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NATIONAL INSTITUTE OF SCIENCE AND TECHNOLOGY (Autonomous)
Approved by AICTE, New Delhi, Affiliated to BPUT: Rourkela
INSTITUTE PARK, PALLUR HILLS, BERHAMPUR, ODISHA - 761008

Year 2022-23 onward

6th Semester

B. Tech. Programme Structure

Electronics and Communication Engineering [ECE]

NIST Institute of Science and Technology (Autonomous)
Institute Park, Pallur Hills, Berhampur, Odisha, INDIA. Pin: 761008.
Web: www.nist.edu

Sixth Semester					
Theory					
Sl. No.	**Category**	**Subject Code**	**Subject Name**	**L-T-P**	**Credit**
1	BSC	22CM6BS01T	Optimization Engineering	3-1-0	4
2	PCC	22EC6PC02T	PCC-9: Microwave Engineering	3-0-0	3
3	PCC	22EC6PC03T	PCC-10: Digital VLSI Design	3-0-0	3
4	PEC	**Professional Elective-3:**			
		22EC6PE01T	Machine Learning	3-0-0	3
		22EC6PE02T	Adaptive Signal Processing		
		22EC6PE03T	Digital Image Processing		
		22EC6PE04T	FPGA Based Design		
		Professional Elective-4:		3-0-0	3
5	PEC	22EC6PE05T	5G and Future Communications		
		22EC6PE06T	Wireless Sensor Networks		
		22EC6PE07T	Satellite Communication		
		22EC6PE08T	Analog VLSI Design		
6	OEC	**Open Elective-3 (For ECE Branch Students):**			**3**
		19EE6OE01T	Electrical Energy Utilization		
		19EE6OE02T	Introduction to Robotics and Autonomous Vehicles		
		19CE6OE01T	Plastic Waste Management		
		19CE6OE02T	Environment and Safety Engineering		
		19ME6OE01T	Introduction to Hybrid Vehicles		
		19ME6OE02T	Engineering Materials		
		19CS6OE01T	Data Analytics		
		19IT6OE01T	Introduction to Operating Systems		
		22ELC6OE02T	Digital Design using Verilog		
		Open Elective-3 (To Other Branch Students):			
		22EC6OE01T	Fundamental of Satellite Communication		
		22EC6OE02T	Introduction to Digital VLSI Design		
Total Credit (Theory)					**19**

Practical					
1	PCC	22EC6PC02L	**PCC Lab-8:** Microwave Engineering Laboratory	0-0-2	1
2	PCC	22EC6PC03L	**PCC Lab-9:** Digital VLSI Design Laboratory	0-0-2	1
3	PSI	22CM6PS01L	Research and Lab-Based Project	0-0-3	2
4	HSMC	22CM6HS01L	Business Communication and Interview Skills	0-0-3	2
Total Semester Credit					**25**

COURSE DESCRIPTION: Optimization Engineering

Degree	B. Tech.	
Level	Undergraduate	
Branch	ECE (Electronics and Communication Engineering)	
Semester	6th	
Subject Name	Optimization Engineering	
Course Type	Theory	
Course Code	22CM6BS01T	
Category	BSC	
Credit Point	4	
Time Commitment	Lecture	36 Hours
	Tutorial	08 Hours
	Practice	Nil
	Total	44 Hours
Recommended Background Knowledge	Optimization Engineering focuses on formulating and solving mathematical models to find the best outcomes under given constraints, requiring knowledge of calculus, linear algebra, and programming basics.	
Subject Description	Optimization Engineering involves designing mathematical models to achieve optimal solutions for real-world problems within given constraints. It applies techniques like linear, nonlinear, and dynamic programming, as well as stochastic methods, across domains such as engineering, economics, and logistics. The subject emphasizes problem-solving, algorithm development, and computational tools for decision-making and resource management.	
Objectives and	**Objectives:** The course should enable the students : 1. To understand the theory of optimization methods and algorithms	

