Attacks oncyber-physical systems
8	**Brief Contents**	**Module 1:** Fundamentals of Hardware Security and Trust for Integrated Circuits, Physical and Invasive Attacks, Side-Channel Attacks and Countermeasures. **Module 2:** Physically Unclonable Functions (PUFs), Hardware-Based True Random Number Generators, CMOS PUF Implementations. **Module 3:** Hardware Trojan, Hardware Security Primitives, Hardware Trojan Detection and Isolation in IP Cores. **Module 4:** Watermarking of Intellectual Property (IP) Blocks, FPGA Security, Passive and Active Metering for Prevention of Piracy. **Module 5:** Access Control, Counterfeit IC Detection, Security Measures for Integrated Circuits.
9	**Text/ Reference Books**	1. "Introduction to Hardware Security and Trust" Springer publisher by Mohammad Tehranipoor and Cliff Wang 2. "Hardware Security: Design, Threats, and Safeguards" CRC Press publisher by Debdeep Mukhopadhyay and Rajat Subhra Chakraborty 3. "Hardware Security: A Hands-on Learning Approach" Morgan Kaufmann publisher by Swarup Bhunia and Mark Tehranipoor

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-058
4	**Title of the subject**	FPGA-Based System Design
5	**Any prerequisite**	Nil
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	The goal of the course is to study the basic principles and methods of FPGA prototyping. Understanding of principles of IC prototyping; hardware and software; design strategies and methods
8	**Brief Contents**	ROM, SPLD, CPLD Architecture and Features of FPGA and designing techniques. Architecture of ROM – ROM Programming – Architecture of SPLDs – SPLDs programming – Architecture of CPLDs, Basics of FPGAs– Structure of FPGAs Implementation of Digital circuits in FPGA processor, Education FPGA kit – FPGA pin assignment – Interfacing Input/Output devices with FPGA, SPI, I2C, I3C, UART protocol RTL design System Design Examples using Xilinx FPGAs – Traffic light Controller, Real Time Clock, VGA, Keyboard, LCD, Embedded Processor Hardware Design.
9	**Text/ Reference Books**	1. M.J.S. Smith, "Application Specific Integrated Circuits", Pearson, 2000. 2. Peter Ashenden, "Digital Design using Verilog", Elsevier, 2007. 3. W. Wolf, "FPGA based system design", Pearson, 2004. 4. Clive Maxfield, "The Design Warriors's Guide to FPGAs", Elsevier, 2004 5. S. Ramachandran, "Digital VLSI System Design: A Design Manual for implementation of Projects on FPGAs and ASICs Using Verilog" Springer Publication, 2007. 6. Wayne Wolf, "FPGA Based System Design", Prentices Hall Modern Semiconductor Design Series.

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-059
4	**Title of the subject**	Quantum Electronics
5	**Any prerequisite**	Microelectronic Devices and Circuits
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Gain insight into the fundamental structure of solids and how their atomic arrangement influences electronic properties. • Grasp the basic principles of quantum mechanics, including wave-particle duality, uncertainty principle, and quantization. • Learn how to solve Schrödinger's wave equation for different potential systems and understand its significance in electronic properties. • Understand the concept of DOS and its importance in determining the electronic properties of materials. • Carrier Transport Phenomenon in Semiconductors.
8	**Brief Contents**	The Crystal Structure of Solids, Introduction to Quantum Mechanics: Principles of Quantum mechanics, Application of Schrodinger's Wave Equations, Introduction to Quantum Theory of Solids: The kronig-Penney Model, Electrical conduction in Solids, DOS, Statistical Mechanics, The semiconductor in Equilibrium Carrier transport Phenomenon, Non-equilibrium Excess Carriers in Semiconductor, PN-Junction, MOSCAP, Thin film Transistors, Quantum Cellular Automata
9	**Lab Content**	NA
10	**Text/ Reference Books**	1. "Quantum Mechanics: Concepts and Applications" by Nouredine Zettili 2. "Semiconductor Physics and Devices" by Donald A. Neamen 3. "Quantum Theory of Solids" by Charles Kittel 4. "Quantum Cellular Automata and Quantum Computing" by S. I. Zernov

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-060
4	**Title of the subject**	RF Circuit Design
5	**Any prerequisite**	Analog IC Design
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Get the idea of various parameters of interest in RF systems. • To understand issues involved in design for GHz frequencies. • To understand theoretical background relevant for design of active and passive circuits for RF front end in wireless digital communication systems.
8	**Brief Contents**	Characteristics of passive components for RF circuits. Passive RLC networks. Transmission lines. Two-port network modeling. S-parameter model. The Smith Chart and its applications, Active devices for RF circuits: SiGe MOSFET, GaAs pHEMT, HBT and MESFET. RF Amplifier design: single and multi-stage amplifiers. Review of analog filter design. Voltage references and biasing. Low Noise Amplifier design: noise types and their characterization, LNA topologies, Power match vs Noise match. Linearity and large- signal performance, RF Power amplifiers: General properties. Class A, AB and C Power amplifiers. Class D, E and F amplifiers. Modulation of power amplifiers, Analog communication circuits, Phase-locked loops, Oscillators and synthesizers.
9	**Lab Content**	None
10	**Text/ Reference Books**	1. D. M. Pozar, "*Microwave Engineering*," 4th Edition, Wiley, 2012. 2. C. Bowick, "*RF circuit design*," 2nd Edition, Newnes, 2007. 3. R. C. Li, "*RF Circuit Design*," 2nd Edition, John Wiley & Sons, 2012. 4. G. Gonzalez, "*Microwave Transistor Amplifiers: Analysis and Design,*" 2nd Edition, Prentice Hall, 1996. 5. T. H. Lee, "*Planar Microwave Engineering: A Practical Guide to Theory, Measurement, and Circuits*," Cambridge University Press, 2004. 6. D. M. Pozar, "*Microwave and RF Design of Wireless Systems*," John Wiley & Sons, 2001.

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-061
4	**Title of the subject**	Mixed Signal SoC Design
5	**Any prerequisite**	None
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Understand the significance of different biasing styles and apply it for different circuits. • Design basic building blocks like sources, sinks, mirrors, up to layout level. • Comprehend the stability issues of the systems and design Op- amp fully compensated against process, supply and temperature variations. • Identify suitable topologies of the constituent subsystems and corresponding circuits as per the specifications of the system Design. • Analog integrated system including parasitic effects up to tape-out.
8	**Brief Contents**	**Module 1:** Process and Temperature Independent Compensation, Resistor Equivalence of a Switched Capacitor, Parasitic-Sensitive and Parasitic-Insensitive Integrators. **Module 2:** Signal-Flow-Graph Analysis, Noise in Switched-Capacitor Circuits, Performance of Sample-and-Hold Circuits. **Module 3:** Ideal D/A Converter, Ideal A/D Converter, Quantization Noise, Charge-Redistribution A/D, Resistor-Capacitor Hybrid. **Module 4:** Basic Phase-Locked Loop (PLL) Architecture, Voltage-Controlled Oscillator (VCO), Divider, Phase Detector, Loop Filter, PLL in Lock. **Module 5:** Linearized Small-Signal Analysis, Second-Order PLL Model, Jitter and Phase Noise, Period Jitter, Probability Density Function of Jitter, Ring and LC Oscillators.
9	**Text/ Reference Books**	1. “Design of Analog CMOS Integrated Circuits” Mc Graw Hill publisher by Behzad Razavi 2. “Analog Integrated Circuit Design” Wiley publisher by Tony Chan Carusone, David Johns, and Kenneth Martin 3. “Analog Design for CMOS VLSI Systems” Kluwer Academic publishers by Franco Maloberti

