DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING, MIT MANIPAL

B. Tech. ELECTRONICS ENGINEERING (VLSI DESIGN AND TECHNOLOGY)

Program Structure (Applicable to 2023 admission onwards)

2nd Year Syllabus

YEAR	THIRD SEMESTER						FOURTH SEMESTER					
	SUB CODE	SUBJECT NAME	L	T	P	C	SUB CODE	SUBJECT NAME	L	T	P	C
II	MAT 2122	ENGINEERING MATHEMATICS – III	2	1	0	3	ECE 2227	ENGINEERING MATHEMATICS – IV	2	1	0	3
	ECE 2122	NETWORK ANALYSIS	3	0	0	3	ECE 2221	VLSI DESIGN	4	0	0	4
	ECE 2123	SIGNALS & SYSTEMS	3	0	0	3	ECE 2222	DIGITAL SIGNAL PROCESSING	3	0	0	3
	ECE 2125	ELECTROMAGNETIC WAVES	3	0	0	3	ECE 2226	PHYSICS OF SEMICONDUCTOR DEVICES	4	0	0	4
	ECE 2126	ANALOG CIRCUITS	4	0	0	4	ECE 2228	COMPUTER ORGANIZATION AND ARCHITECTURE	3	0	0	3
	ECE 2127	DIGITAL CIRCUITS	3	0	0	3	ECE 2229	FPGA BASED SYSTEM DESIGN USING VERILOG	3	0	0	3
	ECE 2143	DIGITAL CIRCUITS LAB	0	0	3	1	ECE 2243	FPGA BASED SYSTEM DESIGN USING VERILOG LAB	0	0	3	1
	ECE 2144	ANALOG CIRCUITS LAB	0	0	3	1	ECE 2244	VLSI DESIGN LAB	0	0	3	1
	Total		**18**	**1**	**6**	**21**			**19**	**1**	**6**	**22**

SEMESTER III

MAT 2122 ENGINEERING MATHEMATICS III [2 1 0 3]

Total number of contact hours: 36

Systems of Linear Equations, Matrices, Solving Systems of Linear Equations, Vector Spaces, Linear Independence, Basis and Rank, Linear Mappings, Affine Spaces. Norms, Inner Products, Lengths and Distances, Angles and Orthogonality, Orthonormal Basis, Orthogonal Complement, Inner Product of Functions, Orthogonal Projections, Rotations. Determinant and Trace, Eigenvalues and Eigenvectors, Cholesky Decomposition, Eigen decomposition and Diagonalization, Singular Value Decomposition, Matrix approximation, Periodic function, Fourier Series expansion. even and odd functions, functions with arbitrary periods, Half range expansions, Fourier transform, basic properties, Parseval's identity and applications.

*Self-directed Learning:
Singular Value Decomposition, Fourier cosine and sine transform application to Heat and Wave equation.

References:

1. Marc Peter Deisenroth, A. Aldo Faisal, Cheng Soon Ong, "*Mathematics for Machine Learning",* Cambridge University Press, 2020.
2. Grewal B.S. – "*Higher Engineering Mathematics",* Khanna Publishers, 43rd edition, 2015
3. Stephen H. Friedberg Lawrence E Spence, Arnold J Insel, *Elementary Linear Algebra: "A Matrix Approach Introduction to Linear Algebra"*, Second Edition, 2019.
4. David Lay, Steven Lay, Judi McDonald, "*Linear Algebra and Its Applications*, Pearson", 2019.
5. Gilbert Strang, *"Introduction to Linear Algebra*", Fifth Edition, Wellesley- Cambridge Press, 2016
6. Mordechai Ben-Ari, *"Mathematical Logic for Computer Science*", Third Edition, Springer, 2012
7. Narayanan, Ramaniah and Manicavachagom Pillay, "*Advanced Engineering Mathematics*", Vol 2 and 3, Vishwanthan Publishers Pvt Ltd. 1998
8. Erwin Kreyszig, *Advanced Engineering Mathematics*, 5th edn., Wiley Eastern, 1985.

ECE 2122 NETWORK ANALYSIS [3 0 0 3]

Total number of contact hours: 36

Network equations; Mesh and nodal analysis; Network theorem- Superposition, Reciprocity, Thevenin's, Norton's theorems, Maximum power transfer theorem; Initial and final conditions in RL, RC and RLC Circuits for DC Excitations. General and Particular solution of the first order and second order circuits. Applications of Laplace transform in finding solution or RC, RL, and RLC networks, Response of RC circuits for step, pulse, square, and ramp input; Two port network- Open circuit impedance parameters, short circuit admittance parameters, transmission parameters, hybrid parameters.