Outcomes	developed for solving various types of optimization problems. 2. To develop and promote and promote research interest in applying optimization techniques in problems of Engineering and Technology. 3. To apply the mathematical results and numerical of optimization theory to different Engineering problems.
	Outcomes: The course should enable the students to: 1. Understand importance of optimization of industrial process management. 2. Apply basic concepts of mathematics to formulate an optimization problem. 3. Analyses and appreciate variety of performance measures for various optimization problems

Assessment/ Evaluation	Mid-Term Examination	30 %
	Quiz Test-1	2.5 %
	Quiz-Test-2	2.5 %
	Surprise Test	5 %
	Assignment-1	2.5 %
	Assignment-2	2.5 %
	Attendance	5 %
	End-Term Examination	50 %
Prescribed Text Book(s)	[1] S. S. Rao, *Engineering Optimization*, New Age International Publications. [2] A. Ravindran, D. T. Philips, J. Solberg, *Operations Research-Principle and Practice*, Second edition, Wiley India Pvt Ltd. [3] H.A.Taha, A.M.Natarajan, P.Balasubramanie, A.Tamilarasi, *Operations Research*, Pearson Education, Eighth Edition.	

Reference Book(s)	[1] S.D.Sharma, *Operations Research*, Kedarnath Publications. [2] F.S.Hiller, G.J.Lieberman, *Operations Research*, Tata McGraw Hill. [3] P.C.Biswal,*Optimization Engineering*, Scitech Publications [4] Prem Kumar Gupta, D.S.Hira, *Operations Research*, S.Chand Publications.

CO's Mapping with PO's and PEO's

Course Outcomes	Course Outcome Statement	PO's / PEO's
CO1	Understand importance of optimization of industrial process management.	
CO2	Apply basic concepts of mathematics to formulate an optimization problem.	
CO3	Analyses and appreciate variety of performance measures for various optimization problems	

DETAILED SYLLABUS:

Module No. 1		**08 Hours**
Idea of Engineering optimization, Classification of optimization Problems, Optimization Problem and Model Formulation. **Linear programming:** Formulation of LPP, Simplex method, Big-M method, Two-phase Method, Dual Simplex method, Sensitivity analysis in linear programming.		

Module No. 2		**08 Hours**
Transportation problems: Finding an initial basic feasible solution by Northwest Corner rule, Vogel's approximation method, Degeneracy, Optimality test, MODI method, stepping stone		

method.

Assignment problems: Hungarian method for solution of Assignment Problems

Integer Programming: Integer Programming, Mixed Integer Programming, Branch and Bound method.

Module No. 3		**10 Hours**
Non-linear programming: Introduction to non-linear programming. Constrained optimization, Multivariable optimization: Method of Lagrange Multipliers, Kuhn-Tucker condition. **Unconstraint optimization**: Powell's Method, Steepest Descent (Cauchy) Method, Conjugate Gradient (Fletcher-Reeves) Method, Newton's Method.		

Module No. 4		**08 Hours**
Game Theory: Concept, Game models, two persons zero sum games and their solution, Pure & Mixed Strategy, solution of 2Xn and mX2 games by graphical approach. **Decision Theory:** Concept, Decision under risk (EMV) & uncertainty.		

Module No. 5		**08 Hours**
Queuing models: General characteristics, Markovian queuing model, M/M/1model, Limited queue capacity, multiple server, Finite sources, Queue discipline.		

COURSE DESCRIPTION: Microwave Engineering

Degree	B. Tech.	
Level	Undergraduate	
Branch	ECE (Electronics and Communication Engineering)	
Semester	6th	
Subject Name	Microwave Engineering	
Course Type	Theory	
Course Code	22EC6PC02T	
Category	PCC	
Credit Point	3	
Time Commitment	Lecture	36 Hours
	Tutorial	08 Hours
	Practice	Nil
	Total	44 Hours
Recommended Background Knowledge	Microwave Engineering involves the study and design of high-frequency circuits and systems, requiring prior knowledge of electromagnetic theory, circuit analysis, and basic communication systems.	
Subject Description	Microwave Engineering focuses on the analysis, design, and application of high-frequency circuits, devices, and systems used in communication, radar, and broadcasting. It covers topics such as waveguides, transmission lines, microwave network theory, and active/passive component design. The subject emphasizes practical applications and performance optimization of microwave systems in real-world scenarios.	
Objectives and	**Objectives:** The course should enable the students to: 1. Understand the characteristics and the design criteria of microwave transmission media for effective transmission of signals	

