Silicon University

Curriculum Structure & Detailed Syllabus

Master of Science (VLSI)

(Two-Year Post-Graduate Program)

Silicon University, Odisha

Silicon Hills, Patia, Bhubaneswar - 751024

https://silicon.ac.in

Effective From Academic Year 2024-25

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Approval History

ACM#	Date	Resolutions
SU-1	27/04/2024	The curriculum structure of M.Sc.(VLSI) was approved in principle by the Academic Council.
SU-2	17/08/2024	The curriculum structure and detailed syllabus of M.Sc. (VLSI) was approved by the Academic Council.

Program Outcomes

Graduates Attributes (GAs) form a set of individually assessable outcomes that are the components indicative of the graduate's potential to acquire competence to practice at the appropriate level.

PO1. Apply knowledge of science, mathematics and domain competence for analyzing and designing VLSI systems for various real world applications.

PO2. Identify, formulate, and analyze engineering problems in VLSI & embedded systems and develop innovative and cost effective solutions.

PO3. Design efficient VLSI, embedded, and sensor based systems with considerations towards societal and environmental aspects.

PO4. Apply reasoning & contextual knowledge to assess security & privacy in design, deployment of VLSI and real-time sytems in sensitive applications.

PO5. Integrate and apply appropriate techniques, resources, and modern EDA tools for modeling and developing prototypes for VLSI and relevant real-world applications.

PO6. Function effectively as an individual or as a member of a multidisciplinary team with professional and managerial skills.

PO7. Work with professional context with intellectual integrity, ethics and social responsibility.

PO8. Communicate effectively and present technical information in oral and written reports supported by diagrams and models for easy visualization.

PO9. Review research literature and conduct independent research in VLSI and its related domains to develop advanced techniques, systems, and tools.

PO10. Recognize the need and engage in continuous lifelong learning to enhance the knowledge & skills in VLSI domain related real world applications.

Program Specific Outcomes (PSOs)

PSO1. Acquire in-depth knowledge & competency in VLSI design & verification, embedded systems, IC fabrication, and prototype development for required applications.

PSO2. Develop and integrate VLSI and embedded systems for real life applications, and optimize their performance using appropriate tools.

PSO3. Utilize cutting-edge technologies, hardware description languages, EDA tools & platforms leading to a rewarding career and a zest for entrepreneurship or higher studies.

Program Educational Objectives (PEOs)

PEO1. Build successful career based on concepts of electonics and design principles of VLSI-based systems using various technologies and tools.

PEO2. Work independently or in a diverse team with effective communication in interdisciplinary environment, and demonstrate leadership in industry and academia.

PEO3. Engage in lifelong learning and career development through analysis, discussion, professional studies, literature study, and continued research.

Course Categories & Definitions

L	Lecture
T	Tutorial
P	Practical / Laboratory / Sessional
WCH	Weekly Contact Hours
UCR	University Core Course
UMC	University Mandatory Course (0-Credit)
PCR	Program Core Course
PEL	Program Elective Course
OEL	Open Elective Course
HNS	Honours (Choice-based) Course
MNR	Minor (Choice-based) Course
OOC	Open Online Course (on NPTEL / Swayam / Other)
INT	Summer Internship
PSI	Practice School / Industry Internship
PRJ	Project Work
SEC	Skill Enhancement Course
VAC	Value Addition Course

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Part I

Curriculum Structure

Curriculum Structure

Semester I								
Category	**Code**	**Course Title**	**WCH** L-T-P			**Credits** L-T-P		
THEORY								
PCR	MT5008	Mathematical Methods for Electronics	3	0	0	3	0	0
PCR	EC5019	Digital Electronic Circuits	3	1	0	3	1	0
PCR	EC5020	Analog Electronic Circuits	3	1	0	3	1	0
PCR	EC5021	Programming for VLSI	3	0	0	3	0	0
PCR	EC5022	Signals & Systems	3	0	0	3	0	0
PRACTICAL								
PCR	EC5023	Digital Electronic Circuits Lab	0	0	4	0	0	2
PCR	EC5024	Analog Electronic Circuits Lab	0	0	2	0	0	1
PCR	EC5025	Programming for VLSI Lab	0	0	2	0	0	1
UCR	HS5003	Communication & Soft Skills	0	0	2	0	0	1
		SUB-TOTAL	**15**	**2**	**10**	**15**	**2**	**5**
		TOTAL	**27**			**22**		

Semester II								
Category	**Code**	**Course Title**	**WCH** L-T-P			**Credits** L-T-P		
THEORY								
PCR	EC5026	Semiconductor Devices	3	0	0	3	0	0
PCR	EC5027	VLSI Design using Verilog HDL	3	1	0	3	1	0
PCR	EC5028	CMOS VLSI Design	3	1	0	3	1	0
PEL		Program Elective - I	3	0	0	3	0	0
PEL		Program Elective - II	3	0	0	3	0	0
PRACTICAL								
PCR	EC5029	Semiconductor Devices Lab	0	0	2	0	0	1
PCR	EC5030	VLSI Design using Verilog HDL Lab	0	0	4	0	0	2
PCR	EC5031	CMOS VLSI Design Lab	0	0	4	0	0	2
		SUB-TOTAL	**15**	**2**	**10**	**15**	**2**	**5**
		TOTAL	**27**			**22**		

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Semester III								
Category	**Code**	**Course Title**	**WCH** L-T-P			**Credits** L-T-P		
THEORY								
PCR	EC6011	Analog VLSI Design	3	0	0	3	0	0
PCR	EC6001	IC Fabrication Technology	3	0	0	3	0	0
PEL		Program Elective - III	3	0	0	3	0	0
PEL		Program Elective - IV	3	0	0	3	0	0
PRACTICAL								
PCR	EC6013	Analog VLSI Design Lab	0	0	2	0	0	1
SEC	EC6014	Emerging Technologies Lab	0	0	4	0	0	2
PRJ	IP4003	Capstone Project	0	0	10	0	0	5
INT	IP4001	Summer Internship	0	0	0	0	0	1
		SUB-TOTAL	**12**	**0**	**16**	**12**	**0**	**9**
		TOTAL	**28**			**21**		

Semester IV								
Category	**Code**	**Course Title**	**WCH** L-T-P			**Credits** L-T-P		
THEORY								
OOC	EC6010	MOOC	0	0	0	3	0	0
PRACTICAL								
PRJ/PSI	IP4002	Project Work / Industry Internship	0	0	24	0	0	12
VAC	VA0001	Yoga/NCC/NSS	0	0	2	0	0	0
		SUB-TOTAL	**0**	**0**	**26**	**3**	**0**	**12**
		TOTAL	**26**			**15**		

		GRAND TOTAL (4 SEMESTERS)	**108**	**80**

Note:

1. Courses offered under each elective are given in “List of Electives” on Page 4.
2. MOOC - Massive Open Online Course (on NPTEL / Swayam / Other).
3. Approved list of courses for MOOC (self study) shall be published by the department. Students are advised to complete the same before the end of 4th semester.
4. Students opting for Project Work shall undergo the same under the guidance of a faculty member.
5. Students selected for Industry Internship shall be attached to a faculty member as mentor.
6. The Value Addition Course (Yoga / NSS / NCC) may be assigned in a different semester depending on available capacity.

List of Electives

Code	Elective # and Subjects
	Program Elective-II
EC5032	Low-Power Digital VLSI Design
EC5033	Microprocessors & Microcontrollers
CS5021	Artificial Intelligence
	Program Elective-II
EC5017	MEMS & Sensor Based Design
EC5035	Soft Computing Techniques
CS5030	Advanced Python Programming
	Program Elective-III
EC6015	Advanced Semiconductor Devices
EC6016	Embedded System Design
EC6017	Mobile Communication & Networks
	Program Elective-IV
EC6018	Mixed-Signal CMOS Design
EC6019	Internet of Things
EC6020	Machine Learning in VLSI

Note:

1. The department shall offer subjects under each program elective depending on available capacity.
2. Unless adequate number of students choose an elective subject offered by the department, the subject shall not be offered and the students shall be assigned with a different elective subject.

Part II

Detailed Syllabus

Category	Code	Mathematical Methods for Electronics	L-T-P	Credits	Marks
PCR	MT5008		3-0-0	3	100

Objectives	The objective of this course is to learn different mathematical techniques and methods of optimization & stochastic processes to create the fundamental foundation for various domains in electronics.
Pre-Requisites	Calculus of single variable & ordinary differential equations, basic concepts on system of linear equations & matrices and elementary probability.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with problem solving activities.

Evaluation Scheme

Attendance	Teacher's Assessment	Mid-Term	End-Term	Total
10	20	20	50	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	Root finding problems, Bisection method, Fixed point iteration, Secant method, Newton-Raphson method, Numerical solution of ordinary differential equation, Euler's method, Improved Euler Method, Runge-Kutta method of fourth order.	**8 Hours**
Module-2	Linear programming, Graphical method, Simplex method, Big-M method, Two phase method, Duality and prime dual relationship, Dual simplex method, Sensitivity & post optimal analysis.	**10 Hours**
Module-3	Graph & Networks, Minimum spanning tree problem, Shortest path problem (Dijkstra's algorithm, Floyd's algorithm), Maximum flow problem.	**7 Hours**
Module-4	Stochastic Process, Discrete time Markov chain, Transition Probability matrix, Chapman-Kolmogorov equations, state classification, Steady state probabilities, First Passage Times, Absorbing State, Continuous time Markov Chain.	**9 Hours**
Module-5	Genetic Algorithm, Working principles, Coding, Fitness function, GA operators, Generation of mating pool, Cross-over, Mutation, Testing and reproduction, Solving optimization problems using GA.	**8 Hours**
	Total	**42 Hours**

Text Books:

T1. E. Kreyszig, ***Advanced Engineering Mathematics***, 9th Edition, Wiley India, 2006.
T2. F. S. Hiller and G. J. Lieberman, ***Introduction to Operations Research***, 7th Edition, McGraw-Hill Education, 2001.
T3. H. A. Taha, ***Operations Research: An Introduction***, 8th Edition, Pearson Education, 2007.
T4. K. Dev, ***Optimization for Engineering Design Algorithms and Examples***, 2nd Edition, PHI Learning, 2012.

Reference Books:

R1. M. K. Jain, S. R. K. Iyengar, and R. K. Jain, ***Numerical Methods for Scientific and Engineering Computation***, 3rd Edition, New Age International Publishers, 2020.
R2. D. B.West, ***Introduction to Graph Theory***, 2nd Edition, Pearson Education, 2001.

R3. A. Ravindran, D. Phillips, and J. J. Solberg, ***Operations Research: Principle and Practice***, 2nd Edition, Wiley India,2010.

Online Resources:

1. https://nptel.ac.in/courses/111101165: by Prof. S. Baskar, IIT Bombay
2. https://nptel.ac.in/courses/111102012: by Dr. A. Mehra, IIT Delhi
3. https://nptel.ac.in/courses/111102096: by Dr. S. Dharmaraja, IIT Delhi
4. https://nptel.ac.in/courses/106108056: by Dr. S. K. Shevade, IISc Bangalore
5. https://nptel.ac.in/courses/112105235: by Prof. D. K. Pratihar, IIT Kharagpur

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Apply numerical methods to solve algebraic, transcendental and ordinary differential equations.
CO2	Model and solve linear programming problems by appropriate methods.
CO3	Model and solve optimization problems of a network.
CO4	Model and apply Markov Models to solve real life engineering problems.
CO5	Apply Genetic Algorithm to solve real life optimization problems.

Program Outcomes Relevant to the Course:

PO1	Apply knowledge of science, mathematics and domain competence for analyzing and designing VLSI systems for various real world applications.
PO2	Identify, formulate, and analyze engineering problems in VLSI & embedded systems and develop innovative and cost effective solutions.
PO3	Design efficient VLSI, embedded, and sensor based systems with considerations towards societal and environmental aspects.
PO4	Apply reasoning & contextual knowledge to assess security & privacy in design, deployment of VLSI and real-time sytems in sensitive applications.
PO5	Integrate and apply appropriate techniques, resources, and modern EDA tools for modeling and developing prototypes for VLSI and relevant real-world applications.
PO10	Recognize the need and engage in continuous lifelong learning to enhance the knowledge & skills in VLSI domain related real world applications.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	2	1	1	1					1	2	1	1
CO2	3	2	2	1	1					1	1	2	1
CO3	3	3	2	2	1					1	2	2	2
CO4	3	2	2	2	1					1	2	1	2
CO5	3	3	2	2	2					1	2	2	2

Category	Code	Digital Electronic Circuits	L-T-P	Credits	Marks
PCR	EC5019		3-1-0	4	100

Objectives	The objective of this course is to study the concepts & techniques associated with digital systems and their design & implementation in VLSI technology.
Pre-Requisites	Knowledge of basic electronics and fundamentals of number systems is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with problem solving activities.

Evaluation Scheme

Attendance	Teacher's Assessment	Mid-Term	End-Term	Total
10	20	20	50	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	**Fundamental Concepts**: Introduction, Analog & Digital Signals, Analog to Digital conversion; **Number Systems and Codes**: Number Systems (Binary, Octal, Hexadecimal), Arithmetic of number systems, 1's and 2's Complement, Signed Binary Numbers, Codes: BCD, Excess-3, Gray Codes, Binary to Gray & Gray to Binary Conversion; Different Logic Gates; Universal Logic Gate Realization.	**10 Hours**
Module-2	**Combinational Logic Design**: Boolean Algebra & Identities, Minimization & Realization using Universal Logic Gates; Sum-of-Products, Product-of-Sums & its canonical forms, Kmap Representation & Simplification of Logic Functions (2, 3, 4 Variable), Don't Care Conditions; **Combinational Logic Circuits**: Adders, Subtractors, Carry-LookAhead Adder, Equality Detector, Comparator; Multiplexer, De-Multiplexer, Decoders, Encoder, Design of Combinational Circuits using Multiplexer and Decoder; Design of Code converter circuits.	**12 Hours**
Module-3	**Sequential Logic Design**: Flip Flops – A 1-bit Memory, Bistable Latch (SR and D), The Clocked SR Flip Flop, J-K, T and D type Flip-Flops, Race Around Condition, Master Slave JK-Flip Flop, Excitation Table of Flip-Flops, Conversion of Flip-Flops; **Shift Registers**: SISO, SIPO, PISO, PIPO and Universal Shift Register.	**12 Hours**
Module-4	**Applications of Shift Registers**: (Serial to Parallel Converter, Parallel to Serial Converter), Ring Counter, Twisted Ring Counter (Johnson Counter), **Counters**: Design of Asynchronous Counters (Up/Down Counter, Mod-N Counter), Design of Synchronous Counters, Gray Code Counter and Random Sequence Counter using State Diagrams.	**11 Hours**
Module-5	**Finite State Machines (FSMs)**: Mealy and Moore Models of Finite State Machines; **System Design using FSM**: Sequence Detector Circuit Design with Overlapping Permitted and Non-overlapping, Vending Machine Design; **Logic Families**: RTL, TTL, CMOS Logic Families.	**11 Hours**
	Total	**56 Hours**

Text Books:

T1. R. P. Jain, ***Modern Digital Electronics***, 4th Edition, McGraw-Hill Education, 2009.
T2. M. M. Mano and M. D. Ciletti, ***Digital Design - with an Introduction to Verilog HDL***, 5th Edition, Pearson Education, 2013.

Reference Books:

R1. D. V. Hall, ***Digital Circuits and Systems***, International Student Edition, McGraw-Hill Education, 1989.
R2. A. Kumar, ***Fundamentals of Digital Circuits***, 3rd Edition, PHI Learning, 2014.
R3. J. F. Wakerly, ***Digital Design: Principles and Practices***, 4th Edition, Pearson Education, 2008.
R4. S. Agarwal and J. Lang, ***Foundations of Analog and Digital Electronic Circuits***, 1st Edition, Morgan Kaufmann, 2005.

Online Resources:

1. https://nptel.ac.in/courses/117106086/: by Prof. S. Srinivasan, IIT Madras
2. https://nptel.ac.in/courses/117103064/: by Prof. A. Mahanta and Prof. R. P. Palanthinkal, IIT Guwahati
3. https://nptel.ac.in/courses/117105080/: by Prof. D. Roychoudhury, IIT Kharagpur
4. https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-002-circuits-andelectronics-spring-2007/video-lectures/
5. https://www.allaboutcircuits.com/video-tutorials/
6. https://www.pannam.com/blog/free-resources-to-learn-electrical-engineering/

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Explain various number systems, codes and Boolean algebra.
CO2	Design and analyze combinational logic circuits.
CO3	Design & analyze various sequential logic circuits and shift register.
CO4	Describe the application of shift register and design of various counter circuits.
CO5	Design, analyze and implement various real-time digital systems using Finite State Machine.

Program Outcomes Relevant to the Course:

PO1	Apply knowledge of science, mathematics and domain competence for analyzing and designing VLSI systems for various real world applications.
PO2	Identify, formulate, and analyze engineering problems in VLSI & embedded systems and develop innovative and cost effective solutions.
PO3	Design efficient VLSI, embedded, and sensor based systems with considerations towards societal and environmental aspects.
PO4	Apply reasoning & contextual knowledge to assess security & privacy in design, deployment of VLSI and real-time sytems in sensitive applications.
PO5	Integrate and apply appropriate techniques, resources, and modern EDA tools for modeling and developing prototypes for VLSI and relevant real-world applications.
PO6	Function effectively as an individual or as a member of a multidisciplinary team with professional and managerial skills.
PO7	Work with professional context with intellectual integrity, ethics and social responsibility.
PO9	Review research literature and conduct independent research in VLSI and its related domains to develop advanced techniques, systems, and tools.
PO10	Recognize the need and engage in continuous lifelong learning to enhance the knowledge & skills in VLSI domain related real world applications.

P.T.O

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	2	3	2	3	2	1					3	1	1
CO2	1	2	3	2	3	2	1				3	1	
CO3	2	3	2	3	3	1	1		1		3	1	1
CO4	2	2	1	2	2	2					3	1	
CO5	1	3	2	3	2	1	1		1	1	3	1	

Category	Code	Analog Electronic Circuits	L-T-P	Credits	Marks
PCR	EC5020		3-1-0	4	100

Objectives	The objective of this course is to analyze circuit configurations, synthesize circuits with given specifications or network functions, and test & improve the designs as required. The students will also be familiar with P-N junction diode, Transistor (BJT and MOSFET) amplifiers, and OPAMP based circuits.
Pre-Requisites	Basics of semiconductor, Circuit analysis, Laplace transform, Fourier transform, and Differential equations are required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with problem solving activities.