*Self-directed Learning:
Two-port Interconnections

References:

1. M. E. Van Valkenberg, "*Network analysis",* Prentice Hall of India, 2000.
2. Ravish R Singh, "*Network analysis and Synthesis",* McGraw Hill, 2013.
3. William H. Hayt, Jack E. Kemmerly, Steven M Durbin, "*Engineering Circuit Analysis",* 8th edition, Tata McGraw Hill India, 2013.
4. Millman, H. Taub, "Pulse, *digital and switching waveforms*", 3nd Edition, *McGraw* Hill, 2017.
5. Joseph Edminister, "*Electric Circuits*", Schaum's Series, McGraw Hill, 2018.
6. *https://nptel.ac.in/courses/108102042

ECE 2123 SIGNALS AND SYSTEMS [3 0 0 3]

Total number of contact hours: 36

Continuous time (CT) and discrete time (DT) signals, Representation and classification of Signals, Elementary signals, time domain operations on signals, correlation between signals; Continuous time and discrete time systems, system properties. LTI system, impulse response, response of LTI system, Convolution, differential/difference equation and block diagram representation; Fourier analysis of signals and systems, LTI systems in frequency domain, Parseval relation, ESD, PSD; LTI system analysis using Laplace transform, transfer function, poles/zeroes, stability; Z-transform, application in LTI system analysis; sampling and re-construction.

*Self-directed Learning:
Generation of signals and Fourier analysis

References:

1. Simon Haykin, Barry Van Veen, "*Signals and Systems",* John Wiley & Sons, NewDelhi,2008
2. A. V. Oppenheim, A. S. Willsky, A. Nawab, "*Signals and Systems",* PHI. Pearson Education, New Delhi, 2015.
3. H. Hsu, R. Ranjan "*Signals and Systems*", Schaums outline, Tata McGraw Hill, New Delhi, 2006.
4. Michael J. Roberts, *"Fundamentals of Signals and Systems*", First Edition, Tata McGraw Hill Publishing Company Limited, 2007.
5. Rodger E. Ziemer, William H. Tranter D. Ronald Fannin, "*Signals and Systems",* Fourth Edition, Pearson Education, 2004.
6. *Signal Processing tool boxes in MATLAB

ECE 2125 ELECTROMAGNETIC WAVES [3 0 0 3]

Total number of contact hours: 36

Review of Electrostatics and Magneto statics: Coordinate system and vectors, Curl and Divergence, Divergence theorem and Stokes theorem in the context of electromagnetics. Uniform Plane Waves: Maxwell's equations, Electromagnetic wave propagation. Transmission Lines: parameters, Transmission line equations and solutions Standing Wave Ratio, power and impedance measurement, Stub impedance matching, Smith Chart and its applications in transmission line calculations, applications of transmission lines. Waveguides: Rectangular waveguides – TE, TM modes, power transmission. Introduction to Cylindrical waveguides.

*Self-Directed Learning
Planar dielectric waveguides

References:

1. *Jr. Hayt and Buck, *"Engineering Electromagnetics"*, 7th Edition, McGraw Hill, 2012.
2. Ryder J. D, "*Networks, Lines, and Fields*", 2nd Edition, PHI, 2015.
3. Shevgaonkar R. K, *"Electromagnetic Waves"*, 2nd Edition, Tata McGraw Hill, 2019.
4. Plonus M. A, "*Applied Electromagnetics*", McGraw Hill, 1988
5. Edminister J. A, "*Electromagnetics"*, 2nd Edition, Schaum's Outline Series, Tata McGraw Hill, 2006.

ECE 2126 ANALOG CIRCUITS [4 0 0 4]

Total number of contact hours: **48**

MOSFET: Structure, operation, I-V Characteristics of MOSFET; Small-Signal Model, PMOS Transistor; MOSFET Biasing, Analysis of Common-Source, Common-Gate Amplifier and Source Follower; Differential Amplifier basics, Operational Amplifier. Linear applications, instrumentation amplifier and bridge amplifier. Active filters: Design and analysis. Non-linear applications of operational amplifier: Log and antilog amplifiers, analog multipliers and dividers, comparators, Schmitt trigger, square wave, triangular wave generators and pulse generators, 555 IC, functional diagram of 555 IC, Astable multi-vibrator, Mono-stable multi-vibrator, Data Converters.