Outcomes	2. Understand the characteristics and operational principles of microwave passive components. 3. Impart knowledge on various microwave tubes, solid state devices and its principle of operations. 4. Understand the design and working of microwave antenna systems.	
	Outcomes: On Completion of this Subject/ Course the students should be able to: 1. Analyze and design the transmission media for effective transmission of microwave signals. 2. Understand the microwave applications and the characteristics and working principle of various microwave passive components. 3. Analyze and calculate different performance parameters of active microwave devices. 4. Explain the working principle of microwave antennas and design Horn antennas for a given specification.	
Assessment/ Evaluation	Mid-Term Examination	30 %
	Quiz Test-1	2.5 %
	Quiz-Test-2	2.5 %
	Surprise Test	5 %
	Assignment-1	2.5 %
	Assignment-2	2.5 %
	Attendance	5 %
	End-Term Examination	50 %
Prescribed Text Book(s)	1) D. M. Pozar, *Microwave Engineering*, 3rd Ed.; John Wiley & Sons Inc,2010, India. 2) S. M. Liao, *Microwave devices and Circuits*, 3rd Ed.; Prentice Hall of India, 2003, India.	

Reference Book(s)	1) M.Kulkarni, *Microwave and Radar Engineering*, 3rd Ed., Umesh Publications, 2003, India. 2) R.E. Collin, *Foundations for Microwave Engineering*, IEEE Press, John Wiley, 2nd Edition, 2002. 3) G. S. Raghuvanshi, *Microwave Engineering*, CENGAGE Learning, 2012, India. 4) Sushrut Das, *Microwave Engineering*, Oxford University Press, 2014, India.	
Digital Learning Resources	Course Name	Microwave Theory and Techniques
	Course Link	https://nptel.ac.in/courses/108/101/108101112//
	Course Instructor	Prof. Girish Kumar, IIT Bombay
	Course Name	Microwave Engineering
	Course Link	https://nptel.ac.in/courses/108/101/108101112//
	Course Instructor	Dr. Ratnajit Bhattacharjee, IIT Guwahati

CO's Mapping with PO's and PEO's

Course Outcomes	Course Outcome Statement	PO's / PEO's
CO1	Analyze and design the transmission media for effective transmission of microwave signals.	
CO2	Understand the microwave applications and the characteristics and working principle of various microwave passive components.	
CO3	Analyze and calculate different performance parameters of active microwave devices.	
CO4	Explain the working principle of microwave antennas and design Horn antennas for a given specification.	

DETAILED SYLLABUS:

Module No. 1		**10 Hours**
Introduction to Microwave: Microwaves Frequency bands, Applications Microwave Propagation: Line of sight propagation. Attenuation of Microwaves by atmospheric gases and Hazards of EM radiation, Radiation hazard limits, radiation protection. **High Frequency Transmission lines:** Lumped-Element Circuit Model for a Transmission Line, Distributed elements concept, Telegrapher's equations, Transmission Line Parameters, Transmission Line Equation, lossless and lossy lines, Input impedance of uniform transmission line, Terminated lossless transmission line, Input impedance relations, reflection coefficient and VSWR, impedance transformation, Transmission line as circuit element, Quarter wave Transformer, The Smith Chart, Solution of Transmission line problems using Smith Chart, Single Stub matching.		