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-062
4	**Title of the subject**	AI-Accelerator Design
5	**Any prerequisite**	NIL
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• This course provides in-depth coverage of the architectural techniques used to design accelerators for training and inference in machine learning. • Get exposure of implementation of CNN network in FPGA board. • Get an idea about the data system bus used in communication between different system blocks. • To design energy-efficient accelerators, develop the intuition to make trade-offs between ML model parameters and hardware implementation techniques.
8	**Brief Contents**	**Module 1:** Deep Understanding of Neural Networks, Linear Algebra Fundamentals, Accelerating Linear Algebra. **Module 2:** Implementation of Deep Learning Kernels, Zynq Series FPGA Architecture, Interface Knowledge. **Module 3:** High-Speed Protocols (Ethernet 100/10 Gbps), SPI, I2C, I3C, UART Protocol RTL Design. **Module 4:** C/C++ Coding for Vivado SDK, Activation Function Verilog Implementation. **Module 5:** Classification Layer HDL Implementation, Optimization for FPGA-based Deep Learning..
9	**Text/ Reference Books**	1. “Efficient Processing of Deep Neural Networks” Morgan & Claypool Publisher by Vivienne Sze, Yu-Hsin Chen, Tien-Ju Yang, and Joel Emer 2. “Artificial Intelligence Hardware Design: Challenges and Solutions” Wiley-IEEE Press publisher by Albert Chun Chen Liu and Oscar Ming Kin Law 3. “From CNN to DNN hardware Accelerators: A Survey on Design, Exploration, Simulation, and Frameworks” Now publisher by Leonardo Rezende Juracy, Rafael Garibotti and Fernando Gehm Moraes

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-063
4	**Title of the subject**	System-on-Chip Design
5	**Any prerequisite**	NIL
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	This course provides in-depth coverage of System-on-Performance Chip Design. Design, optimize, and program a modern System-on-a-Chip to analyze and characterize its computational requirements computational task, and identify performance bottlenecks. Characterize and develop real-time solutions. Implement both hardware and software solutions, formulate hardware/software tradeoffs, and perform hardware/software codesign.
8	**Brief Contents**	Hardware/software co-design: partitioning, real-time scheduling, hardware acceleration; Virtual prototyping: electronic system-level languages and hardware/software co-simulation; High-level synthesis: allocation, scheduling and binding algorithms for C-to-RTL synthesis; SoC integration: SoC communication architectures, IP interfacing, verification and test; FPGA prototyping of hardware/software systems.
9	**Text/ Reference Books**	1. P. Marwedel, Embedded System Design: Embedded Systems Foundations of Cyber-Physical Systems, Third Edition, Springer, 2018. (author's website) 2. D. C. Black, J. Donovan, B. Bunton, A. Keist, SystemC: From the Ground Up, Second Edition, Springer, 2010. 3. G. De Micheli, Synthesis and Optimization of Digital Circuits, McGraw-Hill, 1994.

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-064
4	**Title of the subject**	Embedded Software
5	**Any prerequisite**	Nil
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Convert software programs into equivalent cycle-based hardware and vice versa. • Partition software into hardware and software components with proper interfaces. • Identify and optimize performance bottlenecks in hardware-software architectures
8	**Brief Contents**	Design of embedded systems, architectures and platforms for embedded systems, general purpose vs. application-specific architectures, reconfigurable systems, optimization techniques for design space exploration, software synthesis and code generation, system-level power/energy optimization, Security in embedded systems, embedded software for AI and IoT Applications, embedded system Testing & Validation
9	**Text/ Reference Books**	1. David E. Simon, "An Embedded Software Primer" 2. Daniele Lacamera, "Embedded Systems Architecture" 3. Mohamed Rafiquzzaman, "Microprocessors and microcomputer Based System Design"

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-066
4	**Title of the subject**	Special Topics in IC Design and Technology
5	**Any prerequisite**	NIL
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	This will focus on special topics of contemporary relevance and interest to both VLSI industry and state-of-the-art research.
8	**Brief Contents**	It will cover current research and development topics and in line with VLSI industry and may cover all aspects from Device Technology to chip design flow through ASIC and FPGA, Topics from state-of-the-art design methodologies. Architecture, circuit and layout level issues, Timing and Design closure. Deep sub-micron circuit design-logic and layout issues, FinFET and other novel devices.
9	**Text/ Reference Books**	1. Neil Weste and David Harris, "CMOS VLSI Design: A circuits and Systems perspective", 3rd Ed., Addison Wesley, 2004 2. RF microelectronics, Behzad Razavi, Prentice Hall, 1998. 3. William J. Dally, John W. Poulton, "Digital Systems Engineering, "Cambridge University Press 1999 4. Yaun Taur and Tak H.Ning, "Fundamentals of modern VLSI devices", Cambridge University Press 1999 5. Recent publications from IEEE, IEICE and ACM Journals

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-068
4	**Title of the subject**	Network on Chip
5	**Any prerequisite**	NIL
6	**L-T-P**	3-0-0
7	**Learning Objectives ofthe subject**	1. To learn the basic concepts of NoC design by studying the topologies, router design and MPSoC styles, 2. To learn sample routing algorithms on a NoC with deadlock and livelock avoidance, 3. To understand the role of system-level design and performance metrics in choosing a NoC design
8	**Brief Contents**	Introduction to NoC, OSI layer rules in NoC, Interconnection Networks in Network-on-Chip Network Topologies, Switching Techniques, Routing Strategies, Architecture Design, Switching Techniques and Packet Format, Asynchronous FIFO Design, Wormhole Router Architecture Design - VC Router Architecture Design - Adaptive Router Architecture Design, Routing Algorithms, Test and Fault Tolerance of NOC, 3-D integration of NOC.
9	**Text/ Reference Books**	1. N. Enright Jerger and L-S. Peh, On-Chip Networks, Synthesis Lectures on Computer Architecture, Morgan & Claypool, 2009, 2. A Jantsch and H. Tenhunen, Networks on Chip, Kluwer Academic Publishers, 2003. 3. W. J. Dally, Principles and Practices of Interconnection Networks, Morgan Kaufmann, 2004.