Evaluation Scheme

Attendance	Teacher's Assessment	Mid-Term	End-Term	Total
10	20	20	50	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	**Basic Laws**: Ohm's Law, Nodes, Branches and Loops, Krichhoff's Laws, Voltage & Current Division, Nodal Analysis, Nodal Analysis with Voltage Sources, Mesh Analysis, Mesh Analysis with Current Sources; **Circuit Theorems**: Introduction, Linearity Property, Superposition, Source Transformation, Thevenin's Theorem, Norton's Theorem, Derivations of Thevenin's and Norton's Theorems, Maximum Power Transfer.	**11 Hours**
Module-2	**First-Order Circuits**: Introduction, The Source-free RC Circuit, The Source-free RL Circuit, Step Response of an RC Circuit, Step Response of an RL Circuit, Application to Delay Circuits; **P-N Junction Diodes**: Semiconductor Diode, Diode Equivalent Circuits; Rectifier, Clipper, Clamper.	**11 Hours**
Module-3	**Bipolar Junction Transistor (BJT)**: Construction, Operation, Configurations (CB, CE, CC), Operating Point; **BJT DC Analysis**: Introduction to BJT DC Biasing, Different Biasing Circuits, Design of Different Biasing Circuits; **BJT AC Analysis**: Introduction to BJT Small Signal Model (r_e and h-Models of Different Configurations), Small Signal Models of Different Biasing Circuits, Effect of R_S and R_L.	**12 Hours**
Module-4	**Metal Oxide Semiconductor Field Effect Transistor (MOSFET)**: Construction, Different Types of MOSFETs (Depletion and Enhancement); **MOSFET DC Analysis**: Introduction to MOSFET DC Biasing, Different MOSFET Biasing Circuits (Depletion type & Enhancement type).	**11 Hours**
Module-5	**MOSFET AC Analysis**: Introduction to MOSFET Small Signal Model (Different Configurations), Small Signal Model of Different Biasing Circuits, Effect of R_S and R_L (Depletion type & Enhancement type); **Operational Amplifiers (OP-AMP)**: Introduction, Applications of OP-AMP in Summing Amplifier, Buffer, Differentiator and Integrator, Instrumentation Amplifier.	**11 Hours**
	Total	**56 Hours**

Text Books:

T1. C. K. Alexander and M. N. O. Sadiku, ***Fundamentals of Electric Circuits***, 6th Edition, McGraw-Hill Education, 2019.
T2. R. L. Boylestad and L. Nashelsky, ***Electronic Devices and Circuit Theory***, 11th Edition, Pearson Education, 2015.
T3. B. Razavi, ***Fundamentals of Microelectronics***, 3rd Edition, Wiley India, 2021.

Reference Books:

R1. A Chakrabarti, ***Circuit Theory: Analysis and Synthesis***, 7th Edition, Dhanpat Rai & Co., 2018.
R2. J. Millman and C. C. Halkias, ***Integrated Electronics: Analog and Digital Circuits and Systems***, 2nd Edition, McGraw-Hill Education, 2017.
R3. A. S. Sedra and K. C. Smith, ***Microelectronic Circuits: Theory and Applications (International Version)***, 7th Edition, Oxford University Press, 2017.
R4. P. Horowitz and W. Hill, ***The Art of Electronics***, 2nd Edition, Cambridge University Press, 2006.
R5. A. Malvino and D. J. Bates, ***Electronic Principles***, 7th Edition, McGraw-Hill, 2017.

Online Resources:

1. https://nptel.ac.in/courses/108102042/: by Prof. S. C. Dutta Roy, IIT Delhi
2. https://nptel.ac.in/courses/108106075/: by Prof. V. G. K. Murti, IIT Madras
3. https://nptel.ac.in/courses/117101106/
4. https://nptel.ac.in/courses/108102095/
5. http://www.electrical4u.com/circuit-analysis.htm
6. http://www.allaboutcircuits.com
7. https://www.electronics-tutorials.ws/

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Explain and apply the concepts of network theorems, and their applications.
CO2	Describe on the first order circuits, PN-Junction diode and their applications.
CO3	Explain and analyze the principles of BJT and perform its DC and small signal analysis.
CO4	Analyze the working principle of MOSFET and carry out its DC analysis.
CO5	Explain the AC analysis of MOSFET, design various MOSFET amplifier circuits, and apply OPAMPs in different applications.

Program Outcomes Relevant to the Course:

PO1	Apply knowledge of science, mathematics and domain competence for analyzing and designing VLSI systems for various real world applications.
PO2	Identify, formulate, and analyze engineering problems in VLSI & embedded systems and develop innovative and cost effective solutions.
PO3	Design efficient VLSI, embedded, and sensor based systems with considerations towards societal and environmental aspects.
PO4	Apply reasoning & contextual knowledge to assess security & privacy in design, deployment of VLSI and real-time sytems in sensitive applications.
PO5	Integrate and apply appropriate techniques, resources, and modern EDA tools for modeling and developing prototypes for VLSI and relevant real-world applications.
PO9	Review research literature and conduct independent research in VLSI and its related domains to develop advanced techniques, systems, and tools.
PO10	Recognize the need and engage in continuous lifelong learning to enhance the knowledge & skills in VLSI domain related real world applications.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	2	1	2	1									
CO2	1	2	2	1						1	1	1	
CO3	3	2	1	2							2	1	1
CO4	1	3	2	2	1					1	3	2	1
CO5	2	2	3	1	2				2	2	2	2	2

Category	Code	Programming for VLSI	L-T-P	Credits	Marks
PCR	EC5021		3-0-0	3	100

Objectives	The objective of this course is to introduce programming for various applications in VLSI design and analysis using Python and TCL languages.
Pre-Requisites	Basic analytical & logical skill is required for this course. Prior experience with any other programming language will be beneficial.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with programming activities.

Evaluation Scheme

Attendance	Teacher's Assessment	Mid-Term	End-Term	Total
10	20	20	50	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	**Introduction to Python**: Features of Python, Executing a python program, Interactive and non-interactive modes, Basic syntax, Data types, Variables, Literals, Input/output statements, Keywords, Identifiers, Operators, Precedence & associativity, Expressions, Control statements.	**8 Hours**
Module-2	**Arrays, Strings, and Lists**: Operations, Slicing, Built-in list function, List comprehension, Tuples - Introduction, Accessing elements, Operations using built-in tuple functions, Dictionaries - Introduction, Accessing values in dictionaries, Built-in dictionary functions, Sets, Function, Recursion; Modules - Creating modules, Import statement, Packages.	**8 Hours**
Module-3	**File Handling**: Types of files, Opening and closing files, Reading from and writing to files, Binary files, Command line arguments; **Regular Expression**: Match function, Search function, Matching vs. Searching, Quantifiers, Patterns.	**9 Hours**
Module-4	**Introduction to Tcl**: Overview, Commands and variables, Substitution and evaluation, Mathematical operations, Procedures; Control Flow - Conditional and looping commands; Strings - Strings and string operations, Extracting information; Lists and Arrays - Using lists and arrays, List versus array.	**9 Hours**
Module-5	**File I/O & Program Access**: Reading from and writing to files, Invoking external programs, Multi-process communication; **Advanced Tcl Scripting**: Advanced procedures, Error handling, Scheduling and delaying command execution.	**8 Hours**
	Total	**42 Hours**

Text Books:

T1. R. N. Rao, ***Core Python Programming***, 2nd Edition, DreamTech Press, 2019.
T2. P. Barry, ***Head First Python***, 2nd Edition, O'Reilly Media, 2010.
T3. J. K. Ousterhout, ***Tcl and the Tk Toolkit***, Addison Wesley, 1994.

Reference Books:

R1. J. Zelle, ***Python Programming: An Introduction to Computer Science***, 3rd Edition, Franklin, Beedle & Associates, 2016.
R2. L. Ramalho, ***Fluent Python***, 1st Edition, O'Reilly Media, 2015.

R3. M. Lutz, ***Programming Python***, 4th Edition, O'Reilly Media, 2011.
R4. B. B. Welch, ***Practical Programming in Tcl and Tk***, Prentice Hall, 1995.

Online Resources:

1. https://nptel.ac.in/courses/106/106/106106145/: By Prof. M. Mukund, IIT Madras
2. https://www.tcl.tk/doc/: Tcl/Tk Documentation
3. https://www.tcl.tk/man/tcl8.5/tutorial/tcltutorial.html

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Explore Python syntax and use Python flow control to write simple programs.
CO2	Implement knowledge of functions and different data structures to solve problems.
CO3	Write advanced programs with file I/O, database connectivity, and regular expressions.
CO4	Explain basic TCL commands, its control flow, strings and lists.
CO5	Explore the use of arrays, file operations, error handling and scheduling.

Program Outcomes Relevant to the Course:

PO1	Apply knowledge of science, mathematics and domain competence for analyzing and designing VLSI systems for various real world applications.
PO2	Identify, formulate, and analyze engineering problems in VLSI & embedded systems and develop innovative and cost effective solutions.
PO3	Design efficient VLSI, embedded, and sensor based systems with considerations towards societal and environmental aspects.
PO4	Apply reasoning & contextual knowledge to assess security & privacy in design, deployment of VLSI and real-time sytems in sensitive applications.
PO5	Integrate and apply appropriate techniques, resources, and modern EDA tools for modeling and developing prototypes for VLSI and relevant real-world applications.
PO10	Recognize the need and engage in continuous lifelong learning to enhance the knowledge & skills in VLSI domain related real world applications.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	1			1							1	1	
CO2	2	2	1	1	1					1	1		
CO3	3	1	1	3	2							1	2
CO4	1	2	2		1					1	2	2	
CO5	3	1	2	3	3					1	1	1	2

Category	Code	Signals & Systems	L-T-P	Credits	Marks
PCR	EC5022		3-0-0	3	100

Objectives	The objective of this course is to study the characteristics of different signals and systems in time and frequency domains, and to analyze different signals and systems using Fourier, Laplace and Z-Transform.
Pre-Requisites	Fundamental knowledge of basic mathematics is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with problem solving activities.

Evaluation Scheme

Attendance	Teacher's Assessment	Mid-Term	End-Term	Total
10	20	20	50	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	**Signals**: Introduction, Classification: continuous/discrete-time, commonly used continuous-time signals and discrete-time Signals, Periodic/Aperiodic, Even/Odd, Energy/Power, Operations on Continuous-time and Discrete-time Signals: Addition, Multiplication, Differentiation/Difference, Integration/Accumulation, Shifting, Scaling, Folding.	**8 Hours**
Module-2	**Systems and LTI/LSI Systems**: Introduction, Classification of continuous-time and discrete-time - Linear/Non-linear, Time varying/Time invariant, Causal/Non-causal, Dynamic/Static, Stable/Unstable, Difference equations, Response of LSI system convolution Sum.	**8 Hours**
Module-3	**Analysis by Fourier Series and Fourier Transform**: Fourier series, Convergence of the Fourier series, Trigonometric Fourier series and Exponential Fourier series, Continuous time Fourier Transform, Fourier transform of some useful signals, Properties of the Fourier transform.	**9 Hours**
Module-4	**Analysis by Laplace Transform**: Introduction, Region of Convergence for Laplace transform, and properties of ROC, Laplace transform of some useful signals, Properties of the Laplace transform, The inverse Laplace transform and its properties.	**9 Hours**
Module-5	**Analysis by Z-Transform**: Discrete-time system analysis using the Z-transform, The Region of Convergence, Z-transform of some useful sequences, Properties of Z-transform, Inverse Z-transform.	**8 Hours**
	Total	**42 Hours**

Text Books:

T1. A. V. Oppenheim, A. S. Willsky, and S. H. Nawab, ***Signals and Systems***, 2nd Edition, Prentice Hall India, 1992.

T2. S. Haykin and B. V. Veen, ***Signals and Systems***, 2nd Edition, John Wiley & Sons, 2002.

T3. B. P. Lathi, ***Principles of Signal Processing and Linear Systems***, 2nd Edition, Oxford Univ. Press, 2009.

Reference Books:

R1. H. P. Hsu, ***Signal and System - Schaum's Outlines***, 2nd Edition, McGraw Hill, 2011.

R2. A. N. Kani, ***Signals and Systems***, 2nd Edition, McGraw Hill Education, 2010.

R3. M. J. Roberts, ***Signals and Systems - Analysis using Transform Methods and MATLAB***, 2nd Edition, McGraw hill, 2003.

Online Resources:

1. https://nptel.ac.in/courses/117104074/: by Prof. K.S. Venkatesh, IIT Kanpur
2. https://nptel.ac.in/courses/108105065/: by Prof. T.K. Basu, IIT Kharagpur
3. https://nptel.ac.in/courses/108104100/: by Prof. A. K. Jagannatham, IIT Kanpur
4. https://nptel.ac.in/courses/108105059/: by Prof. S. Mukhopadhyay, IIT Kharagpur
5. https://ocw.mit.edu/resources/res-6-007-signals-and-systems-spring-2011/lecture-notes/
6. https://engineering.purdue.edu/~mikedz/ee301/ee301.html
7. https://stanford.edu/~boyd/ee102/

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Describe different types of signals and systems.
CO2	Analyse various types of LSI systems responses.
CO3	Explain continuous and discrete systems in time & frequency domains using different transforms.
CO4	Describe the system stability and causality using Laplace Transform.
CO5	Analyse discrete time signals and systems using Z-transform.

Program Outcomes Relevant to the Course:

PO1	Apply knowledge of science, mathematics and domain competence for analyzing and designing VLSI systems for various real world applications.
PO2	Identify, formulate, and analyze engineering problems in VLSI & embedded systems and develop innovative and cost effective solutions.
PO3	Design efficient VLSI, embedded, and sensor based systems with considerations towards societal and environmental aspects.
PO4	Apply reasoning & contextual knowledge to assess security & privacy in design, deployment of VLSI and real-time sytems in sensitive applications.
PO5	Integrate and apply appropriate techniques, resources, and modern EDA tools for modeling and developing prototypes for VLSI and relevant real-world applications.
PO6	Function effectively as an individual or as a member of a multidisciplinary team with professional and managerial skills.
PO10	Recognize the need and engage in continuous lifelong learning to enhance the knowledge & skills in VLSI domain related real world applications.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	2	1	1	1	2	1					2	2	
CO2	2	2	2	2	1	1					1		1
CO3	1	1	1	1	1	2				1	2	1	1
CO4	2	2	1	1	3	1				1	2		
CO5	1	1	2	1	1	2				1	2	1	1

Category	Code	Digital Electronic Circuits Lab	L-T-P	Credits	Marks
PCR	EC5023		0-0-4	2	100

Objectives	The objective of the course is to provide hands-on exposure on logic gates, implementation using Boolean algebra, designing digital circuits like counters, registers and apply the knowledge to formulate digital systems.
Pre-Requisites	Knowledge of digital electronics taught in theory class is required
Teaching Scheme	Regular laboratory experiments conducted under supervision of the teacher. Experiments shall comprise of implementation in hardware/software tools.

Evaluation Scheme

Attendance	Daily Performance	Lab Record	Lab Test / Project	Viva-voce	Total
10	30	15	30	15	100

Detailed Syllabus

Experiment-#	Assignment/Experiment
1	Study the pin diagram and investigate logic behavior of AND, OR, NAND, NOR, EX OR, EX-NOR, Invert and Buffer gates, use of Universal gates.
2	Design and test half adder and full adder circuit.
3	Design and test half subtractor and full subtractor circuit.
4	Design and test Code Converters: Gray code to Binary and Binary to Gray.
5	Design and test Seven-Segment Display Circuit.
6, 7	Design and test a given function with universal logic (i) NAND Gates only (ii) NOR Gates only (iii) Minimum number of Gates.
8	Design a circuit to detect the months of a year having 31-days.
9	Design of Multiplexer and De-multiplexer.
10	Mux-based Combinational Circuit Design: Full Adder.
11	Mux-based Combinational Circuit Design: Any 3-Variable Boolean function.
12	Design and investigate operation of SR, D & J-K flip-flops.
13, 14	Implement and test Flip-Flop Conversion circuit.
15	Design and investigate the operation of all types of shift registers.
16	Design and test up/down asynchronous counters.
17	Design a Mod-5 asynchronous counter.
18	Design and test up/down synchronous counters.
19	Design a Mod-6 synchronous counter.
20	Design a synchronous counter to count a random sequence (0, 1, 3, 7, 6, . . .).
21	Design and test Parallel Adder and Accumulator.
22, 23	Design and implement 4-bit X 3-bit Binary Multiplier Circuit.
24	Design, implement and test a Clock-pulse generator:
25, 26	Design and implement a real-life Mealy FSM.
27, 28	Design and implement a real-life Moore FSM.

Text Books:

T1. M. M. Mano and M. D. Ciletti, ***Digital Design: With an Introduction to Verilog HDL***, 5th Edition, Pearson Education, 2013.
T2. R. P. Jain, ***Modern Digital Electronics***, 4th Edition, McGraw-Hill Education, 2009.

Reference Books:

R1. D. V. Hall, ***Digital Circuits and Systems***, International Student Edition, McGraw-Hill Education, 1989.
R2. A. A. Kumar, ***Fundamentals of Digital Circuits***, 3rd Edition, PHI Learning, 2014.
R3. J. F. Wakerly, ***Digital Design: Principles and Practices***, 4th Edition, Pearson Education, 2008.
R4. A. Agarwal and J. Lang, ***Foundations of Analog and Digital Electronic Circuits***, 1st Edition, Morgan Kaufmann, 2005.

Online Resources:

1. https://nptel.ac.in/courses/117106086/: by Prof. S. Srinivasan, IIT Madras
2. https://nptel.ac.in/courses/117103064/: by Prof. A. Mahanta and Prof. R. P. Palanthinkal, IIT Guwahati
3. https://nptel.ac.in/courses/117105080/: by Prof. D. Roychoudhury, IIT Kharagpur
4. https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-002-circuits-andelectronics-spring-2007/video-lectures/
5. https://www.allaboutcircuits.com/video-tutorials/
6. https://www.pannam.com/blog/free-resources-to-learn-electrical-engineering/

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Explain and demonstrate pin diagram and logic behavior of different logic gate ICs.
CO2	Analyze & design various combinational logic circuits.
CO3	Analyze & design various sequential logic circuits.
CO4	Analyze & design counters, adders, accumulators and binary multipliers.
CO5	Design, analyze and implement various real life digital systems using FSM concept.

Program Outcomes Relevant to the Course:

PO1	Apply knowledge of science, mathematics and domain competence for analyzing and designing VLSI systems for various real world applications.
PO2	Identify, formulate, and analyze engineering problems in VLSI & embedded systems and develop innovative and cost effective solutions.
PO3	Design efficient VLSI, embedded, and sensor based systems with considerations towards societal and environmental aspects.
PO4	Apply reasoning & contextual knowledge to assess security & privacy in design, deployment of VLSI and real-time sytems in sensitive applications.
PO5	Integrate and apply appropriate techniques, resources, and modern EDA tools for modeling and developing prototypes for VLSI and relevant real-world applications.
PO6	Function effectively as an individual or as a member of a multidisciplinary team with professional and managerial skills.
PO7	Work with professional context with intellectual integrity, ethics and social responsibility.
PO9	Review research literature and conduct independent research in VLSI and its related domains to develop advanced techniques, systems, and tools.
PO10	Recognize the need and engage in continuous lifelong learning to enhance the knowledge & skills in VLSI domain related real world applications.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	2	2	2	3	2	1					2	1	1
CO2	1	3	3	2	3	2	1				3		
CO3	2	2	2	3	2	1	1		1		2	2	1
CO4	2	2	1	2	2	2					3	1	
CO5	1	3	2	3	3	1	1		1	1	3	2	

Category	Code	Analog Electronic Circuits Lab	L-T-P	Credits	Marks
PCR	EC5024		0-0-2	1	100

Objectives	The objective of this laboratory course is to provide hands-on exposure on design, implement and test transistor biasing, amplifying action & frequency response, and study the linear and nonlinear applications of amplifiers.
Pre-Requisites	Knowledge of analog electronic circuits taught in theory class is required.
Teaching Scheme	Regular laboratory experiments conducted under supervision of the teacher. Experiments shall comprise of implementation in hardware/software tools.