Module No. 2		**08 Hours**
Microwave networks: Scattering Matrix representation of microwave networks, S-matrix properties, S-parameter for two port networks. **Microwave Passive Components:** Power Dividers and Directional Couplers: Basic Principles & Properties, of E-plane Tee, H-plane Tee, magic Tee, Hybrid rings (rate race circuit), isolator, circulator, directional couplers, attenuators. Application of magic Tee and directional coupler. Scattering matrix formulation for E-plane / H-plane Tee, Magic Tee, Directional Coupler. Ferrite devices: Principle of Faraday's rotation, Isolator and Circulator (Principle of Operation).		

Module No. 3		**06 Hours**
Microwave Active Devices: Limitations of conventional tubes in the microwave frequency ranges. Microwave Tubes: Klystron Amplifier and Oscillator, Construction & working principle with supportive expressions of Reflex klystron, Two cavity klystron (Without derivations),		

Multi-cavity Cylindrical Magnetron: Principle of Operation.

High Frequency Solid State Devices: Introduction to microwave semiconductor devices, classification, Transfer Electronic Devices: Gunn-effect diodes, Gunn Diode-Construction & working principle, RWH theory, two-valley model theory, basic mode of operations.

Avalanche Transit-Time Devices: Construction & Principle of operation of IMPATT diodes and TRAPATT Diodes.

Module No. 4		**06 Hours**

Waveguides: Introduction, Types of waveguides, rectangular & circular waveguide, Field equation for TE & TM Modes of propagation through rectangular waveguide & circular waveguide (without derivation), cut off frequency of rectangular & circular waveguide, Wave impedance, phase & group velocity, wavelength and impedance relations, different modes in rectangular and circular waveguides, Field patterns of rectangular waveguide, Illustrative problems.

Microstrip line: Introduction, Modes in microstrip line, characteristic impedance of microstrip line, effective dielectric constant, characteristics impedance equation, Quality factor of microstrip line.

Module No. 5		**06 Hours**

Microwave Antennas: Horn Antennas: Construction and basic principle of Horn Antenna, types of horn antenna: pyramidal and sectoral (E- and H- Plane Horns), Radiation Patterns, basic design equation and characteristics of Horn antenna, Microstrip Patch antennas: Basic, types, radiation mechanisms, Design equations.

COURSE DESCRIPTION: Digital VLSI Design

Degree	B. Tech.	
Level	Undergraduate	
Branch	ECE (Electronics and Communication Engineering)	
Semester	6th	
Subject Name	Digital VLSI Design	
Course Type	Theory	
Course Code	22EC6PC03T	
Category	PCC	
Credit Point	3	
Time Commitment	Lecture	36 Hours
	Tutorial	08 Hours
	Practice	Nil
	Total	44 Hours
Recommended Background Knowledge	A solid understanding of Digital Electronics (logic gates, sequential circuits), CMOS fundamentals (MOSFET operation, fabrication, and scaling), and Basic Circuit Design is essential. Familiarity with SPICE simulations, and testing methodologies will enhance learning.	
Subject Description	The subject **Digital VLSI Design** focuses on the principles and methodologies for designing high-performance digital integrated circuits. It covers topics like CMOS technology, fabrication processes, and MOSFET characteristics, emphasizing logic circuit design and optimization. Students learn to design combinational and sequential circuits, analyze power dissipation, and address timing issues. Advanced topics include layout techniques, clock strategies, and design-for-testability (DFT) methodologies to enhance circuit reliability and manufacturability.	

<table>
<tr><td rowspan="2">Objectives

and

Outcomes</td><td colspan="2">Objectives:

