Silicon University

Curriculum Structure & Detailed Syllabus

Master of Technology
in
Electronics & Communication Engineering

(Two-Year Post-Graduate Program)

Silicon University, Odisha

Silicon Hills, Patia, Bhubaneswar - 751024

https://silicon.ac.in

Effective From Academic Year 2024-25

Version: 1.0.0 (Last Updated: 09-12-2025)

This document has been typeset using LaTeX2ε

Approval History

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

Program Outcomes

Program Outcomes (POs) form a set of individually assessable outcomes that are the components indicative of the post-graduate's potential to acquire competence to practice at the appropriate level.

PO1. Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.

PO2. Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.

PO3. Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.

PO4. Understand and use different software tools for design, analysis and verification in the domain of communication, VLSI and signal processing through design, synthesis, functional, and timing simulation.

PO5. Design and conduct experiments, analyze and interpret data, utilize programming skills for development of simulation experiments.

PO6. Function effectively as an individual or as a member of a multidisciplinary team with sense of ethics, integrity and social responsibility.

PO7. Understand the impact of electronics & communications in an economic, social and environment context.

PO8. Understand intellectual property rights and overall professional & ethical responsibility.

PO9. Communicate effectively in a technically sound manner with a wide range of audience.

PO10. Continue to learn independently and engage in life-long learning.

Program Specific Outcomes (PSOs)

PSO1. Apply concepts of Electronics & Communication Engineering to design and implement complex systems.

PSO2. Develop hardware, software, or embedded solutions & tools for solving real life problems in electronics and communication domains using acquired knowledge of science, mathematics, and engineering.

PSO3. Engage as an electronics and communication engineering specialist in industry, higher studies, research & development, academics, or as an entrepreneur.

Program Educational Objectives (PEOs)

PEO1. To imbibe technical skills to create, find solutions, and propose improvements for complex problems encountered in Electronics & Communication Engineering for betterment of society, mankind, and environment.

PEO2. To inculcate an attitude to adopt changing technologies in Electronics & Communication Engineering through critical observation, survey, experimentation, and research independently or collaboratively.

PEO3. To provide professional & intellectual integrity, motivation to engage in research & development, and communicate innovative ideas effectively for advancement of society.

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

Contents

I Curriculum Structure 1
- **Semester I** 2
- **Semester II** 2
- **Semester III** 3
- **Semester IV** 3
- **List of Electives** 4

II Detailed Syllabus 5

1st Year M.Tech.(ECE) 6
- **Semester I** 6
  - ***Theory*** 6
    - Mathematics for Communication Engineering 6
    - Soft Computing Techniques 8
    - Advanced Semiconductor Devices 10
    - Modern Communication Systems 12
    - IoT & Embedded Systems Design 14
    - Research Methodology & IPR 16
  - ***Practical*** 17
    - Advanced Semiconductor Devices Lab 18
    - IoT & Embedded Systems Design Lab 20
    - Modern Communication Systems Lab 22
- **Semester II** 23
  - ***Theory*** 23
    - Digital IC Design & Verification using HDL 24
    - Advanced Digital Signal Processing 26
    - Machine Learning & Applications 28
    - Digital Integrated Circuit Design 30
    - Smart Sensors for IoT Applications 33
    - Information Theory & Coding 35
    - Low Power Digital VLSI Design 37
    - MEMS & Sensor Based Design 39
    - Adaptive Signal Processing 41
    - English for Research Paper Writing 43
  - ***Practical*** 44
    - VLSI System Design & Verification Lab 45
    - Emerging Technologies Lab 47
    - Pre-Thesis Literature Survey 49

2nd Year M.Tech.(ECE) 51
- **Semester III** 51
  - ***Theory*** 51
    - IC Fabrication Technology 51
    - Embedded C Applications 53
    - Image Processing & Computer Vision 55
    - Analog & Mixed Signal Design 57
    - Industrial IoT 59

Fiber Optic Communication 61
Advanced Microprocessors & Microcontrollers 63
IC Design Testing 65
Advanced Mobile Communication 67

Part I

Curriculum Structure

Curriculum Structure

Semester I									
Category	**Code**	**Course Title**	**WCH** L-T-P			**Credits** L-T-P		
THEORY									
PCR	MT5006	Mathematics for Communication Engineering	3	1	0	3	1	0
PCR	EC5001	Soft Computing Techniques	3	0	0	3	0	0
PCR	EC5002	Advanced Semiconductor Devices	3	0	0	3	0	0
PCR	EC5003	Modern Communication Systems	3	0	0	3	0	0
PCR	EC5004	IoT & Embedded Systems Design	3	1	0	3	1	0
UCR	RS7001	Research Methodology & IPR	2	0	0	2	0	0
PRACTICAL									
PCR	EC5005	Advanced Semiconductor Devices Lab	0	0	2	0	0	1
PCR	EC5006	IoT & Embedded Systems Design Lab	0	0	4	0	0	2
PCR	EC5007	Modern Communication Systems Lab	0	0	2	0	0	1
		SUB-TOTAL	**17**	**2**	**8**	**17**	**2**	**4**
		TOTAL	**27**			**23**		

Semester II									
Category	**Code**	**Course Title**	**WCH** L-T-P			**Credits** L-T-P		
THEORY									
PCR	EC5008	Digital IC Design & Verification using HDL	3	1	0	3	1	0
PCR	EC5009	Advanced Digital Signal Processing	3	1	0	3	1	0
PCR	EC5010	Machine Learning & Applications	3	0	0	3	0	0
PEL		Program Elective - I	3	0	0	3	0	0
PEL		Program Elective - II	3	0	0	3	0	0
UCR	HS5004	English for Research Paper Writing	2	0	0	2	0	0
PRACTICAL									
PCR	EC5011	VLSI System Design & Verification Lab	0	0	4	0	0	2
PCR	EC5012	Emerging Technologies Lab	0	0	4	0	0	2
UCR	RS7002	Pre-Thesis Literature Survey	0	0	2	0	0	1
		SUB-TOTAL	**17**	**2**	**10**	**17**	**2**	**5**
		TOTAL	**29**			**24**		

P.T.O

Semester III								
Category	**Code**	**Course Title**	**WCH** L-T-P			**Credits** L-T-P		
THEORY								
PEL		Program Elective-III	3	0	0	3	0	0
PEL		Program Elective-IV	3	0	0	3	0	0
PEL		Program Elective-V	3	0	0	3	0	0
OOC	EC6010	MOOC	0	0	0	3	0	0
PRACTICAL								
PCR	RS7003	Thesis (Part - I) & Seminar	0	0	12	0	0	6
INT	IP4001	Summer Internship	0	0	0	0	0	1
		SUB-TOTAL	**9**	**0**	**12**	**12**	**0**	**7**
		TOTAL	**21**			**19**		

Semester IV								
Category	**Code**	**Course Title**	**WCH** L-T-P			**Credits** L-T-P		
PRACTICAL								
PCR	RS7004	Thesis (Part - II) & Seminar	0	0	28	0	0	14
VAC	VA0001	Yoga / NCC / NSS	0	0	2	0	0	0
		SUB-TOTAL	**0**	**0**	**30**	**0**	**0**	**14**
		TOTAL	**30**			**14**		

		GRAND TOTAL (4 SEMESTERS)	**107**			**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 3rd semester.
4. 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 - I
EC5013	Digital Integrated Circuit Design
EC5014	Smart Sensors for IoT Applications
EC5015	Information Theory & Coding
	Program Elective - II
EC5016	Low-Power Digital VLSI Design
EC5017	MEMS & Sensor Based Design
EC5018	Adaptive Signal Processing
	Program Elective - III
EC6001	IC Fabrication Technology
EC5037	Embedded C Applications
EC6003	Digital Video Processing & Computer Vision
	Program Elective-IV
EC6004	Analog & Mixed Signal Design
EC6005	Industrial IoT
EC6006	Fiber Optic Communication
	Program Elective-V
EC6007	Advanced Microprocessors & Microcontrollers
EC6008	IC Design Testing
EC6009	Advanced Mobile Communication

Part II

Detailed Syllabus

Category	Code	Mathematics for Communication Engineering	L-T-P	Credits	Marks
PCR	MT5006		3-1-0	4	100

Objectives	The objective of this course is to learn Linear Algebra, Probability theory and other mathematics components which are required to formulate electronics and communication engineering problems.
Pre-Requisites	Knowledge of set theory, matrix algebra, integration, differentiation, and Calculus of several variables 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	Vector Spaces, subspaces, linear independence, basis, dimension, linear transformation, perpendicular vectors and orthogonal subspaces, inner product and projection, least square approximation, orthogonal basis.	**9 Hours**
Module-2	Eigen values and Eigen vector, Diagonalisation, complex vectors and matrices, Singular value decomposition, pseudo inverse of a matrix.	**9 Hours**
Module-3	Joint Distribution of Random variables, Independent Random variables, Covariance and correlation coefficient, Expected value of a Random vector and variance-covariance matrix, Conditional Distribution, Conditional Expectation given a σ Algebra, Multivariate Normal Distribution, The weak and strong law of Large numbers, Central limit Theorem.	**11 Hours**
Module-4	Definitions and properties of stochastic process, Discrete-time Markov chain, Continuous-time Markov chain, Poisson process.	**10 Hours**
Module-5	Optimization Techniques: Calculus of several variables, Implicit function theorem, Nature of singular points, Necessary and sufficient conditions for optimization, Constrained Optimization, Lagrange multipliers, Gradient method - steepest descent method.	**8 Hours**
Module-6	Constrained Optimization: Frank Wolfe's Method, Rosen's Gradient Projection method, Penalty function method, Barrier function method.	**9 Hours**
	Total	**56 Hours**

Text Books:

T1. G. Strang, ***Linear Algebra and Applications***, 4th *Ed.*, Cengage Learning, 2005.

T2. L. B. Castaneda, V. Arunachalam, and S. Dharmaraja, ***Introduction to Probability and Stochastic Processes with Applications***, 1st *Ed.*, Wiley, 2012.

T3. S. S. Rao, ***Optimization: Theory and Application***, 2nd *Ed.*, Wiley Eastern Ltd., 1984.

T4. S. Chandra, Jayadeva, and A. Mehera, ***Numerical Optimization with Applications***, 1st *Ed.*, Narosa Publishing House, 2013.

P.T.O

Reference Books:

R1. K. E. Atkinson, ***An Introduction to Numerical Analysis***, John Wiely & Sons, 1989.
R2. S. S. Rao, ***Engineering Optimization: Theory and Practice***, Wiley-Interscience Publication, 1996.

Online Resources:

1. https://nptel.ac.in/courses/111/107/111107106/: by Prof. P. N. Agrawal, IIT Roorkee
2. https://nptel.ac.in/courses/111104137/: by Prof. A. K. Lal, IIT Kanpur
3. https://nptel.ac.in/courses/111/102/111102134/: by Prof. N. Chatterjee, IIT Delhi
4. https://nptel.ac.in/courses/111107104/: by Prof. S. K. Gupta, IIT Roorkee
5. http://www.math.iitb.ac.in/~baskar/book.pdf
6. http://www2.math.umd.edu/~dlevy/books/na.pdf
7. http://www.sam.math.ethz.ch/~hiptmair/tmp/NumCSE/NumCSE15.pdf

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

CO1	Apply the concepts of least square approximation to engineering problems.
CO2	Use Eigen values and eigenvectors of a matrix to factorize it.
CO3	Apply the concepts of probability to signal processing.
CO4	Apply the concepts of Stochastic Process to signals.
CO5	Optimize and solve real life problems in communication engineering.
CO6	Solve constrained optimization problems in communication engineering.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO4	Understand and use different software tools for design, analysis and verification in the domain of communication, VLSI and signal processing through design, synthesis, functional, and timing simulation.
PO10	Continue to learn independently and engage in life-long learning.

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	2						2	1	1	3
CO2	3	3	3	2						3	1	1	3
CO3	3	3	3	2						2	1	1	3
CO4	3	3	3	3						3	2	1	3
CO5	3	3	2	2						2	2	1	1
CO6	3	3	2	2						2	2	1	1

Category	Code	Soft Computing Techniques	L-T-P	Credits	Marks
PCR	EC5001		3-0-0	3	100

Objectives	The objective of this course is to study the concepts of various soft computing techniques like fuzzy logic, neural networks etc., along with optimization & evolutionary computation, and their applications in communication engineering.
Pre-Requisites	Knowledge of engineering mathematics and basics of programming is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required; sessions are planned to be interactive with focus on theory and 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	Basic Tools of Soft Computing: Evolution of Computing - Soft Computing constituents, Neural Network Artificial Neuron and its model, activation functions, Neural network architecture: single layer and multilayer feed forward networks, recurrent networks.	**10 Hours**
Module-2	Fuzzy Logic: Basic concepts of fuzzy logic, Fuzzy sets and Crisp sets, membership functions, Fuzzy set theory and operations, Extension principle of fuzzy set, fuzzy inference, Fuzzy implications, fuzzy relation, fuzzy reasoning, fuzzy c-means clustering , Defuzzification techniques.	**8 Hours**
Module-3	Artificial Neural Networks: Early neural network architectures - Rosenblatt's Perceptron, ADALINE network, MADALINE network, Examples & applications of neural networks; Unsupervised Learning Neural Networks: Hopfield neural network, Competitive learning, Self-organizing feature map, Reinforcement learning: Q-learning, Temporal difference learning.	**7 Hours**
Module-4	Training of ANN: Generalized delta rule, Hebbian rule; 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 neurofuzzy inference systems (ANFIS).	**9 Hours**
Module-5	Evolutionary Computing: Fundamentals of genetic algorithms, Encoding, Fitness functions, Reproduction Genetic Modeling: Cross cover, Inversion and deletion, Mutation operator, Bit-wise operators, Bitwise operators used in GA. Convergence of Genetic algorithm. GA as an alternative to back propagation, Applications of GA in navigational planning of robots, Particle swarm optimization, ant-colony optimization, Bee colony optimization.	**8 Hours**
	Total	**42 Hours**

Text Books:

T1. J. S. R. Jang, C. T. Sun, and E. Mizutani, ***Neuro-Fuzzy & Soft Computing - A Computational Approach to Learning and Machine Intelligence***, 1st *Ed.*, PHI Learning, 2015.

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

Reference Books:

R1. F. O. Karry and C. De Silva, ***Soft Computing and Intelligent Systems Design - Theory, Tools and Applications***, 1st *Ed.*, Pearson Education, 2009.
R2. S. Haykin, ***Neural Networks : A Comprehensive Foundation***, —edn2, Pearson Education, 1997.

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	Explain the basics of soft computing techniques and their applicability.
CO2	Describe fuzzy principles & inference and defuzzification methods.
CO3	Apply different types of neural networks algorithms for engineering problems.
CO4	Analyze effectiveness of neural networks for solving complex engineering problems.
CO5	Use evolutionary computation with optimization algorithms in real world applications.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO4	Understand and use different software tools for design, analysis and verification in the domain of communication, VLSI and signal processing through design, synthesis, functional, and timing simulation.
PO5	Design and conduct experiments, analyze and interpret data, utilize programming skills for development of simulation experiments.