*Self Directed Learning
Concepts of Feedback, Oscillators

References:

1. Behzad Razavi, "*Fundamental of Microelectronics*", Wiley, 2013.
2. A. S. Sedra, K. C. Smith, "*Microelectronic circuits*", Oxford University Press, 2011.
3. Franco S, "*Design with Op-amps & Analog Integrated Circuits"* McGraw Hill, 4th edition, 2015.
4. *Ramakant A. Gayakwad, "*Op-Amps and Linear Integrated Circuits*", Prentice Hall of India, 2000.

ECE 2127 DIGITAL CIRCUITS [3 0 0 3]

Total number of contact hours: 36

Digital logic, Boolean functions, Boolean algebra, K-maps, combinational circuits, multiplexers, demultiplexer, comparators, decoders, priority encoders, synchronous sequential circuits, flip flops, clocked sequential circuits, counters, asynchronous sequential circuits, Stable and Unstable states, State reduction, race free assignments, Hazards, Pulse mode sequential circuits, Design of Hazard free circuits.

*Self-Directed Learning:
Asynchronous sequential circuits

References:

1. *Donald D Givone, "*Digital Principles and Design*", Tata McGraw Hill, 2002.
2. William I. Fletcher, "*An Engineering approach to Digital Design",* Prentice Hall of
3. India, 2009
4. M. J. S. Smith, "*Application Specific ICs*" Pearson 1997.
5. Samir Palnitkar, "*Verilog HDL: A Guide to Digital Design and Synthesis",* Prentice Hall PTR, 2003.
6. Stephen. Brown and Zvonko Vranesic, "*Fundamentals of Digital Logic with Verilog Design"*, Tata McGraw Hill, 2013.

ECE 2143 DIGITAL CIRCUIT DESIGN LAB [0 0 3 1]

Total number of contact hours: 30

EXPERIMENTS

Basics and universal gates, code converters and arithmetic's circuits, Logic implementation using MUX, DEMUX, Encoders and Decoders, FFs, counters and shift registers, Counters applications, Shift Registers, Design of sequential Circuits.

References:

1. Donald D Givone, *"Digital Principles and Design",* Tata McGraw Hill, 2002.
2. William I. Fletcher, *"An Engineering approach to Digital Design"*, Prentice Hall of India, 2009
3. Samir Palnitkar, *"Verilog HDL: A Guide to Digital Design and Synthesis"*, Prentice Hall 2003.
4. Stephen. Brown and Zvonko Vranesic, "*Fundamentals of Digital Logic with Verilog Design"*, Tata McGraw Hill, 2013.
5. Charles Roth, Lizy K. John, Byeong Kil Lee, *"Digital Systems Design Using Verilog*", Cengage Learning, 2015

ECE 2144 ANALOG CIRCUITS LAB [0 0 3 1]

Total number of contact hours: 30

EXPERIMENTS

MOSFET basics, MOSFET as Switch, amplifier. MOSFET-based oscillator, Differential Amplifier. Linear application of op-amp: Adder, subtractor, Difference amplifier, Filter design using op-amp, Schmitt Trigger Circuits, Monostable and Astable multivibrator using 555 timer.

References:

1. William H. Hayt, Jack E. Kemmerly, Steven M Durbin, *"Engineering Circuit Analysis",* Tata McGraw Hill India, 2013.
2. Behzad Razavi, *"Fundamental of Microelectronics*", Wiley, 2013.
3. R. L. Boylestad, L. Nashelsky, "*Electronic Devices and Circuit Theory",* Pearson Education, 2009.
4. Sergio F, *Design with Op amps and Analog Integrated Circuits*, McGraw Hill, Fourth edition, 2016.