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-069
4	**Title of the subject**	Digital Image Computation
5	**Any prerequisite**	None
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Understand the fundamentals of digital image representation, storage, and color models in image processing. • Learn techniques for image transformation, enhancement, filtering, and noise reduction. • Gain skills in image segmentation, feature extraction, and morphological processing for object analysis. • Apply image compression and machine learning techniques for recognition, classification, and practical applications.
8	**Brief Contents**	This course covers essential techniques and methods in digital image processing, beginning with an introduction to digital images, their representation, and storage, including color models and resolution. It explores image transformations such as Fourier Transform and Discrete Fourier Transform (DFT) for image analysis and filtering, followed by image enhancement techniques like histogram equalization and noise reduction. Students will learn about linear and nonlinear image filtering, segmentation, and feature extraction methods such as SIFT and SURF for object detection and recognition. The course also covers morphological image processing, including dilation, erosion, and shape analysis, as well as image compression methods like JPEG and PNG. Finally, the course applies machine learning techniques for image recognition and classification, with real-world applications in medical imaging, remote sensing, computer vision, and digital photography.
9	**Lab Content**	Not Applicable
10	**Text/ Reference Books**	1. "Digital Image Processing" by Rafael C. Gonzalez and Richard E. Woods 2. "Computer Vision: Algorithms and Applications" by Richard Szeliski 3. ""Pattern Recognition and Machine Learning" by Christopher M. Bishop 4. "Digital Image Processing Using MATLAB" by Rafael C. Gonzalez, Richard E. Woods, and Steven L. Eddins 5. "Practical Python and OpenCV + Case Studies" by Adrian Rosebrock

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-070
4	**Title of the subject**	Audio Signal Processing
5	**Any prerequisite**	Signals and Systems
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Focuses on algorithms for acoustic and audio signal processing, including applications in audio algorithm design and signal analysis. • Emphasizes critical areas such as monophonic and stereophonic echo cancellation, active noise control, and feedback reduction in communication systems. • Addresses real-world challenges in both wired and wireless communication, with an emphasis on audio signal processing technologies used globally in various industries.
8	**Brief Contents**	Audio signal recording, analysis and representation techniques, audio measurement, sound intensity, noise signal analysis and characterization, stationary and nonstationary signals, probabilistic signal processing techniques with applications for acoustic & audio signal analysis, digital filters for audio enhancement. Characteristics of widely interfaced acoustic signals, multiple sub-filters different error, common error and combined error algorithms, monophonic and stereophonic acoustic echo-cancellation, active noise suppression, feedback cancellation.
9	**Text/ Reference Books**	1. D. Manolakis, M. Ingle, S. Kogon, Statistical and Adaptive Signal Processing, McGraw-Hill, Revised Edition 2014. 2. Jacob Benesty, Israel Cohen, Jingdong Chen, Fundamentals of Signal Enhancement and Array Signal Processing, Wiley & Sons, 2018. 3. Udo Zolzer, Digital Audio Signal Processing, Wiley & Sons, 2008. 4. Steven L. Gay, Jacob Benesty, Acoustic Signal Processing for Telecommunication, Springer, 2001.

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-071
4	**Title of the subject**	Advance Digital Signal Processing
5	**Any prerequisite**	Signals and Systems, Digital Signal Processing
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Understand the advanced principles of digital signal processing (DSP) and its applications in real-time systems. • Develop proficiency in advanced DSP techniques such as adaptive filtering, multirate signal processing, and spectral analysis. • Gain expertise in the design and implementation of efficient DSP algorithms for applications like speech, audio, and image processing.
8	**Brief Contents**	Overview of advanced topics in DSP including sampling, quantization, and the z-transform. Emphasis on discrete-time signals and systems, and their mathematical representations. Study of adaptive filter algorithms such as LMS (Least Mean Squares), RLS (Recursive Least Squares), and their applications in noise cancellation, echo cancellation, and channel equalization. Techniques for downsampling and upsampling, interpolation, decimation, and polyphase filters. Applications in data compression and speech signal processing. Advanced methods for spectral estimation, including the periodogram, Bartlett's method, and the Welch method. Wavelet bases. Balian-Low theorem. Multiresolution analysis. (MRA). Focus on real-time and non-stationary signal analysis. Implementation of DSP techniques in communication systems, including OFDM (Orthogonal Frequency Division Multiplexing), channel coding, and modulation schemes.
9	**Text/ Reference Books**	1. “Understanding Digital Signal Processing" by Richard G. Lyons,: Pearson Education. 2. "Digital Signal Processing: Principles, Algorithms, and Applications" by John G. Proakis and Dimitris G. Manolakis 3. "Advanced Digital Signal Processing: Theory and Applications" by Saeed V. Vaseghi Publisher: Wiley-Interscience 4. "Discrete-Time Signal Processing" by Alan V. Oppenheim and Ronald W. Schafer, Publisher: Pearson Education

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-072
4	**Title of the subject**	Biomedical Signal Processing
5	**Any prerequisite**	Understanding of Digital and Analog Signals
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Understand the principles of acquiring and preprocessing physiological signals. • Learn techniques for noise reduction, filtering, and signal enhancement. • Apply time-domain and frequency-domain analysis methods to biomedical signals. • Develop and implement algorithms for feature extraction and pattern recognition in diagnostics.
8	**Brief Contents**	The "Biomedical Signal Processing" course covers the fundamentals and advanced techniques for analysing physiological signals. Topics include signal acquisition and preprocessing, noise reduction, and filtering. Students will explore time-domain and frequency-domain analysis, feature extraction, and pattern recognition methods. The course also delves into advanced topics such as wavelet transforms, machine learning for biomedical signal analysis, and applications in diagnostics and monitoring. Practical sessions involve MATLAB/Python programming for real-world signal processing tasks. By the end of the course, students will be equipped with the skills to develop and implement algorithms for interpreting complex biomedical signals.
9	**Text/ Reference Books**	1. "Biomedical Signal Processing and Signal Modelling" by Eugene N. Bruce 2. "Biomedical Signal Processing: Principles and Techniques" by D. C. Reddy 3. "Advanced Methods of Biomedical Signal Processing" edited by Sergio Cerutti and Carlo Marchesi 4. "Biomedical Signal Analysis: A Case-Study Approach" by Rangaraj M. Rangayyan

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-074
4	**Title of the subject**	Computer Vision
5	**Any prerequisite**	Understanding of Signals
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Understand the principles of image formation and feature detection in computer vision. • Learn techniques for object recognition, classification, and scene reconstruction. • Apply motion analysis and 3D vision methods to interpret visual information. • Develop and implement deep learning algorithms for computer vision using Python and OpenCV.
8	**Brief Contents**	The "Computer Vision" course explores the fundamentals and advanced techniques for enabling machines to interpret and understand visual information from the world. Topics include image formation, feature detection, and matching, as well as object recognition and classification. Students will study motion analysis, 3D vision, and scene reconstruction. Advanced topics such as deep learning for computer vision, including convolutional neural networks (CNNs), are also covered. Practical sessions involve implementing algorithms and applications using Python and OpenCV. By the end of the course, students will be proficient in developing computer vision systems for real-world applications.
9	**Text/ Reference Books**	1. "Computer Vision: Algorithms and Applications" by Richard Szeliski 2. "Multiple View Geometry in Computer Vision" by Richard Hartley and Andrew Zisserman 3. "Deep Learning for Computer Vision" by Rajalingappaa Shanmugamani 4. "Learning OpenCV 4: Computer Vision with Python" by Adrian Kaehler and Gary Bradski