The course should enable the students to:
1. Understand VLSI design fundamentals, including IC technology, design flow, and fabrication processes.
2. Analyze MOSFET structure, operation, and characteristics with SPICE modeling and scaling.
3. Design CMOS combinational and sequential circuits, addressing power and layout considerations.
4. Learn design-for-testability techniques, fault models, and advanced testing methodologies like BIST.</td></tr>
<tr><td colspan="2">Outcomes:
Upon completion of this course, the student will be able to:
1. Explain VLSI design principles, fabrication processes, and modular design concepts.
2. Analyze MOSFET characteristics and design CMOS inverters with performance constraints.
3. Design and optimize CMOS logic circuits, addressing power and timing issues.
4. Apply DFT techniques to improve circuit reliability and fault detection.</td></tr>
<tr><td rowspan="8">Assessment/
Evaluation</td><td>Mid-Term Examination</td><td>30 %</td></tr>
<tr><td>Quiz Test-1</td><td>2.5 %</td></tr>
<tr><td>Quiz-Test-2</td><td>2.5 %</td></tr>
<tr><td>Surprise Test</td><td>5 %</td></tr>
<tr><td>Assignment-1</td><td>2.5 %</td></tr>
<tr><td>Assignment-2</td><td>2.5 %</td></tr>
<tr><td>Attendance</td><td>5 %</td></tr>
<tr><td>End-Term Examination</td><td>50 %</td></tr>
<tr><td>Prescribed Text Book(s)</td><td colspan="2">1. Sung-Mo Kang, Yusuf Leblebici and Chul Woo Kim, CMOS Digital Integrated Circuits: Analysis and Design, 4th Edition, Tata McGraw-Hill Publishing Company Limited, 2015.
2. Debaprasad Das, VLSI Design, 2nd Edition, Oxford University Press,</td></tr>
</table>

	2015, New Delhi.		
Reference Book(s)	1. Neil h. e. weste, David harris and Ayan Banerjee, CMOS VLSI design a circuits and systems perspective, 4th Edition, Pearson Education, 2015. 2. Jan M. Rabaey, Anantha Chandrakasan and Borivoje Nikolic, Digital Integrated Circuits – A Design Perspective, 2nd Edition , PHI Learning, 2016, New Delhi.. 3. Wayne Wolf, Modern VLSI Design System on Chip Design, 3rd Edition, PHI Learning Publisher, 2016, New Delhi. 4. John P. Uyemura, CMOS Logic Circuit Design, 1st Edition, Springer, 2007, US.		
Digital Learning Resources	**Course Name**	Digital VLSI Design	
	Course Link	https://nptel.ac.in/courses/108/103/108103108/	
	Course Instructor	Prof. Chandan Karfa | IIT Guwahati	
	Course Name	CMOS Digital VLSI Design	
	Course Link	https://nptel.ac.in/courses/108/107/108107129/	
	Course Instructor	Prof. Sudeb Dasgupta | IIT Roorkee	

CO's Mapping with PO's and PEO's

Course Outcomes	Course Outcome Statement	PO's / PEO's
CO1	Explain VLSI design principles, fabrication processes, and modular design concepts.	PO1, PO2, PO4, PO5, PO7, PO10, PO11, PO12, PEO1, PEO2.
CO2	Analyze MOSFET characteristics and design CMOS inverters with performance constraints.	PO1, PO2, PO3, PO4, PO7, PO8, PO10, PO12, PEO1, PEO2.
CO3	Design and optimize CMOS logic circuits, addressing power and timing issues.	PO1, PO2, PO4, PO5, PO8, PO10, PO11, PEO1, PEO2.

CO4	Apply DFT techniques to improve circuit reliability and fault detection.	PO1, PO2, PO3, PO4, PO7, PO8, PO10, PO11, PO12, PEO1, PEO2.

DETAILED SYLLABUS:

Module No. 1	**Introduction and MOS Transistor**	**12 Hours**
Introduction: IC technology an overview, Classification of IC technology, VLSI Design challenges, VLSI Design Flow, Design Hierarchy, Concept of Regularity, Modularity and Locality, VLSI Design Styles. Fabrication Processes Flow–Basic Concepts, the CMOS n-Well and p-well Process, Layout Design Rules, Stick Diagrams, Mask Layout Design. **MOS Transistor:** The MOS System under External Bias, Structure and Operation of MOS Transistor (MOSFET), MOSFET Current-Voltage Characteristics, SPICE models for MOS transistor, MOSFET Scaling, MOSFET Capacitance.		