Evaluation Scheme

Attendance	Daily Performance	Lab Record	Lab Test / Project	Viva-voce	Total
10	30	15	30	15	100

Detailed Syllabus

Experiment-#	Assignment/Experiment
1	Verification of Network Theorems by modelling and simulation (Superposition, Thevenin, Norton, Maximum Power Transfer) both in DC & AC
2	Verification of Network Theorems (Superposition, Thevenin, Norton, Maximum Power Transfer) both in DC & AC.
3	Study of resonance in R-L-C series & parallel circuit.
4	Familiarization of electronic components and devices (Testing of semiconductor diodes and transistors using digital multi-meter).
5	Study and use of Oscilloscope, signal generator to view waveforms and measure amplitude and frequency of a given waveform.
6	V-I characteristics of semiconductor diode and determining its DC and AC resistances.
7	Study of static characteristics of BJT in CE configuration.
8	Design & simulate the BJT bias circuits and compare the results.
9	Design & simulate the MOSFET bias circuits and compare the results.
10	Design & simulate the BJT common-emitter circuit and perform the AC analysis.
11	Design & simulate the MOSFET common-source circuit and perform the AC analysis.
12	Design & simulate a common-emitter amplifier to determine the bandwidth by the frequency response analysis.
13	Design and study the operation of Op-Amp as inverting amplifier, non-inverting amplifier, summing amplifier.
14	Design and study the operation of Op-Amp as differentiator, integrator, square wave generator.

Text Books:

T1. C. K. Alexander and M. N. O. Sadiku, ***Fundamentals of Electric Circuits***, 6th Edition, McGraw Hill Education, 2019.

T2. R. L. Boylestad and L. Nashelsky, ***Electronic Devices and Circuit Theory***, 11th Edition, Pearson Education, 2015.

Reference Books:

R1. A Chakrabarti, ***Circuit Theory: Analysis and Synthesis***, 7th Edition, Dhanpat Rai & Co., 2018.

R2. L. K. Maheshwari and M. M. S. Anand, ***Laboratory Experiments and PSPICE Simulations in Analog Electronics***, 1st Edition, PHI Learning, 2009.
R3. L. K. Maheshwari and M. M. S. Anand, ***Laboratory Manual for Introductory Electronics Experiments***, John Wiley & Sons, 1980.
R4. K. A. Navas, ***Electronics Lab Manual, Vol-2***, 6th Edition, PHI Learning, 2018.

Online Resources:

1. https://nptel.ac.in/courses/108102042/: by Prof. S. C. Dutta Roy, IIT Delhi
2. https://nptel.ac.in/courses/108106075/: by Prof. V. G. K. Murti, IIT Madras
3. http://www2.ece.ohio-state.edu/ee327/
4. https://wiki.analog.com/university/courses/alm1k/alm_circuits_lab_outline
5. https://wiki.analog.com/university/courses/electronics/labs

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Demonstrate network theorems and resonance circuits.
CO2	Identify and use various electronic components, instruments, and semiconductor diodes.
CO3	Explain the characteristics of transistors, and design, implement, and test transistors in analog circuits for various applications.
CO4	Analyze the DC and AC performance of BJT and FET, and explain the frequency response of single & multi-stage BJT and compare the results.
CO5	Design electronic circuits using Op-Amps for various applications and test them.

Program Outcomes Relevant to the Course:

PO1	Apply knowledge of science, mathematics and domain competence for analyzing and designing VLSI systems for various real world applications.
PO2	Identify, formulate, and analyze engineering problems in VLSI & embedded systems and develop innovative and cost effective solutions.
PO3	Design efficient VLSI, embedded, and sensor based systems with considerations towards societal and environmental aspects.
PO4	Apply reasoning & contextual knowledge to assess security & privacy in design, deployment of VLSI and real-time sytems in sensitive applications.
PO5	Integrate and apply appropriate techniques, resources, and modern EDA tools for modeling and developing prototypes for VLSI and relevant real-world applications.
PO9	Review research literature and conduct independent research in VLSI and its related domains to develop advanced techniques, systems, and tools.
PO10	Recognize the need and engage in continuous lifelong learning to enhance the knowledge & skills in VLSI domain related real world applications.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	3	2		2						2	2	1
CO2	3	3	2	1	2					1	1	2	1
CO3	3	3	2	1	3				1	2	2	1	2
CO4	3	3	3	2	3				2	2	2	1	1
CO5	3	2	2	2	2				2	2	2	2	1

Category	Code	Programming for VLSI Lab	L-T-P	Credits	Marks
PCR	EC5025		0-0-2	1	100

Objectives	The objective of this laboratory course is to develop programming skills using Python and Tcl languages to solve VLSI design problems.
Pre-Requisites	Knowledge of programming and basic problem-solving skills is required.
Teaching Scheme	Regular laboratory experiments to be conducted under supervision of the faculty with use of ICT as and when required. Experiments shall comprise of programming assignments.

Evaluation Scheme

Attendance	Daily Performance	Lab Record	Lab Test / Project	Viva-voce	Total
10	30	15	30	15	100

Detailed Syllabus

Experiment-#	Assignment/Experiment
	Programming in Python
1	Write, compile, test, and debug simple Python programs.
2	Write programs using control structures (if, if-elif-else).
3	Write programs using loop control structure (while loops).
4	Write programs using loop control structure (for loops).
5	Solve mathematical problems (sin(x), cos(x) etc.) using Taylor's series expansion.
6	Write program based on the concept of lists and tuples.
7	Write program based on the concept of set and dictionaries.
8, 9	Write programs by defining functions and calling them.
10	Write programs using user-defined functions.
	Programming in Tcl/Tk
11	Write, compile, test, and debug simple Tcl scripts.
12	Write Tcl scripts on file operations.
13	Evaluation & substitutions of variables.
14	Execution of mathematical functions.
15	Execution of control flow and looping constructs.

Text Books:

T1. R. N. Rao, ***Core Python Programming***, 2nd Edition, DreamTech Press, 2019.
T2. J. K. Ousterhout, ***Tcl and the Tk Toolkit***, Addison Wesley, 1994.

Reference Books:

R1. J. Zelle, ***Python Programming: An Introduction to Computer Science***, 3rd Edition, Franklin, Beedle & Associates, 2016.
R2. L. Ramalho, ***Fluent Python***, 1st Edition, O'Reilly Media, 2015.
R3. M. Lutz, ***Programming Python***, 4th Edition, O'Reilly Media, 2011.
R4. B. B. Welch, ***Practical Programming in Tcl and Tk***, Prentice Hall, 1995.

Online Resources:

1. https://nptel.ac.in/courses/106/106/106106145/: By Prof. M. Mukund, IIT Madras
2. https://www.tcl.tk/doc/: Tcl/Tk Documentation
3. https://www.tcl.tk/man/tcl8.5/tutorial/tcltutorial.html

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Explore Python syntax and use Python flow control to solve simple problems.
CO2	Implement various mathematical functions using Python programming.
CO3	Implement user-defined functions and different data structures in Python.
CO4	Execute basic Tcl commands for file handling and variable substitution.
CO5	Explore & implement mathematical functions and loops in Tcl scripts.

Program Outcomes Relevant to the Course:

PO1	Apply knowledge of science, mathematics and domain competence for analyzing and designing VLSI systems for various real world applications.
PO2	Identify, formulate, and analyze engineering problems in VLSI & embedded systems and develop innovative and cost effective solutions.
PO3	Design efficient VLSI, embedded, and sensor based systems with considerations towards societal and environmental aspects.
PO4	Apply reasoning & contextual knowledge to assess security & privacy in design, deployment of VLSI and real-time sytems in sensitive applications.
PO5	Integrate and apply appropriate techniques, resources, and modern EDA tools for modeling and developing prototypes for VLSI and relevant real-world applications.
PO7	Work with professional context with intellectual integrity, ethics and social responsibility.
PO10	Recognize the need and engage in continuous lifelong learning to enhance the knowledge & skills in VLSI domain related real world applications.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	2	2								1	2		1
CO2		1	2	3	2						1		2
CO3	1		3	2	2		1			1	2	1	1
CO4	2	2									1	2	2
CO5	1		3	2	3		1			1	2	2	2

Category	Code	Communication & Soft Skills	L-T-P	Credits	Marks
UCR	HS5003		0-0-2	1	100

Objectives	The objectives of this laboratory course are to develop effective communication and soft skills, such as negotiation, assertiveness, teamwork, leadership, presentation, writing e-mails, business letters, and reports, etc.
Pre-Requisites	Knowledge of English and basic communication skills is required.
Teaching Scheme	Regular laboratory classes pair through and/or team activities with regular assessments, presentations, discussions, role-playing, audio-visual supplements, writing activities, business writing practices and vocabulary enhancement.

Evaluation Scheme

Attendance	Daily Performance	Lab Record	Lab Test / Project	Viva-voce	Total
10	30	15	30	15	100

Detailed Syllabus

Experiment-#	Assignment/Experiment
1	Introduction to the course and diagnostic test
2	Personality development and soft skills for professionals
3	Group Discussion (GD): Mock GD 1
4	Group Discussion (GD): Mock GD 2
5	Verbal Ability
6	Writing a compelling resume and cover letter
7	Personal Interview FAQs
8	Mock Personal Interview (PI)
9	Assertive communication and negotiation skills
10	Teamwork and leadership skills
11	Powerpoint Presentation 1
12	Powerpoint Presentation 2
13	Writing business letters, email etiquette
14	Preparing Analytical Reports

Text Books:

T1. M. A. Rizvi, ***Effective Technical Communication***, 2nd Edition, Tata McGraw-Hill, 2017.
T2. M. Raman and S. Sharma, ***Technical Communication: Principles and Practice***, 3rd Edition, Oxford University Press, 2015.

Reference Books:

R1. S. John, ***The Oxford Guide to Writing and Speaking***, 3rd Edition, Oxford University Press, 2013.
R2. S. Kumar and P. Lata, ***Communication Skills***, 2nd Edition, Oxford University Press, 2015.
R3. B. K. Das, K. Samantray, R. Nayak, S. Pani, and S. Mohanty, ***An Introduction to Professional English and Soft Skills***, 2nd Edition, Cambridge University Press, 2012.

Online Resources:

1. https://nptel.ac.in/courses/109/106/109106094/: By Prof. A. Iqbal, IIT Madras
2. https://nptel.ac.in/courses/109/104/109104031/: By Dr. T. Ravichandran, IIT Kanpur

3. https://www.coursera.org/specializations/business-english
4. https://ocw.mit.edu/courses/comparative-media-studies-writing/21w-732-5-introduction-to-technical-communication-explorations-in-scientific-and-technical-writing-fall-2006/download-course-materials/

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Communicate assertively and make successful negotiations in business situations.
CO2	Improve skills like verbal ability, GD, PI & writing resumes for career success.
CO3	Develop effective team work abilities and take leadership in real-life situations.
CO4	Demonstrate & apply various techniques of effective oral presentation.
CO5	Compose effective business correspondences such as e-mail, business letters, and reports.

Program Outcomes Relevant to the Course:

PO6	Function effectively as an individual or as a member of a multidisciplinary team with professional and managerial skills.
PO7	Work with professional context with intellectual integrity, ethics and social responsibility.
PO8	Communicate effectively and present technical information in oral and written reports supported by diagrams and models for easy visualization.
PO10	Recognize the need and engage in continuous lifelong learning to enhance the knowledge & skills in VLSI domain related real world applications.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1						2	1	1		1			1
CO2						1	1	1			1		1
CO3						3	1	1		1	1		1
CO4						3	1	3		1	1		1
CO5						1	2	1		1	1	1	1

Category	Code	Semiconductor Devices	L-T-P	Credits	Marks
PCR	EC5026		3-0-0	3	100

Objectives	The objective of this course is study the characteristics of different semiconductor devices used in modern electronic equipment and explore the nanoscale CMOS structures and materials for application in advanced technology nodes.
Pre-Requisites	Basic knowledge of physics of semiconductor devices is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with problem solving activities.

Evaluation Scheme

Attendance	Teacher's Assessment	Mid-Term	End-Term	Total
10	20	20	50	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	**Introduction**: Semiconductors, Energy bands and charge carriers, Electrons in periodic lattices, E-K diagrams, Effective mass, Density of states (D(E)), Thermal equilibrium, Fermi-Dirac distribution function (f(E)) for electrons and holes, Fermi energy, Fermi level and carrier concentrations.	**9 Hours**
Module-2	**P-N Junction Diodes**: Introduction & construction of P-N junction diode, Energy band diagram and depletion region of a P-N junction, Built-in potential, Diode I-V characteristics under forward and reverse bias conditions, Breakdown mechanisms - Zener breakdown, Avalanche breakdown, Zener diode as a voltage regulator.	**8 Hours**
Module-3	**Bipolar Junction Transistors**: BJT structure and configurations, Small signal parameters, Heterojunction BJT, Ebers-Moll model, Applications of BJT.	**8 Hours**
Module-4	**Field Effect Transistors (MOSFET & CMOS)**: MOSFET structure, Energy band diagram, Surface accumulation, Depletion and inversion conditions, Threshold voltage, I-V characteristics, C-V characteristics of ideal MOS capacitor, The C-MOS technology, MESFETs, MODFETs, TFTs.	**9 Hours**
Module-5	**Modern Day Transistors**: Heterojunction MOSFETs; Multiple Gate MOS Structures: Double Gate MOSFET, FinFET and Surrounding Gate MOSFET.	**8 Hours**
	Total	**42 Hours**

Text Books:

T1. D. A. Neamen, ***Semiconductor Physics and Devices***, 4th Edition, McGraw-Hill Education, 2012.
T2. S. M. Sze and K. N. Kwok, ***Physics of Semiconductor Devices***, 3rd Edition, John Wiley & Sons, 2006.
T3. J. Millman and C. C. Halkias, ***Electronic Devices and Circuits***, Tata McGraw-Hill Edition, 1991.

Reference Books:

R1. G. Streetman and S. K. Banerjee, ***Solid State Electronic Devices***, 7th Edition, Pearson Education, 2014.
R2. C. C. Hu, ***Modern Semiconductor Devices for Integrated Circuits***, 1st Edition, Pearson Education, 2010.
R3. R. S. Muller and T. I. Kamins, ***Device Electronics for Integrated Circuits***, 3rd Edition, Wiley, 2007.
R4. Y. Tsividis and M. Colin, ***Operation and Modelling of MOS Transistor***, 3rd Edition, Oxford University Press, 2011.

Online Resources:

1. https://nptel.ac.in/courses/108108122
2. https://www.digimat.in/nptel/courses/video/108107129/L01.html
3. https://www.digimat.in/nptel/courses/video/117107149/L42.html
4. http://www.digimat.in/nptel/courses/video/117108047/L17.html
5. https://nptel.ac.in/courses/117108047

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Explain the fundamentals of energy band structure in semiconductors and carrier distribution under equilibrium.
CO2	Articulate the characteristic of P-N junction diode and its applications.
CO3	Describe the structure and characteristics of Bipolar Junction Transistors.
CO4	Explain the characteristics of MOS transistor, CMOS technology, and different FET structures.
CO5	Explore the advanced transistor configurations used in modern electronic devices.

Program Outcomes Relevant to the Course:

PO1	Apply knowledge of science, mathematics and domain competence for analyzing and designing VLSI systems for various real world applications.
PO2	Identify, formulate, and analyze engineering problems in VLSI & embedded systems and develop innovative and cost effective solutions.
PO3	Design efficient VLSI, embedded, and sensor based systems with considerations towards societal and environmental aspects.
PO4	Apply reasoning & contextual knowledge to assess security & privacy in design, deployment of VLSI and real-time sytems in sensitive applications.
PO5	Integrate and apply appropriate techniques, resources, and modern EDA tools for modeling and developing prototypes for VLSI and relevant real-world applications.
PO9	Review research literature and conduct independent research in VLSI and its related domains to develop advanced techniques, systems, and tools.
PO10	Recognize the need and engage in continuous lifelong learning to enhance the knowledge & skills in VLSI domain related real world applications.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	3	2		1					1	3	2	3
CO2	3	3	2	1	1					1	3	3	2
CO3	3	3	2	2	1					1	3	3	3
CO4	3	3	3	2	2					2	2	3	2
CO5	3	3	3	2	2				1	2	3	3	2

Category	Code	VLSI Design Using Verilog HDL	L-T-P	Credits	Marks
PCR	EC5027		3-1-0	4	100

Objectives	The objective of this course is to study the Verilog HDL techniques for the design and analysis of digital circuits & systems.
Pre-Requisites	Digital Electronic Circuits and basic knowledge on MOSFET is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with problem solving activities.

Evaluation Scheme

Attendance	Teacher's Assessment	Mid-Term	End-Term	Total
10	20	20	50	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	**Introduction**: Hierarchical Modeling - Modules, Instances, Basic Concepts -Lexical Conventions, Whitespace, Comments, Operators, Data Types – Value Set, Nets, Registers, Vectors, Arrays, Parameters, Strings Modules and Ports - Modules, Port Declaration, Port Connection Rules, Connecting Ports to External Signals.	**10 Hours**
Module-2	**Combinational Circuit Design - I**: Dataflow Modeling – Continuous Assignments, Delays, Expressions, Operators, and Operands, Operator Types, Examples; Gate-Level Modeling - Gate Types, Gate Delays, Rise, Fall, and Turn-off Delays, Min/Typical/Max Values; Switch-Level Modeling - Switch-Modeling Elements: MOS Switches, CMOS Switches.	**10 Hours**
Module-3	**Combinational Circuit Design - II**: Behavioral Modeling - initial Statement, Always Statement, Adders, Subtractors, Comparator, MUX and DeMUX (using if...else and case Construct); Loops - While Loop, For Loop, Repeat Loop, Forever loop (with relevant examples); Structural Modeling - 4-bit Adders, 2-bit Multiplier, 4-bit Comparator, 8:1-MUX and 1:8-DeMUX.	**12 Hours**
Module-4	**Multiplexer as Universal Logic**: Design of Basic Gates, Boolean Expressions, and other Combinational Logic Circuits using Multiplexers; **Decoders and Encoders**: 1:2 Decoders, 2:4 Decoder, Test Bench of Decoder, Priority Encoders, Test Bench of Priority Encoder; **Latches & Flip-Flops**: D Latch, Flip-Flop, Positive and Negative Edge-Triggered D Flip-Flop.	**12 Hours**
Module-5	**Sequential Circuit Design**: Synchronous and Asynchronous Reset, Counter Design using Synthesizable Constructs – Synchronous Counters, Asynchronous Counter, BCD Up–Down Counter; **Finite State Machine (FSM)**: Melay & Moore Machines; Verilog implementation of Sequence Detector (Overlapping Permitted and Non-overlapping), Vending Machine.	**12 Hours**
	Total	**56 Hours**

Text Books:

T1. S. Palnitkar, ***Verilog HDL: A guide to Digital Design and Synthesis***, 4th Edition, SunSoft Press, 1996.
T2. V. Taraate, ***Digital Logic Design Using Verilog***, 2nd Edition, Springer, 2016.

Reference Books:

R1. S. Ramachandran, ***Digital VLSI Systems Design***, 2nd Edition, Springer, 2006.

R2. C. H. Roth Jr., L. K. John, B. K. Lee, ***Digital Systems Design Using Verilog***, 2nd Edition, Cengage Learning, 2015.
R3. D. E. Thomas, P. R. Moorby, ***The Verilog Hardware Description Language***, 5th Edition, Kluwer Academic Publishers, 2002.
R4. M. D. Ciletti, ***Advanced Digital Design with Verilog HDL***, 2nd Edition, Pearson Education, 2010.

Online Resources:

1. https://nptel.ac.in/courses/108103179: by Prof. S. R. Ahamed, IIT Guwahati
2. https://www.chipverify.com/verilog/verilog-tutorial
3. https://www.javatpoint.com/verilog
4. https://www.edaplayground.com/

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Explain the basic concepts and syntax of Verilog HDL.
CO2	Design & analyze combinational logic circuits using data flow, gate and switch level modeling.
CO3	Apply structural modeling of Verilog HDL to design combinational logic circuits.
CO4	Design combinational logic circuits using multiplexer as universal logic through Verilog HDL.
CO5	Apply synthesizable constructs of Verilog to design sequential and FSM based circuits.