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of Subject**	EE-076
4	**Title of the Subject**	Internet of Bio-Nano Things
5	**Prerequisite**	Linear Algebra, Signals and Systems, Digital Communication, Probability and Statistics, Computational Theory
6	**L-T-P**	3-0-0
7	**Learning Objectives**	This course will cover communication techniques and technologies to conceive networks on the nanoscale. Instead of the standard use of electromagnetic waves, we will perform the emission and detection of molecules according to the paradigm of Molecular Communications. We will follow a network architecture approach from a computer network perspective, see the picture on the right. In the physical layer, we will introduce models for the communication channels through molecular means, as well as for emitters and receivers. In the link layer, we will address mechanisms for the information flow and error control mechanisms. In this course, we will not only study theoretical concepts but will conduct many hands-on activities in the MATLAB simulator to model the physical and link layers.
8	**Brief Contents**	Introduction to Molecular communication: Why, what, and how? Applications areas: Biological engineering, Medical and healthcare applications, Industrial applications, Environmental applications, Information and communication technology applications, Nature-made biological nanomachines, Basic physical concepts, Chemical reactions and the master equation, Chemical reactions and the master equation (part 2), Basics of biochemistry, Brownian motion, First arrival time distribution, Concentration and counting, Modulation techniques, Transportation Mechanisms, Timing channels, Concentration channels, Noise and intersymbol interference, Molecular MIMO, Signal transduction, Information theory of molecular communication, Experimental approaches, Jamming bacterial communications: new strategies to combat bacterial infections and the development of biofilms, Quorum sensing and cell-to-cell communication in the dental biofilm.
9	**Text and Reference Books**	1. R. G. Gallager, “Stochastic Processes: Theory for Applications,” 1st edition, Cambridge University Press, 2013. 2. T. Nakano, A. Eckford, “Molecular Communication”, 1st edition, Cambridge University Press, 2013. 3. P. Peebles, “Probability, Random Variables, and Random Signals”, 4th edition, New York, NY: McGraw-Hill, 2017. 4. D. R. Demuth, R. J. Lamont, “Bacterial Cell-to-Cell Communication”, 1st Edition, Cambridge University Press, 2006. 5. S.M. Ross, “Stochastic Processes”, 2nd Edition, Wiley, 1996. 6. S. Karlin, and H. M. Taylor, “A First Course in Stochastic Processes”, 2nd edition, Academic Press, 1975. 7. Research Papers

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-079
4	**Title of the subject**	Cyber Security
5	**Any prerequisite**	NA
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Develop a understanding of cybersecurity principles and techniques • Explore foundational concepts, and emerging technologies • Gain skills in cryptography, threat detection, network security • Understand policies, compliance, and cyber risk management
8	**Brief Contents**	Introduction to Cybersecurity: Importance, Threat Landscape, Security Goals, Symmetric and Asymmetric Cryptography, Hash Functions, Digital Signatures, Network Security Essentials: Firewalls, Intrusion Detection Systems. Viruses, Worms, Ransomware, SQL Injection, Cloud and IoT Security Challenges, IoT Threats, and Countermeasures, Artificial Intelligence in Security, AI-based Threat Detection, Machine Learning Models for Security, Zero Trust Architecture: Concepts, Zero Trust Network Access, Implementation Strategies, Security Policies and Compliance, Cyber Risk Management and Governance: Risk Assessment, Business Continuity, Disaster Recovery, Future of Cyber Security
9	**Lab Content**	NA
10	**Text/ Reference Books**	1. Introduction to Modern Cryptography by Jonathan Katz, Yehuda Lindell, 2025, Chapman & Hall/CRC 2. Cryptography and Network Security: Principles and Practice by William Stallings, 2021, Pearson 3. Zero Trust Networks: Building Secure Systems in Untrusted Networks by Evan Gilman, Doug Barth, 2017, O'Reilly Media 4. Computer Security: Principles and Practice by William Stallings, Lawrie Brown, 2017, Pearson 5. The Web Application Hacker's Handbook: Finding and Exploiting Security Flaws by Dafydd Stuttard, Marcus Pinto, 2011, Wiley

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-081
4	**Title of the subject**	Optimization Techniques
5	**Any prerequisite**	NA
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	This course introduces optimization techniques, covering both linear and non-linear programming. While the primary focus is on convex optimization, the course also explores techniques for optimizing non-convex functions. Following a foundational overview of linear algebra and probability theory, students will learn to formulate engineering problems involving minima and maxima within the framework of optimization.
8	**Brief Contents**	The content covers various optimization and computational techniques, including network flow models and algorithms such as shortest path methods (Dijkstra, label-correcting, and auction algorithms), max-flow and min-cost flow problems (Ford-Fulkerson, simplex methods), and transformations in optimization. It delves into solving linear and nonlinear programming problems using iterative methods, line search techniques, Hessian-based approaches (Newton, conjugate directions, quasi-Newton), and constrained optimization (Lagrange variables, KKT conditions, quadratic programming, convex problems, mixed integer models, and interior point methods). Additionally, it introduces OR models, linear programming techniques (simplex, artificial variables, two-phase, big-M), transportation and assignment problems, sequencing, replacement, game theory, inventory management, and dynamic programming with engineering applications. The final module explores quantum information theory, including density operators, entanglement, teleportation, Shannon entropy, quantum channels, cryptography, and quantum key distribution.
9	**Text/ Reference Books**	1. Boyd, Stephen, Stephen P. Boyd, and Lieven Vandenberghe. Convex optimization. Cambridge university press, 2004. 2. D. Bertsekas Nonlinear programming, 2nd Edition, Athena Scientific, 1999, Nashua. 3. V. Chvatal Linear programming, W. H. Freeman, 1983, New York. 4. E. K. P. Chong and S. Zak, An introduction to optimization, 2nd Edition, 2004, John Wiley and Sons (Asia) Pvt. Ltd., Singapore 5. R. Fletcher, Practical methods of optimization, 2nd Edition, Wiley, 2000, New York 6. D. Luenberger, Linear and nonlinear programming, 2nd Edition, 1984, Kluwer Academic Publisher, New York 7. O. L. Mangasarian, Nonlinear programming, SIAM, 1987, Philadelphia