Module No. 2	**Static Characteristics and MOS Inverters– Switching Characteristics and Interconnect Effects**	**12 Hours**
Static Characteristics: Introduction, Resistive-Load Inverters, Enhancement-Load nMOS Inverter, Depletion-LoadnMOS Inverter, CMOS Inverter. **MOS Inverters– Switching Characteristics and Interconnect Effects:** Introduction, Delay-Time Definitions, Calculation of Delay-Times, Inverter Design with Delay Constraints, Switching Power Dissipation of CMOS Inverters		

Module No. 3	**Combinational MOS Logic Circuits**	**08 Hours**
Combinational MOS Logic Circuits: CMOS Logic Circuits, Complex Logic Circuits, Layout of Complex CMOS Logic Gates, AOI and OAI Gates, Pseudo-nMOS Gate, CMOS Full-Adder Circuit, CMOS Transmission Gates (Pass Gates), Pass Transistor Circuits, Complementary Pass-Transistor Logic (CPL), Power dissipation.		

Module No. 4	**Sequential MOS Logic Circuits**	**06 Hours**
Sequential MOS Logic Circuits: Static and Dynamic Latches and Registers, Timing issues, pipelines, clock strategies, Clocked Latch and Flip-Flop Circuits and CMOS D-Latch.		

Module No. 5	**Design for Testability**	**06 Hours**
Design for Testability: Introduction, Fault Types and Models, Controllability and Observability, Scan-Based Techniques, Built-In Self-Test (BIST) Techniques (Pseudo Random Pattern Generator, Linear Feedback Shift Register as an ORA , Output Response Analyzer, Built-In Logic Block Observer), Current Monitoring IDDQ Test.		

COURSE DESCRIPTION: Machine Learning

Degree	B. Tech.	
Level	Undergraduate	
Branch	ECE (Electronics and Communication Engineering)	
Semester	6th	
Subject Name	Machine Learning	
Course Type	Theory	
Course Code	22EC6PE01T	
Category	PEC	
Credit Point	3	
Time Commitment	Lecture	36 Hours
	Tutorial	08 Hours
	Practice	Nil
	Total	44 Hours
Recommended Background	Probability and Statistics, Python, Data Manipulation, Algorithm Implementation, Data Structures and Algorithms.	

Knowledge	
Subject Description	Machine Learning (ML) is a branch of artificial intelligence that enables systems to learn from data and improve performance without explicit programming. This course introduces core ML concepts, including supervised, unsupervised, and reinforcement learning, with a focus on their applications across industries. Students will explore data preprocessing, feature engineering, and model evaluation techniques to develop robust and interpretable models. Key algorithms for classification, regression, clustering, and association rule mining are covered, alongside the practical use of tools and libraries like Python's scikit-learn. The course also delves into neural networks, their architectures, learning processes, and an introduction to deep learning. Emphasis is placed on solving real-world problems through hands-on exercises and projects. Students will gain a solid foundation in both theoretical principles and practical implementation. By the end, learners will be prepared to apply ML techniques to diverse challenges in domains such as healthcare, finance, and technology.
Objectives and Outcomes	**Objectives:** The course should enable the students to: 1. **Understand the Fundamentals of Machine Learning**: To introduce the fundamental concepts of machine learning, including human vs. machine learning, data preprocessing, model training, and evaluation techniques. 2. **Develop Feature Engineering Skills**: To explore feature engineering concepts, including feature transformation, subset selection, and the application of Bayesian methods for conceptual learning and decision-making. 3. **Master Supervised and Unsupervised Learning Techniques**: To study and implement supervised learning algorithms for classification and regression, as well as unsupervised learning techniques for clustering and association rule mining. 5. **Explore Neural Networks and Deep Learning Basics**: To understand the structure and functioning of artificial neural networks, learning processes, activation functions, and an overview of deep learning concepts.