Program Outcomes Relevant to the Course:

PO1	Apply knowledge of science, mathematics and domain competence for analyzing and designing VLSI systems for various real world applications.
PO2	Identify, formulate, and analyze engineering problems in VLSI & embedded systems and develop innovative and cost effective solutions.
PO3	Design efficient VLSI, embedded, and sensor based systems with considerations towards societal and environmental aspects.
PO4	Apply reasoning & contextual knowledge to assess security & privacy in design, deployment of VLSI and real-time sytems in sensitive applications.
PO5	Integrate and apply appropriate techniques, resources, and modern EDA tools for modeling and developing prototypes for VLSI and relevant real-world applications.
PO6	Function effectively as an individual or as a member of a multidisciplinary team with professional and managerial skills.
PO7	Work with professional context with intellectual integrity, ethics and social responsibility.
PO9	Review research literature and conduct independent research in VLSI and its related domains to develop advanced techniques, systems, and tools.
PO10	Recognize the need and engage in continuous lifelong learning to enhance the knowledge & skills in VLSI domain related real world applications.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	2				3	1				1	2	1	1
CO2	2	2	3	2	3	1				1	2	2	1
CO3	2	2	3	2	3	1					2	3	2
CO4	1	3	3	3	2	1	2		1		1	3	2
CO5	1	3	3	3	2	1			2	1	1	3	1

Category	Code	CMOS VLSI Design	L-T-P	Credits	Marks
PCR	EC5028		3-1-0	4	100

Objectives	The objective of this course is to study the design, fabrication & testing of devices, circuits & systems using integrated micro fabrication technologies providing an in-depth coverage of the state of the art in VLSI technology.
Pre-Requisites	Fundamental knowledge on MOSFETs and Digital Electronic Circuits is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with problem solving activities.

Evaluation Scheme

Attendance	Teacher's Assessment	Mid-Term	End-Term	Total
10	20	20	50	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	**Introduction**: Historical Perspective, VLSI Design Methodologies, VLSI Design Flow, Design Hierarchy, Concept of Regularity, Modularity and Locality, VLSI Design Styles; **Fabrication of MOSFETs**: Introduction, Fabrication Processes Flow – Basic Concepts, The CMOS n-Well Process, Layout Design Rules, Stick Diagrams & Layout of complex CMOS Logic Gates (Euler Method).	**11 Hours**
Module-2	**MOS Transistors**: The Metal Oxide Semiconductor (MOS) Structure, The MOS System under External Bias, Structure and Operation of MOS Transistor (MOSFET), MOSFET Current-Voltage Characteristics, MOSFET Scaling and Small-Geometry Effects, MOSFET Capacitance.	**11 Hours**
Module-3	**MOS Inverter Circuits**: Introduction, Voltage Transfer Characteristics, Noise Margin Definitions, NMOS Transistors as Load Devices, CMOS Inverters, Sizing of Inverters; **Static MOS Gate Circuits**: Introduction, CMOS Gate Circuits, Complex CMOS Gates, MUX Circuits, Calculation of Inverter Equivalent for NAND, NOR and other Complex Logic Circuits, Flip-flops and Latches.	**12 Hours**
Module-4	**High Speed CMOS Logic Design**: Introduction, Switching Time Analysis, Detailed Load Capacitance Calculation, Calculation of Interconnect Parasitics, Calculation of Interconnect Delay (Elmore Delay), Power Dissipation in CMOS Gates, Power and Delay Tradeoffs.	**12 Hours**
Module-5	**Transfer Gate and Dynamic Logic Design**: Introduction, Basic Concepts of Pass Transistor, CMOS Transmission Gate Logic, Dynamic logic, Domino logic, NORA logic; **Semiconductor Memory**: DRAM, SRAM Cell Design & Operation, Memory Array Architecture.	**10 Hours**
	Total	**56 Hours**

Text Books:

T1. S. -M. Kang and Y. Leblebici, ***CMOS Digital Integrated Circuits - Analysis and Design***, 3rd Edition, McGraw-Hill Education, 2002.

T2. J. P. Rabaey, A. P. Chandrakasan, and B. Nikolić, ***Digital Integrated Circuits: A Design Perspective***, 2nd Edition, Pearson Education, 2016.

Reference Books:

R1. D. A. Hodges, H. G. Jackson, and R. Saleh, ***Analysis and Design of Digital Integrated Circuits in Deep Submicron Technology***, 3rd International Edition, McGraw-Hill Education, 2005.
R2. N. H. E. Weste, D. Harris, and A. Banerjee, ***CMOS VLSI Design - A Circuits and Systems Perspective***, 4th Edition, Pearson Education, 2015.
R3. R. J. Baker, ***CMOS Circuit Design, Layout, and Simulation***, 3rd Edition, John Wiley & Sons, 2010.
R4. D. A. Pucknell and K. Eshraghian, ***Basic VLSI Design***, 3rd Edition, PHI Learning, 1995.

Online Resources:

1. https://nptel.ac.in/courses/117106092/: by Prof. S. Srinivasan, IIT Madras
2. https://nptel.ac.in/courses/117106093/: Dr. N. Dasgupta, IIT Madras
3. https://nptel.ac.in/courses/117101058/: by Prof. A. N. Chandorkar, IIT Bombay
4. https://nptel.ac.in/courses/108107129/: by Prof. S. Dasgupta, IIT Roorkee
5. https://nptel.ac.in/courses/106105161/: by Prof. I. Sengupta, IIT Kharagpur

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Identify suitable method to design circuits and systems using modern tools by following appropriate design flow and fabrication steps.
CO2	Explain the structure and operational analysis of MOSFET under external bias condition before and after scaling.
CO3	Design, implement and investigate Inverter, combinational and sequential logic circuits using CMOS technology.
CO4	Investigate switching characteristics of inverter to estimate its delay time and power consumption.
CO5	Design and analyze transmission gates, different dynamic logic, and various memory cells.

Program Outcomes Relevant to the Course:

PO1	Apply knowledge of science, mathematics and domain competence for analyzing and designing VLSI systems for various real world applications.
PO2	Identify, formulate, and analyze engineering problems in VLSI & embedded systems and develop innovative and cost effective solutions.
PO3	Design efficient VLSI, embedded, and sensor based systems with considerations towards societal and environmental aspects.
PO4	Apply reasoning & contextual knowledge to assess security & privacy in design, deployment of VLSI and real-time sytems in sensitive applications.
PO5	Integrate and apply appropriate techniques, resources, and modern EDA tools for modeling and developing prototypes for VLSI and relevant real-world applications.
PO7	Work with professional context with intellectual integrity, ethics and social responsibility.
PO9	Review research literature and conduct independent research in VLSI and its related domains to develop advanced techniques, systems, and tools.
PO10	Recognize the need and engage in continuous lifelong learning to enhance the knowledge & skills in VLSI domain related real world applications.

P.T.O

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	3	3	3	3					1	3	3	1
CO2	3	2	2	2	2				2		2	2	1
CO3	3	3	3	3	3		1			2	3	3	2
CO4	3	3	2	3	2				1		3	2	1
CO5	3	2	3	2	3		1		2	1	2	3	2

Category	Code	Low Power Digital VLSI Design	L-T-P	Credits	Marks
PEL	EC5032		3-0-0	3	100

Objectives	The objective of this course is to model power consumption and study the techniques to design low power digital VLSI circuits and systems.
Pre-Requisites	Knowledge of Digital Electronic Circuits and Digital VLSI Design is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required; sessions are planned to be interactive with problem solving activities.

Evaluation Scheme

Attendance	Teacher's Assessment	Mid-Term	End-Term	Total
10	20	20	50	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	**Introduction**: Need for low power VLSI chips, Sources of Dissipation in Digital Integrated Circuits, Degrees of Freedom, Emerging Low Power Approaches - An Overview; **Device & Technology Impact on Low Power Electronics**: Introduction, Dynamic Dissipation in CMOS, Effects of and on Speed, Constraints on Reduction, Transistor Sizing and Optimal Gate Oxide Thickness, Impact of Technology Scaling, Technology and Device Innovations.	**8 Hours**
Module-2	**Low Power Circuit Techniques**: Introduction, Power Consumption in Circuits, Flip-flops and Latches, Logic, High Capacitance Nodes; **Energy-Recovery CMOS**: A Simple Example, A look at some practical details, Retractile Logic, Reversible Pipelines, High-Performance Approaches.	**8 Hours**
Module-3	**Low Power Clock Distribution**: Power Dissipation in Clock Distribution, Single Driver vs. Distributed Buffers, Buffer and Device Sizing under Process Variations, Zero Skew vs. Tolerable Skew, Chip and Package Co-Design of Clock Network.	**9 Hours**
Module-4	**Logic Synthesis for Low Power**: Introduction, Power Estimation Techniques, Power Minimization Techniques; **Low Power Arithmetic Components**: Introduction, Circuit Design Style, Adders, Multipliers, Division.	**9 Hours**
Module-5	**Low Power Memory Design**: Introduction, Sources and Reductions of Power Dissipation in Memory Subsystem, Sources of Power Dissipation in DRAM and SRAM, Low Power DRAM Circuits, Low Power SRAM Circuits.	**8 Hours**
	Total	**42 Hours**

Text Books:

T1. J. M. Rabaey and M. Pedram, ***Low Power Design Methodologies***, Springer India, 2009.
T2. K. Roy and S. C. Prasad, ***Low-Power CMOS VLSI Circuit Design***, Wiley India, 2009.

Reference Books:

R1. G. K. Yeap, ***Practical Low Power Digital VLSI Design***, Kluwer Academic Publishers, 1998.
R2. A. P. Chandrakasan and R. W. Brodersen, ***Low Power Digital CMOS Design***, Kluwer Academic Publishers, 2012.

R3. A. Bellaouar and M. Elmasry, ***Low-Power Digital VLSI Design: Circuits and Systems***, Kluwer Academic Publishers, 1995.
R4. K. S. Yeo, S. S. Rofail, and W. -L. Goh, ***CMOS/BiCMOS ULSI: Low Voltage, Low Power***, 1st Indian Reprint, Pearson Education, 2002.

Online Resources:

1. https://nptel.ac.in/courses/106105034: by Prof. A. Pal, IIT Kharagpur
2. http://www.ocw.titech.ac.jp/index.php?module=General&action=T0300&JWC=201820800&lang=EN&vid=03

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Describe the need of low power VLSI design and impact on low power electronics.
CO2	Explain low power circuit design techniques and energy recovery CMOS circuit methods.
CO3	Analyze and design low power clock distribution network for VLSI chips.
CO4	Perform logic synthesis for low power systems and design low power arithmetic components.
CO5	Design low power memory circuits like DRAM and SRAM.

Program Outcomes Relevant to the Course:

PO1	Apply knowledge of science, mathematics and domain competence for analyzing and designing VLSI systems for various real world applications.
PO2	Identify, formulate, and analyze engineering problems in VLSI & embedded systems and develop innovative and cost effective solutions.
PO3	Design efficient VLSI, embedded, and sensor based systems with considerations towards societal and environmental aspects.
PO4	Apply reasoning & contextual knowledge to assess security & privacy in design, deployment of VLSI and real-time sytems in sensitive applications.
PO5	Integrate and apply appropriate techniques, resources, and modern EDA tools for modeling and developing prototypes for VLSI and relevant real-world applications.
PO6	Function effectively as an individual or as a member of a multidisciplinary team with professional and managerial skills.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	1	1								1		
CO2	3	2	1	1		1							
CO3	2	3	2	1							2	1	2
CO4	2	2	3	2	1	1					2	2	1
CO5	2	3	3	2	1	1					2	1	1

Category	Code	Microprocessors & Microcontrollers	L-T-P	Credits	Marks
PEL	EC5033		3-0-0	3	100

Objectives	The objective of this course is to be familiar about different microprocessors & microcontrollers, be able to develop assembly level programs as per user or industry requirements, and interface with other external devices.
Pre-Requisites	Basic knowledge of Digital Electronic Circuits is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with problem solving activities.

Evaluation Scheme

Attendance	Teacher's Assessment	Mid-Term	End-Term	Total
10	20	20	50	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	**Introduction**: 8085 microprocessor & its organization, General architecture, Bus organization, Memory concepts, Pins and Signals, Timing diagram, Instruction Set & programming, Addressing modes, Memory interfacing, Interrupts.	**10 Hours**
Module-2	**Intel 8086 Microprocessor**: Bus Interface unit, Execution Unit, Register Organization, Memory Segmentation, Pin architecture, Minimum and Maximum mode, Physical Memory Organization, Memory Interfacing, Interrupts, Addressing Modes, Instructions; Advanced Co-processor Architectures – Intel 80386, Pentium.	**8 Hours**
Module-3	Interfacing with Peripheral ICs: System level interfacing design with various ICs like 8255 Programmable Peripheral Interface, 8257 DMA Controller, 8259 Programmable Interrupt Controller, 8251 Programmable Communication Interface.	**8 Hours**
Module-4	Microcontrollers: 8051 systems – Introduction to 8051 Microcontrollers, Architecture, Memory Organization, Special Function Register, Port Operation, Memory Interfacing, I/O Interfacing, Serial Data Transfer Scheme, On board Communication Interfaces-I2C Bus, SPI Bus, USART, External Communication Interfaces-RS232, USB.	**8 Hours**
Module-5	**Microcontroller Programming**: 8051 Instruction set, Interrupts, Programming and Applications: Servo motor, Stepper motor control; High Performance RISC Architecture: Introduction to RISC Processors, ARM-Arcon RISC Machine, Core & Architecture, Registers, ARM processor family.	**8 Hours**
	Total	**42 Hours**

Text Books:

T1. R. S. Gaonkar, ***Microprocessor Architecture, Programming, and Applications with the 8085***, 6th Edition, Penram International Publishing, 2013.

T2. A. K. Ray and K. M. Bhurchandani, ***Advanced Microprocessors and Peripherals***, 2nd Edition, McGraw Hill Education, 2006.

T3. M. A. Mazidi, J. G. Mazidi, R. McKinlay, ***The 8051 Microcontroller and Embedded Systems: Using Assembly and C***, 2nd Edition, Pearson Education, 2011.

T4. A. N. Sloss, D. Symes, C. Wright, ***ARM System Developer's Guide: Designing and Optimizing System Software***, Elsevier, 2012.

Reference Books:

R1. K. Kant, ***Microprocessors and Microcontrollers: Architecture, Programming and System Design 8085, 8086, 8051, 8096***, 2nd Edition, Prentice Hall India, 2013.
R2. D. Hall, ***Microprocessors and Interfacing***, 3rd Edition, McGraw-Hill Education, 2017.
R3. K. J. Ayala, ***The 8051 Microcontroller***, 3rd Edition, Cengage Learning, 2007.

Online Resources:

1. https://nptel.ac.in/courses/108107029/: by Dr. P.Agarwal, IIT Roorkee
2. https://nptel.ac.in/courses/106108100/: by Prof. Krishna Kumar IISc Bangalore
3. http://www.electrical4u.com/circuit-analysis.htm
4. http://www.allaboutcircuits.com
5. https://www.electronics-tutorials.ws/

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Describe the architecture & functionality of 8085 Microprocessor, modes of operation & memory management, and develop programs for the same.
CO2	Explain the architecture, programming & memory interfacing of 8086 Microprocessor, virtual memory and co-processor architecture in different advanced processors.
CO3	Interface external devices to the processor like 8255 PPI, 8251 USART, 8279 KeyBoard/display according to user requirements to create products and solutions for real life applications.
CO4	Differentiate the functionality of microprocessor and microcontrollers and program a microcontroller to perform tasks according to the requirements.
CO5	Design, formulate and implement microprocessor and microcontroller based systems using ARM and state of the art tools.

Program Outcomes Relevant to the Course:

PO1	Apply knowledge of science, mathematics and domain competence for analyzing and designing VLSI systems for various real world applications.
PO2	Identify, formulate, and analyze engineering problems in VLSI & embedded systems and develop innovative and cost effective solutions.
PO3	Design efficient VLSI, embedded, and sensor based systems with considerations towards societal and environmental aspects.
PO4	Apply reasoning & contextual knowledge to assess security & privacy in design, deployment of VLSI and real-time sytems in sensitive applications.
PO5	Integrate and apply appropriate techniques, resources, and modern EDA tools for modeling and developing prototypes for VLSI and relevant real-world applications.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	2	3	3	3	2						2	2	2
CO2	2	3	3	3	3	1					2		2
CO3	3	3	2	2	3						2	1	2
CO4	2	3	3	3	3	1					2		2
CO5	2	3	3	3	3	1					3		1

Category	Code	Artificial Intelligence	L-T-P	Credits	Marks
PEL	CS5021		3-0-0	3	100

Objectives	The objective of the course is to study the basics of Artificial Intelligence (AI), problem solving techniques, methods of knowledge representation and applications of AI in various information processing applications.
Pre-Requisites	Knowledge of algorithms and data structures is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with problem solving activities.

Evaluation Scheme

Attendance	Teacher's Assessment	Mid-Term	End-Term	Total
10	20	20	50	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	Artificial Intelligence: Introduction to AI; Intelligent Agents: Agents and Environment, Good Behavior, The nature of Environments, The structure of agents; Problem-solving: Solving Problems by Searching: Problem-Solving Agents, Example Problems, Searching for Solutions, Uninformed search strategies, Searching with Partial Information.	**8 Hours**
Module-2	Informed Search and Exploration: Informed (Heuristic) Search Strategies, Heuristic Functions, Local Search Algorithms and Optimization Problems; Constraint Satisfaction Problems: Constraint Satisfaction Problems, Backtracking search for CSPs, Local Search for Constraint Satisfaction Problems; Adversarial Search: Games, Optimal Decisions in Games, Alpha-Beta Pruning; Knowledge and Reasoning: Knowledge-Based Agents, The Wumpus World.	**10 Hours**
Module-3	Knowledge and Reasoning: Logic, Propositional Logic, Reasoning Patterns in Propositional Logic; First-Order Logic: Syntax and Semantics of First-Order Logic, Using FOL, Knowledge Engineering in FOL; Inference in FOL: Propositional vs. First-Order Logic, Unification and Lifting, Forward Chaining, Backward Chaining, Resolution.	**8 Hours**
Module-4	Planning: The Planning Problem,Planning with State-Space Search, Partial-Order Planning, Planning Graphs; Uncertain Knowledge and Reasoning: Acting under Uncertainty, Bayes Rule and its use; Probabilistic Reasoning: Representing Knowledge in an Uncertain Domain. The Semantics of Bayesian Networks.	**8 Hours**
Module-5	Learning: Learning from Observations: Forms of Learning, Inductive Learning, Learning Decision Trees; Statistical Learning, Instance Based Learning, Neural Networks; Reinforcement Learning: Passive and Active Reinforcement Learning.	**8 Hours**
	Total	**42 Hours**

Text Books:

T1. S. J. Russell and P. Norvig, ***Artificial Intelligence - A Modern Approach***, 3rd Edition, Pearson Education, 2016.

T2. D. W. Patterson, ***Introduction to Artificial Intelligence & Expert Systems***, Pearson Education, 2015.

Reference Books:

R1. E. Rich, K. Knight, and S. B. Nair, ***Artificial Intelligence***, 3rd Edition, McGraw Hill, 2017.
R2. G. F. Luger, ***Artificial Intelligence***, 5th Edition, Pearson Education, 2009.
R3. M. Negnevitsky, ***Artificial Intelligence: A Guide to Intelligent Systems***, 2nd Edition, Pearson Education, 2008.
R4. N. J. Nilson, ***Principles of Artificial Intelligence***, 1st Edition, Narosa, 2002.