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	2	1	1						3	2	2
CO2	3	2	2	2	2						3	2	2
CO3	2	3	3	3	2						3	2	1
CO4	2	3	3	3	2						3	3	3
CO5	2	2	3	2	3						2	3	2

Category	Code	Advanced Semiconductor Devices	L-T-P	Credits	Marks
PCR	EC5002		3-0-0	3	100

Objectives	The objective of this course is to study the characteristics of different advanced semiconductor devices including MOSFETs and advanced CMOS technologies used in modern electronics equipment.
Pre-Requisites	Basics of 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 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: Review of quantum mechanics, Electrons in periodic lattices, E-K diagrams, Energy bands in solids; Electrons and Holes in Semiconductors: Silicon crystal structure, Donors and acceptors in the band model, 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.	**10 Hours**
Module-2	PN Junction Diode: P-N junction characteristics; Building blocks of the pn junction theory, Energy band diagram and depletion layer of a pn junction, Built-in potential, Carrier injection under forward bias-Quasi-equilibrium boundary condition; Current continuity equation, I-V characteristics, Reverse biased P-N junction: Avalanche breakdown, Zener diode.	**8 Hours**
Module-3	MOS Capacitor and MOSFET: The MOS structure, Energy band diagrams, Surface accumulation, Surface depletion, Flat-band condition and flat-band voltage, Threshold condition and threshold voltage, C-V characteristics of ideal MOS capacitor, Basic structure of MOSFET, Threshold Voltage of MOSFET, Inversion charge and I-V Characteristics	**8 Hours**
Module-4	Scaling and Short Channel Effects: ITRS roadmap for semiconductor, different groups of MOSFETs, Three MOS types, low leakage MOSFETs, Gate-Oxide Scaling, GIDL and Gate tunnel currents, Gate length scaling, Short channel effects.	**8 Hours**
Module-5	Advanced CMOS Technologies and Nanoscale Devices: Heterojunction MOSFET, Strained Si MOSFET for higher mobility, Staggered heterojunction MOSFET, High-K materials, Gate stack and Channel stack technology, Reverse short channel effect and HALO doping, SOI technologies: SOI CMOS design, 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 *Ed.*, McGraw-Hill, 2012.
T2. S. M. Sze and K. N. Kwok, ***Physics of Semiconductor Devices***, 3rd *Ed.*, John Wiley & Sons, 2006.

T3. A. Sarkar, S. De, and C. K. Sarkar, ***VLSI Design and EDA Tools***, 1st *Ed.*, SciTech, 2013.

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 and T. I. Kamins, ***Device Electronics for Integrated Circuits***, 3rd *Ed.*, Wiley, 2007.
R4. Y. Tsividis and M. Colin, ***Operation and Modelling of MOS Transistor***, 3rd *Ed.*, Oxford University Press, 2011.
R5. C. K Maiti, S. Chattopadhyay, and L. K. Bera, ***Strained-Si Heterostructure Field Effect Devices***, 1st *Ed.*, CRC Press, 2007.

Online Resources:

1. https://nptel.ac.in/courses/108108122/: by Prof. D. N. Nath, IISc Bangalore
2. https://nptel.ac.in/courses/117108047/: by Dr. N. Bhat and others, 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

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	Describe the detail characteristic of p-n junction diode and its applications.
CO3	Articulate MOS transistor structure and its characteristics.
CO4	Understand the limitations of downscaling the size of MOS transistor.
CO5	Explore advanced CMOS technologies and the nanoscale MOS structures.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO4	Understand and use different software tools for design, analysis and verification in the domain of communication, VLSI and signal processing through design, synthesis, functional, and timing simulation.
PO5	Design and conduct experiments, analyze and interpret data, utilize programming skills for development of simulation experiments.
PO7	Understand the impact of electronics & communications in an economic, social and environment context.
PO10	Continue to learn independently and engage in life-long learning.

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		1			2	3	2	3
CO2	3	3		3	2		2			2	3	3	2
CO3	3	3		3	3		2			3	3	3	3
CO4	3	3		2	3		2			2	2	3	2
CO5	3	3		3	2		3			2	3	3	2

Category	Code	Modern Communication Systems	L-T-P	Credits	Marks
PCR	EC5003		3-0-0	0	100

Objectives	The objective of this course is to study the basic concepts of digital communication systems including the performance of optimum receiver in presence of AWGN, multi-channel, multi-carrier systems and spread spectrum techniques.
Pre-Requisites	Knowledge of analog and digital communication 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	Digital Communication Systems: Introduction, concepts of sampling in transmitting multiple band limited signals, concepts of signal reconstruction, quantization of signals, uniform and non-uniform quantization system, companding, μ-law and A-law compressions, input-output characteristics, PCM, DPCM and DM.	**9 Hours**
Module-2	Digital Modulation Schemes: Representation of digitally modulated signals, Generation, Detection, Signal-space diagram, Error probability calculation and power spectra: Binary phase shift keying (BPSK), Quadrature phase shift keying (QPSK), Quadrature Amplitude modulation (QAM), Binary frequency shift keying (BFSK), and Minimum shift keying (MSK).	**9 Hours**
Module-3	Optimum Receivers: Base-band signal Receiver, Peak signal to RMS noise output voltage ratio, Probability of error, Optimum threshold, Optimum receiver for both base-band and pass-band: Calculation of optimum filter transfer function, Optimum filter realization using matched filter, Probability error of the matched filter, Optimum filter realization using correlator.	**8 Hours**
Module-4	Multi-channel and Multi-carrier Systems: Multichannel Digital Communications in AWGN Channels; Binary Signals, M-ary Orthogonal Signals. Multicarrier Communications; Single Carrier verses Multicarrier Modulation, Capacity of a Non ideal Linear Filter Channel, OFDM, Modulation & Demodulation using OFDM.	**8 Hours**
Module-5	Spread Spectrum Signals for Digital Communication: Model of Spread spectrum Digital Communication System, Direct Sequence Spread Spectrum Signals, Error Rate Performance of the Decoder, Some Applications of DS Spread Spectrum Signals, Frequency-Hopped Spread-Spectrum Signals, Performance of FH Spread Spectrum Signals in an AWGN Channel, A CDMA System Based on FH Spread Spectrum Signals.	**8 Hours**
	Total	**42 Hours**

Text Books:

T1. H. Taub, D. L. Schilling, and G. Saha, ***Principles of Communication Systems***, 4th *Ed.*, Tata McGraw-Hill, 2013.

T2. B. P. Lathi and Z. Ding, ***Modern Digital and Analog Communication Systems***, 4th *Ed.*, Oxford University Press, 2010.

T3. S. Haykin, ***An Introduction to Analog and Digital Communications***, 2nd *Ed.*, Wiley, 2007.
T4. J. G. Proakis and M. Salehi, ***Digital Communication***, 5th *Ed.*, McGraw-Hill, 2014.

Reference Books:

R1. L. W. Couch-II, ***Digital and Analog Communication System***, 8th *Ed.*, Pearson Education, 2013.
R2. B. Sklar, ***Digital Communications - Fundamentals and Applications***, 2nd *Ed.*, Pearson Education, 2009.

Online Resources:

1. https://nptel.ac.in/courses/117101051: by Prof. B. K. Dey, IIT Bombay
2. https://nptel.ac.in/courses/117104115: by Prof. A. K. Jagannatham
3. https://freevideolectures.com/course/2314/communication-engineering/32
4. https://www.digimat.in/nptel/courses/video/117105136/L39.html
5. https://freevideolectures.com/course/4701/nptel-principles-communication-systems-i/51

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

CO1	Explain the sampling theorem, practical issues related to sampling, signal reconstruction, quantization, encoding along with applications.
CO2	Apply digital modulation & demodulation techniques considering bandwidth, SNR and power spectral efficiency.
CO3	Design optimum receivers for pass band and base band communications and compare the performance of correlator receiver with matched filter reception.
CO4	Apply the concepts of high-speed signal transmission simultaneously (multiplexing) using multiple carrier signals for efficient bandwidth requirements.
CO5	Analyze the performance of spread spectrum systems in the presence of inter reference and AWGN.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO4	Understand and use different software tools for design, analysis and verification in the domain of communication, VLSI and signal processing through design, synthesis, functional, and timing simulation.
PO5	Design and conduct experiments, analyze and interpret data, utilize programming skills for development of simulation experiments.
PO9	Communicate effectively in a technically sound manner with a wide range of audience.
PO10	Continue to learn independently and engage in life-long learning.

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	2				2	1	2	2	1
CO2	3	3	2	3	2				2	1	3	2	1
CO3	2	3	2	1					1		2	1	1
CO4	3	2	3	2	3				2	1	3	2	1
CO5	3	2	2	1					1	1	2	1	2

Category	Code	IoT & Embedded Systems Design	L-T-P	Credits	Marks
PCR	EC5004		3-1-0	4	100

Objectives	The objective of this course is to learn the different components of IoT and design IoT and Embedded Systems for real world applications.
Pre-Requisites	Basic knowledge of Microcontrollers and Sensors is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required; sessions are planned to be interactive with focus on theory and 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 IoT : Applications of IOT, Structure of IoT, Physical and logical design of IoT, IoT Level and deployment template.	**10 Hours**
Module-2	IoT Sensors: Industrial sensors - Description & Characteristics – First Generation, Advanced Generation, Integrated IoT Sensors, Polytronics Systems, Sensors' Swarm, Printed Electronics, IoT Generation Roadmap.	**10 Hours**
Module-3	IoT Reference Model: Domain, information, functional and communication models; Application Protocols for IoT: UPnP, CoAP, MQTT, XMPP. REST API, AMSP, DDS, Web Socket; IP-based protocols: 6LoWPAN, RPL; Authentication Protocols; IEEE 802.15.4.	**12 Hours**
Module-4	Embedded Systems: Application Areas, Categories of embedded systems, Overview of embedded system architecture, Hardware architecture, Software architecture, Application Software, Communication Software.	**12 Hours**
Module-5	ARM Architecture: Architecture Versions, Processor Naming, Instruction Set Development, Thumb-2 and Instruction Set Architecture. Cortex-M3 Basics: Registers, General Purpose Registers, Operation Mode, Exceptions and Interrupts, Vector Tables, Stack Memory Operations, Reset Sequence. CortexM3Instruction Sets, Instruction Descriptions.	**12 Hours**
	Total	**56 Hours**

Text Books:

T1. A. Bahaga and V. Madisetti, ***Internet of Things: A Hands-on Approach***, 1st *Ed.*, University Press, 2014.
T2. J. Yiu, ***The Definitive Guide to the ARM Cortex-M3***, 2nd *Ed.*, Elsevier, 2010.

Reference Books:

R1. O. Hersent, D. Boswarthick, O. Elloumi, ***The Internet of Things - Key Applications & Protocols***, Student Edition, Wiley, 2015.
R2. S.Furber, ***ARM System-on-Chip Architecture***, 2nd *Ed.*, Pearson Education, 2015.

Online Resources:

1. https://nptel.ac.in/courses/106/105/106105195/: by Prof. S. Misra, IIT Kharagpur.
2. https://nptel.ac.in/courses/108/108/108108098/: by Prof. T. V. Prabhakar, IISc Bangalore
3. https://nptel.ac.in/courses/106/105/106105166/: by Prof. S. Misra, IIT Kharagpur
4. https://nptel.ac.in/courses/108/102/108102169/: by Prof. D. V. Gadre and Prof. B. N. Subudhi, IIT Jammu

5. https://nptel.ac.in/courses/106/105/106105193/: by Prof. I. Sengupta and Prof. K. Datta, IIT Kharagpur

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

CO1	Describe the different designs of IoT and their levels of deployment.
CO2	Explain the different industrial sensors and their applications.
CO3	Articulate the IoT reference model and application protocols.
CO4	Describe the application areas of embedded systems and their architectures.
CO5	Explain the different versions of ARM processors architecture and instructions.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO4	Understand and use different software tools for design, analysis and verification in the domain of communication, VLSI and signal processing through design, synthesis, functional, and timing simulation.
PO5	Design and conduct experiments, analyze and interpret data, utilize programming skills for development of simulation experiments.

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	2	3	2						1	2	2
CO2	3	3	2	2	2						3	3	3
CO3	2	2	3	2	2						3	2	2
CO4	3	2	2	3	2						1	2	2
CO5	3	3	2	2	2						3	3	3

Category	Code	Research Methodology & IPR	L-T-P	Credits	Marks
UCR	RS7001		2-0-0	2	100

Objectives	The objective of this course is to introduce the principles and practices involved in conducting scientific research. The course is designed to cover three broad areas - The Scientific Method and Hypothesis Testing, Review of Literature and writing Technical Reports, and the elements of Intellectual Property Rights (IPR).
Pre-Requisites	Basic knowledge of probability & statistics will be helpful.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with focus on problem solving & examples.

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 research, its significance and meaning; Types of research - fundamental, pure, theoretical, applied and experimental; Identification of the research problem and formulation of hypothesis; Research design and errors in research, error analysis; The Scientific Method as the established way of doing research; Data collection, measurement and scaling techniques.	**8 Hours**
Module-2	Meaning and need for hypothesis, Types of hypothesis, Functions and characteristics of a good hypothesis; Statistical testing of hypothesis – T-test, Chi-squared test; Sampling methods, Types of sampling, Probability and non-probability sampling; One-sample and two-sample tests, Correlation and regression analysis.	**8 Hours**
Module-3	Literature - types and review; Literature survey using the web, Search engines; Journal, report and thesis writing; Types of reports, Structure of the research report and presentation of results.	**7 Hours**
Module-4	Code of ethics in research - Intellectual Property Rights; Details of patents, Copyrights, Trademarks and Trade Secrets.	**5 Hours**
	Total	**28 Hours**

Text Books:

T1. C. R. Kothari & G. Garg, ***Research Methodology: Methods and Techniques***, 2nd *Ed.*, New Age International Publishers, 2004.
T2. D. Chawla & N.Sodhi, ***Research Methodology: Concepts and Cases***, 2nd *Ed.*, Vikas Publishing, 2016.

Reference Books:

R1. E. L. Lehman & J. P. Romano, ***Testing Statistical Hypothesis***, 3rd *Ed.*, Springer, 2008.
R2. R. Panneerselvam, ***Research Methodology***, 2nd *Ed.*, Prentice Hall India, 2013.

Online Resources:

1. https://nptel.ac.in/courses/127106227: by Prof. S. Banerjee, IIT Madras
2. https://nptel.ac.in/courses/109105115: by Prof. A. Malik, IIT Kharagpur
3. https://nptel.ac.in/courses/109105112: by Prof. T. K. Bandyopadhyay, IIT Kharagpur
4. https://ocw.mit.edu/courses/sloan-school-of-management/15-347-doctoral-seminar-in-research-methods-i-fall-2004/readings/: MIT Open Courseware (MIT-OCW).

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

CO1	Disseminate the scientific method as a structured way of conducing scientific research.
CO2	Apply statistical principles for conducting hypothesis testing.
CO3	Conduct effective review of literature and write technical reports.
CO4	Acquire knowledge of the various intellectual property rights.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO4	Understand and use different software tools for design, analysis and verification in the domain of communication, VLSI and signal processing through design, synthesis, functional, and timing simulation.
PO5	Design and conduct experiments, analyze and interpret data, utilize programming skills for development of simulation experiments.
PO8	Understand intellectual property rights and overall professional & ethical responsibility.
PO9	Communicate effectively in a technically sound manner with a wide range of audience.
PO10	Continue to learn independently and engage in life-long learning.