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-083
4	**Title of the subject**	Internet of Things
5	**Any prerequisite**	None
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• To introduce the concept of Internet of Things (IoT), reference layer and various protocols and software. • To make the students capable of building IoT systems using sensors, single board computers and open source IoT platforms.
8	**Brief Contents**	Evolution of IoT, IoT architecture reference layer, IoT protocols, software and gateway protocols, IoT point to point communication technologies IoT Communication Pattern, Introduction to Cloud computation and Big data analytics, IoT security, Sensors: Working Principles: Different types Interface Electronic Circuit for Smart Sensors and Challenges for Interfacing the Smart Sensor, Usefulness of Silicon Technology in Smart Sensor And Future scope of research in smart sensor
9	**Lab Content**	None
10	**Text/ Reference Books**	**Text Books:** 1. IoT Fundamentals: Networking Technologies, Protocols and Use Cases for Internet of Things, David Hanes, Gonzalo Salgueiro, Patrick Grossetete, Rob Barton and Jerome Henry, Cisco Press, 2017 2. Internet of Things – A hands-on approach, Arshdeep Bahga, Vijay Madisetti, Universities Press, 2015 3. Internet of Things: Architecture, Design Principles and Applications, Rajkamal, McGraw Hill Higher Education **Reference Books:** 1. The Internet of Things – Key applications and Protocols, Olivier Hersent, David Boswarthick, Omar Elloumi and Wiley, 2012 2. “From Machine-to-Machine to the Internet of Things – Introduction to a New Age of Intelligence”, Jan Holler, Vlasios Tsiatsis, Catherine Mulligan, Stamatis, Karnouskos, Stefan Avesand. David Boyle and Elsevier, 2014. 4. Architecting the Internet of Things, Dieter Uckelmann, Mark Harrison, Michahelles and Florian (Eds), Springer,2011. 5. Jacob Fraden, “Handbook of Modern Sensors: physics, Designs and Applications”, 2015, 3rd edition, Springer, New York. 6. Jon. S. Wilson, “Sensor Technology Handbook”, 2011, 1st edition, Elsevier, Netherland.

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-085
4	**Title of the subject**	Software Defined Radio
5	**Any prerequisite**	Understanding of basic concepts of communication systems and signals
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	Understand different models for Software Defined Radio in detail, like Software Defined Radio Architecture for performance optimization. Program and test software-defined radio transceivers; Implement different physical layer communication protocol/algorithm using Software Defined Radio.
8	**Brief Contents**	Introduction: The requirement for software defined radio, Software defined radio architectures; Ideal Software defined radio architectures, required hardware specifications, Digital aspects of a Software Defined radio, Current technology limitations Introduction to USRP radios and GNU Radio software platform and Coding; implementation on SDR: Digital modulation and demodulation; AM transceiver, Time and frame synchronization, channel estimation and equalization; Machine learning with SDR
9	**Lab Content**	NA.
10	**Text/ Reference Books**	1. Travis F. Collins, Robin Getz, Di Pu, and Alexander M. Wyglinski, “Software-Defined Radio for Engineers,” Artech House, 2018 2. F. Xiong,. Digital Modulation Techniques, Artech House, 2006. ProQuest eBook Central. ISBN: 9781580538640 3. J. G. Proakis and M. Salehi, Digital Communications, McGraw-Hill, 5th ed., 2008. (ISBN 978-0-07-295716-7) 4. J. Vanakka, “Digital Synthesizers and Transmitter for Software Radio”, Springer, 2005

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-086
4	**Title of the subject**	Quantum Communication
5	**Any prerequisite**	None
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Introduce key concepts and theories of Quantum Communication. • Explain the working principles of quantum communication systems. • Explore fundamental limits of quantum communication over classical and quantum channels. • Discuss practical implementation and challenges in quantum communication systems.
8	**Brief Contents**	Vector Spaces, Inner-Product Spaces, Linear Independence and Basis, Finite-Dimensional Hilbert Spaces, Linear Operators and Projectors, Eigenvalue Decomposition, Tensor Products, Analysis and Probability, Limits, Infimum, Supremum, and Continuity, Compact Sets and Convexity, Qubits and Axioms of Quantum Systems, Positive Operator-Valued Measure (POVM), Helstrom Decision Theory and Quantum Communication Systems, Quantum Modulation Schemes, Density Operators and Quantum Entanglement, Quantum Teleportation and Cryptography, Shannon Entropy and Classical Information Theory, Quantum Channels and Noisy Transmission, Quantum Key Distribution
9	**Lab Content**	NA
10	**Text/ Reference Books**	1. “Quantum Communications”, Gianfranco Cariolaro, Springer, 2015. 2. “Quantum Communication, Quantum Networks, and Quantum Sensing”, Ivan B. Djordjevic, Academic Press, 2022. 3. Principles of Quantum Communication Theory: A Modern Approach”, Sumeet Khatri, and Mark M. Wilde, 2021 4. Quantum Computation and Quantum Information”, Michael Nielsen and Isaac Chuang, Cambridge University Press, 2010.

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-087
4	**Title of the subject**	5G and 6G Standards
5	**Any prerequisite**	Advanced Communication Systems
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Trace the evolution from 1G to 6G, highlighting key concepts, performance metrics, and advancements. • Study 5G standards, architecture, technologies, use cases, and the role of 3GPP and ITU. • Discover 6G vision, emerging standards, features, enabling technologies, and use cases. • Analyze regulatory, security, spectrum management, and deployment challenges for 5G and 6G.
8	**Brief Contents**	Evolution of Mobile Networks, 1G to 6G Advancements, Performance Metrics and Spectrum Utilization, Energy Efficiency and Sustainability in Wireless Networks, 5G Architecture and Core Technologies, Network Slicing and Virtualization, mmWave Communications and Massive MIMO, 5G NR Interface and Channel Modulation, 5G Use Cases and Applications, Standardization Bodies: 3GPP, ITU, GSMA, 6G Vision and Roadmap, Key Enabling Technologies for 6G, Security and Privacy in 5G/6G Networks, Spectrum Allocation and Regulatory Challenges, Future Trends and Research in 5G/6G Deployment.
9	**Lab Content**	NA
10	**Text/ Reference Books**	1. Wireless Communications: Principles and Practice by Theodore S. Rappaport, 2nd Edition, Pearson Education. 2. Xingqin Lin and Namyoon Lee, 5G and Beyond: Fundamentals and Standards, Springer, Edition Number1 3. Abdulrahman Yarali, From 5G to 6G: Technologies, Architecture, AI, and Security, Wiley-IEEE Press