Online Resources:

1. https://nptel.ac.in/courses/106105077/: by Prof. S. Sarkar & Prof. A. Basu, IIT Kharagpur
2. https://nptel.ac.in/courses/106105079/: by Prof. P. Mitra, IIT Kharagpur
3. https://nptel.ac.in/courses/106106140/: by Prof. D. Khemani, IIT Madras

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Explore agents and working environments with utilization of uninformed techniques in state space search.
CO2	Apply search techniques for Game playing and solving CSP problems.
CO3	Interpret Logic, Inference rules for decision making and represent knowledge using semantic nets, frames.
CO4	Apply Planning and Reasoning to handle uncertainty in real life.
CO5	Use Learning to solve complex real life problems in science, engineering and business.

Program Outcomes Relevant to the Course:

PO1	Apply knowledge of science, mathematics and domain competence for analyzing and designing VLSI systems for various real world applications.
PO2	Identify, formulate, and analyze engineering problems in VLSI & embedded systems and develop innovative and cost effective solutions.
PO3	Design efficient VLSI, embedded, and sensor based systems with considerations towards societal and environmental aspects.
PO4	Apply reasoning & contextual knowledge to assess security & privacy in design, deployment of VLSI and real-time sytems in sensitive applications.
PO5	Integrate and apply appropriate techniques, resources, and modern EDA tools for modeling and developing prototypes for VLSI and relevant real-world applications.
PO6	Function effectively as an individual or as a member of a multidisciplinary team with professional and managerial skills.
PO7	Work with professional context with intellectual integrity, ethics and social responsibility.
PO10	Recognize the need and engage in continuous lifelong learning to enhance the knowledge & skills in VLSI domain related real world applications.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	2	3	1	1	3						1	1	
CO2	3	2	2	1	1					1	1		
CO3	2	2	2	3	2		1					1	1
CO4	3	3	1	2	2	1	1			1	1		
CO5	2	1	1	1	3	1				1	2	2	1

Category	Code	MEMS & Sensor Based Design	L-T-P	Credits	Marks
PEL	EC5017		3-0-0	3	100

Objectives	The objective of this course is to learn the concepts of microsystems, benefits of miniaturization, principles of micro-machining & micro-fabrication to develop miniaturized sensors & systems for diverse applications.
Pre-Requisites	Fundamental knowledge of sensors and transducers is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with problem solving activities.

Evaluation Scheme

Attendance	Teacher's Assessment	Mid-Term	End-Term	Total
10	20	20	50	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	**MEMS & Microsystems**: Introduction, MEMS products, Difference between Microsystems and Microelectronics, Multidisciplinary approach of MEMS, Evolution of Microfabrication, Microsystems and Miniaturization, Microsystem applications in Automotive Industry, MEMS applications in other industries, Markets for Microsystems.	**7 Hours**
Module-2	**Materials & Fabrication Processes in Microsystem Design**: Materials for MEMS: Substrate and Wafers, Active substrate materials, Silicon as substrate, compound, and piezoresistive materials, GaAs, Quartz, PZT, Polymers, Packaging materials; Fabrication Processes: Introduction, Photolithography, Ion implantation, Diffusion, Oxidation, CVD, PVD, Sputtering, deposition by Epitaxy, Wet etching of silicon: Isotropic etching, Anisotropic etching, TMAH, EDP; Micromanufacturing: Bulk Micromachining, Surface Micromachining, LIGA.	**10 Hours**
Module-3	**Engineering Mechanics for Microsystem Design**: Introduction, Static bending of Thin Plates, Mechanical Vibration (Resonant Vibration, Micro-accelerometers, Design of accelerometers, damping concepts and resonant microsensors), Thermo-mechanics (Creep deformation and thermal stresses), Thin-film mechanics.	**7 Hours**
Module-4	**Working Principle of MEMS**: Microsensors: Acoustic wave, Biosensors, Chemical, Optical, Pressure, Thermal sensors; Micro-actuation: Thermal forces, SMA, Piezoelectric crystals and Electrostatic forces; Concepts of Microgrippers, Micromotors, Microvalves and Micropumps, Micro-accelerometers, Microfluidics; Microsystems Design: Introduction, Design Considerations, Process Design, Mechanical Design, Finite Element Method, Computer-Aided Design.	**10 Hours**
Module-5	**Case Study of Selected MEMS**: Blood Pressure (BP) Sensor, Microphone, Acceleration Sensors, Gyro and its design considerations; Top Concerns of MEMS Products: Performance, Accuracy, Repeatability, Reliability, Cost and Market Uncertainties.	**8 Hours**
	Total	**42 Hours**

Text Books:

T1. T. -R. Hsu, ***MEMS & Microsystems - Design and Manufacture***, 1st Edition, McGraw-Hill Education, 2017.
T2. C. Liu, ***Foundations of MEMS***, 2nd Edition, Pearson Education, 2012.

Reference Books:

R1. S. E. Lyshevski, ***Nano- and Micro-Electromechanical Systems : Fundamentals of Nano- and Microengineering (Vol. 8)***, CRC Press, 2005.
R2. D. A. Bell, ***Electronic Instrumentation and Measurements***, 2nd Edition, Oxford University Press, 2007.
R3. G. K. Ananthasuresh, K. J. Vinoy, S. Gopalkrishnan, K. N. Bhat, and V. K. Aatre, ***Micro and Smart Systems***, 1st Edition, Wiley India, 2012.
R4. E. Gaura and R. M. Newman, ***Smart MEMS and & Sensor Systems***, 1st Edition, Imperial College Press, 2006.

Online Resources:

1. https://nptel.ac.in/courses/108/108/108108113/: by Prof. H. J. Pandya, IISc Bangalore
2. https://nptel.ac.in/courses/117/105/117105082/: by Prof. S. Kal, IIT Kharagpur
3. https://nptel.ac.in/courses/112/104/112104181/: by Dr. S. Bhattacharya, IIT Kanpur

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Describe in detail the concepts of MEMS and Microsystems.
CO2	Explain the materials and fabrication processes in microsystem design.
CO3	Apply engineering mechanics in design of MEMS for sensing and actuation.
CO4	Analyze the working principles of MEMS and investigate the design parameters.
CO5	Design advanced MEMS sensors and explain the design considerations using case studies.

Program Outcomes Relevant to the Course:

PO1	Apply knowledge of science, mathematics and domain competence for analyzing and designing VLSI systems for various real world applications.
PO2	Identify, formulate, and analyze engineering problems in VLSI & embedded systems and develop innovative and cost effective solutions.
PO3	Design efficient VLSI, embedded, and sensor based systems with considerations towards societal and environmental aspects.
PO4	Apply reasoning & contextual knowledge to assess security & privacy in design, deployment of VLSI and real-time sytems in sensitive applications.
PO5	Integrate and apply appropriate techniques, resources, and modern EDA tools for modeling and developing prototypes for VLSI and relevant real-world applications.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	1	2	1							2	1	1
CO2	3	2	3	2							2	1	1
CO3	3	3	3	2	2						3	2	3
CO4	3	2	3	3	2						3	3	3
CO5	3	3	3	3	2						3	3	3

Category	Code	Soft Computing Techniques	L-T-P	Credits	Marks
PEL	EC5035		3-0-0	3	100

Objectives	The objective of this course is to study concepts of soft computing, such as, Fuzzy Logic, Artificial Neural Network, and optimization techniques like Genetic Algorithm, etc., and their application to solve real world problems.
Pre-Requisites	Basic knowledge of mathematics, critical thinking & problem solving is required. Programming skill in MATLAB is desirable.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with problem solving activities.

Evaluation Scheme

Attendance	Teacher's Assessment	Mid-Term	End-Term	Total
10	20	20	50	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	**Basic Tools of Soft Computing**: Evolution of Computing - Soft Computing constituents, Difference between soft computing and hard computing, Fuzzy logic, Basics of fuzzy logic theory, Crisp and fuzzy sets, Biological background of Neural Networks and its architecture, Basics of Genetic Algorithm and Particle Swarm Optimization, Characteristics of Soft computing and its applications.	**7 Hours**
Module-2	**Fuzzy Logic Systems**: Operations on Fuzzy Sets, Membership Functions, Fuzzy relations, Fuzzy rules, Propositions, Implications and inferences, Zadeh's compositional rule of inference, Methods of Defuzzification; **Fuzzy Logic Controller**: Fuzzy Inference System, Mamdani, Takagi and Sugeno architectures, Examples and applications of fuzzy logic controller. Introduction to fuzzy PI and fuzzy PID control.	**12 Hours**
Module-3	**Artificial Neural Networks**: Neural network architectures, Single layer feed forward network, Multi-layer feed forward network, Recurrent networks; Early neural network architectures - Rosenblatt's Perceptron, ADALINE network, MADALINE network, Examples and applications of neural networks.	**7 Hours**
Module-4	**Training of ANN**: Back propagation algorithm, Effect of tuning parameters of the back propagation algorithm; Radial Basis Function networks & Least Square training algorithm; Kohenen self–organizing map and learning vector quantization networks; Recurrent neural networks, Simulated annealing neural networks; Adaptive Neuro-Fuzzy Inference Systems (ANFIS).	**10 Hours**
Module-5	**Evolutionary Computing**: Concept of Genetics, GA architectures, GA operators- Encoding, Crossover, Selection, Mutation Introduction to other optimization techniques and hybrid evolutionary algorithms.	**6 Hours**
	Total	**42 Hours**

Text Books:

T1. J. S. R. Jang, C. T. Sun, and E. Mizutani, ***Neuro Fuzzy and Soft Computing: A Computational Approach to Learning and Machine Intelligence***, 1st Edition, Pearson Education, 2015.

T2. S. Rajasekaran and G. A. V. Pai, ***Neural Networks, Fuzzy Systems and Evolutionary Algorithms : Synthesis and Applications***, 2nd Revised Edition, PHI Learning, 2017.

Reference Books:

R1. F. O. Karry and C. De Silva, ***Soft Computing and Intelligent Systems Design - Theory, Tools and Applications***, 1st Edition, Pearson Education, 2009.
R2. S. Haykin, ***Neural Networks: A Comprehensive Foundation***, 2nd Edition, Pearson Education, 1999.
R3. T. J. Ross, ***Fuzzy Logic with Engineering Applications***, 3rd Edition, Wiley, 2011.

Online Resources:

1. https://nptel.ac.in/courses/127/105/127105006/: by Prof. D. K. Pratihar, IIT Kharagpur
2. https://nptel.ac.in/courses/106/105/106105173/: by Prof. D. Samanta, IIT Kharagpur
3. https://nptel.ac.in/courses/117/105/117105084/: by Prof. S. Sengupta, IIT Kharagpur

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Describe different soft computing techniques and their applicability.
CO2	Apply fuzzy principles & inferences in designing fuzzy-logic based systems.
CO3	Apply different types of neural networks in electrical & electronics engineering problems.
CO4	Analyze effectiveness of neural networks for solving complex engineering problems.
CO5	Explore evolutionary computation techniques with focus on genetic algorithm.

Program Outcomes Relevant to the Course:

PO1	Apply knowledge of science, mathematics and domain competence for analyzing and designing VLSI systems for various real world applications.
PO2	Identify, formulate, and analyze engineering problems in VLSI & embedded systems and develop innovative and cost effective solutions.
PO3	Design efficient VLSI, embedded, and sensor based systems with considerations towards societal and environmental aspects.
PO4	Apply reasoning & contextual knowledge to assess security & privacy in design, deployment of VLSI and real-time sytems in sensitive applications.
PO5	Integrate and apply appropriate techniques, resources, and modern EDA tools for modeling and developing prototypes for VLSI and relevant real-world applications.
PO6	Function effectively as an individual or as a member of a multidisciplinary team with professional and managerial skills.
PO7	Work with professional context with intellectual integrity, ethics and social responsibility.
PO8	Communicate effectively and present technical information in oral and written reports supported by diagrams and models for easy visualization.
PO9	Review research literature and conduct independent research in VLSI and its related domains to develop advanced techniques, systems, and tools.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	2	1		1		1		1			1	1	1
CO2	1		2	1	2						1		1
CO3	1	2		1	2	1	1				1		1
CO4	1		1	1					3		1		1
CO5	1	1	1	1					2		1		1

Category	Code	Advanced Python Programming	L-T-P	Credits	Marks
PEL	CS5030		3-0-0	3	100

Objectives	The objective of this course is to study the semantics of Python programming language and its application in OOPS, file and error handling, database management and machine learning.
Pre-Requisites	Basic analytical & logical skill is required for this course. Prior experience with basic python programming language will be beneficial.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with programming activities.

Evaluation Scheme

Attendance	Teacher's Assessment	Mid-Term	End-Term	Total
10	20	20	50	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	**Review of Python**: Use IDLE to develop programs, Basic coding skills, Working with data types, variables, numeric data, string data; Python functions, Boolean expressions, Selection structure, Iteration structure, Working with lists, List of lists, tuples, dates & times, dictionaries.	**8 Hours**
Module-2	**Classes in Python**: OOPS Concepts, Classes and objects, Classes in Python, Constructors, Data hiding, Creating classes, Instance methods, Special methods, Class variables, Inheritance, Polymorphism, Type Identification, Custom exception classes, Iterators, Generators and decorators.	**8 Hours**
Module-3	**I/O and Error Handling**: Introduction, Data streams, Creating data streams, Access modes, Writing data to a file, Reading data from a file, Additional file methods, Handling I/O exceptions, Errors, Run-time errors, The exception model, Exception hierarchy, Handling multiple exceptions, Working with directories.	**9 Hours**
Module-4	**Working with Databases**: Relational databases, SQL statements for data manipulation, Using SQLite Manager to work with a database, Using Python to work with a database, Creating a GUI that handles an event, Working with components.	**9 Hours**
Module-5	**Machine Learning with Python**: Using Numpy for numerical data, Using Pandas for data analysis, Matplotlib for plotting, Seaborn for statistical plots, Interactive dynamic visualizations, SciKit for machine learning.	**8 Hours**
	Total	**42 Hours**

Text Books:

T1. M. Urban and J. Murach, ***Murach'S Python Programming***, 1st Edition, Mike Murach & Associatesh, 2017.
T2. M. Lutz, ***Programming Python***, 4th Edition, O'Reilly Media, 2011.

Reference Books:

R1. J. Zelle, ***Python Programming: An Introduction to Computer Science***, 3rd Edition, Franklin, Beedle & Associates, 2016.

R2. R. L. Halterman, ***Fundamentals of Python Programming***, Draft Copy, Southern Adventist University (Available online at: https://cs.appstate.edu/~rmp/cs2435/pythonbook.pdf), 2019.
R3. L. Ramalho, ***Fluent Python***, 1st Edition, O'Reilly Media, 2015.
R4. P. Barry, ***Head First Python***, 2nd Edition, O'Reilly Media, 2010.

Online Resources:

1. https://python-course.eu/advanced-python/
2. https://nptel.ac.in/courses/106/106/106106182/: By Prof. S. Iyengar, IIT Ropar
3. https://nptel.ac.in/courses/106/106/106106212/: By Prof. R. Rengasamy, IIT Madras
4. https://nptel.ac.in/courses/106/107/106107220/: By Prof. A. Ramesh, IIT Roorkee

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Explain the basic principles of Python programming language.
CO2	Articulate object oriented programming concepts as used in Python programming.
CO3	Apply the commonly used operations involving file systems and regular expressions.
CO4	Access relational databases and develop GUI applications using Python.
CO5	Implement machine learning algorithms and exploit advanced tools in Python.

Program Outcomes Relevant to the Course:

PO1	Apply knowledge of science, mathematics and domain competence for analyzing and designing VLSI systems for various real world applications.
PO2	Identify, formulate, and analyze engineering problems in VLSI & embedded systems and develop innovative and cost effective solutions.
PO3	Design efficient VLSI, embedded, and sensor based systems with considerations towards societal and environmental aspects.
PO4	Apply reasoning & contextual knowledge to assess security & privacy in design, deployment of VLSI and real-time sytems in sensitive applications.
PO5	Integrate and apply appropriate techniques, resources, and modern EDA tools for modeling and developing prototypes for VLSI and relevant real-world applications.
PO6	Function effectively as an individual or as a member of a multidisciplinary team with professional and managerial skills.
PO7	Work with professional context with intellectual integrity, ethics and social responsibility.
PO10	Recognize the need and engage in continuous lifelong learning to enhance the knowledge & skills in VLSI domain related real world applications.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	1	2		1									
CO2	1	3	1		1		1			1			
CO3		2	1			2							1
CO4	3			3	3		1			1	1		1
CO5	3	1	2	2	3	2	1			1	2		2

Category	Code	Semiconductor Devices Lab	L-T-P	Credits	Marks
PCR	EC5029		0-0-2	1	100

Objectives	The objective of this laboratory course is to learn the characteristics of various semiconductor devices through simulation using standard TCAD tools.
Pre-Requisites	Knowledge of the semiconductor devices taught in theory class is required
Teaching Scheme	Regular lab classes conducted under supervision of the teacher with demonstration of theoretical concepts and the use of the TCAD tool.

Evaluation Scheme

Attendance	Daily Performance	Lab Record	Lab Test / Project	Viva-voce	Total
10	30	15	30	15	100

Detailed Syllabus

Experiment-#	Assignment/Experiment
1	Determination of knee voltage and forward dynamic resistance of a P-N junction diode.
2	Determination of the Reverse Characteristic curve of Zener diode.
3	Demonstration of Zener diode as a voltage regulator.
4	Demonstration of BJT as an amplifier.
5	Study of characteristics of Heterojunction BJT using TCAD.
6	Demonstration of BJT as a switch to control LED
7	Determination of the Transfer characteristics of enhancement MOSFET and determine threshold voltage.
8	Design of MOSFET device(channel length 1μm) and study of its characteristics (VGS vs. ID) and (VDS vs. ID) using TCAD.
9	Extraction of threshold voltage and subthreshold slope from the MOSFET characteristic using TCAD.
10	Extraction of DIBL from the MOSFET characteristic using TCAD.
11	Study the effect of gate oxide scaling and use of different High-k materials as the gate oxide using TCAD.
12	Study the effect of channel length scaling on the characteristic of MOSFETs using TCAD.
13	Compare the characteristics of single gate and multiple gate transistors using TCAD.

Text Books:

T1. D. A. Neamen, ***Semiconductor Physics and Devices***, 4th Edition, McGraw-Hill Education, 2012.
T2. S. M. Sze and K. N. Kwok, ***Physics of Semiconductor Devices***, 3rd Edition, John Wiley & Sons, 2006.
T3. A. Sarkar, S. De, and C. K. Sarkar, ***VLSI Design and EDA Tools***, 1st Edition, SciTech Publications, 2013.

Reference Books:

R1. G. Streetman and S. K. Banerjee, ***Solid State Electronic Devices***, 7th Edition, Pearson Education, 2014.
R2. C. C. Hu, ***Modern Semiconductor Devices for Integrated Circuits***, 1st Edition, Pearson Education, 2010.
R3. R. S. Muller and T. I. Kamins, ***Device Electronics for Integrated Circuits***, 3rd Edition, Wiley, 2007.
R4. Y. Tsividis and M. Colin, ***Operation and Modelling of MOS Transistor***, 3rd Edition, Oxford University Press, 2011.

Online Resources:

1. https://nptel.ac.in/courses/108108122
2. https://www.digimat.in/nptel/courses/video/108107129/L01.html
3. https://www.digimat.in/nptel/courses/video/117107149/L42.html
4. http://www.digimat.in/nptel/courses/video/117108047/L17.html
5. https://nptel.ac.in/courses/117108047

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Describe the characteristics of pn junction diode and its applications.
CO2	Explain the operation of a BJT and its response to signals of different frequencies.
CO3	Investigate the characteristic of MOSFET structures for advanced CMOS technology nodes.
CO4	Explain the application of BJT as an amplifier.
CO5	Explore multi-gate CMOS structures and evaluate their performance.