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	1	1					1	1	1	2
CO2	2	2	1	1	1					1		1	1
CO3					3				2	1		1	2
CO4								3		1		1	2

Category	Code	Advanced Semiconductor Devices Lab	L-T-P	Credits	Marks
PCR	EC5005		0-0-2	1	100

Objectives	The objective of this laboratory course is to provide hands-on exposure on the characteristics of different semiconductor devices used in modern electronics equipment.
Pre-Requisites	Knowledge of physics of semiconductor devices and topics taught in the theory class are required.
Teaching Scheme	Regular laboratory experiments executed under the supervision of teachers. Demonstration on theoretical concepts and TCAD tool shall be given.

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 of MOSFET (channel length 1μm) and study of its characteristics ($V_{GS} \sim ID$) and ($V_{DS} \sim ID$).
2	Design of a MOSFET and extraction of analog/RF performance parameters from the characteristic curves.
3	Design of a MOSFET and extraction of linearity performance parameters from the characteristic curves.
4	Study of the effect of gate oxide scaling and channel length scaling on the characteristic of MOSFETs.
5	Design of MOSFET using different High-K materials and comparison of their characteristics.
6	Design and study the characteristics of heterojunction MOSFET.
7	Design of a Tunnel FET and extraction of analog/RF performance parameters from the characteristic curves.
9	Design of SOI FinFET and extraction of its analog/RF performance parameters from the characteristic curves.
10	Design of Gate all-around (GAA) MOSFET and extraction of its analog/RF performance parameters from the characteristic curves.
11	Study and analysis of short channel effect in nanoscale devices.
12	Design and study the sensitivity characteristics of MOSFET as a biosensor.
13	Study of linearity performance of advanced nanoscale devices (FinFET/TFET/GAA FET).

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.
T3. A. Sarkar, S. De, and C. K. Sarkar, ***VLSI Design and EDA Tools***, 1st *Ed.*, SciTech, 2013.

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 and T. I. Kamins, ***Device Electronics for Integrated Circuits***, 3rd *Ed.*, Wiley, 2007.
R4. Y. Tsividis and M. Colin, ***Operation & Modelling of MOS Transistor***, 3rd *Ed.*, Oxford Univ. Press, 2011.
R5. C. K. Maiti, S. Chattopadhyay, and L. K. Bera, ***Strained-Si Heterostructure Field Effect Devices***, 1st *Ed.*, CRC Press, Taylor & Francis Group, 2007.

Online Resources:

1. https://nptel.ac.in/courses/108108122/: by Prof. D. N. Nath, IISc Bangalore
2. https://nptel.ac.in/courses/117108047/: by Dr. N. Bhat and others, 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

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

CO1	Explain the MOS transistor structure and its characteristics.
CO2	Extract the parameters for linearity and RF performance measurement of a MOSFET.
CO3	Understand the limitations of down scaling the size of MOS transistor.
CO4	Realize the importance of High-K gate dielectrics for advanced CMOS design.
CO5	Investigate the characteristic of hetero-junction MOSFET structures for advanced CMOS technology nodes.
CO6	Explore multi-gate CMOS structures and evaluate their performance.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO4	Understand and use different software tools for design, analysis and verification in the domain of communication, VLSI and signal processing through design, synthesis, functional, and timing simulation.
PO5	Design and conduct experiments, analyze and interpret data, utilize programming skills for development of simulation experiments.
PO7	Understand the impact of electronics & communications in an economic, social and environment context.
PO10	Continue to learn independently and engage in life-long learning.

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		2			1	3	3	3
CO2	3	2		3	3		2			2	3	3	3
CO3	3	3		3	3		2			2	3	2	3
CO4	3	3		3	2		2			1	3	3	2
CO5	3	3		3	2		3			2	3	3	3
CO6	3	3		2	3		3			2	3	2	3

Category	Code	IoT & Embedded Systems Design Lab	L-T-P	Credits	Marks
PCR	EC5006		0-0-4	2	100

Objectives	The objective of this laboratory course is to provide practical exposure on concepts of Arduino board, GSM module, use of sensors and web server for design of IoT and Embedded systems.
Pre-Requisites	Knowledge on concepts of microcontrollers and sensors is required.
Teaching Scheme	Regular Laboratory experiments executed under supervision of the teacher with focus on designing of IoT and Embedded systems for real world applications with the help of hardware and software.

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 Different Internet Protocols like HTTP, TCP/IP etc.
2	Introduction to Arduino MEGA 2560 and Interfacing Push Button, LED, LDR, Potentiometer, Buzzer and Relay with Arduino MEGA 2560.
3-4	Interfacing below sensors with Arduino MEGA 2560 LM35 (Temperature Sensor), DHT11 (Temperature and Humidity Sensor), PIR (Passive Infrared Sensor), DS18B20 (One Wire Temperature Sensor), HC-SR04 (Ultrasonic Sensor).
5	Interfacing Display Devices (Liquid Crystal Display) to display the sensor output.
6-7	Wireless Transceiver (NRF24L01) interfacing with Arduino UNO to wirelessly transmit sensor output value.
8-9	Controlling Sensors with DTMF Technology using GSM Module SIM900A.
10-11	Uploading Sensor Data wirelessly to Thing Speak cloud using GSM Module SIM900A.
12-13	Front End Designing with Node-RED.
14-15	Web Service Development for IoT based applications (Database and their Management).
16-17	Using ESP8266/ESP32 as a WiFi Client to upload sensor data to Thing Speak API.
18-19	Configuring ESP8266 as a Web Server.
20-21	Interfacing of Bluetooth with Arduino/Raspberry Pi to send sensor data to smart phone using Bluetooth.

Text Books:

T1. A. Bahaga and V. Madisetti, ***Internet of Things: A Hands-on Approach***, 1st *Ed.*, University Press, 2014.
T2. J. Yiu, ***The Definitive Guide to the ARM Cortex-M3***, 2nd *Ed.*, Elsevier, 2010.

Reference Books:

R1. O. Hersent, D. Boswarthick, O. Elloumi, ***The Internet of Things - Key Applications & Protocols***, Student Edition, Wiley, 2015.
R2. S.Furber, ***ARM System-on-Chip Architecture***, 2nd *Ed.*, Pearson Education, 2015.

Online Resources:

1. https://nptel.ac.in/courses/108/108/108108098/:by Prof. T. V. Prabhakar,IISc Bangalore
2. https://nptel.ac.in/courses/106/105/106105195/:by Prof. S. Misra, IIT Kharagpur.
3. https://nptel.ac.in/courses/106/105/106105166/:by Prof. S. Misra, IIT Kharagpur
4. https://nptel.ac.in/courses/106/106/106106182/:by Prof. S. Iyengar, IIT Madras
5. https://nptel.ac.in/courses/115/104/115104095/:by Prof. M. Verma, IIT Kanpur
6. https://nptel.ac.in/courses/106/104/106104189/:by Dr. R. Misra, IIT Patna

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

CO1	Explain different IoT protocols.
CO2	Interface external devices using Arduino board, sensors, display devices etc.
CO3	Interface wireless transceiver for different applications.
CO4	Develop wireless sensor data control using GSM module.
CO5	Design and develop web service for IoT applications.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO4	Understand and use different software tools for design, analysis and verification in the domain of communication, VLSI and signal processing through design, synthesis, functional, and timing simulation.
PO5	Design and conduct experiments, analyze and interpret data, utilize programming skills for development of simulation experiments.

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	2	3	2						1	2	2
CO2	3	3	2	2	2						3	3	3
CO3	2	2	3	2	2						3	2	2
CO4	3	2	2	3	2						1	2	2
CO5	3	3	2	2	2						3	3	3

Category	Code	Modern Communication Systems Lab	L-T-P	Credits	Marks
PCR	EC5007		0-0-2	1	100

Objectives	The objective of this laboratory course is to provide in-depth practical exposure on digital communication systems with TDM, FDM, Pulse modulations, Digital modulation techniques, audio, video as well as spreading and dispreading concepts.
Pre-Requisites	Knowledge of analog & digital communication and topics taught in the theory class are required.
Teaching Scheme	Regular Laboratory experiments executed under supervision of the teacher with the help of hardware and simulation through software.

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	Hardware/Simulation of the Pulse Code Modulation (PCM) and demodulation Technique using MATLAB Simulink.
2	Hardware/Simulation of Time division multiplexing (TDM) using MATLAB Simulink.
3	Hardware/Simulation of frequency division multiplexing (FDM) and frequency division de-multiplexing using MATLAB Simulink.
4	Hardware/Simulation of generation and reception of signals in Amplitude Shift Keying (ASK) using MATLAB Simulink.
5	Hardware/Simulation of generation and reception of signals in Frequency Shift Keying (FSK) using MATLAB Simulink.
6	Hardware/Simulation of generation and reception of signals in Phase Shift Key (PSK) using MATLAB Simulink.
7	Hardware/Simulation of generation and reception of signals in Quadrature Phase Shift Key (QPSK) using MATLAB Simulink.
8	Simulation of M-ary Phase Shift Keying (M-ary PSK) using MATLAB.
9	Simulation of M-ary Quadrature Amplitude Modulation (M-ary QAM) using MATLAB.
10	Study of Performance Analysis of different digital modulation techniques by using MATLAB.
11	Simulation of Direct Sequence Spread Spectrum (DS-SS) using MATLAB.
12	Multiplexing of signals using OFDM

Text Books:

T1. H. Taub, D. L. Schilling, and G. Saha, ***Principles of Communication Systems***, 4th *Ed.*, Tata McGraw-Hill, 2013.

T2. B. P. Lathi and Z. Ding, ***Modern Digital and Analog Communication Systems***, 4th *Ed.*, Oxford University Press, 2010.

Reference Books:

R1. L. W. Couch-II, ***Digital and Analog Communication System***, 8th *Ed.*, Pearson Education, 2013.

R2. B. Sklar, ***Digital Communications - Fundamentals and Applications***, 2nd *Ed.*, Pearson Education, 2009.

Online Resources:

1. https://nptel.ac.in/courses/117101051: by Prof. B. K. Dey, IIT Bombay
2. https://nptel.ac.in/courses/117104115: by Prof. A. K. Jagannatham
3. https://freevideolectures.com/course/2314/communication-engineering/32
4. https://www.digimat.in/nptel/courses/video/117105136/L39.html
5. https://freevideolectures.com/course/4701/nptel-principles-communication-systems-i/51

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

CO1	Convert analog to digital signal and vice-versa.
CO2	Transmit multiple signals using Time Division Multiplexing.
CO3	Realize different digital modulation schemes and their effect in communications with the help of spectrum analyzer.
CO4	Explain spreading concepts and methods to spread and dispread the given signals.
CO5	Describe multiplexing of signals using OFDM.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO4	Understand and use different software tools for design, analysis and verification in the domain of communication, VLSI and signal processing through design, synthesis, functional, and timing simulation.
PO5	Design and conduct experiments, analyze and interpret data, utilize programming skills for development of simulation experiments.
PO9	Communicate effectively in a technically sound manner with a wide range of audience.
PO10	Continue to learn independently and engage in life-long learning.

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	2				2	1	2	2	1
CO2	2	2	2	2					2	1	2	2	1
CO3	3	3	2	3	2				2	1	3	2	1
CO4	3	2	2	1					1	1	2	1	2
CO5	3	2	3	2	3				2	1	3	2	1

Category	Code	Digital IC Design & Verification using HDL	L-T-P	Credits	Marks
PCR	EC5008		3-1-0	4	100

Objectives	The objective of this course is to provide in-depth knowledge on the Verilog HDL and System Verilog HDL techniques for digital VLSI system design and verification.
Pre-Requisites	Knowledge of digital electronic circuits and MOSFET 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: Evolution of Logic Design, System and Logic Design Abstractions, Integrated Circuit Design and Methodologies, Verilog Design Description, Concept of Concurrency; Verilog Operators: Arithmetic, Logical, Equality and Inequality, Bitwise, Relational, Reduction, and Shift.	**12 Hours**
Module-2	Verilog Constructs and Combinational Design: The Role of Constructs, Logic Gates and Synthesizable RTL, Tristate Logic, Arithmetic Circuits, Procedural Block, Multi-bit Adders and Subtractors.	**10 Hours**
Module-3	Multiplexers: Multiplexer as Universal logic, the if...else and case Construct, 4:1 MUX Using if...else and case, Design Combinational Logic Using Multiplexers; Decoders and Encoders: 1:2 Decoders, 2:4 Decoder, Test bench of Decoder, Priority Encoders, Test bench of Encoder.	**10 Hours**
Module-4	Sequential Design Using Verilog: Sequential Logic, Flip-Flop, Positive and negative Edge-Triggered D Flip-Flop, Synchronous and Asynchronous Reset; Synchronous Counter Design Using Synthesizable Constructs: Synchronous Counters, Gray Counters, BCD Up-Down Counter; Finite State Machines Using Verilog: Moore Versus Mealy Machines, Level to Pulse Converter, FSM Encoding Styles, One-Hot Encoding, Sequence Detectors Using FSMs.	**12 Hours**
Module-5	System Verilog for Verification: Verification Guidelines, Process, and Methodology, Basic Test bench Functionality, Directed Testing, Methodology Basics, Constrained-Random Stimulus, Functional Coverage, Test bench Components, Layered Test bench, Building a Layered Test bench, Simulation Environment Phases, Maximum Code Reuse.	**12 Hours**
	Total	**56 Hours**

Text Books:

T1. S. Palnitkar, ***Verilog HDL : A Guide to Digital Design and Synthesis***, 2nd *Ed.*, Pearson Education, 2003.

T2. C. Spear and G. Tumbush, ***System Verilog for Verification: A Guide to Learning the Testbench Language Features***, 3rd *Ed.*, Springer, 2012.

Reference Books:

R1. K. Mishra, ***Advanced Chip Design: Practical Examples in Verilog***, 1st *Ed.*. Create Space Independent Pub, 2013.

R2. V. Taraate, ***Digital Logic Design Using Verilog***, 2nd *Ed.*, Springer, 2016.

R3. C. H. Roth Jr., L. K. John, B. K. Lee, ***Digital Systems Design Using Verilog***, 1st *Ed.*, Cengage Learning, 2015.
R4. D. E. Thomas, P. R. Moorby, ***The Verilog Hardware Description Language***, 5th *Ed.*, Kluwer Academic Publishers, 2002.

Online Resources:

1. https://nptel.ac.in/courses/108103179: by Prof. S. R. Ahamed, IIT Guwahati
2. http://www.ece.uah.edu/~gaede/cpe526/SystemVerilog_3.1a.pdf
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	Describe the basic concepts, constructs and syntax of Verilog HDL.
CO2	Analyze, design and test combinational logic circuits using dataflow, gate level, structural, behavioral and switch level modeling.
CO3	Analyze, design and test combinational logic circuits using multiplexer as universal logic and design different types of decoders & encoders.
CO4	Analyze, design and verify sequential logic circuits & FSMs through Verilog HDL using synthesizable constructs.
CO5	Develop procedure to carry out design verification using System Verilog HDL.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO4	Understand and use different software tools for design, analysis and verification in the domain of communication, VLSI and signal processing through design, synthesis, functional, and timing simulation.
PO10	Continue to learn independently and engage in life-long learning.