SEMESTER IV

MAT 2227 ENGINEERING MATHEMATICS – IV [2 1 0 3]

Total number of contact hours: 36

Construction of a Probability Space, Discrete and Continuous Probabilities, Sum Rule, Product Rule, and Bayes' Theorem, Summary Statistics and Independence, Distributions: Binomial, Poisson, uniform, normal, Chi-square and exponential distributions. Two and higher dimensional random variables, covariance, correlation coefficient. Moment generating function, functions of one dimensional and two-dimensional random variables. Static probabilities: review and prerequisites generating functions, difference equations. Dynamic probability: definition and description with examples. Markov chains, transition probabilities. Differentiation of Univariate Functions, Partial Differentiation and Gradients, Gradients of Vector-Valued Functions, Gradients of Matrices, Useful Identities for Computing Gradients, Backpropagation and Automatic Differentiation, Higher-Order Derivatives, Linearization and Multivariate Taylor Series. Basic solution, Convex sets and function, Simplex Method, Optimization Using Gradient Descent, Constrained Optimization and Lagrange Multipliers.

*Self-directed Learning:
Markov chains, Transition probabilities.

References:

1. Marc Peter Deisenroth, A. Aldo Faisal, Cheng Soon Ong, Mathematics for Machine Learning, Cambridge University Press, 2020.
2. P L Meyer, Introductory Probability and Statistical Applications, Addison Wiley.
3. Medhi. J. Stochastic Processes, Wiley Eastern.
4. Murray R. Spiegel, *Vector Analysis Theory and Problems*, Schaum's Outline Series, 2019.
5. Hamdy A. Taha, "*Operations Research: An Introduction",* 8th Edn., Pearson Education (2008).
6. Sheldon M. Ross, *Introduction to Probability Models* Eleventh Edition Elsevier.
7. E. S. Page, L. B. Wilson, *An Introduction to Computational Combinatorics*, Cambridge University Press.
8. Bhat U R, *Elements of Applied Stochastic Processes*, John Wiley.
9. *https://youtu.be/CgP-3HctGe4

ECE 2221 VLSI DESIGN [4 0 0 4]

Total number of lecture hours: 48

MOS Transistor, CMOS logic, Inverter, Power: Dynamic Power, Static Power, Fabrication of MOS transistor, Latch-up in CMOS, Stick Diagrams, Layout Design Rules, Static CMOS, Ratioed Circuits, Dynamic Circuits, Pass Transistor Logic, Transmission Gates, with examples, Domino, Dual Rail Domino, CPL, Cascode Voltage Switch Logic, Bi-CMOS inverter circuits. Static latches and Registers, Dynamic latches and Registers, Sense Amplifier Based Register, clocking strategies, Subsystem design, Sheet resistance and delay models.

References:

1. Jan M Rabaey, *"Digital Integrated Circuits*", Prentice Hall India, 2003.
2. Weste. N and Eshraghian K, *"Principles of CMOS VLSI Design"*, 2nd Edition, Addison Wesley Publication.
3. Sung Mo Kang and Yusuf Leblebici, "*CMOS digital Integrated circuits design and analysis*", 3rd edition, Tata McGraw Hill.
4. Pucknell D. A. and Eshraghian K., *"Basic VLSI Design",* PHI publication, 2009.
5. Amar Mukherjee, *"Introduction to NMOS & CMOS VLSI systems Design",* Prentice Hall, 1986.

ECE-2222 DIGITAL SIGNAL PROCESSING [3 0 0 3]

Total number of contact hours: **36**

Discrete Fourier transform (DFT), properties, linear filtering; efficient computation of DFT, FFT algorithm, Goertzel algorithm; Implementation of Discrete time filters, Structures for IIR and FIR filters; Classical design of IIR filters by impulse invariance, bilinear transformation and matched Z - transform, characteristics and design of commonly used filters - Butterworth, Chebyshev and elliptic filters. Spectral transformation, direct design of IIR filters; design of linear phase FIR filters using window functions, frequency sampling design; Power spectrum estimation, non-parametric methods of PSD estimation.

*Self-directed Learning:
Parametric methods of PSD estimation: AR, ARMA and MA modeling

References:

1. *Proakis J. G, Manolakis D. G. Mimitris D., *"Introduction to Digital Signal Processing"* Prentice Hall, India, 2007.
2. Oppenheim A.V, Schafer R. W, "*Discrete Time Signal Processing*", Pearson Education, 2004.
3. Ifeachar, Jervis, "*Digital Signal Processing - A Practical approach*", Pearson Education, Asia, 2003.
4. Rabiner L. R, Gold D. J, "*Theory and applications of digital signal processing",* Prentice Hall, India, 1998.
5. Sanjit Mitra K, *"Digital Signal Processing - A computer-based approach",* TMH, 2007.