Program Outcomes Relevant to the Course:

PO1	Apply knowledge of science, mathematics and domain competence for analyzing and designing VLSI systems for various real world applications.
PO2	Identify, formulate, and analyze engineering problems in VLSI & embedded systems and develop innovative and cost effective solutions.
PO3	Design efficient VLSI, embedded, and sensor based systems with considerations towards societal and environmental aspects.
PO4	Apply reasoning & contextual knowledge to assess security & privacy in design, deployment of VLSI and real-time sytems in sensitive applications.
PO5	Integrate and apply appropriate techniques, resources, and modern EDA tools for modeling and developing prototypes for VLSI and relevant real-world applications.
PO7	Work with professional context with intellectual integrity, ethics and social responsibility.
PO8	Communicate effectively and present technical information in oral and written reports supported by diagrams and models for easy visualization.
PO9	Review research literature and conduct independent research in VLSI and its related domains to develop advanced techniques, systems, and tools.
PO10	Recognize the need and engage in continuous lifelong learning to enhance the knowledge & skills in VLSI domain related real world applications.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	2	1	2	3		2	2	2	2	3	1	1
CO2	3	2	1	3	3		2	2	2	2	3	2	2
CO3	3	3		3	3		2	2	3	2	3	2	2
CO4	3	3		3	2		2	2	3	3	3	3	2
CO5	3	3		3	2		3	2	3	2	3	3	3

Category	Code	VLSI Design Using Verilog HDL Lab	L-T-P	Credits	Marks
PCR	EC5030		0-0-4	2	100

Objectives	The objective of this course is to provide hands-on exposure on the Verilog HDL techniques for design and analysis of digital circuits & systems.
Pre-Requisites	Knowledge of digital electronic circuits and basics of MOSFET is required.
Teaching Scheme	Regular laboratory experiments to be conducted under supervision of the faculty with focus on implementation in hardware / software tools.

Evaluation Scheme

Attendance	Daily Performance	Lab Record	Lab Test / Project	Viva-voce	Total
10	30	15	30	15	100

Detailed Syllabus

Experiment-#	Assignment/Experiment
1	Study and practice of basic Verilog programing styles, datatypes, syntax and its usage.
2	Design & verification of simple logic gates and its verification through test-bench.
3	Design & verification of combinational circuit using dataflow model.
4	Design & verification of combinational circuit using Behavioral model.
5	Design & verification of combinational circuit using Gate level model.
6	Design & verification of combinational circuit (Full Adder) using structural model.
7	Design & verification of combinational circuit (Full Subtractor) using structural model.
8	Design & verification of 4:1 Mux using vector.
9	Design & verification of combinational circuit using Mux.
10	Design & verification of combinational circuit using Decoder.
11	Design & verification of positive & negative level sensitive Latches.
12	Design & verification of positive & negative edge triggered Flip Flops.
13	Design & verification of JK-Flip Flop using other Flip Flops.
14, 15	Design and verification of asynchronous up & down counter using T-Flip Flop.
16	Design and verification of Mod-6 asynchronous counter using T-Flip Flop.
17, 18	Design and verification of synchronous up & down counter using T-Flip Flop.
19	Design and verification of Mod-5 synchronous counter using T-Flip Flop.
20	Design and verification of a skip counter which will count the sequence (0, 1, 3, 6, 7).
21, 22	Design and verification of Mealy based Finite State Machine.
23, 24	Design and verification of Moore based Finite State Machine.
25, 26	Design and verification of a sequence detector circuit to detect the sequence (1011) with overlapping permitted.
27, 28	Design and verification of a sequence detector circuit to detect the sequence (1011) with overlapping not permitted.

Text Books:

T1. S. Palnitkar, ***Verilog HDL: A guide to Digital Design and Synthesis***, 4th Edition, SunSoft Press, 1996.
T2. V. Taraate, ***Digital Logic Design Using Verilog***, 2nd Edition, Springer, 2016.

Reference Books:

R1. K. Mishra, ***Advanced Chip Design: Practical Examples in Verilog***, 1st Edition, Createspace Independent Publishers, 2013.
R2. C. H. Roth Jr., L. K. John, B. K. Lee, ***Digital Systems Design Using Verilog***, 2nd Edition, Cengage Learning, 2015.
R3. D. E. Thomas, P. R. Moorby, ***The Verilog Hardware Description Language***, 5th Edition, Kluwer Academic Publishers, 2002.

Online Resources:

1. https://nptel.ac.in/courses/117106086: by Prof. S. Srinivasan, IIT Madras
2. https://nptel.ac.in/courses/108103179: by Prof. S. R. Ahamed, IIT Guwahati
3. https://www.chipverify.com/verilog/verilog-tutorial
4. https://www.javatpoint.com/verilog
5. https://www.edaplayground.com/

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Use different EDA Tools for design, synthesis and verification of digital circuits.
CO2	Explain different abstraction levels of Verilog HDL.
CO3	Implement various combinational circuits and analyze their behavior.
CO4	Design different synchronous and asynchronous sequential circuits.
CO5	Construct and analyze different finite state machines.

Program Outcomes Relevant to the Course:

PO1	Apply knowledge of science, mathematics and domain competence for analyzing and designing VLSI systems for various real world applications.
PO2	Identify, formulate, and analyze engineering problems in VLSI & embedded systems and develop innovative and cost effective solutions.
PO3	Design efficient VLSI, embedded, and sensor based systems with considerations towards societal and environmental aspects.
PO4	Apply reasoning & contextual knowledge to assess security & privacy in design, deployment of VLSI and real-time sytems in sensitive applications.
PO5	Integrate and apply appropriate techniques, resources, and modern EDA tools for modeling and developing prototypes for VLSI and relevant real-world applications.
PO6	Function effectively as an individual or as a member of a multidisciplinary team with professional and managerial skills.
PO7	Work with professional context with intellectual integrity, ethics and social responsibility.
PO10	Recognize the need and engage in continuous lifelong learning to enhance the knowledge & skills in VLSI domain related real world applications.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	1	2	3	2						2		1
CO2	2	2	2	2	3						3		2
CO3	2	2	3	3	2	1					2	2	1
CO4	2	1	2	2	2	2	1			1	3	1	2
CO5	2	2	2	3	3	2	1			2	3	2	2

Category	Code	CMOS VLSI Design Lab	L-T-P	Credits	Marks
PCR	EC5031		0-0-4	2	100

Objectives	The objective of this laboratory course is to provide hands-on exposure on preparing schematic, layout, and simulation of complex digital systems.
Pre-Requisites	Fundamentals of MOSFET and digital electronics is required. The laboratory experiments shall go along with the topics taught in the theory class.
Teaching Scheme	Regular Laboratory classes with use of ICT as and when required. Practicals are planned to be interactive with focus on problem solving activities and real time applications with the help of software, FPGA and other peripherals.

Evaluation Scheme

Attendance	Daily Performance	Lab Record	Lab Test / Project	Viva-voce	Total
10	30	15	30	15	100

Detailed Syllabus

Experiment-#	Assignment/Experiment
1	Schematic design and layout of CMOS Inverter and its simulation.
2	Schematic design and layout of CMOS NAND gate and its simulation.
3, 4	Schematic design and layout of CMOS NOR gate and its simulation.
5, 6	Schematic design and layout of CMOS AND gate and its simulation.
7, 8	Schematic design and layout of CMOS OR gate and its simulation.
9, 10	Design & Simulation of CMOS Half Adder Circuit (Schematic and Layout).
11, 12	Design & Simulation of CMOS Full Adder Circuit (Schematic and Layout).
13, 14	Design & Simulation of CMOS Full Subtractor Circuit (Schematic and Layout).
15, 16	Design & Simulation of CMOS 2:1 Mux Circuit (Schematic and Layout.)
17, 18	Design & Simulation of CMOS 1:2 De-Mux Circuit (Schematic and Layout).
19, 20	Design & Simulation of CMOS Boolean Expressions (Schematic and Layout).
21, 22	Design & Simulation of CMOS Flip-Flops (Schematic and Layout).
23, 24	Schematic design, layout, and simulation of a CMOS Domino Logic Circuit.
25, 26	Schematic design, layout, and simulation of a NORA Logic Circuit.
27, 28	Schematic design and simulation of an ALU or a 4-bit Microprocessor with limited instructions.

Text Books:

T1. S. -M. Kang and Y. Leblebici, ***CMOS Digital Integrated Circuits - Analysis and Design***, 3rd Edition, McGraw-Hill Education, 2002.

T2. D. A. Hodges, H. G. Jackson, and R. Saleh, ***Analysis and Design of Digital Integrated Circuits in Deep Submicron Technology***, 3rd International Edition, McGraw Hill Education, 2005.

Reference Books:

R1. J. P. Rabaey, A. P. Chandrakasan, and B. Nikolić, ***Digital Integrated Circuits: A Design Perspective***, 2nd Edition, Pearson Education, 2016.

R2. N. H. E. Weste, D. Harris, and A. Banerjee, ***CMOS VLSI Design - A Circuits and Systems Perspective***, 4th Edition, Pearson Education, 2015.

R3. R. J. Baker, ***CMOS Circuit Design, Layout, and Simulation***, 3rd Edition, John Wiley & Sons, 2010.
R4. D. A. Pucknell and K. Eshraghian, ***Basic VLSI Design***, 3rd Edition, PHI Learning, 1995.

Online Resources:

1. http://vlsi-iitg.vlabs.ac.in/
2. http://cmosedu.com/
3. https://elearn.nptel.ac.in/shop/iit-workshops/completed/lab-workshop-vlsi-fundamentals/

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Explain the VLSI Design flow from specification to fabrication.
CO2	Design and implement the basic logic gates using CMOS technology.
CO3	Design, implement, and investigate digital combinational circuits using CMOS technology.
CO4	Design and implement digital sequential logic circuits using CMOS technology.
CO5	Implement digital circuits using dynamic logic.

Program Outcomes Relevant to the Course:

PO1	Apply knowledge of science, mathematics and domain competence for analyzing and designing VLSI systems for various real world applications.
PO2	Identify, formulate, and analyze engineering problems in VLSI & embedded systems and develop innovative and cost effective solutions.
PO3	Design efficient VLSI, embedded, and sensor based systems with considerations towards societal and environmental aspects.
PO4	Apply reasoning & contextual knowledge to assess security & privacy in design, deployment of VLSI and real-time sytems in sensitive applications.
PO5	Integrate and apply appropriate techniques, resources, and modern EDA tools for modeling and developing prototypes for VLSI and relevant real-world applications.
PO9	Review research literature and conduct independent research in VLSI and its related domains to develop advanced techniques, systems, and tools.
PO10	Recognize the need and engage in continuous lifelong learning to enhance the knowledge & skills in VLSI domain related real world applications.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	3	3	3	1				1	1	2	2	2
CO2	3	2	3	2	3				2	1	1	1	1
CO3	3	3	2	2	3				2	2	1	2	1
CO4	3	2	3	3	3				1	2	2	2	1
CO5	3	3	3	3	3				2	1	2	2	2

Category	Code	Analog VLSI Design	L-T-P	Credits	Marks
PCR	EC6011		3-0-0	3	100

Objectives	The objective of this course is to analyze and design various analog integrated circuits like Amplifiers, Op-Amp, Band Gap Reference & Current Mirrors and their applications.
Pre-Requisites	Knowledge of Analog Electronic Circuits and Circuit Theory is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with problem solving activities.

Evaluation Scheme

Attendance	Teacher's Assessment	Mid-Term	End-Term	Total
10	20	20	50	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	**Introduction to Analog Design**: General Concepts, Levels of Abstraction, Robust Analog Design; **Basic MOS Device Physics**: General Considerations, MOS I-V Characteristics, Second order effects, MOS Small Signal Model.	**8 Hours**
Module-2	**Single-Stage Amplifiers**: Basic Concepts, Common-Source Stage, Common-Source Stage with Resistive Load, CS Stage with Diode-Connected Load, CS Stage with Current-Source Load, CS Stage with Triode Load, CS Stage with Source Degeneration, Source Follower, Common-Gate Stage, Cascode Stage, Folded Cascode.	**8 Hours**
Module-3	**Differential Amplifiers**: Single-Ended and Differential Operation, Basic Differential Pair, Qualitative Analysis, Quantitative Analysis, Common-Mode Response, Differential Pair with MOS Loads, Gilbert Cell.	**9 Hours**
Module-4	**Passive and Active Current Mirrors**: Basic Current Mirrors, Cascode Current Mirrors, Active Current Mirrors, Large-Signal Analysis, Small-Signal Analysis, Common-Mode Properties; **Band Gap References**: General Considerations, Supply-Independent Biasing, Temperature-Independent References, Negative-TC Voltage, Positive-TC Voltage, Bandgap Reference.	**8 Hours**
Module-5	**Operational Amplifiers**: General Considerations, Performance Parameters, One-Stage Op Amps, Two-Stage Op Amps, Gain Boosting, Comparison, Common-Mode Feedback, Input Range Limitations, Slew Rate, Power Supply Rejection.	**9 Hours**
	Total	**42 Hours**

Text Books:

T1. B. Razavi, ***Design of Analog CMOS Integrated Circuits***, 1st Edition, McGraw-Hill Education, 2002.
T2. D. Holberg and P. Allen, ***CMOS Analog Circuit Design***, 3rd Edition, Oxford University Press, 2013.

Reference Books:

R1. P. Gray, P. Hurst, S. Lewis, and R. Meyer, ***Analysis and Design of Analog Integrated Circuits***, 4th Edition, John Wiley & Sons, 2001.
R2. B. Razavi, ***Fundamentals of Microelectronics***, 1st Edition, John Wiley & Sons, 2008.

R3. T. C. Carusone, D. A. Johns, and K. A. Martin, ***Analog Integrated Circuit Design***, 2nd Edition, Wiley India, 2012.
R4. K. R. Laker and W. M. C. Sansen, ***Design of Analog Integrated Circuits and Systems***, McGraw-Hill Education, 1994.

Online Resources:

1. https://nptel.ac.in/courses/117101105/: by Prof. A. N. Chandorkar, IIT Bombay
2. https://nptel.ac.in/courses/117106030/: by Dr. N. Krishnapura, IIT Madras
3. https://nptel.ac.in/courses/108106105/: by Prof. S. Aniruddhan, IIT Madras
4. https://nptel.ac.in/courses/108106068/: by Prof. K. R. Rao, IIT Madras
5. https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-002-circuits-and-electronics-spring-2007/

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Analyze and design single-stage amplifiers for various applications.
CO2	Demonstrate the performance parameters and design single-stage amplifiers as per needs.
CO3	Design and analyze passive and active current mirrors circuits.
CO4	Analyze and design band-gap reference circuits.
CO5	Design Op-Amps to meet different performance metrics for various applications.

Program Outcomes Relevant to the Course:

PO1	Apply knowledge of science, mathematics and domain competence for analyzing and designing VLSI systems for various real world applications.
PO2	Identify, formulate, and analyze engineering problems in VLSI & embedded systems and develop innovative and cost effective solutions.
PO3	Design efficient VLSI, embedded, and sensor based systems with considerations towards societal and environmental aspects.
PO4	Apply reasoning & contextual knowledge to assess security & privacy in design, deployment of VLSI and real-time sytems in sensitive applications.
PO5	Integrate and apply appropriate techniques, resources, and modern EDA tools for modeling and developing prototypes for VLSI and relevant real-world applications.
PO6	Function effectively as an individual or as a member of a multidisciplinary team with professional and managerial skills.
PO7	Work with professional context with intellectual integrity, ethics and social responsibility.
PO9	Review research literature and conduct independent research in VLSI and its related domains to develop advanced techniques, systems, and tools.
PO10	Recognize the need and engage in continuous lifelong learning to enhance the knowledge & skills in VLSI domain related real world applications.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	2	3	3		1					1	1		
CO2	3	3	1	1	2	1				1	1		
CO3	2	2	3	1		1	1				2	1	1
CO4	2	3	3	2		1			1		2	1	1
CO5	2	3	3	2		1	1		1		2	1	1

Category	Code	IC Fabrication Technology	L-T-P	Credits	Marks
PCR	EC6001		3-0-0	3	100

Objectives	The objective of this course is to learn the fabrication flow and IC integration process of semiconductor devices & semiconductor ICs.
Pre-Requisites	Basic knowledge on semiconductor devices such as NMOS, PMOS, CMOS, BJT etc. and digital VLSI design are desired.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with problem solving activities.

Evaluation Scheme

Attendance	Teacher's Assessment	Mid-Term	End-Term	Total
10	20	20	50	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	**Introduction**: Moore's Law and material processing, Defects in crystals, Eutectic phase diagram, Solid solubility, Homogeneous nucleation, Heterogeneous Nucleation; **Growth Processes**: Crystal Growth – Necking and dislocation free CZ crystal growth, Segregation of impurities along length and diameter, Defects in CZ crystals, FZ Crystal growth; **Epitaxy**: Vapor phase epitaxy, LPE, MBE, CVD deposition of Polysilicon, SILOX Process	**9 Hours**
Module-2	**Diffusion**: Constant & limited source diffusion, Concentration dependent diffusion, Field assisted diffusion, Junction depth, Open tube and closed tube diffusion, Diffusion sources. **Ion Implantation**: Basic process, Ion Implantation Systems, Ion penetration and profile, Ion Implantation Damage.	**8 Hours**
Module-3	**Annealing Oxidation**: Purpose, Dry and wet oxidation, Deal-Grove model, Oxidation system, Properties of oxides – Masking and charges in oxides; **Deposition Processes**: Fundamentals of vacuum systems, Vacuum evaporation of thin films, DC and RF Sputtering of thin films, Interconnects, Contacts and dielectrics in IC Fabrication, Deposition of Silicon Nitride, Silicides and insulating layers.	**9 Hours**
Module-4	**Lithography**: Pattern generation and mask making, Optical Lithography – Contact, Proximity and Projection Printing, Photoresists – Negative, Positive, Lift-off process, Electron beam and X-ray lithographic techniques; **Etching**: Wet Etching, Isotropic and Anisotropic Etching, Plasma Etching, Reactive Ion Beam Etching.	**8 Hours**
Module-5	**IC Process Integration**: Bipolar Transistor Fabrication, Isolation techniques, P-MOS, N-MOS and C-MOS processes, IC Fabrication Process Integration, IC Process Yield and Reliability.	**8 Hours**
	Total	**42 Hours**

Text Books:

T1. S. M. Sze, ***VLSI Technology***, 2nd Edition, Tata McGraw Hill, 2003.
T2. S. K. Gandhi, ***VLSI Fabrication Principles: Silicon and Gallium Arsenide***, 2nd Edition, Wiley India,

1994.

Reference Books:

R1. J. Plummer, M. Deal, and P. Griffin, ***Silicon VLSI Technology: Fundamentals, Practice, and Modeling***, Prentice Hall, 2000.
R2. M. J. Madou, ***Fundamentals of Micro Fabrication: The Science of Miniaturization***, 2nd Edition, CRC Press, 2002.
R3. S. Mahajan, ***Principles of Growth and Processing of Semiconductors***, McGraw-Hill Education, 1999.
R4. S. A. Campbell, ***The Science & Engineering of Microelectronics Fabrication***, 2nd Edition, Oxford University Press, 2001.