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	3	3	3	2						1	2	2	1
CO3	3	3	3	2						1	2		1
CO4	3	3	3	2						1	1	2	1
CO5	1	2	2	2						1	1	2	1

Category	Code	Advanced Digital Signal Processing	L-T-P	Credits	Marks
PCR	EC5009		3-1-0	4	100

Objectives	The objectives of this course is to study the mathematical modeling of discrete time random signals, choose appropriate filter structures, estimation, prediction and filtering techniques, and develop DSP based real-time data processing systems for high speed applications.
Pre-Requisites	Knowledge of Signals & Systems and Digital Signal Processing 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	Review of Discrete Time Systems: Design of FIR Digital filters - Window method, Park-McClellan's method; Design of IIR Digital Filters - Butterworth and Chebyshev; Lowpass, Bandpass, Bandstop and High pass filters.	**10 Hours**
Module-2	Multirate Signal Processing: Basic multirate operations, Up-sampling and down sampling, Time domain and frequency domain analysis, Identities of multirate operations, Efficient transversal structure, Rate conversion, Polyphase representation, Multirate filter banks.	**12 Hours**
Module-3	Linear Estimation and Prediction: Representations of a stationary random process, Forward and backward linear prediction, AR Lattice structure, ARMA processes & Lattice - Ladder Filters, Wiener filters.	**12 Hours**
Module-4	Parametric and Non-parametric Spectral Estimation: Estimation of spectra from finite duration observations of a signal - Periodogram, Use of DFT in power spectrum estimation, Non-parametric spectral estimation, Parametric spectral estimation.	**12 Hours**
Module-5	Adaptive systems: Adaptive linear combiner: the performance function, gradient and minimum mean square error. Adaptive algorithms: LMS and RLS, Applications.	**10 Hours**
	Total	**56 Hours**

Text Books:

T1. J. G. Proakis and D. G. Manolakis, ***Digital Signal Processing: Principles, Algorithm and Applications***, 4th *Ed.*, Prentice Hall, 2007.

T2. A. V. Oppenheim and R. W. Schafer, ***Discrete-Time Signal Processing***, 3rd *Ed.*, Pearson Education, 2004.

T3. B. Widrow and S. D. Stearns, ***Adaptive Signal Processing***, edn1, Pearson Education, 2002.

Reference Books:

R1. L. R. Rabiner and B. Gold, ***Theory and Application of Digital Signal Processing***, 2nd *Ed.*, Prentice Hall India, 1992.

R2. J. R. Johnson, ***Introduction to Digital Signal Processing***, 2nd *Ed.*, Prentice Hall India, 1992.

R3. A. N. Kani, ***Digital Signal Processing***, 2nd *Ed.*, McGraw-Hill Education, 2017.

R4. P. R. Babu, ***Digital Signal Processing***, 4th *Ed.*, Scitech Publication, 2011.

R5. A . Ambardar, ***Analog and Digital Signal processing***, 2nd *Ed.*, CL Engineering, 1999.

Online Resources:

1. https://nptel.ac.in/courses/108/106/108106151/: by Prof. C. S. Ramalingam, IIT Madras
2. https://nptel.ac.in/courses/117102060/: by Prof. S. C. Dutta Roy, IIT Delhi
3. https://nptel.ac.in/courses/117104070/: by Prof. T. K. Basu, IIT Kharagpur
4. https://nptel.ac.in/courses/117101001/: by Prof. V. M. Gadre, IIT Bombay

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

CO1	Design IIR and FIR filters using various techniques.
CO2	Explain the concepts of multirate signal processing.
CO3	Analyze the linear estimation and prediction.
CO4	Estimate power spectrum of signals using different techniques.
CO5	Describe the concepts of adaptive systems.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO5	Design and conduct experiments, analyze and interpret data, utilize programming skills for development of simulation experiments.
PO7	Understand the impact of electronics & communications in an economic, social and environment context.

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	2		3		1				2	2	1
CO2	2	3	2		2		2				2	1	1
CO3	3	2	1		3		1				2	1	2
CO4	3	2	3		3		2				3	1	1
CO5	3	2	1		2		2				2	1	2

Category	Code	Machine Learning & Applications	L-T-P	Credits	Marks
PCR	EC5010		3-0-0	3	100

Objectives	The objective of this course is to learn patterns and concepts from data using various machine learning techniques focusing on recent advances. Students will explore supervised & unsupervised learning paradigms, deep learning technique and various feature extraction strategies.
Pre-Requisites	Knowledge of algorithms, optimization, and matrix theory 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 and real-life examples.

Evaluation Scheme

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

Detailed Syllabus

Module-#	Topics	Hours
Module-1	**Linear Regression & Classification**: Overview of supervised learning, Linear regression models and least squares, Multiple linear and polynomial regression, Ridge regression, Least angle regression and Lasso, Elastic Net.	**9 Hours**
Module-2	**Dimensionality Reduction**: Principal Components, Kernel Principal Component Analysis (PCA), Linear Discriminant Analysis, Independent Component Analysis, Locally Linear Embedding (LLE), Feature Selection.	**8 Hours**
Module-3	**Model Assessment & Selection**: Bias, Variance, and model complexity, Bias-variance trade-off, Cross-validation, Bootstrap methods, Regression and classification trees, Boosting methods, AdaBoost and Random forest.	**8 Hours**
Module-4	**Support Vector Machines**: Generative model for discrete data (Bayesian concept learning, Naive Bayes classifier), Support Vector Machine (SVM) for classification, Reproducing Kernels, SVM for Regression.	**9 Hours**
Module-5	**Neural Networks**: Model of a neuron, Least Mean Squares (LMS), Perceptron and its learning algorithm, Multi-Layer Perceptron (MLP) and Back Propagation algorithm (BPA), Heuristics for improving performance of BPA, Higher order convergence methods for BPA (Newton method, Conjugate gradient method); Radial Basis Function Networks, Self-Organizing Maps.	**8 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 *Ed.*, Springer Verlag, 2009.

T2. S. Haykin, ***Neural Networks: A Comprehensive Foundation***, 2nd *Ed.*, Pearson Education, 1999.

Reference Books:

R1. C. Bishop, ***Pattern Recognition and Machine Learning***, 1st *Ed.*, Springer, 2007.

R2. T. Mitchel, ***Machine Learning***, 1st *Ed.*, McGraw-Hill Education, 1997.

R3. G. James, D. Witten, T. Hastie, and R. Tibshirani, ***An Introduction to Statistical Learning with Applications in R***, 7th *Ed.*, Springer, 2013.

R4. K. P. Murphy, ***Machine Learning: A Probabilistic Perspective***, 4th *Ed.*, MIT Press, 2012.

Online Resources:

1. https://nptel.ac.in/courses/106/106/106106202/: by Prof. C. G. Jansson, IIT Madras
2. https://nptel.ac.in/courses/106/105/106105152/: by Prof. S. Sarkar, IIT Kharagpur
3. https://github.com/josephmisiti/awesome-machine-learning: An exhaustive index of machine learning concepts and programming materials.
4. http://mlss.cc/: Machine Learning Summer School Study Material

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

CO1	Formulate and solve machine learning problems using linear models of regression and classification.
CO2	Explain unsupervised learning models of dimensionality reduction and factor analysis.
CO3	Analyze the building blocks of probabilistic model assessment and selection.
CO4	Classify data sets using regression, SVM and decision tree based models.
CO5	Apply the concepts of neural networks for solving real-world problems.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO5	Design and conduct experiments, analyze and interpret data, utilize programming skills for development of simulation experiments.
PO6	Function effectively as an individual or as a member of a multidisciplinary team with sense of ethics, integrity and social responsibility.
PO9	Communicate effectively in a technically sound manner with a wide range of audience.
PO10	Continue to learn independently and engage in life-long learning.

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	3		1	2			1	1	3	3	2
CO2	3	3	2		1	2			1	1	3	3	2
CO3	3	3	2		1	2			1	1	3	3	2
CO4	3	3	2		2	2			1	1	3	3	2
CO5	3	3	2		2	2			1	1	3	3	2

Category	Code	Digital Integrated Circuit Design	L-T-P	Credits	Marks
PEL	EC5013		3-0-0	3	100

Objectives	The objective of this course is to provide in-depth knowledge of MOSFET, its manufacturing process including analysis and design of digital integrated circuits & systems using state-of-the-art technology.
Pre-Requisites	Knowledge of digital electronic circuits and MOSFET 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**: Historical Perspective, Issues in Digital Integrated Circuit Design, Quality Metrics of a Digital Design, Cost of an Integrated Circuit, Functionality & Robustness, Performance, Power & Energy Consumption; Manufacturing Process: Introduction, Manufacturing CMOS Integrated Circuits, The Silicon Wafer, Photolithography, Some Recurring Process Steps, Simplified CMOS Process Flow, Design Rules - The Contract between Designer & Process Engineer, Packaging Integrated Circuits, Package Materials, Interconnect Levels, Thermal Considerations in Packaging.	**8 Hours**
Module-2	**The Devices**: The MOS(FET) Transistor, A First Glance, MOS Transistor under Static Conditions, Dynamic Behavior, Actual MOS Transistor - Some Secondary Effects, SPICE Models for the MOS Transistor; The Wire: Introduction, First Glance, Interconnect Parameters - Capacitance, Resistance, and Inductance, Electrical Wire Models, The Ideal Wire, Lumped Model, Lumped RC model, Distributed rc Line, Transmission Line.	**8 Hours**
Module-3	**The CMOS Inverter**: Introduction, Static CMOS Inverter - An Intuitive Perspective, Evaluating the Robustness of the CMOS Inverter: Static Behavior, Switching Threshold, Noise Margins, Robustness Revisited, Performance of CMOS Inverter: Dynamic Behavior, Computing the Capacitances, Propagation Delay: First-Order Analysis, Propagation Delay from a Design Perspective, Power, Energy, and Energy-Delay, Dynamic Power Consumption, Static Consumption, Putting It All Together.	**9 Hours**
Module-4	**Combinational CMOS Logic Gates**: Introduction, Static CMOS Design, Complementary CMOS, Ratioed Logic, Pass-Transistor Logic, Dynamic CMOS Design, Dynamic Logic: Basic Principles, Speed and Power Dissipation of Dynamic Logic, Issues in Dynamic Design, Cascading Dynamic Gates.	**8 Hours**

Cont'd. . .

Module-#	Topics	Hours
Module-5	**Sequential Logic Circuits**: Introduction, Timing Metrics for Sequential Circuits, Classification of Memory Elements, Static Latches and Registers, Bistability Principle, Multiplexer-Based Latches, Master-Slave Edge-Triggered Register, Low-Voltage Static Latches, Static SR Flip-Flops—Writing Data by Pure Force, Dynamic Latches and Registers, Dynamic Transmission-Gate Edge-triggered Registers, C2MOS-A Clock-Skew Insensitive Approach, True Single-Phase Clocked Register (TSPCR), Pipelining: An approach to optimize sequential circuits, Latch- vs. Register-Based Pipelines, NORA-CMOS-A Logic Style for Pipelined Structures.	**9 Hours**
	Total	**42 Hours**

Text Books:

T1. J. P. Rabaey, A. P. Chandrakasan, and B. Nikolić, ***Digital Integrated Circuits: A Design Perspective***, 2nd *Ed.*, Pearson Education India, 2016.

T2. S. M. Kang, Y. Leblebici, and C. Kim, ***CMOS Digital Integrated Circuits - Analysis and Design***, 4th *Ed.*, McGraw-Hill, 2019.

Reference Books:

R1. N. H. E. Weste, D. Harris, and A. Banerjee, ***CMOS VLSI Design - A Circuits and Systems Perspective***, 4th *Ed.*, Pearson Education, 2010.

R2. R. J. Baker, ***CMOS Circuit Design, Layout & Simulation***, 3rd *Ed.*, John Wiley & Sons, 2010.

R3. D. A. Pucknell and K. Eshraghian, ***Basic VLSI Design***, 3rd *Ed.*, PHI Learning, 1995.

R4. D. A. Hodges, H. G. Jackson, and R. Saleh, ***Analysis and Design of Digital Integrated Circuits in Deep Sub-Micron Technology***, 3rd *International Ed.*, McGraw-Hill Education, 2004.

Online Resources:

1. https://nptel.ac.in/courses/117/106/117106092/: by Prof. S. Srinivasan, IIT Madras
2. https://nptel.ac.in/courses/117/106/117106093/: by 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/108/107/108107129/: by Prof. S. Dasgupta, IIT Roorkee
5. https://nptel.ac.in/courses/106/105/106105161/: by Prof. I. Sengupta, IIT Kharagpur
6. https://ocw.mit.edu/courses/6-374-analysis-and-design-of-digital-integrated-circuits-fall-2003/pages/lecture-notes/

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

CO1	Understand different methods of designing integrated circuits and systems using modern tools by following appropriate design flow and fabrication steps.
CO2	Acquire in-depth knowledge of the structure and operational analysis of MOSFET and electrical model of wire used in integrated circuits.
CO3	Design application specific CMOS inverter with optimal performance by considering its static and dynamic behavior.
CO4	Design and analyze combinational logic circuits using static and dynamic design styles.
CO5	Design and analyze sequential logic circuits using various state of the art design styles.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.

Cont'd. . .

PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO4	Understand and use different software tools for design, analysis and verification in the domain of communication, VLSI and signal processing through design, synthesis, functional, and timing simulation.
PO10	Continue to learn independently and engage in life-long learning.

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	1									1	1
CO2	3	1	2							1		1	1
CO3	3	3	2	2						1	2	1	2
CO4	3	3	2	2						1	2	1	2
CO5	3	3	2	2						1	2	1	2

Category	Code	Smart Sensors for IoT Applications	L-T-P	Credits	Marks
PEL	EC5014		3-0-0	3	100

Objectives	The objective of this course is to study the design and implementation of IoT applications using Smart Sensors, Protocols and IoT infrastructure for various applications by using sensors.
Pre-Requisites	Basic knowledge of sensors, transducer and protocols 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 & case studies.