ECE 2226 PHYSICS OF SEMICONDUCTOR DEVICES [4 0 0 4]

Total number of contact hours: 48

Electrical Conduction in Solids, Density of States Function, The Fermi–Dirac Probability Function, Charge Carriers in Semiconductors, Dopant Atoms and Energy Levels, The Extrinsic Semiconductor, Statistics of Donors and Acceptors, Charge Neutrality, Position of Fermi Energy Level, Carrier Drift, Carrier Diffusion, Graded Impurity Distribution, The Hall Effect, Carrier Generation and Recombination, Characteristics of Excess Carriers, Ambipolar Transport, Quasi-Fermi Energy Levels, Excess Carrier Lifetime, Surface Effects, Basic

Structure of the p-n Junction, Reverse Applied Bias, Junction Breakdown, No uniformly Doped Junctions, p-n Junction Current, Generation–Recombination Currents and High-Injection Levels, Small-Signal Model of the p-n Junction, Charge Storage and Diode Transients, The Tunnel Diode, The Schottky Barrier Diode, Metal–Semiconductor Ohmic Contacts, Heterojunctions, The Two-Terminal MOS Structure, Capacitance–Voltage Characteristics, The Basic MOSFET Operation.

*Self-directed Learning:
Frequency Limitations, CMOS Technology, Nonideal Effects, MOSFET Scaling.

References:

1. Neamen, Donald A. *Semiconductor Physics and Devices*: Basic Principles. 4th ed. New York, NY: McGraw-Hill, 2012.
2. *S. M. Sze*, *"Physics of Semiconductor Device*," Wiley Interscience Publication, New York 1981
3. Streetman, Ben G., and Sanjay Banerjee. *Solid State* Electronic Devices. 6th ed. Upper Saddle River, N.J.: Pearson/Prentice Hall, 2006.

ECE 2228 COMPUTER ORGANIZATION AND ARCHITECTURE [3 0 0 3]

Total number of contact hours: 38

Fundamentals of a computing system, Computer Instructions, Memory and Register Operations, Assembly Language, Bus Architecture. Processor Organization, Register transfer language, Control Organization, Hardwired and Micro-programmed Control, Execution of a complete instruction, Memory organization, Cache design, Virtual memory and Virtual machines, Accessing I/O devices, I/O interfacing, DMA, Pipelining, hazards, forwarding versus stalling, Control hazards, ILP, branch prediction, Pre-fetching techniques, Dynamic and static scheduling, Super scalar Processors, VLIW Processors, Limits on ILP, Thread level Parallelism, Flynn's classification for parallelism, Vector processors, Cache coherence, Hardware Multithreading, Graphical Processing Units, Multi-core Organization.

*Self-directed Learning:
Graphical Processing Units.

References:

1. John L. Hennessy and David A Patterson, *Computer Organization and Design, The Hardware/Software Interface*, Morgan Kaufmann / Elsevier, Fourth Edition, 2007.
2. M. Morris Mano, *Computer System Architecture*, Prentice Hall of India Pvt Ltd, Third edition, 2002. ISBN: 81-203-0855-7.
3. Thomas C. Bartee, *Digital Computer Fundamentals*, Tata McGraw Hill, 6th Edition,
4. Nicholas Carter, *Schaum's outline of Computer Architecture*, Tata McGraw Hill, 2006,
5. A. S. Tanenbaum, T. Austin, *Structured Computer Organization*, Prentice Hall, 2012
6. John P.Hayes , *Computer Architecture and Organization*, WCB/McGraw Hill, 1998
7. A. Silberschatz, P. B. Galvin, G. Gagne, *Operating System Concepts*, John Wiley.