1	**Semester**	I
2	**Type of course**	Elective
3	**Code of the subject**	EE-088
4	**Title of the subject**	Smart Antenna System
5	**Any prerequisite**	None
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Understand the fundamental parameters of antenna and use of cellular concepts and basic architecture, features and benefits of smart antennas. • Able to integrate smart antenna technology with overall communication system design, principle and its performance. • Understand the beamforming techniques and adaptive array techniques. • Understand the implementation of smart antennas for Direct sequence CDMA systems and examine some of the challenges involved in applying smart antennas to CDMA. .
8	**Brief Contents**	Fundamental Parameters of Antenna and cellular concepts, Mobile antennas and mobile Radio Propagation and Modelling. Antennas for Mobile Communication. Different Types of Antennas, Introduction to Smart Antenna systems, need of smart antenna, Fixed Beam forming networks, Switched Beam Systems, Adaptive Antenna Systems, Smart Antennas Techniques for CDMA, Analysis Using Smart Antennas – A Vector Based Approach
9	**Lab Content**	None
10	**Text/ Reference Books**	**1.** Antennas for all applications, 3rd edition, by J.D. Krauss, TMH. **2.** Antenna & Wave Propagation, K.D. Prasad, Satyaprakash publications. 4. Wireless Communications: Principles and practice, 2nd edition, Theodore S. Rappaport, PHI. 5. Joseph C. Liberti and Theodore S. Rappaport, Smart Antennas for Wireless Communications IS 95 and Third Generation CDMA Applications, Prentice Hall PTR 6. Balanis C A, Antenna Theory: design and applications, Wiley 7. Frank Gross, Smart Antennas for Wireless Communications- McGraw Hill 8. Ahmed El-Zooghby, Smart Antenna Engineering, Artech House Publishers 9. Constantine Balanis, Introduction to Smart Antennas, Morgan and Claypool Publisher. 10. F.B. Gross - Smart Antennas for Wireless Communications, McGraw-Hill., 2005.

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-089
4	**Title of the subject**	Advanced Optical Communication
5	**Any prerequisite**	Advanced Communication Systems
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Learn the fundamentals of optical communication, including fiber properties, light propagation, dispersion, and nonlinearity. • Explore optical sources, detectors, modulation techniques, and design aspects for transmitters and receivers with a focus on SNR and BER. • Understand WDM principles, components, optical amplifiers, and noise management in system performance. • Analyze high-speed modulation techniques, optical networks, emerging technologies, and scalability challenges.
8	**Brief Contents**	Overview of Optical Communication Systems, Optical Fiber Types and Light Propagation, Dispersion and Nonlinear Effects in Fibers, Optical Fiber Waveguides and Specialty Fibers, Optical Sources: LEDs and Laser Diodes, Photodetectors and Receiver Sensitivity, Optical Receivers and Coherent Detection, Point-to-Point Optical Links and Power Budget, Wavelength Division Multiplexing (WDM) Principles and System Design Considerations, Optical Amplifiers: EDFAs and Raman Amplifiers, Optical Network Architectures and Topologies, Optical Cross-Connects and ROADMs, Elastic Optical Networks and Space-Division Multiplexing, Quantum Optical Communication and Future Trends.
9	**Lab Content**	NA
10	**Text/ Reference Books**	1. Fiber Optic Communications by Gerd Keiser, 5th Edition, McGraw Hill Education. 2. Optical Fiber Communications: Principles and Practice by John Senior, 3rd Edition, Pearson Education. 3. Optical Networks: Design and Implementation by Rajiv Ramaswami and Kumar Sivarajan, Third Edition.

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-092
4	**Title of the subject**	Data Communication Protocol
5	**Any prerequisite**	Knowledge of fundamentals of data structures and associated algorithms
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Define and understand the meaning and role of protocol, the concept of layering, appreciate the role of TCP/IP layer model • Demonstrate the basic concepts of error detection, checking and correction at data link layer and application to flow control protocols. • Apply formulae to practical communication systems and analyse their performances in transmitting data signals.
8	**Brief Contents**	The course will focus on the design and implementation techniques essential for engineering robust networks. Topics include networking principles, Transmission Control, Protocol/Internet Protocol, naming and addressing (Domain Name System), data encoding/decoding techniques, link layer protocols, routing protocols, transport layer services, congestion control, quality of service, network services, Software Defined Networks (SDNs), programmable routers and overlay networks, wireless and mobile networking, security in computer networks, multimedia networking, and network management.
9	**Lab Content**	NA.
10	**Text/ Reference Books**	1. Data and Computer Communications by William Stallings 2. Data communication & Networking by Bahrouz Forouzan. 3. Computer Networks by Andrew S. Tanenbaum

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-613
4	**Title of the subject**	Next-Generation Communication Systems
5	**Any prerequisite**	None
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Understand the communication requirements and challenges in autonomous systems. • Explore various wireless communication technologies and network protocols. • Learn sensor network integration and data fusion techniques for autonomous system functionality.
8	**Brief Contents**	This course focuses on communication technologies for autonomous system. It covers communication requirements and challenges in autonomous environments. Topics include signal representation, transmission, and reception. The course also explores multipath fading, path-loss, and noise in communication systems, and how they affect signal quality. Additionally, it covers various next generation wireless communication technologies, network protocols (TCP/IP, UDP, real-time protocols), and machine-to-machine (M2M) communication. The course also explores sensor networks, data fusion techniques etc.
9	**Lab Content**	NA
10	**Text/ Reference Books**	1. “Communication Systems" by Simon Haykin 2. “Wireless Communications: Principles and Practice" by Theodore S. Rappaport 3. “Autonomous Vehicles: Opportunities, Strategies, and Disruptions" by Daniel P. K. Riewoldt 4. “Introduction to Autonomous Robots: Mechanisms, Sensors, Actuators, and Algorithms" by Nikolaus Correll et al. 5. “Principles of Modern Wireless Communication Systems, Theory and Practice,” A. Jagannatham, McGraw Hill Education (India) Private Limited, 2016.

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-065
4	**Title of the subject**	High Performance Computing Systems
5	**Any prerequisite**	VLSI Architecture
6	**L-T-P**	3-0-0
7	**Learning Objectives ofthe subject**	• To get in-depth analysis of issues in High Performance Computing systems including Parallel Computing, New Processor Architectures, Power-Aware Computing and Communication, Advanced Topics on Peta scale Computing and Optical Systems. • To understand parallel models of computation such as dataflow, and demand-driven computation.
8	**Brief Contents**	Parallel Processing Concepts; Levels and model of parallelism: Instruction, Transaction, Task, Thread, Memory, Function, Data Flow models, Demand-driven computation; Parallel architectures: Superscalar architectures, Multi-core, Multi- threaded, Server and cloud; Fundamental design issues in HPC: Load balancing, scheduling, Synchronization and resource management; Operating systems for scalable HPC; Parallel languages and programming environments; Fundamental limitations in HPC, Benchmarking HPC, Scalable storage systems, Accelerated HPC, Power-aware HPC Design.
9	**Text/ Reference Books**	1. “High Performance Computing: Modern Systems and Practices" by Thomas Sterling, Matthew Anderson, Maciej Brodowicz, Morgan Kaufmann, 2017. 2. “Introduction to High Performance Computing for Scientists and Engineers" by Georg Hager and Gerhard Wellein, CRC Press, 2010. 3. “Parallel Computer Architecture: A Hardware/Software Approach" by David Culler and Jaswinder Pal Singh, Morgan Kaufmann 1998. 4. “Dataflow Supercomputing" by Patrick K. O'Neil, Springer International Publishing AG, 2017. 5. “Power-Aware Computing" by Andrea Biedenkapp, Rainer Hartenstein, et al. 6. “Introduction to High Performance Computing for Scientists and Engineers" by Georg Hager and Gerhard Wellein