Evaluation Scheme

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

Detailed Syllabus

Module-#	Topics	Hours
Module-1	**Smart Sensor Basics**: Introduction, Mechanical-Electronic Transitions in Sensing, Nature of Sensors, Integration of Micromachining and Microelectronics.	**7 Hours**
Module-2	**Sensor Outputs**: Introduction, Sensor Output Characteristics, Other Sensing Technologies: Capacitive, Piezoelectric, Hall Effect, Chemical Sensors, Improving Sensor Characteristics; Digital Output Sensors: Incremental Optical Encoders, Digital Techniques, Noise/Interference Aspects; Low-Power, Low-Voltage Sensors: Impedance; Analysis of Sensitivity Improvement: Thin Diaphragm, Increased Diaphragm Area.	**10 Hours**
Module-3	**Interfacing Mechanism**: Introduction, Amplification and Signal Conditioning: Instrumentation Amplifiers, SLEEPMODE Operational Amplifier, Rail-to-Rail Operational Simplifiers, Switched-Capacitor Amplifier, Barometer Application Circuit, 4-20 mA Signal Transmitter, Schmitt Trigger, Inherent Power-Supply Rejection; Separate Versus Integrated Signal Conditioning: Integrated Passive Elements, Integrated Active Elements; Digital Conversion.	**9 Hours**
Module-4	**Communications for Smart Sensors**: Introduction, Standards, Automotive Protocols: SAE J1850, CAN Protocol, Other Protocols; Industrial Networks, Protocols in Silicon: MCU With Integrated SAE J1850 and CAN, Neuronfi Chips and LonTalk Protocol, MI-Bus, Other MCUs and Protocols; Other Aspects of Network Communications: MCU Protocols, Transition Between Protocols and Systems, Protocol as a Module.	**9 Hours**
Module-5	**Case Study**: Biomimetic Materials and Structures for Sensor Applications; Smart Sensor Microsystems: Application-Dependent Design and Integration Approaches; Significance of IoT in the Agricultural Sector; Precision Agriculture Using Advanced Technology of IoT, Unmanned Aerial Vehicle, Augmented Reality and Machine Learning.	**7 Hours**
	Total	**42 Hours**

Text Books:

T1. R. Frank, ***Understanding Smart Sensors***, 3rd *Ed.*, Artech House, 2013.
T2. C. M. Kyung, H. Yasuura, Y. Liu, and Y-L. Lin, ***Smart Sensors and Systems: Innovations for Medical, Environmental, and IoT Applications***, Springer, 2017.

T3. D. Gupta, V. C. de Albuquerque, A. Khanna, and P. L. Mehta, ***Smart Sensors for Industrial Internet of Things: Challenges, Solutions and Applications***, Springer, 2021.

Reference Books:

R1. K. Iniewski, ***Smart Sensors: For Industrial Applications***, CRC Press, 2013.
R2. V. K. Awaar, P. Jugge, and P. Nayak, ***Significance of Smart Sensors in IoT Applications***, 1st *Ed.*, CRC Press, 2021.
R3. H. Yasuura, C. M. Kyung, Y. Liu, and Y. L. S. Lin, ***Smart Sensors at the IoT Frontier***, Springer, 2017.

Online Resources:

1. https://nptel.ac.in/courses/108106165: by Prof. S. Talukder, IISER Bhopal
2. https://nptel.ac.in/courses/108108147: by Prof. H. J. Pandya, IISc Bangalore

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

CO1	Explain the basics of smart sensors and integration mechanisms.
CO2	Analyze various sensing principles and characteristics of smart sensing technologies.
CO3	Articulate sensor interfacing schemes for designing smart applications.
CO4	Explain different communication protocols for smart sensors with MCUs.
CO5	Analyze and implement smart sensor applications in the real-world.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO4	Understand and use different software tools for design, analysis and verification in the domain of communication, VLSI and signal processing through design, synthesis, functional, and timing simulation.
PO5	Design and conduct experiments, analyze and interpret data, utilize programming skills for development of simulation experiments.
PO7	Understand the impact of electronics & communications in an economic, social and environment context.
PO9	Communicate effectively in a technically sound manner with a wide range of audience.
PO10	Continue to learn independently and engage in life-long learning.

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	2	1		1		2	1	2	1	1
CO2	3	2	3	1	2		1		1	2	3	2	3
CO3	3	2	3	2	3				1	3	2	3	2
CO4	3	2	3	2	3				2	3	3	3	3
CO5	3	3	2	2	2				2	3	2	2	3

Category	Code	Information Theory & Coding	L-T-P	Credits	Marks
PEL	EC5015		3-0-0	3	100

Objectives	The objective of this course is to study the fundamentals of information theory like information measure in source, encoding of source output, modeling of communication channels, error control coding and convolutional code.
Pre-Requisites	Basic knowledge of probability theory, random variables, random processes, and digital communication 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	Information Theory: Introduction, Measure of information, Information content of message, Average Information content of symbols in Long Independent sequences, Average Information content of symbols in Long dependent sequences, Mark-off Statistical Model for Information Sources, Entropy and Information rate of Mark off Sources.	**8 Hours**
Module-2	Source Coding: Encoding of the Source Output, Shannon's Encoding Algorithm Shannon-Fano Encoding Algorithm, Source coding theorem, Prefix Codes, Kraft McMillan Inequality property (KMI), Huffman Codes, Arithmetic Coding, The Lempel-Ziv Algorithm.	**9 Hours**
Module-3	Information Channels: Communication Channels, Discrete Communication channels and Channel Matrix, Joint probability Matrix, Binary Symmetric Channel, differential entropy, mutual Information, Channel Capacity, Channel Capacity of Binary Symmetric Channel, Channel capacity Theorem.	**8 Hours**
Module-4	Error Control Coding: Introduction, Examples of Error control coding, methods of Controlling Errors, Types of Errors, types of Codes, Linear Block Codes: matrix description of Linear Block Codes, Error detection & Correction capabilities of Linear Block Codes, Single error correction Hamming code. Binary Cyclic Codes: Algebraic Structure of Cyclic Codes, Encoding using an (n-k) Bit Shift register, Syndrome Calculation, BCH codes.	**9 Hours**
Module-5	Convolution Codes: Convolution Encoder, Time domain approach, Transform domain approach, Code Tree, Trellis and State Diagram, The Viterbi Algorithm.	**8 Hours**
	Total	**42 Hours**

Text Books:

T1. R. Bose, ***Information Theory, Coding and Cryptography***, 3rd *Ed.*, Tata McGraw-Hill, 2016.
T2. T. K. Moon, ***Elements of Information Theory***, 2nd *Ed.*, Wiley Interscience, 2006.

Reference Books:

R1. S. Haykin, ***Digital Communications***, Student Edition, Wiley India, 2008.
R2. N. N. Rao, ***Error Correction Coding***, Student Edition, Wiley India, 2006.

Online Resources:

1. https://nptel.ac.in/courses/117101053: by Prof. S. N. Merchant, IIT Bombay
2. https://nptel.ac.in/courses/108108168: by Prof. H. Tyagi, IISc Bangalore
3. https://nptel.ac.in/courses/108102117: by Prof. R. Bose, IIT Delhi
4. https://nptel.ac.in/courses/117108097: by Prof. P. S. Nuggehalli, IISc Bangalore

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

CO1	Describe the concepts of dependent & independent sources, measure of information, entropy, rate of information and order of a source.
CO2	Analyze the source information using different source coding techniques and different inequality schemes.
CO3	Represent the model of discrete communication channels using input, output and joint probabilities.
CO4	Design the encoding and decoding circuits for Linear Block codes, cyclic codes and BCH.
CO5	Analyze convolutional codes and apply Viterbi algorithm for determining a code word comprising of the check bits computed convolutional code.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO4	Understand and use different software tools for design, analysis and verification in the domain of communication, VLSI and signal processing through design, synthesis, functional, and timing simulation.
PO10	Continue to learn independently and engage in life-long learning.

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						2		1	1
CO2	3	2	2	1						3	1	1	1
CO3	2	2	1	2						1	1	1	1
CO4	3	1	2	1						2	2	2	2
CO5	2	2	2	1						2	1	2	2

Category	Code	Low Power Digital VLSI Design	L-T-P	Credits	Marks
PEL	EC5016		3-0-0	3	100

Objectives	The objective of this course is to understand the need of low power design, model power consumption and apply various techniques to design low power digital VLSI circuits & 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 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**: 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 the low power VLSI design and device and technology impact on low power electronics.
CO2	Explain low power circuit design techniques and energy recovery CMOS circuit method.
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 the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO4	Understand and use different software tools for design, analysis and verification in the domain of communication, VLSI and signal processing through design, synthesis, functional, and timing simulation.
PO10	Continue to learn independently and engage in life-long learning.

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
CO2	2	2	2	2						1	1	2	1
CO3	3	3	3	2						1	2	2	1
CO4	3	3	3	2						1	1	2	1
CO5	3	3	3	2						1	1	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 *Ed.*, McGraw-Hill Education, 2017.
T2. C. Liu, ***Foundations of MEMS***, 2nd *Ed.*, 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 *Ed.*, 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 *Ed.*, Wiley India, 2012.
R4. E. Gaura and R. M. Newman, ***Smart MEMS and & Sensor Systems***, 1st *Ed.*, 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 the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO4	Understand and use different software tools for design, analysis and verification in the domain of communication, VLSI and signal processing through design, synthesis, functional, and timing simulation.
PO5	Design and conduct experiments, analyze and interpret data, utilize programming skills for development of simulation experiments.
PO6	Function effectively as an individual or as a member of a multidisciplinary team with sense of ethics, integrity and social responsibility.
PO10	Continue to learn independently and engage in life-long learning.

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	2		2	1				1	2	2	2
CO2	2	2	2	2	2						2	1	2
CO3	3	2	1		3						2	2	2
CO4	3	2	3	2	2						3	1	1
CO5	3	2	1		2					2	2	1	2

Category	Code	Adaptive Signal Processing	L-T-P	Credits	Marks
PEL	EC5018		3-0-0	3	100

Objectives	The objective of this course is to study the theory of adaptive systems, recursive & non-recursive algorithms for different adaptive problems and their characteristics including applications to adaptive systems, adaptive filters, LMS and RLS.
Pre-Requisites	Knowledge of signals & systems, digital signal processing, random processes and matrix theory 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**: Adaptive Systems – Definition and characteristics, General properties, Open and Closed Loop Adaptations, Applications; The Filtering Problem, Linear Optimum Filters, Adaptive Filters, Approaches to The Development of Linear Adaptive Filters; **Wiener Filters**: Principle of Orthogonality, Minimum Mean-Square Error, Wiener–Hopf Equations, Error-Performance Surface, Canonical Form, of the Error-Performance Surface.	**8 Hours**
Module-2	**The Adaptive Linear Combiner**: Performance function, Gradient and Mean Square Error, Examples. Theory of Adaptation with Stationary Signals: Properties of the Quadratic Performance Surface, Significance of Eigen values, Eigen vectors, correlation matrix; **Searching the Performance Surface**: A simple gradient search algorithm, Stability and Rate of convergence, the learning curve; Gradient Estimation and its Effects on Adoption: The performance penalty, Variance of the gradient estimate, Maladjustment. Limitation of the Steepest-Descent Algorithm, Newton's Method.	**9 Hours**
Module-3	**Stochastic Gradient Descent**: Principles, LMS Algorithm – Signal-Flow Graph, Optimality Considerations, Applications, Natural Modes, Learning Curves, Transient Behavior and Convergence Considerations, Mis-adjustment, Efficiency; Normalized LMS Algorithm and Its Generalization: The Solution to a Constrained Optimization Problem, Stability; **Block-Adaptive Filters**: Basic Ideas, Block LMS Algorithm, Convergence Properties of the Block LMS Algorithm.	**10 Hours**
Module-4	**Least Square Method**: Statement of the Linear Least-Squares Estimation Problem, Data Windowing, Principle of Orthogonality, Minimum Sum of Error Squares, Normal Equations and Linear Least-Squares Filters; **Recursive Least-Squares (RLS) Algorithm**: Regularization, Reformulation of the Normal Equations, The Matrix Inversion Lemma, The Exponentially Weighted RLS Algorithm, Selection of the Regularization Parameter, Update Recursion for the Sum of Weighted Error Squares, Learning Curve, Efficiency.	**8 Hours**

Cont'd. . .

Module-#	Topics	Hours
Module-5	**Applications**: Adaptive Modeling and System Identification using adaptive filter, Inverse Adaptive Modeling, De-convolution, and equalization using adaptive filter.	**7 Hours**
	Total	**42 Hours**

Text Books:

T1. B. Widrow and S. D. Stearns, ***Adaptive Signal Processing***, 1st *Ed.*, Pearson Education, 2002.
T2. S. Haykin, ***Adaptive Filter Theory***, 5th *International Ed.*, Pearson Education, 2014.
T3. J. G. Proakis and D. G. Manolakis, ***Digital Signal Processing: Principles, Algorithm and Applications***, 4th *Ed.*, Prentice Hall, 2007.
T4. A. H. Sayed, ***Fundamentals of Adaptive Filtering***, 1st *Ed.*, John Wiley, 2003.

Reference Books:

R1. M. H. Hayes, ***Statistical Digital Signal Processing and Modeling***, Reprint, Wiley India, 2008.
R2. B. Farhang-Boroujen, ***Adaptive Filters: Theory and Applications***, 2nd *Ed.*, John Wiley & Sons, 2013.

Online Resources:

1. https://nptel.ac.in/courses/117105075/: by Prof. M. Chakraborty, IIT Kharagpur
2. https://nptel.ac.in/courses/108103158/:by Prof. P. K. Bora, IIT Guwahati

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

CO1	Describe adaptive signal processing systems and explain the concept of Wiener filtering.
CO2	Explain the characteristics and performance of adaptive systems.
CO3	Apply gradient based and LMS based approaches to develop adaptive systems.
CO4	Apply the concepts of least square algorithms to design adaptive systems.
CO5	Explore the applications of adaptive algorithms in system identification.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO5	Design and conduct experiments, analyze and interpret data, utilize programming skills for development of simulation experiments.
PO7	Understand the impact of electronics & communications in an economic, social and environment context.

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	2		3		1				2	2	1
CO2	2	3	2		2		2				2	1	1
CO3	3	2	1		3		1				2	1	2
CO4	3	2	3		3		2				3	1	1
CO5	3	2	1		2		2				2	1	2

Category	Code	English for Research Paper Writing	L-T-P	Credits	Marks
UCR	HS5004		2-0-0	2	100

Objectives	The objective of this course is to give learners an exposure to different aspects of research related technical writing and to help them write such matter effectively through practice.
Pre-Requisites	Basic knowledge of English grammar and the ability to read and write using the English language.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with focus on technical writing activities.

Evaluation Scheme

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

Detailed Syllabus

Module-#	Topics	Hours
Module-1	Technical Communication: Differentiating between general and technical writing, purpose of writing, plain English, mechanics of writing, elements of style. Essentials of English Grammar: basic word order, tense forms, reported speech, use of passives, conditionals, concord, clauses, common errors.	**9 Hours**
Module-2	Elements of Writing: Process writing, developing an effective paragraph, qualities of a paragraph, structuring a paragraph, types of essays, writing reports.	**5 Hours**
Module-3	Key Reading Skills: sub-skills of reading, local and global comprehension, types of technical texts, critical analysis of technical texts, note-making, the purpose and importance of literature review, evaluating literature.	**5 Hours**
Module-4	Developing Writing Skills: writing abstracts, technical letters, project reports, elements of proposal writing.	**6 Hours**
Module-5	Research and Writing: The research paper as a form of communication, Writing a review of Literature, developing a hypothesis, formulating a thesis statement, plagiarism issues.	**3 Hours**
	Total	**28 Hours**

Text Books:

T1. C. Ellison, ***McGraw-Hill's Concise Guide to Writing Research Papers***, McGraw-Hill, 2010.
T2. A. Wallwork, ***English for Writing Research Papers***, Springer, 2011.
T3. R. A. Day, ***How to Write and Publish a Scientific Paper***, 7th *Ed.*, Greenwood, 2011.

Reference Books:

R1. R. Goldbort, ***Writing for Science***, Yale University Press, 2006.
R2. N. J. Higham, ***Handbook of Writing for the Mathematical Sciences***, 2nd *Ed.*, SIAN, 1998.
R3. C. R. Kothari & G. Garg, ***Research Methodology: Methods and Techniques***, 2nd *Ed.*, New Age International Publishers, 2014.