	Outcomes: Upon completion of this course, the student will be able to: 1. Demonstrate a solid understanding of machine learning concepts and tools, including data preprocessing, inductive bias, and the bias-variance tradeoff. (Knowledge Level: Apply) 2. Design and implement feature engineering and Bayesian learning techniques to enhance model performance and interpretability. (Knowledge Level: Analyze) 3. Apply supervised and unsupervised learning algorithms to solve real-world problems in classification, regression, clustering, and association rule mining. (Knowledge Level: Evaluate) 4. Develop and train artificial neural networks using backpropagation and explore deep learning architectures for complex problem-solving. (Knowledge Level: Create)	
Assessment/ Evaluation	Mid-Term Examination	30 %
	Quiz Test-1	2.5 %
	Quiz-Test-2	2.5 %
	Surprise Test	5 %
	Assignment-1	2.5 %
	Assignment-2	2.5 %
	Attendance	5 %
	End-Term Examination	50 %
Prescribed Text Book(s)	1. Saikat Dutt, Subramanian Chandramouli, Amit Kumar Das, “Machine Learning”, Pearson Education. 2. C. M. Bishop, Pattern Recognition and Machine Learning, Springer, 2010.	
Reference Book(s)	1. J. Friedman, T. Hastie, and R. Tibshirani.The elements of statistical learning.Vol. 1, no. 10. New York:Springer series in statistics, 2001. 2. S. Shalev-Shwartz, and S. Ben-David. Understanding machine learning:	

	From theory to algorithms. Cambridge university press, 2014.	
Digital Learning Resources	**Course Name**	Introduction to Machine Learning
	Course Link	https://nptel.ac.in/courses/106/106/106106139/
	Course Instructor	Dr. Balaraman Ravindran, IIT Madras
	Course Name	Introduction To Machine Learning - IITKGP
	Course Link	https://www.youtube.com/@machinelearning-sudeshnasa3607/videos
	Course Instructor	Prof. Sudeshna Sarkar, IIT Kharagpur

CO's Mapping with PO's and PEO's

Course Outcomes	Course Outcome Statement	PO's / PEO's
CO1	Demonstrate a solid understanding of machine learning concepts and tools, including data preprocessing, inductive bias, and the bias-variance tradeoff.	PO1, PO2, PO3, PO4, PO5, PO7, PO8, PO11, PO12, PEO1, PEO2.
CO2	Design and implement feature engineering and Bayesian learning techniques to enhance model performance and interpretability.	PO1, PO2, PO3, PO4, PO5, PO7, PO8, PO10, PEO1, PEO2.
CO3	Apply supervised and unsupervised learning algorithms to solve real-world problems in classification, regression, clustering, and association rule mining.	PO1, PO2, PO3, PO4, PO5, PO7, PO8, PO11, PO12, PEO1, PEO2.
CO4	Develop and train artificial neural networks using backpropagation and explore deep learning architectures for complex problem-solving.	PO1, PO2, PO3, PO4, PO5, PO7, PO8, PO11, PEO1, PEO2.

DETAILED SYLLABUS:

Module No. 1		**10 Hours**
Introduction to Machine Learning, Model Preparation, Modelling and Evaluation, Human learning versus machine learning, types of machine learning, applications of machine learning, tools for machine learning, Machine Learning Activities, Data structures for machine learning, Data Preprocessing, selecting a model, training a model, model representation and interpretability, evaluating performance of a model, improving performance of a model, Learning theory, Hypothesis and targe class, Hilbert space, Inductive bias and bias-variance tradeoff.		

Module No. 2		**06 Hours**
Feature Engineering, Bayesian Concept Learning, Introduction to feature engineering, featur transformation, feature subset selection, Importance of Bayesian methods, Bayes' theorem, concep learning through Bayes' theorem, Bayesian Belief Network.		

Module No. 3		**06 Hours**
Supervised Learning –Classification, Regression, Example of supervised learning, classification mode classification learning steps, common classification algorithms – KNN, Decission trees random fores SVM, example of regression, common regression algorithms.		

Module No. 4		**06 Hours**
Unsupervised Learning –Clustering, pattern finding using association rules, Unsupervised learnin versus supervised learning, applications of unsupervised learning, clustering and its types, Aprior algorithm for association rule learning.		