Online Resources:

1. https://nptel.ac.in/courses/108101089/: by Prof. A. N. Chandorkar, IIT Bombay
2. https://nptel.ac.in/courses/113106062/: by Prof. P. Swaminathan, IIT Madras
3. https://nptel.ac.in/courses/103106075/: by Dr. S. Ramanathan, IIT Madras
4. https://ocw.mit.edu/courses/6-780-semiconductor-manufacturing-spring-2003/
5. https://nptel.ac.in/courses/117/106/117106093/: by Dr. N. Dasgupta, IIT Madras

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Explain basic concepts IC fabrication like crystal growth and epitaxy.
CO2	Describe the diffusion and ion implantation process for IC fabrication.
CO3	Explain annealing oxidation and other material deposition processes.
CO4	Analyze & articulate lithography process and various etching processes.
CO5	Analyze and explain IC fabrication process integration.

Program Outcomes Relevant to the Course:

PO1	Apply knowledge of science, mathematics and domain competence for analyzing and designing VLSI systems for various real world applications.
PO2	Identify, formulate, and analyze engineering problems in VLSI & embedded systems and develop innovative and cost effective solutions.
PO3	Design efficient VLSI, embedded, and sensor based systems with considerations towards societal and environmental aspects.
PO4	Apply reasoning & contextual knowledge to assess security & privacy in design, deployment of VLSI and real-time sytems in sensitive applications.
PO5	Integrate and apply appropriate techniques, resources, and modern EDA tools for modeling and developing prototypes for VLSI and relevant real-world applications.
PO10	Recognize the need and engage in continuous lifelong learning to enhance the knowledge & skills in VLSI domain related real world applications.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	1	2	1	1								1	1
CO2	2	2	2	2							1	1	1
CO3	2	2	1	2	2						2	2	3
CO4	1	3	3	2	2					1	3	3	3
CO5	2	3	3	3	2					1	3	3	3

Category	Code	Advanced Semiconductor Devices	L-T-P	Credits	Marks
PEL	EC6015		3-0-0	3	100

Objectives	The objective of this course is to study the characteristics of different semiconductor devices used in modern electronic equipment and explore the nanoscale CMOS structures and materials for application of the device in advanced technology nodes.
Pre-Requisites	Knowledge of physics of semiconductor devices is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with problem solving activities.

Evaluation Scheme

Attendance	Teacher's Assessment	Mid-Term	End-Term	Total
10	20	20	50	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	**MOSFET**: ITRS roadmap for semiconductors, Different groups of MOSFETs, Gate length scaling, Short channel effects, Scattering mechanisms, Hot carrier effect, Buried channel device, Gate oxide scaling and Gate leakage currents in MOSFETs.	**9 Hours**
Module-2	**Advanced Materials for MOSFETs**: High-K materials, Gate stack and Channel stack technology, Reverse short channel effect and HALO doping, FDSOI technology.	**9 Hours**
Module-3	**Heterostructure FETs**: Heterojunction MOSFETs, Strain engineering for higher mobility (Strained-Si/Strained-SiGe), Staggered heterojunction MOSFETs, Tunnel FETs.	**8 Hours**
Module-4	**Nanoscale Devices**: Multiple Gate MOS Structures – Double Gate MOSFET, FinFET, Surrounding Gate MOSFET, HEMTs – AlGaN/GaN HEMT structure and operation.	**8 Hours**
Module-5	**Applications of MOSFETs**: RF performance and linearity analysis of MOSFETs for high frequency applications, MOSFET application as bio sensor, optoelectronic devices (LEDs, LASERs, Photo diodes, Solar cells).	**8 Hours**
	Total	**42 Hours**

Text Books:

T1. D. A. Neamen, ***Semiconductor Physics and Devices***, 4th Ed., McGraw-Hill, 2012.
T2. S. M. Sze and K. N. Kwok, ***Physics of Semiconductor Devices***, 3rd Ed., John Wiley & Sons, 2006.

Reference Books:

R1. G. Streetman and S. K. Banerjee, ***Solid State Electronic Devices***, 7th Ed., Pearson, 2014.
R2. C. C. Hu, ***Modern Semiconductor Devices for Integrated Circuits***, 1st Ed., Pearson, 2010.
R3. R. S. Muller, T. I. Kamins, and M. Chan, ***Device Electronics for Integrated Circuits***, 3rd Edition, John Wiley & Sons, 2003.
R4. C. K. Maiti, S. Chattopadhyay, and L. K. Bera, ***Strained-Si Heterostructure Field Effect Devices***, 1st Edition, CRC Press, Taylor & Francis Group, 2007.

Online Resources:

1. https://nptel.ac.in/courses/108108122: by Prof. Prof. D. N. Nath, IISc Bangalore
2. https://nptel.ac.in/courses/117108047: by Dr. N. Bhat, et al., IISc Bangalore
3. https://www.digimat.in/nptel/courses/video/108107129/L01.html
4. https://www.digimat.in/nptel/courses/video/117107149/L42.html
5. http://www.digimat.in/nptel/courses/video/117108047/L17.html
6. https://www.sciencedirect.com/topics/engineering/optoelectronic-device
7. Selected papers from various scientific journals.

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Illustrate the limitations of downscaling the size of MOS transistor.
CO2	Explore the use of advanced materials in the MOS structure and their benefits.
CO3	Describe the advantages of Heterojunction MOSFET structures.
CO4	Summarize the advantages of nanoscale MOS structures and HEMTs.
CO5	Explain the applications of MOSFETs in different domains.

Program Outcomes Relevant to the Course:

PO1	Apply knowledge of science, mathematics and domain competence for analyzing and designing VLSI systems for various real world applications.
PO2	Identify, formulate, and analyze engineering problems in VLSI & embedded systems and develop innovative and cost effective solutions.
PO3	Design efficient VLSI, embedded, and sensor based systems with considerations towards societal and environmental aspects.
PO4	Apply reasoning & contextual knowledge to assess security & privacy in design, deployment of VLSI and real-time sytems in sensitive applications.
PO5	Integrate and apply appropriate techniques, resources, and modern EDA tools for modeling and developing prototypes for VLSI and relevant real-world applications.
PO9	Review research literature and conduct independent research in VLSI and its related domains to develop advanced techniques, systems, and tools.
PO10	Recognize the need and engage in continuous lifelong learning to enhance the knowledge & skills in VLSI domain related real world applications.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	1	2	2	2	1				1	1	2		2
CO2	3	3	2	2	2				1	2	2	1	2
CO3	3	1	3	1	1				1	1	1	1	1
CO4	3	3	3	2	2				2	2	2	2	2
CO5	3	3	3	2	2				3	2	2	2	2

Category	Code	Embedded System Design	L-T-P	Credits	Marks
PEL	EC6016		3-0-0	3	100

Objectives	The objective of this course is to study the components, programming, integration, and life cycle management of hardware & firmware to design & develop embedded systems for real-world applications.
Pre-Requisites	Knowledge of microprocessor & microcontrollers, basic electronics, digital electronic circuits and operating systems is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with focus on problem solving activities.

Evaluation Scheme

Attendance	Teacher's Assessment	Mid-Term	End-Term	Total
10	20	20	50	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	**Introduction**: Definition of Embedded System, Embedded Systems Vs General Computing Systems, History of Embedded Systems, Classification, Major Application Areas, Purpose of Embedded Systems, Characteristics and Quality Attributes of Embedded Systems.	**8 Hours**
Module-2	**Typical Embedded Systems**: Core of the Embedded System: General Purpose and Domain Specific Processors, ASICs, PLDs, Memory: ROM, RAM, Memory according to the type of Interface, Memory Shadowing, Memory selection for Embedded Systems, Sensors and Actuators.	**8 Hours**
Module-3	**Embedded Firmware**: Reset Circuit, Brown-out Protection Circuit, Oscillator Unit, Real Time Clock, Watchdog Timer, Embedded Firmware Design Approaches and Development Languages.	**8 Hours**
Module-4	**RTOS based Design**: Operating system basics, Types of operating systems, Tasks, Processes and Threads, Multiprocessing and Multitasking, Task Scheduling, Task Communication, Task Synchronization, Choosing an RTOS.	**9 Hours**
Module-5	**Integration & Testing**: Integration of Hardware & Firmware, Board Power up; Embedded System Development Environment: Integrated Development Environment (IDE), Types of files generated on cross-compilation, Disassembler/Decompiler, Simulators, Emulators & Debugging, Target Hardware Debugging; Product Enclosure Design & Development: Tools, Development Techniques, Embedded Product Development Life Cycle (EDLC): Definition and Objectives of EDLC, Phases of EDLC, EDLC Approaches (Modeling the EDLC).	**9 Hours**
	Total	**42 Hours**

Text Books:

T1. K. V. Shibu, ***Introduction to Embedded Systems***, 1st Edition, Tata McGraw-Hill, 2009.
T2. R. Kamal, ***Embedded Systems – Architecture, Programming and Design***, 12th Edition, Tata McGraw-Hill, 2007.

Reference Books:

R1. D. E. Simon, ***An Embedded Software Primer***, 1st Edition, Addison Wesley, 1999.
R2. J. Ganssle, ***The Art of Designing Embedded Systems***, 2nd Edition, Elsevier, 2008.

R3. K. Short, ***Embedded Microprocessor System Design***, 1st Edition, Prentice Hall, 1998.
R4. C. Baron, J. Geffroy, and G. Motet (Eds), ***Embedded System Applications***, Springer, 1997.

Online Resources:

1. https://nptel.ac.in/courses/106105159/: by Prof. A. Basu, IIT Kharagpur
2. https://nptel.ac.in/courses/108102045/: by Prof. S. Chaudhary, IIT Delhi

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Describe the fundamental building blocks of a typical embedded system.
CO2	Explain the attributes of embedded systems and the co-design approach for embedded hardware and firmware development.
CO3	Apply design principles & development steps to design hardware for embedded systems.
CO4	Illustrate the operating system and internals of RTOS based embedded firmware design.
CO5	Assemble, manage, and test an embedded system's development life cycle (EDLC).

Program Outcomes Relevant to the Course:

PO1	Apply knowledge of science, mathematics and domain competence for analyzing and designing VLSI systems for various real world applications.
PO2	Identify, formulate, and analyze engineering problems in VLSI & embedded systems and develop innovative and cost effective solutions.
PO3	Design efficient VLSI, embedded, and sensor based systems with considerations towards societal and environmental aspects.
PO4	Apply reasoning & contextual knowledge to assess security & privacy in design, deployment of VLSI and real-time sytems in sensitive applications.
PO5	Integrate and apply appropriate techniques, resources, and modern EDA tools for modeling and developing prototypes for VLSI and relevant real-world applications.
PO6	Function effectively as an individual or as a member of a multidisciplinary team with professional and managerial skills.
PO7	Work with professional context with intellectual integrity, ethics and social responsibility.
PO10	Recognize the need and engage in continuous lifelong learning to enhance the knowledge & skills in VLSI domain related real world applications.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	1	1	1		1						1		2
CO2	3	2	3		1		2			1	2	1	2
CO3	1	2	1	1	1		1				1	1	2
CO4	2	1	1	1	2	1					1	1	2
CO5	2	3	3	1	2	1	1			2	3	1	2

Category	Code	Mobile Communication & Networks	L-T-P	Credits	Marks
PEL	EC6017		3-0-0	3	100

Objectives	The objectives of this course is to study the concepts of communication networks, wireless communication with its challenges & developments, wireless application protocols & standards, and Bluetooth technology.
Pre-Requisites	Basic knowledge of computer networking & wireless transmission is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with focus on examples and latest trends.

Evaluation Scheme

Attendance	Teacher's Assessment	Mid-Term	End-Term	Total
10	20	20	50	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	**Communication Networks**: LANs, MANs, WANs, Switching techniques, Wireless ATM networks, TCP/IP protocol architecture, OSI protocol architecture, Internetworking.	**8 Hours**
Module-2	**Wireless Communication Technology**: Propagation modes, LOS transmission, Fading in the mobile environment, Free-space Attenuation, Attenuation over Reflecting Surfaces, Radio wave Propagation, Propagation Path-loss Models, Cost 231 Model.	**8 Hours**
Module-3	**Cellular Wireless Networks**: Principles of cellular network, first, second and third Generation systems; Multiple Access Technologies: Basic features of FDMA, TDMA, and CDMA, Mobile IP and wireless Access Protocol: Mobile IP, Wireless Application Protocol, Internet control message protocol, Message authentication, Service primitives and parameters.	**9 Hours**
Module-4	**Wireless LAN Technology**: Overview, Infrared LANs, Spread spectrum LANs , Narrowband microwave LANs. IEEE 802.11 Wireless LAN: IEEE 802 protocol architecture, IEEE 802.11 architecture and services, IEEE 802.11 MAC, IEEE 802.11 physical layer.	**9 Hours**
Module-5	**Bluetooth**: Overview, Radio specification, baseband specification, Link manager specification, Logical Link control and adaptation protocol; Wi-MAX standards, Wi-Fi standards, Zig-bee.	**8 Hours**
	Total	**42 Hours**

Text Books:

T1. U. Dalal, ***Wireless Communication and Networks***, 1st Edition, Oxford University Press, 2015.
T2. I. S. Misra, ***Wireless Communication and Networks: 3G and Beyond***, 2nd Edition,McGraw-Hill Education, 2017.

Reference Books:

R1. V. K. Garg, ***Wireless Communication and Networking: Essential Reading***, Morgan Kaufman, 2008.
R2. T. S. Rappaport, ***Wireless Communications***, 2nd Edition, Pearson Education, 2010.
R3. D. Tse and P. Viswanath, ***Fundamentals of Wireless Communication***, Cambridge Univ. Press, 2005.

Online Resources:

1. https://nptel.ac.in/courses/106/105/106105082/: by Prof. A. Pal, IIT Kharagpur
2. https://nptel.ac.in/courses/106/108/106108098/: by Prof. H.S. Jamadagni, IISc Bangalore
3. https://nptel.ac.in/courses/106/105/106105081/: by Prof. S. Ghosh, IIT Kharagpur
4. https://nptel.ac.in/courses/106/105/106105183/: by Prof. S. Chakraborty and Prof. S. K. Ghosh, IIT Kharagpur

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Explain the fundamentals of mobile communication networks and various prototols.
CO2	Analyze radio propagation, fading, attenuation, channel modeling and other path losses.
CO3	Explain & compare various wireless application protocols & mobile IP implementations.
CO4	Explain the technical features of IEEE wireless LAN standard.
CO5	Describe the technical details of different IEEE wireless communication protocols.

Program Outcomes Relevant to the Course:

PO1	Apply knowledge of science, mathematics and domain competence for analyzing and designing VLSI systems for various real world applications.
PO2	Identify, formulate, and analyze engineering problems in VLSI & embedded systems and develop innovative and cost effective solutions.
PO3	Design efficient VLSI, embedded, and sensor based systems with considerations towards societal and environmental aspects.
PO4	Apply reasoning & contextual knowledge to assess security & privacy in design, deployment of VLSI and real-time sytems in sensitive applications.
PO5	Integrate and apply appropriate techniques, resources, and modern EDA tools for modeling and developing prototypes for VLSI and relevant real-world applications.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	2	3	3	3	2						2		
CO2	3	3	3	2	3						3		1
CO3	1	2	3	3	3						3		
CO4	1	2	2	3	3						2		1
CO5	2	3	3	3	3						3		

Category	Code	Mixed Signal CMOS Design	L-T-P	Credits	Marks
PEL	EC6018		3-0-0	3	100

Objectives	The objective of this course is to study the inter-conversion of analog & digital signals, design of systems involving mixed signals, and their practical application in various fields.
Pre-Requisites	Basic knowledge of signal processing, and analog & digital communication techniques is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with problem solving activities.

Evaluation Scheme

Attendance	Teacher's Assessment	Mid-Term	End-Term	Total
10	20	20	50	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	**Analog & Discrete-time Signal Processing**: Introduction to sampling theory; Time Domain Description of Reconstruction, The Sample-and Hold (S/H) Spectral Response, The Reconstruction Filter (RCF); Analog Continuous Time Filters: Passive and Active Filters; Basics of Analog Discrete-time Filters.	**8 Hours**
Module-2	**Switched-Capacitor Filters**: Non-idealities in switched-capacitor filters; Switched-capacitor filter architectures; Switched-capacitor filter applications.	**8 Hours**
Module-3	**Analog to Digital Converters**: Basics of data converters, Successive approximation ADCs, Dual slope ADCs, Flash ADCs, Pipeline ADCs, DACs.	**9 Hours**
Module-4	**Mixed-signal Layout**: Interconnects and data transmission; Voltage mode signaling and data transmission; Current-mode signaling and data transmission.	**9 Hours**
Module-5	**Frequency Synthesizers & Synchronization**: Basics of PLL, Analog PLLs; Digital PLLs; DLLs.	**8 Hours**
	Total	**42 Hours**

Text Books:

T1. R. J. Baker, ***CMOS Mixed-Signal Circuit Design***, Wiley India, IEEE Press, 2008.
T2. B. Razavi, ***Design of Analog CMOS Integrated Circuits***, 1st Edition, McGraw-Hill Education, 2002.

Reference Books:

R1. R. V. dePlassche, ***CMOS Integrated ADCs and DACs***, Indian Edition, Springer, 2005.
R2. A. B. Williams, ***Electronic Filter Design Handbook***, McGraw-Hill Education, 1981.
R3. R. Schaumann and M. E. V. Valkenburg, ***Design of Analog Filters***, Oxford University Press, 2008.

Online Resources:

1. https://nptel.ac.in/courses/117105143/
2. https://nptel.ac.in/content/storage2/nptel_data3/html/mhrd/ict/text/117105143/lec60.pdf
3. http://www.digimat.in/nptel/courses/video/117105143/L22.html
4. http://www.nptelvideos.in/2012/11/communication-engineering.html

P.T.O

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Apply various techniques for processing of analog and discrete-time signals.
CO2	Design switched-capacitor filters for various mixed-signal applications.
CO3	Convert analog signals to digital form and vice versa.
CO4	Analyze voltage & current mode signaling and data transmission in mixed-signal layout.
CO5	Design & differentiate between various types frequency synthesizers.

Program Outcomes Relevant to the Course:

PO1	Apply knowledge of science, mathematics and domain competence for analyzing and designing VLSI systems for various real world applications.
PO2	Identify, formulate, and analyze engineering problems in VLSI & embedded systems and develop innovative and cost effective solutions.
PO3	Design efficient VLSI, embedded, and sensor based systems with considerations towards societal and environmental aspects.
PO4	Apply reasoning & contextual knowledge to assess security & privacy in design, deployment of VLSI and real-time sytems in sensitive applications.
PO5	Integrate and apply appropriate techniques, resources, and modern EDA tools for modeling and developing prototypes for VLSI and relevant real-world applications.
PO6	Function effectively as an individual or as a member of a multidisciplinary team with professional and managerial skills.
PO10	Recognize the need and engage in continuous lifelong learning to enhance the knowledge & skills in VLSI domain related real world applications.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	1	1	1							1	1		
CO2	3	2	3	1	1	1							1
CO3	2	3	3	1	3					1	2	1	2
CO4	2	2	1	2	2	1					1	2	1
CO5	2	3	3	2	3	1					2	1	2

Category	Code	Internet of Things	L-T-P	Credits	Marks
PEL	EC6019		3-0-0	3	100

Objectives	The objective of the course is to study the design of Internet of Things (IoT), implementation, protocols, networking, and security elements, along with principles of IoT devices, data analytics, and case studies on various applications.
Pre-Requisites	Basic knowledge of computer networks, internet technology, basic electronics, analog electronics, digital electronics, and computer programming is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with problem solving activities.