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-067
4	**Title of the subject**	Sensors for Autonomous System
5	**Any prerequisite**	None
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Understanding the fundamentals and functionality of micro sensors. • Exploring sensor usage in autonomous systems. • Examining sensor integration for real-time applications. • Learning mathematical modeling and estimation techniques for real-world systems. • Studying various approaches, including optimization techniques, to achieve desired system outcomes.
8	**Brief Contents**	Introduction and Historical Background, Microsensors, Sensor Principles/Classification-Physical Sensors, Methods for Data Acquisition, Modelling Dynamic Systems using Transfer Functions, Multiple-input-Multiple-output Systems, Feedback control methods, Rule based and Optimization Approaches, Hardware Development, System Dependability, Fault Detection, Diagnosis and Prognosis.
9	**Lab Content**	NA
10	**Text/ Reference Books**	1. "Introduction to Sensors and Actuators" by John R. Gardner. 2. "Sensor Fusion Approaches for Positioning, Navigation, and Mapping: How Autonomous Vehicles and Robots Navigate in the Real World: With MATLAB Examples" by Mohamed M. Atia 3. "Robotics and Smart Autonomous Systems" by Rashmi Priyadarshini, Ram Mohan Mehra, Amit Sehgal, and Prabhu Jyot Singh

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-073
4	**Title of the subject**	Data Analytics
5	**Any prerequisite**	Should have knowledge of one Programming Language (Java preferably), Practice of SQL (queries and sub queries), exposure to Linux Environment.
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Understand the Big Data Platform and its Use cases • Provide an overview of Apache Hadoop • Understand Map Reduce Jobs • Provide hands on Hadoop Eco System • Apply analytics on Structured, Unstructured Data • Exposure to Data Analytics with R
8	**Brief Contents**	Types of Digital Data, Introduction to Big Data, Big Data Analytics, History of Hadoop, Apache Hadoop, Analyzing Data with Unix and Hadoop, Hadoop Streaming, Hadoop Echo System, IBM Big Data Strategy, HDFS Concepts, Command Line Interface, Hadoop file system interfaces, Data flow, Data Ingest with Flume and Scoop and Hadoop archives, Map Reduce Anatomy of a Map Reduce Job Run, Failures, Job Scheduling, Shuffle and Sort, Task Execution, Map Reduce Types and Formats, Map Reduce Features, Introduction to PIG, Execution Modes of Pig, User Defined Functions, Data Processing operators, Data Analytics with R Machine Learning, Big Data Analytics with BigR.
9	**Lab Content**	NA
10	**Text/ Reference Books**	1. "Data Analytics Made Accessible" by Anil Maheshwari (2023 Edition) 2. "Advancing Into Analytics: From Excel to Python and R" by George Mount (2021) 3. "Python for Data Analysis: Data Wrangling with Pandas, NumPy, and IPython" by Wes McKinney (2017) 4. "The Data Warehouse Toolkit: The Definitive Guide to Dimensional Modeling" by Ralph Kimball and Margy Ross (2013) 5. "Data Mining: Concepts and Techniques" by Jiawei Han, Micheline Kamber, and Jian Pei (2011)

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-075
4	**Title of the subject**	Reinforcement Learning
5	**Any prerequisite**	Understanding of Signals
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Understand the fundamentals of reinforcement learning and Markov decision processes (MDPs). • Learn key algorithms such as Q-learning, Monte Carlo methods, and temporal-difference learning. • Explore advanced techniques in deep reinforcement learning using neural networks. • Implement reinforcement learning algorithms and apply them to real-world problems using Python.
8	**Brief Contents**	The "Reinforcement Learning" course delves into the core concepts and methodologies of reinforcement learning (RL), where agents learn to make decisions by interacting with their environment. Topics include Markov decision processes (MDPs), dynamic programming, Monte Carlo methods, and temporal-difference learning. Students will explore advanced RL techniques such as Q-learning, policy gradients, and deep reinforcement learning using neural networks. The course also covers applications in robotics, game playing, and autonomous systems. Practical sessions involve implementing RL algorithms using Python and frameworks like TensorFlow or PyTorch. By the end of the course, students will be capable of designing and deploying RL solutions for complex problems.
9	**Text/ Reference Books**	1. "Reinforcement Learning: An Introduction" by Richard S. Sutton and Andrew G. Barto 2. "Deep Reinforcement Learning Hands-On" by Maxim Lapan 3. "Reinforcement Learning: State-of-the-Art" edited by Marco Wiering and Martijn van Otterlo 4. "Python Reinforcement Learning" by Sudharsan Ravichandran

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-078
4	**Title of the subject**	Quantum Computing
5	**Any prerequisite**	NA
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	This course serves as an introduction to the quantum computational model, focusing on understanding and analysing fundamental quantum algorithms. It also explores the limitations of quantum algorithms and provides the essential tools and techniques to demonstrate these constraints.
8	**Brief Contents**	Introduction: Elementary quantum mechanics: linear algebra for quantum mechanics, Quantum states in Hilbert space, The Bloch sphere, Density operators, generalized measurements, no-cloning theorem. Quantum correlations: Bell inequalities and entanglement, Schmidt decomposition, superdense coding, teleportation. Quantum cryptography: quantum key distribution. Quantum gates and algorithms: Universal set of gates, quantum circuits, Solovay-Kitaev theorem, Deutsch-Jozsa algorithm, factoring. Programming a quantum computer: The IBMQ, coding a quantum computer using a simulator to carry out basic quantum measurement and state analysis.
9	**Text/ Reference Books**	1. Phillip Kaye, Raymond Laflamme et. al., An introduction to Quantum Computing, Oxford University press, 2007. 2. Chris Bernhardt, Quantum Computing for Everyone, The MIT Press, Cambridge, 2020 3. David McMahon-Quantum Computing Explained-Wiley-Interscience, IEEE Computer Society (2008). 4. Quantum Computation and Quantum Information, M. A. Nielsen &I. Chuang, Cambridge University Press (2013). 5. (5) Quantum Computing, A Gentle Introduction, Eleanor G. Rieffel and Wolfgang H. Polak MIT press (2014)

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-080
4	**Title of the subject**	Deep Learning for Autonomous Systems
5	**Any prerequisite**	Machine Learning
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Provide an in-depth understanding of deep learning techniques and their applications in autonomous systems. • Enable students to design and implement neural networks for perception, decision-making, and control in autonomous systems. • Introduce state-of-the-art deep learning frameworks and tools for real-world deployment. • Foster the ability to address challenges like dynamic environments, uncertainty, and real-time processing in autonomous systems.
8	**Brief Contents**	Introduction: Defining Autonomous Systems, Artificial Intelligence, Machine Learning, and Deep learning. Overview of the 3 pillars of Autonomous Vehicles: Perception, Prediction, Planning and Quick overview of sensing modalities. Deep learning for Perception, Introduction to deep learning, Neural Network, CNN, regularization techniques. State-of-the-art techniques: Self supervised learning, Vision Transformer, and Deep learning for Prediction. Introduction to Recurrent Neural Networks, Graph Neural Network, Transformer, Diffusion. Generative Models: Variational Autoencoders (VAEs) and Generative Adversarial Networks (GANs) for simulation and environment modeling. Case Studies and Applications: Real-world examples in autonomous vehicles, drones, and robotic systems, addressing challenges in dynamic and uncertain environments.
9	**Text/ Reference Books**	1. Deep Learning From Scratch: Building with Python from First Principles by Seth Weidman. 2. Deep Learning for Computer Vision with Python