Online Resources:

1. https://msu.edu/course/be/485/bewritingguideV2.0.pdf: Michigan State University Press, USA, Technical Writing Guide, 2007.

2. http://web.mit.edu/me-ugoffice/communication/technical-writing.pdf: Sentence Structure of Technical Writing, Nicole Kelley, MIT, USA, 2006.
3. http://www.inf.ed.ac.uk/teaching/courses/pi/2017_2018/slides/Technical-Writing-Basics.pdf: Notes from Pocketbook of Technical Writing for Engineers and Scientists by Leo Finkelstein, NY, 2007.
4. https://www.shs-conferences.org/articles/shsconf/pdf/2016/04/shsconf_erpa2016_01090.pdf: A need analysis of technical writing skill of engineering students in India, JCK Evangeline & K. Ganesh, DOI: 10.1051/ shsconf/20162601090, 2016

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

CO1	Understand the importance and application of technical communication and apply essentials of English grammar to make research writing effective.
CO2	Apply the elements of technical writing to produce effective research papers.
CO3	Develop critical reading and analysis skills of technical research papers and texts.
CO4	Develop the ability to write technical articles and effectively present the ideas.
CO5	Develop research acumen by understanding the key skills of research.

Program Outcomes Relevant to the Course:

PO6	Function effectively as an individual or as a member of a multidisciplinary team with sense of ethics, integrity and social responsibility.
PO7	Understand the impact of electronics & communications in an economic, social and environment context.
PO8	Understand intellectual property rights and overall professional & ethical responsibility.
PO9	Communicate effectively in a technically sound manner with a wide range of audience.
PO10	Continue to learn independently and engage in life-long learning.

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	3	3	1	2	3
CO2						3			3	3	1	2	3
CO3						3	1	1	3	3	2	2	3
CO4						2		1	3	3	2	2	3
CO5						2	1	3	3	3	2	2	3

Category	Code	VLSI System Design & Verification Lab	L-T-P	Credits	Marks
PCR	EC5011		0-0-4	2	100

Objectives	The objective of this course is to provide practical experience to analyze & design digital VLSI systems for real-world applications through Verilog HDL, and to make the students ready for the VLSI industry.
Pre-Requisites	Knowledge of digital electronics and digital VLSI is required.
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
	All experiments will be carried out using Verilog HDL
1	Introduction to EDA Tools for simulation and synthesis.
2	Design and verification of simple logic gates and its verification through test-bench.
3	Design and verification of combinational circuit using dataflow model.
4	Design and verification of combinational circuit using Behavioural model.
5	Design and verification of combinational circuit using Gate level model.
6	Design and verification of combinational circuit (Full Adder) using structural model.
7	Design and verification of combinational circuit (Full Subtractor) using structural model.
8	Design and verification of 4:1 Mux using vector.
9	Design and verification of combinational circuit using Mux.
10-11	Design and verification of positive & negative level sensitive Latches.
12-13	Design and verification of positive & negative edge triggered Flip Flops.
14-15	Design and verification of JK-Flip Flop using other Flip Flops.
16-17	Design and verification of asynchronous up/down counter using T-Flip Flop.
18-19	Design and verification of synchronous up/down counter using T-Flip Flop.
20-21	Design and verification of Melay based Finite State Machine.
22-23	Design and verification of Moore based Finite State Machine.

Text Books:

T1. S. Palnitkar, ***Verilog HDL : A Guide to Digital Design and Synthesis***, 2nd *Ed.*, Pearson Education, 2003.

T2. C. Spear and G. Tumbush, ***System Verilog for Verification: A Guide to Learning the Testbench Language Features***, 3rd *Ed.*, Springer, 2012.

P.T.O

Reference Books:

R1. K. Mishra, ***Advanced Chip Design: Practical Examples in Verilog***, 1st *Ed.*. Create Space Independent Pub, 2013.
R2. V. Taraate, ***Digital Logic Design Using Verilog***, 2nd *Ed.*, Springer, 2016.
R3. C. H. Roth Jr., L. K. John, B. K. Lee, ***Digital Systems Design Using Verilog***, 1st *Ed.*, Cengage Learning, 2015.
R4. D. E. Thomas, P. R. Moorby, ***The Verilog Hardware Description Language***, 5th *Ed.*, Kluwer Academic Publishers, 2002.

Online Resources:

1. https://nptel.ac.in/courses/108103179: by Prof. S. R. Ahamed, IIT Guwahati
2. http://www.ece.uah.edu/~gaede/cpe526/SystemVerilog_3.1a.pdf
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	Understand different abstraction levels of Verilog HDL.
CO3	Implement various combinational circuits and analyze their behavior.
CO4	Design several synchronous and asynchronous sequential circuits.
CO5	Analyze and construct different Finite State machines.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO4	Understand and use different software tools for design, analysis and verification in the domain of communication, VLSI and signal processing through design, synthesis, functional, and timing simulation.
PO5	Design and conduct experiments, analyze and interpret data, utilize programming skills for development of simulation experiments.

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	3	3							2	1
CO2	1	2	2	3	3						1	2	2
CO3	2	3	3	3	3						2	3	2
CO4	1	2	3	3	3						2	2	2
CO5	1	3	3	3	3						3	3	2

Category	Code	Emerging Technologies Lab	L-T-P	Credits	Marks
PCR	EC5012		0-0-4	2	100

Objectives	The objective of this laboratory course is to provide practical exposure on latest & advanced tools & technologies of current demand in various electronics & communication engineering domains so as to make the students adapt to the fast-changing world of technology and make them ready for the industry.
Pre-Requisites	Knowledge of subjects taught in previous semester is required. Additional topics (if any) required for conducting the experiments shall be taught in the lab.
Teaching Scheme	Regular laboratory experiments to be conducted under the supervision of the teacher. Demonstration will be given for each experiment.

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	To interface ADC with ARM-7.
2	To interface ZIGBEE with ARM-7 to control more external device.
3	To interface RFID module with ARM-7.
4	To interface OLED with Arduino/RaspberryPi and write a program to print temperature and humidity readings on it.
5	To interface Bluetooth with Arduino/RaspberryPi and write a program to send sensor data to smart phone using Bluetooth.
6	To interface Bluetooth with Arduino/RaspberryPi and write a program to send sensor data to smart phone using Bluetooth.
7	Write a program on Arduino/RaspberryPi to upload temperature and humidity data to thing speak cloud.
8	Write a program on Arduino/RaspberryPi to retrieve temperature and humidity data from thing speak cloud.
9	To install MySQL data base on RaspberryPi and perform basic SQL queries.
10	Write a program on Arduino/RaspberryPi to publish temperature data to MQTT broker.
11	Write a program on Arduino/RaspberryPi to subscribe to MQTT broker for temperature data and print it.
12	Write a program to create TCP server on Arduino/RaspberryPi and respond with humidity data to TCP client when requested.
13	Write a program to create UDP server on Arduino/RaspberryPi and respond with humidity data to UDP client when requested.
14	Sending message to PC through serial port by three different tasks on priority Basis.
15	Write simple applications using RTX (ARM Keil's real time operating system, RTOS).

P.T.O

Text Books:

T1. K. V. Shibu, ***Introduction to Embedded Systems***, 2nd *Ed.*, McGraw-Hill Education, 2017.
T2. R. Kamal, ***Embedded Systems - Architecture, Programming and Design***, 12th Reprint, Tata McGraw-Hill, 2007.
T3. A. Bahga and V. Madisetti, ***Internet of Things : A Hands-On Approach***, 1st *Ed.*, Universities Press, 2014.
T4. D. Hanes, G. Salgueiro, P. Grossetete, R. Barton, and J. Henry, ***IoT Fundamentals : Networking Technologies, Protocols, and Use Cases for the Internet of Things***, 1st *Ed.*, Pearson Education, 2017.

Reference Books:

R1. D. E. Simon, ***An Embedded Software Primer***, Addison Wesley, 1999.
R2. D. Kellmereit and D. Obodovski, ***The Silent Intelligence: The Internet of Things***, 1st *Ed.*, Lightning Source, 2014.
R3. M. Schwartz, ***Internet of Things with Arduino Cook book***, Packt Publishing, 2016.

Online Resources:

1. https://nptel.ac.in/courses/106105159/: by Prof. A. Basu, IIT Kharagpur
2. https://nptel.ac.in/courses/106/105/106105195/: by Prof. S. Misra, IIT Kharagpur.
3. https://nptel.ac.in/courses/108/108/108108098/: by Prof. T. V. Prabhakar, IISc Bangalore
4. https://nptel.ac.in/courses/108/105/108105064/: by Prof. A. Barua, IIT Kharagpur
5. https://nptel.ac.in/courses/106/104/106104189/: by Dr. R. Misra, IIT Patna

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

CO1	Explain the pin diagram of the ARM7 processor.
CO2	Realize and conceive different applications using the ARM7 processor.
CO3	Develop expertise on designing systems with Arduino/RaspberryPi.
CO4	Use Arduino/RaspberryPi for different practical applications.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO4	Understand and use different software tools for design, analysis and verification in the domain of communication, VLSI and signal processing through design, synthesis, functional, and timing simulation.
PO5	Design and conduct experiments, analyze and interpret data, utilize programming skills for development of simulation experiments.
PO10	Continue to learn independently and engage in life-long learning.

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	2	1					1	2	1	1
CO2	3	3	2	1						1	2	1	1
CO3	3	2	2	2	1					1	2	2	1
CO4	3	2	2	1						1	2	1	2

Category	Code	Pre-Thesis Literature Survey	L-T-P	Credits	Marks
UCR	RS7002		0-0-2	1	100

Objectives	The objective of this practical course is to enable the student to choose a particular research problem and effectively conduct literature survey to determine the latest research works done and solutions proposed by in that domain.
Pre-Requisites	Familiarity with internet search tools and a focused reading habit is required.
Teaching Scheme	The research guide of the student shall closely work with the student to determine a research problem and guide the student to read through research papers and their references. The student is expected to finally prepare a comprehensive literature survey report on the assigned research problem.

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	Importance of literature survey, reputed publishers, conferences, journals, impact factor of journals, citation count and other metrics.
2	Determine problem statement and obtain relevant publications using different search tools, subscribed Journals and various other sources.
3 - 8	Study research papers with their references, evaluate proposed solutions, and prepare a final list of relevant & quality publications to consider for literature survey.
9 - 12	Write the synopsis of studied research papers and perform systematic analysis of the proposed solutions to determine their pros and cons.
13 - 14	Compile the findings and prepare a comprehensive literature survey report.

Text Books:

T1. A. Booth, A. Sutton, M. Clowes, and M. M-St James, ***Systematic Approaches to a Successful Literature Review***, 3rd *Ed.*, Sage Publications, 2021.

Reference Books:

R1. D. Ridley, ***The Literature Review: A Step-by-Step Guide for Students***, 2nd *Ed.*, Sage Publications, 2012.

R2. D. Harris, ***Literature Review and Research Design: A Guide to Effective Research Practice***, 1st *Ed.*, Routledge Publishers, 2019.

Online Resources:

1. https://nptel.ac.in/courses/121106007/: by Dr. P. Haridoss and Prof. E. Prasad, IIT Madras
2. https://archive.nptel.ac.in/courses/110/105/110105091/: by Prof. A. Malik, IIT Kharagpur

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

CO1	Understand literature survey and collect relevant quality publications on problem statement.
CO2	Study research papers and their references in a systematic manner in the research area.
CO3	Perform scientific comparison between the proposed approaches of relevant publications.

Cont'd. . .

CO4	Compile the findings of literature survey and write a comprehensive literature review.

Program Outcomes Relevant to the Course:

PO5	Design and conduct experiments, analyze and interpret data, utilize programming skills for development of simulation experiments.
PO7	Understand the impact of electronics & communications in an economic, social and environment context.
PO8	Understand intellectual property rights and overall professional & ethical responsibility.
PO9	Communicate effectively in a technically sound manner with a wide range of audience.
PO10	Continue to learn independently and engage in life-long learning.

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	2	1	1	2
CO2					2		1	2	2	3	1	1	2
CO3					2		1	3	3	3	1	1	3
CO4					3		2	3	3	3	2	2	3

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

Objectives	The objective of this course is to understand and explore the fabrication flow and IC integration processes of semiconductor devices and semiconductor ICs.
Pre-Requisites	Basic knowledge on semiconductor devices and digital VLSI design is desired.
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**: 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 and closed tube diffusion, Diffusion sources; **Ion Implantation**: Basic process, Ion Implantation Systems, Ion penetration & 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. K. Gandhi, ***VLSI Fabrication Principles: Silicon and Gallium Arsenide***, 2nd *Ed.*, Wiley, 1994.
T2. S. M. Sze, ***VLSI Technology***, 2nd *Ed.*,McGraw-Hill Education, 2017.

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 *Ed.*, 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 *Ed.*, 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 the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO10	Continue to learn independently and engage in life-long learning.

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		2								1
CO2	2	2	2								1	1	1
CO3	2	2	2								2	1	1
CO4	1	3	3							1	1	2	1
CO5	2	3	3							1	1	2	1

Category	Code	Embedded C Applications	L-T-P	Credits	Marks
PEL	EC5037		3-0-0	3	100

Objectives	The objective of this course is to learn the in-depth concepts of embedded C programming techniques, GPIO, peripheral operations, and serial communication standards by leveraging industry standard MCUs.
Pre-Requisites	Knowledge of computer programming and basic electronics is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with focus on design & 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	**C Programming**: Names, Types, and Type declarations, Storage classes, Linkage and Scope, Character constants, Arrays, Other types, Operators and Expressions, Increment and Decrement operators, Precedence and Associativity, Program Flow and Control, Functions, Recursion, Demonstration and practice.	**8 Hours**
Module-2	**Advanced Topics in C**: Pointers, Multidimensional arrays, Structures, Input and Output, Memory Management, Miscellaneous functions, Demonstration and practice.	**9 Hours**
Module-3	**Introduction to STM MCU**: Principal MCU components, Bit Serial Ports, S/W for MCU programming, STM project development, Memory-Mapped peripherals, Core memory addresses, Peripheral memory addresses; HAL_GPIO module – GPIO pin hardware, LED Test demonstration, Enabling multiple outputs, Push-Button test; Clock speed – Setting the PIN clock speed, Demonstration and practice.	**9 Hours**
Module-4	**Interrupts, Timer and UART**: NVIC specifications; Interrupt Process – External Interrupts; STM timer peripherals, Timer configurations, LED test programs; UART & USARTs – Transmit and Receive programming, Demonstration and practice.	**8 Hours**
Module-5	**ADC and PWM**: ADC Functions – ADC module with HAL, Conversion modes, Channels, Groups, and Ranks, Demonstrations; General purpose timer PWM signal generation, Timer H/W architecture, PWM signals with HAL; Introduction to I2C, SPI, Demonstration and practice.	**8 Hours**
	Total	**42 Hours**

Text Books:

T1. P.S. Deshpande and O. G. Kakde, ***C and Data Structures***, 1st *Ed.*, Dreamtech Press, 2003.
T2. E. Balagurusamy, ***Programming in ANSI C***, 7th *Ed.*, McGraw-Hill Education, 2017.
T3. C. Noviello, ***Mastering STM32***, 2nd *Ed.*, Leanpub, 2022.