Evaluation Scheme

Attendance	Teacher's Assessment	Mid-Term	End-Term	Total
10	20	20	50	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	**Introduction**: Introduction to IoT, Physical Design, Logical Design, Enabling Technologies, Levels & Deployments, M2M, Difference between IoT and M2M, IoT Design Methodology, NFV, IoT Systems Management, SNMP and its limitations, Network Operator Requirements, NETCONF, YANG.	**9 Hours**
Module-2	**Protocols and Domain Specific IoT**: Generic Web-Based Protocols: SOAP, REST, HTTP, RESTful, and WebSockets, IoT Application Layer Protocols: CoAP, MQTT, AMQP, REST and XMPP; Domain Specific IoT: Home Automation, Smart Cities, Environment, Retail, Logistics, Agriculture, Industry, Health & Lifestyle IoT in Energy Sectors, Virtual Sensors.	**7 Hours**
Module-3	**Sensors and Circuits**: Temperature Sensor (RTD, Thermistor, Thermocouple, IC type), Humidity sensor: Capacitive, Displacement sensor: LVDT, Acceleration sensor, Pressure sensor; S/C Circuits: ADC concept, Deflection bridge, amplifier, integrator, and differentiator.	**9 Hours**
Module-4	**Device Level Concepts**: Interoperability in IoT, Arduino Programming, Integration of Sensors and Actuators, Microcontrollers, Embedded C programming, Analog Interfacing, Serial, SPI, I2C, Ethernet-based data Communication; DHCP, Web Client, Telnet, MQTT; IoT using Raspberry Pi: Introduction, Raspberry Pi OS, IoT with Raspberry Pi, Raspberry Pi Interfaces: Serial, SPI, I2C.	**10 Hours**
Module-5	**Data Analytics for IoT**: Introduction, Apache Hadoop: MapReduce programming model, MapReduce job execution, job execution workflow, Hadoop cluster setup, YARN, Apache Oozie: setting of Oozie, Oozie workflow for IoT data analysis; Apache Spark, Apache Storm.	**7 Hours**
	Total	**42 Hours**

Text Books:

T1. A. Bahaga and V. Madisetti, ***Internet of Things: A Hands-on Approach***, 1st Edition, University Press, 2014.

T2. M. Schwartz, ***Internet of Things with Arduino Cookbook***, Packt Publishing, 2016.

T3. C. D. Johnson, ***Process Control Instrumentation Technology***, 8th Edition, Pearson Education, 2014.

Reference Books:

R1. R. Kamal, ***Internet of Things: Architecture and Design Principles***, 1st Edition, McGraw-Hill Education, 2017.
R2. A. K. Ghosh, ***Introduction to Measurement and Instrumentation***, 3rd Edition, PHI Learning, 2009.
R3. J. P. Bentley, ***Principles of Measurement Systems***, 4th Edition, Pearson Education, 2005.

Online Resources:

1. https://nptel.ac.in/courses/106105195/: by Prof. S. Misra, IIT Kharagpur.
2. https://nptel.ac.in/courses/108108098/: by Prof. T. V. Prabhakar, IISc Bangalore
3. https://nptel.ac.in/courses/106105166/: by Prof. S. Misra, IIT Kharagpur
4. https://nptel.ac.in/courses/108105064/: by Prof. A. Barua, IIT Kharagpur
5. https://nptel.ac.in/courses/106106182/: by Prof. S. Iyengar, IIT Madras
6. https://nptel.ac.in/courses/115104095/: by Prof. M. Verma, IIT Kanpur
7. https://nptel.ac.in/courses/106104189/: by Dr. R. Misra, IIT Patna

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Describe the basics of IoT technologies, design paradigms, and network management protocols.
CO2	Examine the domain-specific IoT and communication protocols.
CO3	Describe the principles of sensors, signal conditioning circuits, and their application to IoT.
CO4	Develop programs for IoT Applications using Arduino and Raspberry Pi.
CO5	Apply the concepts of data analytics in Internet of Things.

Program Outcomes Relevant to the Course:

PO1	Apply knowledge of science, mathematics and domain competence for analyzing and designing VLSI systems for various real world applications.
PO2	Identify, formulate, and analyze engineering problems in VLSI & embedded systems and develop innovative and cost effective solutions.
PO3	Design efficient VLSI, embedded, and sensor based systems with considerations towards societal and environmental aspects.
PO4	Apply reasoning & contextual knowledge to assess security & privacy in design, deployment of VLSI and real-time sytems in sensitive applications.
PO5	Integrate and apply appropriate techniques, resources, and modern EDA tools for modeling and developing prototypes for VLSI and relevant real-world applications.
PO9	Review research literature and conduct independent research in VLSI and its related domains to develop advanced techniques, systems, and tools.
PO10	Recognize the need and engage in continuous lifelong learning to enhance the knowledge & skills in VLSI domain related real world applications.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	2	3	2	2	1					2	2	2	
CO2	2	3	3	2	1					2	2	2	
CO3	2	3	3	3	2				2	3	3	3	
CO4	3	3	3	3	3				2	3	3	3	2
CO5	2	2	2	2	1				1	3	3	3	1

Category	Code	Machine Learning in VLSI	L-T-P	Credits	Marks
PEL	EC6020		3-0-0	3	100

Objectives	The objective of this course is to study various supervised and unsupervised algorithms to discover patterns in data and make predictions based on the patterns for solving business problems.
Pre-Requisites	Basic knowledge of Engineering Mathematics is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with problem solving activities.

Evaluation Scheme

Attendance	Teacher's Assessment	Mid-Term	End-Term	Total
10	20	20	50	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	**Supervised Learning**: Introduction to Regression Models Dimensionality and Structured Models, Model Selection and Bias-Variance Tradeoff, Simple Linear Regression, Hypothesis Testing and Confidence Intervals, Multiple Linear Regression, Introduction to Classification Problems, Logistic Regression, Multivariate Logistic Regression, Discriminant Analysis, Linear Discriminant Analysis.	**9 Hours**
Module-2	**Linear Model Selection & Regularization**: Introduction and Best-Subset Selection, Stepwise Selection, Backward stepwise selection Estimating test error, Validation and cross-validation (K-fold Cross-Validation), shrinkage methods: ridge regression and lasso regression, Tuning parameter selection, Dimension Reduction Methods.	**9 Hours**
Module-3	**Generative Model for Discrete Data**: Bayesian concept learning, Naive Bayes classifier, Tree-Based Methods: Tree-based methods, Classification trees, Bagging and Random forests, Boosting, Bayesian Additive Regression Trees.	**8 Hours**
Module-4	**Unsupervised Learning**: Clustering (K-means, spectral clustering), Feature Extraction (Principal Component Analysis (PCA), kernel based PCA, Independent Component Analysis (IDA), Non-negative matrix factorization), Mixture of Gaussians, Expectation Maximization (EM) algorithm.	**9 Hours**
Module-5	**Deep Learning**: Introduction to Neural Networks, Convolutional Neural Networks, Recurrent Neural Networks, Time-Series Forecasting, Fitting Neural Networks, Interpolation and Double Descent.	**7 Hours**
	Total	**42 Hours**

Text Books:

T1. T. Hastie, R. Tibshirani, and J. Friedman, ***The Elements of Statistical Learning: Data Mining, Inference and Prediction***, 2nd Edition, Springer Verlag, 2009.
T2. S. Haykin, ***Neural Networks and Learning Machines***, 3rd Edition, Pearson Education, 2008.

Reference Books:

R1. Y. G. James, D. Witten, T. Hastie, and R. Tibshirani, ***An Introduction to Statistical Learning with Applications in R***, 2nd Edition, Springer, 2013.
R2. C. M. Bishop, ***Pattern Recognition and Machine Learning***, 1st Edition, Springer, 2006.

Online Resources:

1. https://nptel.ac.in/courses/106106139/: by Dr. B. Ravindran, IIT Madras
2. https://nptel.ac.in/courses/106105152/: by Prof. S. Sarkar, IIT Kharagpur

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Apply supervised machine learning models to solve real life problems.
CO2	Analyze a problem and select the most suitable supervised learning models.
CO3	Apply classification techniques, regression and decision tree based models.
CO4	Extract important features from the given data set and apply clustering techniques.
CO5	Apply deep learning models to solve real world problems.

Program Outcomes Relevant to the Course:

PO1	Apply knowledge of science, mathematics and domain competence for analyzing and designing VLSI systems for various real world applications.
PO2	Identify, formulate, and analyze engineering problems in VLSI & embedded systems and develop innovative and cost effective solutions.
PO3	Design efficient VLSI, embedded, and sensor based systems with considerations towards societal and environmental aspects.
PO4	Apply reasoning & contextual knowledge to assess security & privacy in design, deployment of VLSI and real-time sytems in sensitive applications.
PO5	Integrate and apply appropriate techniques, resources, and modern EDA tools for modeling and developing prototypes for VLSI and relevant real-world applications.
PO10	Recognize the need and engage in continuous lifelong learning to enhance the knowledge & skills in VLSI domain related real world applications.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	2	3	3	3	2					1	2	2	2
CO2	2	3	3	3	3					1	2		2
CO3	3	3	2	2	3					1	2	1	2
CO4	2	3	3	3	3					1	2		2
CO5	2	3	3	3	3					1	3		1

Category	Code	Analog VLSI Design Lab	L-T-P	Credits	Marks
PCR	EC6013		0-0-2	1	100

Objectives	The objective of the course is to provide hands-on exposure on designing various analog VLSI circuits such as Amplifier, Current-Mirror, Bandgap Reference Circuit and OP-AMPs for different applications.
Pre-Requisites	Knowledge of circuit theory & analog electronic circuits taught in theory classes is required.
Teaching Scheme	Regular laboratory experiments to be conducted under supervision of the faculty with use of ICT as and when required, sessions are planned to be interactive with focus on implementation in hardware / software tools.

Evaluation Scheme

Attendance	Daily Performance	Lab Record	Lab Test / Project	Viva-voce	Total
10	30	15	30	15	100

Detailed Syllabus

Experiment-#	Assignment/Experiment
1	Design and study of NMOS Characteristics and extract its small signal parameters.
2	Design and study of PMOS Characteristics and extract its small signal parameters.
3	Design and study of single stage Common Source Amplifier and extract its small signal parameters and voltage gain.
4	Design and study of single stage Common Source Amplifier with source degeneration and extract its small signal parameters and voltage gain.
5	Design and study of Source follower Circuit.
6	Design and study of Cascode Amplifier.
7, 8	Design and study of different types of Current Mirror Circuits.
9	Design and study of simple Differential Amplifier.
10	Design and study of Cascode Differential Amplifier.
11	Design and study of Gilbert Cell.
12, 13	Design and study of Bandgap Reference Circuit.
14, 15	Design and study of two stage OpAMP circuit.

Text Books:

T1. B. Razavi, ***Design of Analog CMOS Integrated Circuits***, Indian Edition, McGraw-Hill Education, 2002.
T2. D. Holberg and P. Allen, ***CMOS Analog Circuit Design***, 3rd Edition, Oxford University Press, 2013.

Reference Books:

R1. P. R. Gray, P. J. Hurst, R. G. Meyer, and S. H. Lewis, ***Analysis and Design of Analog Integrated Circuits***, 5th Edition, John Wiley & Sons, 2009.
R2. B. Razavi, ***Fundamentals of Microelectronics***, 1st Edition, John Wiley & Sons, 2008.
R3. T. C. Carusone, D. A. Johns, and K. A. Martin, ***Analog Integrated Circuit Design***, 2nd Edition, Wiley India, 2012.
R4. K. R. Laker and W. M. C. Sansen, ***Design of Analog Integrated Circuits and Systems***, McGraw-Hill Education, 1994.

Online Resources:

1. https://nptel.ac.in/courses/117101105/: by Prof. A. N. Chandorkar, IIT Bombay
2. https://nptel.ac.in/courses/117106030/: by Dr. N. Krishnapura, IIT Madras
3. https://nptel.ac.in/courses/108106105/: by Prof. S. Aniruddhan, IIT Madras
4. https://nptel.ac.in/courses/108106068/: by Prof. K. R. Rao, IIT Madras
5. https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-002-circuits-and-electronics-spring-2007/

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Design and demonstrate the characteristics of different MOSFETs.
CO2	Analyze and design different single stage amplifiers.
CO3	Design and analyze of passive and active current mirrors circuits.
CO4	Design and demonstrate band-gap reference circuits.
CO5	Construct and simulate Operational Amplifiers to meet different performance metrics.

Program Outcomes Relevant to the Course:

PO1	Apply knowledge of science, mathematics and domain competence for analyzing and designing VLSI systems for various real world applications.
PO2	Identify, formulate, and analyze engineering problems in VLSI & embedded systems and develop innovative and cost effective solutions.
PO3	Design efficient VLSI, embedded, and sensor based systems with considerations towards societal and environmental aspects.
PO4	Apply reasoning & contextual knowledge to assess security & privacy in design, deployment of VLSI and real-time sytems in sensitive applications.
PO5	Integrate and apply appropriate techniques, resources, and modern EDA tools for modeling and developing prototypes for VLSI and relevant real-world applications.
PO6	Function effectively as an individual or as a member of a multidisciplinary team with professional and managerial skills.
PO7	Work with professional context with intellectual integrity, ethics and social responsibility.
PO9	Review research literature and conduct independent research in VLSI and its related domains to develop advanced techniques, systems, and tools.
PO10	Recognize the need and engage in continuous lifelong learning to enhance the knowledge & skills in VLSI domain related real world applications.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	2	2	3	3	1		1				1	1	1
CO2	3	1	2	3	2		2		2		2		1
CO3	3	1	2	2	1	1	1		1	1	1	1	2
CO4	2	2	3	2	1	2	1		2	1	2	2	2
CO5	3	1	3	3	1	1	1		2	1	2	1	1

Category	Code	Emerging Technologies Lab	L-T-P	Credits	Marks
SEC	EC6014		0-0-4	2	100

Objectives	The objective of this laboratory course is to provide practical exposure on latest technologies & tools of current demand in various electronics, VLSI, and IoT domains so as to make the students adapt to the fast changing technology world and make them adequately ready for the industry.
Pre-Requisites	Knowledge of all subjects and topics taught in the class is required.
Teaching Scheme	Regular laboratory experiments to be conducted under supervision of the faculty with use of ICT as and when required; sessions are planned to be interactive with focus on implementation in hardware/software tools.

Evaluation Scheme

Attendance	Daily Performance	Lab Record	Lab Test / Project	Viva-voce	Total
10	30	15	30	15	100

Detailed Syllabus

Experiment-#	Assignment/Experiment
1	Write a MATLAB program to generate the discrete sequences (i) unit step (ii) unit impulse (iii) ramp (iv) periodic sinusoidal sequences.
2	Generate a uniformly distributed length 1000 random sequence in the range (0,1). Plot the histogram and the probability function for the sequence. Compute the mean and variance of the random signal.
3	Generate a Gaussian (normal) distributed length 1000 random sequence. Compute the mean and variance of the random signal by a suitable method.
4	Write a program to find the trigonometric Fourier series coefficients of a rectangular periodic signal. Reconstruct the signal by combining the Fourier series coefficients with appropriate weightings.
5	Write a program to find the exponential Fourier series coefficients of a periodic square signal. Plot the discrete magnitude spectrum of the signal.
6	Find the Fourier transform of a square pulse. Plot its amplitude and phase spectrum.
7	Generate a discrete time sequence of N=1000 independent and identically distributed random variables uniformly distributed random numbers in the interval (-0.5,0.5) and compute the auto-correlation of the sequence.
8	Interface LED with ARM-7 and write program to flash LED.
9	Interface seven segment display with ARM-7.
10	Interface LCD with ARM-7 and display desired text.
11	Interface and control relay with ARM-7.
12, 13	Interface and control the speed of DC motor with ARM-7.
14	Interface and control stepper motor with ARM-7.
15, 16	Interface ADC with ARM-7 and convert analog signal to digital signal.
17, 18	Interface and use RFID module with ARM-7.
19, 20	Interface LED/Buzzer with Arduino/Raspberry Pi and write a program to turn ON LED for 1 sec after every 2 seconds.

Cont'd. . .

Experiment-#	Assignment/Experiment
21, 22	Interface Push button/Digital sensor (IR/LDR) with Arduino/Raspberry Pi and write a program to turn ON LED when push button is pressed or at sensor detection.
23, 24	Interface motor using relay with Arduino/Raspberry Pi and write a program to turn ON motor when push button is pressed.
25	Interface OLED with Arduino and write a program to print temperature and humidity readings on it.
26	Interface OLED with Raspberry Pi and write a program to print temperature and humidity readings on it.
27	Interface Bluetooth with Arduino and write a program to send sensor data to smartphone using Bluetooth.
28	Interface Bluetooth with Raspberry Pi and write a program to send sensor data to smartphone using Bluetooth.

Text Books:

T1. J. G. Proakis and D. G. Manolakis, ***Digital Signal Processing: Principles, Algorithm and Applications***, 4th Edition, Prentice Hall, 2007.
T2. K. V. Shibu, ***Introduction to Embedded Systems***, 1st Edition, Tata McGraw-Hill, 2009.
T3. R. Kamal, ***Embedded Systems: Architecture, Programming and Design***, 3rd Edition, Tata McGraw-Hill, 2017.

Reference Books:

R1. R. Pratap, ***Getting Started with MATLAB: A Quick Introduction for Scientists & Engineers***, South Asia Edition, Oxford University Press, 2010.
R2. D. E. Simon, ***An Embedded Software Primer***, Addison Wesley, 1999.
R3. M. Schwartz, ***Internet of Things with Arduino Cook book***, Packt Publishing, 2016.

Online Resources:

1. https://nptel.ac.in/courses/108107115/: by Prof. Y. V. Hote, IIT Roorkee
2. https://nptel.ac.in/courses/103106118/: by Prof. N. Kaisare, IIT Madras
3. https://nptel.ac.in/courses/106105159/: By Prof A. Basu, IIT Kharagpur
4. https://nptel.ac.in/courses/106105195/: By Prof. S. Misra, IIT Kharagpur.
5. https://nptel.ac.in/courses/108108098/: By Prof. T. V. Prabhakar, IISc Bangalore
6. https://nptel.ac.in/courses/108105064/: By Prof. A. Barua, IIT Kharagpur

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Explain and generate different types of signals using MATLAB.
CO2	Implement continuous & discrete systems in time & frequency domains using different transforms through MATLAB.
CO3	Realize & conceive different applications using the ARM-7 processor.
CO4	Develop expertise on designing systems with Arduino/Raspberry Pi.
CO5	Explore & use Arduino/Raspberry Pi for different real world applications.

Program Outcomes Relevant to the Course:

PO1	Apply knowledge of science, mathematics and domain competence for analyzing and designing VLSI systems for various real world applications.
PO2	Identify, formulate, and analyze engineering problems in VLSI & embedded systems and develop innovative and cost effective solutions.

Cont'd. . .

PO3	Design efficient VLSI, embedded, and sensor based systems with considerations towards societal and environmental aspects.
PO4	Apply reasoning & contextual knowledge to assess security & privacy in design, deployment of VLSI and real-time sytems in sensitive applications.
PO5	Integrate and apply appropriate techniques, resources, and modern EDA tools for modeling and developing prototypes for VLSI and relevant real-world applications.
PO7	Work with professional context with intellectual integrity, ethics and social responsibility.
PO10	Recognize the need and engage in continuous lifelong learning to enhance the knowledge & skills in VLSI domain related real world applications.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	1	1								1	2		2
CO2	2	2	3	2	3					1	3		2
CO3	2		2	2	2		1			1	2	2	3
CO4	3	2	2	3	3		1			1	2	3	2
CO5	3		3	2	3		1			2	3	3	3

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