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-082
4	**Title of the subject**	Advanced Control System
5	**Any prerequisite**	Understanding of Systems
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Understand state-space representation and concepts of controllability and observability. • Learn advanced control methods such as optimal, robust, and adaptive control. • Apply modern control design techniques like pole placement and LQR. • Develop and simulate advanced control systems using MATLAB/Simulink for real-world applications.
8	**Brief Contents**	Control theory for designing and analysing complex control systems. State-space representation, controllability, observability, and state feedback control. Students will explore advanced methods like optimal control, robust control, and adaptive control systems. Modern control design techniques such as pole placement, linear quadratic regulator (LQR), and H-infinity control. Students will study the application of these techniques in systems with uncertainty and nonlinearity. Practical sessions involve MATLAB/Simulink to model and simulate advanced control systems, preparing students to tackle real-world control engineering challenges.
9	**Text/ Reference Books**	1. "Modern Control Engineering" by Ogata Katsuhiko 2. "Feedback Control of Dynamic Systems" by Gene F. Franklin, J. Da Powell, and Abbas Emami-Naeini 3. "Advanced Control Engineering" by Roland S. Burns 4. "Robust Control: The Parameter Space Approach" by Kemin Zhou and John C. Doyle

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-093
4	**Title of the subject**	Drone Technology and Robotics
5	**Any prerequisite**	None
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Design, construct, and program basic autonomous robots. • Apply standard signal processing and control algorithms effectively. • Develop and implement UAV drone systems. • Gain an understanding of various engine types and their applications. • Comprehend static and dynamic stability, dynamic instability, and associated control principles.
8	**Brief Contents**	Robotics: Robotics and AI, Embedded Systems, Agent-Task-Environment model. AI and the Internet of Things: Real World Use-Cases: Automated vacuum cleaners, Smart thermostat solutions. Introduction to Drones: Introduction to Unmanned Aircraft Systems, History of UAV drones, classification of drones, System Composition, applications. Design of UAV Drone Systems: Introduction to Design and Selection of the System, Design for Stealth. Avionics Hardware of Drones: Autopilot, AGL-pressure sensors servos-accelerometer, gyros-actuators, power supply-processor, integration, installation, configuration.
9	**Lab Content**	None
10	**Text/ Reference Books**	1. Reg Austin "Unmanned Aircraft Systems UAV design, development and deployment", Wiley, 2010. 2. Robert C. Nelson, Flight Stability and Automatic Control, McGraw-Hill, Inc, 1998. 3. The Art of Robotics: An introduction to engineering, F Martin, Addison-Wesley.

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-612
4	**Title of the subject**	Sensors and Actuators
5	**Any prerequisite**	None
6	**L-T-P**	3-0-2
7	**Learning Objectives of the subject**	• Understand the principles and working mechanisms of various types of sensors and actuators. • Explore calibration techniques and the characteristics of different sensors in real-world environments. • Gain hands-on experience in controlling actuators such as motors and solenoids for the development of autonomous systems.
8	**Brief Contents**	This course covers the principles, design, and applications of sensors and actuators in modern systems. Topics include the working principles of various types of sensors such as temperature, pressure, humidity, proximity, and motion sensors. Students will explore the characteristics and calibration. The course also focuses on actuators, including motors, solenoids, and piezoelectric devices, discussing their control use for the development for autonomous systems. Practical sessions will involve designing and implementing systems that use sensors and actuators for real-time monitoring and actuation applications.
9	**Lab Content**	The lab covers experiments on different types of sensors, including temperature sensors (thermocouples, RTDs, thermistors), light and proximity sensors (LDR, IR, ultrasonic), pressure and force sensors (strain gauges, load cells), motion and acceleration sensors (accelerometers, gyroscopes), gas and humidity sensors (MQ-series, DHT11/DHT22), and magnetic sensors (Hall-effect). Additionally, students work with actuators such as DC motors, stepper motors, servo motors, and pneumatic/hydraulic actuators. The lab also focuses on interfacing sensors with microcontrollers like Arduino or Raspberry Pi, enabling real-time data acquisition and control. Advanced topics include smart sensors, IoT applications, and wireless sensor networks.
10	**Text/ Reference Books**	1. Introduction to Sensors and Actuators by John R. Gardner 2. Sensors and Actuators: Engineering System Instrumentation by D. Patranabis 3. Sensors and Transducers by D. Patranabis 4. The Art of Electronics by Paul Horowitz and Winfield Hill

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-615
4	**Title of the subject**	Autonomous Systems
5	**Any prerequisite**	None
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Understand the principles and applications of autonomous systems in robotics, drones, and self-driving vehicles. • Learn the integration and role of sensors like LIDAR, radar, cameras, and IMUs in perception and data collection. • Implement computer vision and deep learning techniques for object detection, tracking, and decision-making in autonomous systems. • Apply path planning, SLAM-based localization, reinforcement learning, and control algorithms for autonomous navigation and decision-making.
8	**Brief Contents**	Introduction to autonomous systems and their applications in robotics, drones, and self-driving vehicles, followed by an exploration of key sensors like LIDAR, radar, cameras, and IMUs (Inertial Measurement Units) and their role in perception and data collection. The course covers computer vision techniques for image processing, feature extraction, object detection, and tracking, along with deep learning architectures such as CNNs and RNNs for decision-making and navigation. Students will also study sensor fusion methods, including Kalman filtering and deep sensor fusion, to combine data from multiple sensors for enhanced accuracy. The syllabus includes path planning, real-time navigation, localization using SLAM, and reinforcement learning for decision-making in dynamic environments. Control systems for vehicle dynamics and the ethical, safety, and security aspects of autonomous systems are also discussed. Finally, the course delves into real-world applications through case studies and hands-on projects.
9	**Lab Content**	NA
10	**Text/ Reference Books**	1. "Autonomous Systems: A Comprehensive Approach" by Michael A. Hsieh 2. "Autonomous Robots: From Biological Inspiration to Implementation and Control" by George A. Bekey 3. "Computer Vision: Algorithms and Applications" by Richard Szeliski 4. "Autonomous Vehicles: Opportunities, Strategies, and Disruptions" by Chris Gerdes, Wade H. H. 5. "Deep Learning" by Ian Goodfellow, Yoshua Bengio, and Aaron Courville 6. "Robotics: Modelling, Planning and Control" by Bruno Siciliano, Lorenzo Sciavicco, Luigi Villani, and Giuseppe Oriolo