Reference Books:

R1. K. R. Venugopal and S. R. Prasad, ***Mastering C***, 3rd *Ed.*, McGraw-Hill Education, 2017.
R2. T. V. Sickle, ***Programming Microcontrollers in C***, 2nd *Ed.*, LLH Publishing, 2001.

R3. M. A. Mazidi, S. Chen, and E. Ghaemi, ***STM32 Arm Programming for Embedded Systems (Using C Language with STM32 Nucleo)***, 1st *Ed.*, Microdigitaled, 2018.

Online Resources:

1. https://nptel.ac.in/courses/106104128: By Prof. S. Nandakumar, IIT Kanpur
2. https://nptel.ac.in/courses/106105171: By Prof. A. Basu, IIT Kharagpur
3. https://nptel.ac.in/courses/106105193: By Prof. I. Sengupta and Prof. K. Datta, IIT Kharagpur
4. https://nptel.ac.in/courses/108105102: By Prof. Santanu Chattopadhyay, IIT Kharagpur
5. https://www.st.com/content/st_com/en/support/learning/stm32-education.html

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

CO1	Explain the concepts of C programming required to program any MCU.
CO2	Develop advanced C programming skills for embedded system applications.
CO3	Program an Industry standard MCU using embedded C programming.
CO4	Describe interrupts, timers, and UART operations for real-time applications.
CO5	Analyze the ADC and PWM operations using embedded C programming techniques.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO4	Understand and use different software tools for design, analysis and verification in the domain of communication, VLSI and signal processing through design, synthesis, functional, and timing simulation.
PO5	Design and conduct experiments, analyze and interpret data, utilize programming skills for development of simulation experiments.
PO10	Continue to learn independently and engage in life-long learning.

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	2	2					2	2	2	1
CO2	2	2	3		1					1	2	3	1
CO3	3	2	2	2	1						2	2	2
CO4	3	2	2	1						1	3	2	1
CO5	2	2	1	1						1	2	2	1

Category	Code	Image Processing & Computer Vision	L-T-P	Credits	Marks
PEL	EC6003		3-0-0	3	100

Objectives	The objective of this course is to study the fundamentals, transformation, filtering, restoration, compression, segmentation, description and recognition of images and their applications in various real life problems.
Pre-Requisites	Knowledge of digital signal processing, matrices, convolution, 1-D filters, and Fourier transform 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	**Image Fundamentals**: Steps in digital image processing, sampling and quantization, relationship between pixels, imaging geometry; Image Enhancement: Some basic gray level transformations, Histogram equalization and matching; Filtering in spatial domain, Smoothing and sharpening spatial filters.	**8 Hours**
Module-2	**Filtering in Frequency Domain**: Preliminary concepts, 2D DFT and its properties, basic filtering in the frequency domain, smoothing and sharpening frequency domain filters, Homomorphic filtering; Image Restoration: Noise models, Restoration in the presence of noise only-spatial filtering, Estimating the degradation functions, Inverse filtering.	**8 Hours**
Module-3	**Color Image Processing**: Color fundamentals, Color models, Color conversions, Pseudo-color processing, Wavelets and Multi-resolution Processing: Multi-resolution expansions, wavelet transforms in one and two dimension.	**8 Hours**
Module-4	**Image Compression**: Image compression models, Some basic compression methods, Loss-less and Lossy compression; Morphological Image Processing: Dilation and erosion, Opening and closing, Some basic morphological algorithms; Image Segmentation: Detection of discontinuities, Point line and edge detection, Thresholding, Region based segmentation.	**9 Hours**
Module-5	**Representation & Description**: Chain codes, Signatures, Skeletons, Boundary descriptors, Shape numbers, Fourier descriptors, Regional descriptors, Principal components for description; Object Recognition: Recognition based on decision-theoretic methods, matching, Optimum statistical classifiers, Bayes classifier, Perceptron for two pattern classes (linearly and nonlinearly separable).	**9 Hours**
	Total	**42 Hours**

Text Books:

T1. R. C. Gonzalez, ***Digital Image Processing***, 3rd *Ed.*, Pearson Education, 2008.
T2. S. Sridhar, ***Digital Image Processing***, 2nd *Ed.*, Oxford University Press, 2014.

Reference Books:

R1. A. K. Jain, ***Fundamentals of Digital Image Processing***, 2nd *Ed.*, Prentice Hall, 2004.
R2. A. L. Bovik, ***Handbook of Image and Video Processing***, 3rd *Ed.*, Academic Press, 2017.

Online Resources:

1. https://nptel.ac.in/courses/117105079/: by Prof. P. K. Biswas, IIT Kharagpur
2. https://nptel.ac.in/courses/117105135/: by Prof. P. K. Biswas, IIT Kharagpur
3. https://nptel.ac.in/courses/106105032/: by Dr. G. Harit, IIT Kharagpur
4. https://nptel.ac.in/courses/117/104/117104069/: by Prof. S. Gupta, IIT Kanpur

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

CO1	Analyze image acquisition and perform basic image processing operations.
CO2	Apply image enhancement in both spatial and frequency domains for noise removal and better quality improvement.
CO3	Analyze color imaging, color models, color image processing and multi-resolution processing.
CO4	Apply image compression techniques for storage and transmission purpose.
CO5	Interpret Image segmentation and its use in object detection and recognition.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO4	Understand and use different software tools for design, analysis and verification in the domain of communication, VLSI and signal processing through design, synthesis, functional, and timing simulation.
PO5	Design and conduct experiments, analyze and interpret data, utilize programming skills for development of simulation experiments.
PO6	Function effectively as an individual or as a member of a multidisciplinary team with sense of ethics, integrity and social responsibility.
PO10	Continue to learn independently and engage in life-long learning.

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	1				1	1		
CO2	2	1	1	1	2	1				1	1	1	1
CO3	1	1	2	1	2	1				1	2	2	1
CO4	1	2	2	2	1	1				1	2	1	1
CO5	1	2	2	1	2	1				2	2	2	2

Category	Code	Analog & Mixed Signal Design	L-T-P	Credits	Marks
PEL	EC6004		3-0-0	3	100

Objectives	The objective of this course is to study, analyze, and build analog integrated circuits for various applications, apply Op-Amp circuits for designing the comparators, frequency compensation techniques for amplifiers and analyze operations of VCOs & different types of PLLs and design them.
Pre-Requisites	Knowledge of analog electronic circuits and electrical network analysis 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	**Analog Design**: General Concepts, Levels of Abstraction, Robust Analog Design; 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-2	**Differential Amplifiers**: Single-Ended and Differential Operation, Basic Differential Pair, Qualitative Analysis, Quantitative Analysis, Common-Mode Response, Differential Pair with MOS Loads, Gilbert Cell.	**8 Hours**
Module-3	**Passive and Active Current Mirrors**: Basic Current Mirrors, Cascode Current Mirrors, Active Current Mirrors, Large-Signal Analysis, Small-Signal Analysis, Common-Mode Properties; Bandgap References: General Considerations, Supply-Independent Biasing, Temperature-Independent References, Negative-TC Voltage, Positive-TC Voltage, Bandgap Reference.	**9 Hours**
Module-4	**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.	**8 Hours**
Module-5	**Frequency Response of Amplifiers**: General Considerations, Miller Effect, Association of Poles with Nodes, Common-Source Stage, Source Followers, Common-Gate Stage, Cascode Stage, Differential Pair; Phase-Locked Loops-Concept of Voltage controlled Oscillator, Phase locked loop terminologies, Types of PLL, PFD/CP non-idealities, Jitter, Delay Locked Loop, Applications.	**9 Hours**
	Total	**42 Hours**

Text Books:

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

Reference Books:

R1. P. R. Gray, P. J. Hurst, S. H. Lewis, and R. G. Meyer, ***Analysis and Design of Analog Integrated Circuits***, 5th *Ed.*, John Wiley & Sons, 2009.

R2. B. Razavi, ***Fundamentals of Microelectronics***, 1st *Ed.*, John Wiley & Sons, 2008.
R3. T. C. Carusone, D. Johns, and K. Martin, ***Analog Integrated Circuit Design***, 2nd *Ed.*, 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/117/101/117101105/: 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/108/106/108106105/: by Prof. S. Aniruddhan, IIT Madras
4. https://nptel.ac.in/courses/108/106/108106068/: by Prof. K. R. Rao, IIT Madras
5. https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-374-analysis-and-design-of-digital-integrated-circuits-fall-2003/

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	Compute the performance parameters and design single-stage amplifiers for various applications.
CO3	Design passive and active current mirrors and band-gap reference circuits.
CO4	Design Op-Amps to meet required performance metrics for specific applications.
CO5	Analyze and design different types of Phase-Locked Loops.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO4	Understand and use different software tools for design, analysis and verification in the domain of communication, VLSI and signal processing through design, synthesis, functional, and timing simulation.
PO10	Continue to learn independently and engage in life-long learning.

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	1		2						1	1	1
CO2	3	3	2	1	2						1	1	2
CO3	3	3	2	2	3					1	2	1	2
CO4	3	3	3	2	3					1	2	1	2
CO5	3	3	2	2	2					1	2	1	2

Category	Code	Industrial IoT	L-T-P	Credits	Marks
PEL	EC6005		3-0-0	3	100

Objectives	The objective of this course is to study the design and implementation of IoT applications, industrial automation, and automation environments through a network by connecting the sensors to the cloud network and extracting data from the cloud to the connected devices.
Pre-Requisites	Knowledge of knowledge of IoT protocols and architecture is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required; sessions are planned to be interactive with focus on on theory and 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	Technical Requirements of Industrial IoT: IoT Background, IoT key technologies, What is the I-IoT? Use cases of the IIOT, IoT and IIoT Similarities and difference, IoT Analytics and AI, Industry environments and scenarios covered by IIoT.	**8 Hours**
Module-2	Industrial Process and Devices Technical requirements: The Industrial Process, The CIM Pyramid, The I-IoT data flow.	**7 Hours**
Module-3	Industrial Data Flow and Devices Technical requirements: The I-IoT data flow in the factory Measurements and the actuator chain, Controllers, Industrial Protocols, SCADA, ERP and MES.	**8 Hours**
Module-4	Implementing the Industrial IoT Data Flow Discovering OPC: OPC Classic, OPC UA. Understanding the I-IoT edge, Implementing the IIoT data flow.	**9 Hours**
Module-5	Implementing a Cloud Industrial IoT solution with AWS Technical requirements: AWS Architecture, Registering for AWS, IoT Core, Storing Data, AWS analytics; Understanding Diagnostics, Maintenance, and Predictive Analytics: Technical Requirements, The different classes of analytics, I-IoT analytics technologies, Building I-IoT analytics, Understanding the role of the infrastructure Deploying analytics.	**10 Hours**
	Total	**42 Hours**

Text Books:

T1. G. Veeneri and A. Capasso, ***Hands-On Industrial Internet of Things***, 1st *Ed.*, Packt Publishing, 2018.
T2. I. Butun, ***Industrial IoT***, 1st *Ed.*, Springer, 2020.
T3. A. Suresh, M. nandagopal, P. Raj, E. A. Neeba, and J-W. Lin, ***Industrial IoT Application Architectures and Use Cases***, 1st *Ed.*, CRC Press, 2020.

Reference Books:

R1. O. Hersent, D. Boswarthick, and O. Elloumi, ***The Internet of Things - Key applications & Protocols***, Wiley, 2012.
R2. A. Gichrist, ***Industry 4.0: The Industrial Internet of Things***, 1st *Ed.*, Apress, 2017.

Online Resources:

1. https://nptel.ac.in/courses/106105195/: by Prof. S. Misra, IIT Kharagpur.
2. https://nptel.ac.in/courses/106/105/106105166/: by Prof. S. Misra, IIT Kharagpur
3. https://nptel.ac.in/courses/108/105/108105064/: by Prof. A. Barua, IIT Kharagpur

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

CO1	Explain the fundamental components and technologies of Industrial IoT.
CO2	Analyze the Industrial process and devices.
CO3	Design network protocols & software layers for data flow in an industrial set up.
CO4	Implement data flow from the edge to the cloud by means of OPC UA and Node-Red.
CO5	Develop IIoT solutions on cloud and perform data analytics for real life applications.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO5	Design and conduct experiments, analyze and interpret data, utilize programming skills for development of simulation experiments.
PO9	Communicate effectively in a technically sound manner with a wide range of audience.
PO10	Continue to learn independently and engage in life-long learning.

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		1						1	1	1
CO2	3	2	3		2						3	1	3
CO3	3	3	3		3				2	2	3	2	3
CO4	3	3	3		3				2	2	3	3	3
CO5	3	3	3		3				1	2	3	3	3

Category	Code	Fiber Optic Communication	L-T-P	Credits	Marks
PEL	EC6006		3-0-0	3	100

Objectives	The objective of this course is to study the design and analysis of modern optical communication systems for providing worldwide connectivity.
Pre-Requisites	Knowledge of physics, electronics, and networks 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**: The basic communications system, Nature of light, Advantages of fibers, Applications of Fiber optic communications; Optical Fibers and Connection losses: Terminology of light, Classification of fibers, SI fibers: NA and Multipath dispersion, Attenuation and Dispersion, Graded index fiber, V-number, Connector and splice, Losses during coupling between source to fiber, fiber to fiber.	**9 Hours**
Module-2	**Optical Sources & Amplifiers**: LEDs, LED operating characteristics, LASER principles, LASER diodes and operating Characteristics, Fiber Lasers, Optical Amplifiers; Light Detectors: Principles of Photo detection, Photomultiplier, Optical Detectors, PIN photodiode and Avalanche Photodiode.	**9 Hours**
Module-3	**Distribution Networks & Components**: Distribution Networks, Directional Couplers, Star couplers, Switches, Optical Isolator, WDM, Fiber Bragg Gratings, Arrayed-waveguide Gratings, MEMs Switches, Attenuator, Circulator, Polarization Controller.	**8 Hours**
Module-4	**Modulation**: LED Modulation and circuits, LASER-Diode Modulation and circuits, Analog-Modulation formats, Digital modulation formats, Electro-absorption modulators, Optic-Heterodyne Receivers.	**8 Hours**
Module-5	**Optical Fiber Transmitters & Receivers**: Introduction, Direct intensity modulation, Direct optical modulation, Digital communication system, Basic components of a digital fiber optic communication receiver, Coherent optical fiber detection system; System Design: Design of analog systems, Design of digital systems.	**8 Hours**
	Total	**42 Hours**

Text Books:

T1. J. C. Palais, ***Fiber Optic Communications***, 5th *Ed.*, Pearson Education, 2013.
T2. S. C. Gupta, ***Textbook on Optical Fiber Communication and its Applications***, PHI Learning, 2012.

Reference Books:

R1. R. P. Khare, ***Fiber Optics and Optoelectronics***, Oxford University Press, 2008.
R2. G. Keiser, ***Optical Fiber Communications***, 4th *Ed.*, Tata McGraw-Hill, 2013.
R3. J. M. Senior, ***Optical Fiber Communication: Principles and Practice***, 3rd *Ed.*, Pearson Education, 2013.

R4. H. Kolimbiris, ***Fiber Optics Communications***, Pearson Education, 2006.