8. R. E. Bryant and D. R. O'Hallaron, *Computer Systems: A Programmer's Perspective*, Prentice Hall.

ECE2243 FPGA BASED SYSTEM DESIGN [3 0 0 3]

Total number of lecture hours: 38

Verilog HDL Coding Style: Lexical Conventions - Ports and Modules – Operators - Gate Level Modeling - System Tasks &Compiler Directives - Test Bench - Data Flow Modeling - Behavioral level Modeling -Tasks & Functions. Overview of FPGA Architectures and Technologies: FPGA Architectural options, coarse vs fine grained, vendor specific issues (emphasis on Xilinx FPGA), Antifuse, SRAM and EPROM based FPGAs, FPGA logic cells, interconnection network and I/O Pad. Verilog Modelling of Combinational and Sequential Circuits: Behavioral, Data Flow and Structural Realization – Adders – Multipliers- Comparators - Flip Flops - Realization of Shift Register - Realization of a Counter- Synchronous and Asynchronous FIFO –Single port and Dual port RAM – Pseudo Random LFSR – Cyclic Redundancy Check. Synchronous Sequential Circuit: State diagram-state table –state assignment-choice of flipflops – Timing diagram –One hot encoding Mealy and Moore state machines – Design of serial adder using Mealy and Moore state machines - State minimization – Sequence detection- Design examples: Sequence detector, Serial adder, Vending machine using One Hot Controller. System Design Examples using Xilinx FPGAs – Traffic light Controller, Real Time Clock

*Self-directed Learning:
Interfacing using FPGA: VGA, Keyboard, LCD, Embedded Processor Hardware Design.

References:

1. M.J.S. Smith, *"Application Specific Integrated Circuits*", Pearson, 2000.
2. Peter Ashenden, "*Digital Design using VHDL*", Elsevier, 2007.
3. Peter Ashenden, "*Digital Design using Verilog",* Elsevier, 2007.
4. W. Wolf, "*FPGA based system design*", Pearson, 2004.
5. Clive Maxfield, "*The Design Warriors's Guide to FPGAs",* Elsevier, 2004
6. Samir Palnitkar, *"Verilog HDL: A Guide to Digital Design and Synthesis*" Prentice Hall, Second Edition, 2003.
7. T.R. Padmanabhan, B.Bala Tripura Sundari, "*Design through Verilog HDL*" Wiley Interscience, 2004.
8. S. Ramachandran, "*Digital VLSI System Design: A Design Manual for implementation of Projects on FPGAs and ASICs Using Verilog"* Springer Publication, 2007.
9. Wayne Wolf, "*FPGA Based System Design*", Prentices Hall Modern Semiconductor Design Series.
10. Stephen Brown & ZvonkoVranesic, "*Digital Logic Design with Verilog HDL*" TATA McGraw Hill Ltd. 2nd Edition 2007.

ECE-2243 FPGA-BASED SYSTEM DESIGN LAB [0 0 3 1]

Total number of contact hours: **30**

EXPERIMENTS

Introduction to XILINX ISE tool – simulation, synthesis and downloading, Dataflow Modelling, Sequential Modelling, Structural Modelling, Switch Level and Mixed-mode

Modelling, Task and functions, user defined primitive, implementation of traffic light controller, waveform generation, stepper motor control using FPGA. Open ended design – DSP, MAC units etc.

References:

1. M.J.S. Smith, *"Application Specific Integrated Circuits"*, Pearson, 2000.
2. Peter Ashenden, *"Digital Design using Verilog"*, Elsevier, 2007. 4. W. Wolf, "FPGA based system design", Pearson, 2004.
3. Clive Maxfield, *"The Design Warriors's Guide to FPGAs"*, Elsevier, 2004
4. Samir Palnitkar, *"Verilog HDL: A Guide to Digital Design and Synthesis"* Prentice Hall, Second Edition, 2003.
5. Wayne Wolf, *"FPGA Based System Design*", Prentices Hall Modern Semiconductor Design Series.

ECE 2244 VLSI DESIGN LAB [0 0 3 1]

Total number of contact hours: **30**

EXPERIMENTS

Introduction to ASIC Design flow using EDA tool. Verilog modeling of combinational and sequential digital circuits using Verilog. Synthesize digital circuits targeting suitable library and by setting area and timing constraints. Analyze the various generated reports such as Area, Power, and Delay for the Synthesized netlist. Plan the physical design of digital circuits for synthesized netlist using EDA tool and generate GDS-II file. Mini project using EDA tool.

References:

1. Charles Roth, Lizy Kurian John, Byeong Kil Lee, *"Digital System Design Using Verilog"*, Cengage Learning 2015.
2. Samir 2. Palnitkar, *"Verilog HDL: A Guide to Digital Design and Synthesis"*, Prentice Hall Professional, 2003.
3. Digital Lab Manual, Revision 2.0, University Support Team, Cadence, Bengaluru, 2017.
4. Cadence PVS User Guide, 2023.