Online Resources:

1. https://nptel.ac.in/courses/108/104/108104113/: by Dr. P. Kumar, IIT Kanpur
2. https://nptel.ac.in/courses/117/101/117101002/: by Prof. R. K. Shevgaonkar, IIT Bombay
3. https://nptel.ac.in/courses/117104127/: by Dr. P. Kumar, IIT Kanpur

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

CO1	Describe the concepts of fiber optic communications, optical fiber classifications, attenuation, dispersion, and connection losses.
CO2	Explain and design different types of optical sources, amplifiers, and detectors.
CO3	Describe and analyze distribution networks and its various components.
CO4	Analyze the performance of modulation process, circuits for analog and Digital OFC systems.
CO5	Design optical transmitters and receivers as per application requirements.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO4	Understand and use different software tools for design, analysis and verification in the domain of communication, VLSI and signal processing through design, synthesis, functional, and timing simulation.
PO5	Design and conduct experiments, analyze and interpret data, utilize programming skills for development of simulation experiments.
PO7	Understand the impact of electronics & communications in an economic, social and environment context.
PO9	Communicate effectively in a technically sound manner with a wide range of audience.
PO10	Continue to learn independently and engage in life-long learning.

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		1				1	1	1
CO2	3	3	2	2	2		1			1	2	2	2
CO3	3	3	2	2	2		1		1	1	2	2	2
CO4	3	3	2	3	2		1			2	2	2	2
CO5	3	3	3	1	2		1		2	2	2	2	2

Category	Code	Advanced Microprocessors & Microcontrollers	L-T-P	Credits	Marks
PEL	EC6007		3-0-0	3	100

Objectives	The objective of this course is to study different advanced microprocessors & microcontrollers, develop assembly level programs as per industry requirements and interface them with other external devices.
Pre-Requisites	Knowledge of digital electronics circuits and 8085 Microprocessor is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required; sessions are planned to be interactive with focus on theory and 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	**Intel 8086 Microprocessor**: Features, Internal Architecture, Pin Architecture, Physical Address Generation, Memory Segmentation, Minimum and Maximum mode, Memory Interfacing, Interrupts, Addressing Modes., Instructions.	**8 Hours**
Module-2	**Intel 80286, 80386, 80486 Processors**: Features, Internal Architecture, Pin Description of 80286. Features, Internal Architecture, Pin Architecture, Operating Modes, Paging Mechanism of 80386; Salient Features and Architecture of 80486.	**9 Hours**
Module-3	**Intel Arithmetic Coprocessors 80X87**: Internal Pin, Block Architecture, Instruction Set & Programming of 80287, Features and Architecture of 80387; **Pentium Processors**: Features, System Architecture, Signal Pins, Memory Systems & instructions of 80586 (Pentium-I), Introduction to Pentium II, III, IV processors.	**9 Hours**
Module-4	**Intel 8051 Microcontroller**: Features, Architecture, Pin Configuration, Memory Organization, Instruction set, Addressing Modes Programming, Interrupts, Communication Interfaces, Interfacing with DAC, ADC, Stepper Motor.	**8 Hours**
Module-5	**ARM Processor**: Introduction to RISC Processors, Overview of ARM Architecture, Registers, Modes, ARM Instruction Set, Assembly Programming.	**8 Hours**
	Total	**42 Hours**

Text Books:

T1. A. K. Ray and K. M. Bhurchandani, ***Advanced Microprocessors and Peripherals***, 2nd *Ed.*, Tata McGraw-Hill, 2006.

T2. B. B. Brey, ***The Intel Microprocessors (Architecture, Programming, and Interfacing)***, 8th *Ed.*, Pearson Education, 2009.

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

T4. J. Yiu, ***The Definitive Guide to ARM Cortex-M0 and Cortex-M0+ Processors***, 2nd *Ed.*, Elsevier Science & Technology, 2015.

T5. A. N. Sloss, D. Symes, and C. Wright, ***ARM System Developers Guide***, Elsevier, 2012.

Reference Books:

R1. M. A. Mazidi, ***ARM Assembly Language Programming & Architecture***, 2nd *Ed.*, MicroDigitaled.com, 2016.
R2. A. N. Kani, ***8086 Microprocessors and its Applications***, 2nd *Ed.*, Tata McGraw-Hill, 2017.
R3. K. J. Ayala, ***The 8051 Microcontroller***, 3rd *Ed.*, Cengage Learning, 2007.

Online Resources:

1. https://nptel.ac.in/courses/108105102: by Prof. S. Chattopadhyay, IIT Kharagpur
2. https://nptel.ac.in/courses/106108100/: by Prof. K. Kumar, IISc Bangalore
3. https://nptel.ac.in/courses/117104072: by Dr. S. P. Das, IIT Kanpur
4. https://archive.nptel.ac.in/courses/117106111/: by Dr. M. Sankaran, IIT Madras

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

CO1	Develop programming skills for various applications using 8086 Microprocessor.
CO2	Explain the architecture, functionality and programming of advanced microprocessors.
CO3	Explore Intel co-processors and Pentium processors for application based programming.
CO4	Design 8051 microcontrollers interfacing with external devices for different applications.
CO5	Design, formulate and implement advanced MPMC based systems using ARM processors.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO4	Understand and use different software tools for design, analysis and verification in the domain of communication, VLSI and signal processing through design, synthesis, functional, and timing simulation.
PO5	Design and conduct experiments, analyze and interpret data, utilize programming skills for development of simulation experiments.

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	1	3						2	3	3
CO2	2	3	2	1	3						2	3	3
CO3	2	3	2	1	3						3	3	3
CO4	2	3	2	1	3						3	3	3
CO5	2	2	2	1	3						3	3	3

Category	Code	IC Design Testing	L-T-P	Credits	Marks
PEL	EC6008		3-0-0	0	100

Objectives	The objective of this course is to study the VLSI testing techniques for the design and analysis of digital VLSI circuits & systems.
Pre-Requisites	Knowledge on digital electronic circuits, MOSFET, and digital VLSI 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	**Fault Modeling**: Defects, Errors, and Faults, Functional Versus Structural Testing, Levels of Fault Models, Different Fault Models, Single Stuck-at Fault, Fault Equivalence, Equivalence of Single Stuck-at Faults, Fault Collapsing, Fault Dominance and Checkpoint Theorem.	**8 Hours**
Module-2	**Combinational Circuit Test Generation**: Algorithms and Representations, Structural vs. Functional Test, Definition of Automatic Test-Pattern Generator, Search Space Abstractions, Algorithm Completeness, ATPG Algebras, Algorithm Types, Redundancy Identification (RID), Testing as a Global Problem, Definitions, Significant Combinational ATPG Algorithms, D-Calculus and D-Algorithm (Roth), PODEM (Goel), FAN (Fujiwara and Shimino), Test Generation Systems.	**9 Hours**
Module-3	**Sequential Circuit Test Generation**: ATPG for Single-Clock Synchronous Circuits, A Simplified Problem, Time-Frame Expansion Method, Use of Nine-Valued Logic, Development of Time-Frame Expansion Methods, Approximate Methods, Implementation of Time-Frame Expansion Methods, Complexity of Sequential ATPG, Cycle-Free Circuits, Cyclic Circuits, Clock Faults and Multiple-Clock Circuits, Asynchronous Circuits, Simulation-Based Sequential Circuit ATPG, CONTEST Algorithm.	**8 Hours**
Module-4	**I_{DDQ} Test**: Motivation, Faults Detected, Testing Methods, Fault Coverage Metrics, Test Vector Selection from Stuck-Fault Vector Sets, Instrumentation Problems, Current Limit Setting, Testing Effectiveness, Limitations, Delta I_{DDQ} Testing, I_{DDQ} Built-In Current Testing, I_{DDQ} Design for Testability.	**8 Hours**
Module-5	**Design for Testability**: Digital DFT and Scan Design - Ad-Hoc DFT Methods, Scan Design, Scan Design Rules, Tests for Scan Circuits; Built-in Self-Test - The Economic Case for BIST, Chip/Board Area Cost vs. Tester Cost & System Downtime Cost, Random Logic BIST Definitions, BIST Process, BIST Pattern Generation (Pseudo-Random Pattern Generation-LFSR), BIST Response Compaction (Transition Count Response Compaction, LFSR for Response Compaction, Modular LFSR Response Compaction), Built-in Logic Block Observers, Test-Per-Clock BIST Systems, Test-Per-Scan BIST Systems.	**9 Hours**
	Total	**42 Hours**

Text Books:

T1. M. L. Bushnell and V. D. Agarwal, ***Essentials of Electronic Testing for Digital, Memory and Mixed Signal VLSI Circuits***, Kluwer Academic Publishers, 2004.
T2. Z. Navabi, ***Digital System Test & Testable Design: Using HDL Model & Architecture***, Springer, 2010.

Reference Books:

R1. M. Abramovici, M. A. Breuer, and A. D. Friedman, ***Digital Systems and Testable Design***, Jaico Publishing House, 2001.
R2. L-T. Wang, C-W. Wu, X. Wen, ***VLSI Test Principles and Architectures***, Morgan Kaufmann, 2006.
R3. P. K. Lala, ***Digital Circuit Testing and Testability***, Academic Press, 2002.
R4. N. K. Jha and S. G. Gupta, ***Testing of Digital Systems***, Cambridge University Press, 2003.

Online Resources:

1. https://nptel.ac.in/courses/117105137: by Prof. S. Chattopadhyay, IIT Kharagpur
2. https://nptel.ac.in/courses/117103125: by Dr. S. Biswas and others, IIT Guwahati
3. https://ocw.tudelft.nl/courses/vlsi-test-technology-reliabillity/
4. http://www.ee.ncu.edu.tw/~ares/course_VLSI_Testing.htm

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

CO1	Explain fault modeling of VLSI circuits and systems.
CO2	Design various testing techniques of combinational VLSI circuits.
CO3	Design various testing technique of sequential VLSI circuits.
CO4	Analyze and design I_{DDQ} testing method for different VLSI circuits.
CO5	Design VLSI circuits for testability using BIST and scan-based techniques.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO4	Understand and use different software tools for design, analysis and verification in the domain of communication, VLSI and signal processing through design, synthesis, functional, and timing simulation.
PO5	Design and conduct experiments, analyze and interpret data, utilize programming skills for development of simulation experiments.
PO6	Function effectively as an individual or as a member of a multidisciplinary team with sense of ethics, integrity and social responsibility.

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
CO2	2	3	3	2	3	1					2	1	1
CO3	2	2	3	2	2	1					2	1	1
CO4	3	3	3	3	2	1				1	2	1	2
CO5	3	3	3	2	3	1				1	2	1	1

Category	Code	Advanced Mobile Communication	L-T-P	Credits	Marks
PEL	EC6009		3-0-0	0	100

Objectives	The objective of this course is to study advanced wireless communications, signal processing and state-of-the-art techniques of mobile communications networks.
Pre-Requisites	Knowledge of wireless communication systems and mobile communication 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	**Wireless Communications and Diversity**: Fast Fading Wireless Channel Modeling, Rayleigh/Ricean Fading Channels, BER Performance in Fading Channels, Diversity modeling for Wireless Communications, BER Performance Improvement with diversity, Types of Diversity - Frequency, Time, Space; Broadband Wireless Channel Modeling: WSSUS Channel Modeling, RMS Delay Spread, Doppler Fading, Jakes Model, Autocorrelation, Jakes Spectrum.	**11 Hours**
Module-2	**Cellular Communications**: Introduction to Cellular Communications, Frequency reuse, Multiple Access Technologies, Cellular Processes - Call Setup, Handover, Tele-traffic Theory.	**7 Hours**
Module-3	**OFDM**: Introduction to OFDM, Principles of OFDM Wireless Communication, Channel Estimation, Multicarrier Modulation and Cyclic Prefix, Channel model and SNR performance, OFDM Issues - PAPR Frequency and Timing Offset Issues, OFDMA, SCFDMA.	**8 Hours**
Module-4	**MIMO**: Introduction, Principles of MIMO Wireless Communication, MIMO Channel Capacity, SVD and Eigen modes of the MIMO Channel, MIMO Spatial Multiplexing - BLAST, MIMO Diversity - Alamouti, OSTBC, MRT, MIMO - OFDM, Introduction to Massive MIMO.	**8 Hours**
Module-5	**UWB (Ultrawide Band)**: UWB Definition and Features, UWB Wireless Channels, UWB Data Modulation, Uniform Pulse Train, Bit-Error Rate Performance of UWB; 5G Technology: Introduction to 5G, 5G air interface requirements, Overview of antenna technologies used in 5G, Overview resource allocation in 5G networks.	**8 Hours**
	Total	**42 Hours**

Text Books:

T1. T. Rappaport, ***Wireless Communications: Principles and Practice***, 2nd *Ed.*, Prentice Hall, 2009.
T2. E. Biglieri, ***MIMO Wireless Communications***, 3rd *Ed.*, Cambridge University Press, 2010.

Reference Books:

R1. D. Tse and P. Viswanath, ***Fundamentals of Wireless Communications***, Cambridge University Press, 2005.
R2. A. Goldsmith, ***Wireless Communications***, Cambridge University Press, 2005.

R3. F. Monserrat and P. Marsch, ***5G Mobile and Wireless Communications Technology***, Cambridge University Press, 2016.
R4. A. Paulraj, ***Introduction to Space-Time Wireless Communications***, Cambridge University Press, 2003.
R5. J. G. Proakis, ***Digital Communications***, 5th *Ed.*, McGraw-Hill, 2008.

Online Resources:

1. https://nptel.ac.in/courses/117104115: by Prof. A. K. Jagannatham, IIT Kanpur
2. https://nptel.ac.in/courses/106106167: by Prof. R. D. Koilpillai, IIT Madras
3. https://nptel.ac.in/courses/108105134: by Prof. S. S. Das, IIT Kharagpur
4. https://nptel.ac.in/courses/108105179: by Prof. A. K. Dutta, IIT Kharagpur

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

CO1	Describe current and upcoming technologies wireless communications for broadband wireless networks.
CO2	Explain the fundamentals of cellular communication systems.
CO3	Enhance OFDM performance using MIMO and OFDMA techniques.
CO4	Explore the use of MIMO in 5G and its techniques for mobile communication.
CO5	Apply OFDM-based standards such as 4G LTE, 5G, and Wi-Fi in the real world.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO4	Understand and use different software tools for design, analysis and verification in the domain of communication, VLSI and signal processing through design, synthesis, functional, and timing simulation.
PO5	Design and conduct experiments, analyze and interpret data, utilize programming skills for development of simulation experiments.
PO6	Function effectively as an individual or as a member of a multidisciplinary team with sense of ethics, integrity and social responsibility.
PO7	Understand the impact of electronics & communications in an economic, social and environment context.
PO9	Communicate effectively in a technically sound manner with a wide range of audience.
PO10	Continue to learn independently and engage in life-long learning.

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	2	1	1	1		1	1	1	2	3
CO2	2		3	2	1	1	2		1	1	1	2	3
CO3	3		3	2	2	1	1		1	1	2	2	3
CO4	3		3	2	2	1	1		1	1	2	2	3
CO5	2		3	2	1	1	1		1	1	1	2	3

Silicon University

Department of Electronics Engineering
SiliconTech, Bhubaneswar

This document has been typeset using LaTeX 2ε