Module No. 5		**08 Hours**

Introduction to Python libraries: NumPy, Pandas, Matplotlib, and Seaborn, Data handling, visualization. Data Preprocessing: Handling missing data, Normalization, standardization, and feature scaling, Encoding categorical data. Introduction to Basic ML Models using python: Linear Regression and Logistic Regression, K-Nearest Neighbour (KNN) Algorithm.

COURSE DESCRIPTION: Adaptive Signal Processing

Degree	B. Tech.	
Level	Undergraduate	
Branch	ECE (Electronics and Communication Engineering)	
Semester	6th	
Subject Name	Adaptive Signal Processing	
Course Type	Theory	
Course Code	22EC6PE02T	
Category	PEC	
Credit Point	3	
Time Commitment	Lecture	36 Hours
	Tutorial	08 Hours
	Practice	Nil
	Total	44 Hours
Recommended Background Knowledge	Basic of Signals and Systems, Digital Signal Processing.	
Subject Description	Adaptive signal processing concerns with processing of signals where the processing parameters are adjusted continuously to suit time varying signal environmental conditions. The study of adaptive signal processing involves development of various adaptation algorithms and assessing them in terms of convergence rate, computational complexity, robustness against noisy data, hardware complexity, numerical stability etc. This course demonstrates the design of important class of adaptive filters, LMS, RLS and Kalman filters	

<table>
<tr><td rowspan="2">Objectives and Outcomes</td><td colspan="2">Objectives:
The course should enable the students to:
1. Understand the concept and need of adaptive filter.
2. Learn the concepts of training and convergence and the trade-off between performance and complexity.
3. Gain knowledge about Linear Prediction algorithm and Kalman filter.
4. Demonstrate applications of adaptive systems to sample problems.</td></tr>
<tr><td colspan="2">Outcomes:
Upon completion of this course, the student will be able to:
1. Explain the role and importance of adaptive signal processing.
2. Design various mathematical models for Adaptive System.
3. Understand the properties of Kalman filtering.
4. Apply computer based simulation tools to understand the theoretical concepts of adaptive signal processing in various communication applications.</td></tr>
<tr><td rowspan="8">Assessment/ Evaluation</td><td>Mid-Term Examination</td><td>30 %</td></tr>
<tr><td>Quiz Test-1</td><td>2.5 %</td></tr>
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<tr><td>End-Term Examination</td><td>50 %</td></tr>
<tr><td>Prescribed Text Book(s)</td><td colspan="2">1. B. Widrow and S.D. Stearns, Adaptive Signal Processing, Pearson Education, 2006.
2. S. Haykin, Adaptive Filter Theory, Prentice-Hall, 4-th edition, 2001.</td></tr>
</table>

Reference Book(s)	1. Monson H. Hayes, Statistical Digital Signal Processing And Modeling, Wiley India, 2008. 2. John G. Proakis, Dimitris G.Manolakis, Digital Signal Processing, Principles, Algorithms and Applications, Pearson Education / PHI, 2007. 3. Sanjit K Mitra, Digital Signal Processing, new edition, TMH, 2009. 4. B. Farhang-Boroujen, Adaptive Filters Theory and Applications, John Wiley and Sons, 2013.	
Digital Learning Resources	Course Name	Adaptive Techniques in Signal Processing
	Course Link	https://nptel.ac.in/courses/117/105/117105075/
	Course Instructor	Prof. Mrityunjoy Chakraborty, Department of Electronics & Electrical Communication Engineering, I.I.T, Kharagpur

CO's Mapping with PO's and PEO's

Course Outcomes	Course Outcome Statement	PO's / PEO's
CO1	Explain the role and importance of adaptive signal processing.	PO1, PO2, PO3, PO4, PO5, PO7, PO8, PO10, PO11, PO12, PEO1, PEO2.
CO2	Design various mathematical models for Adaptive System.	PO1, PO2, PO3, PO4, PO5, PO7, PO8, PO10, PO11, PO12, PEO1, PEO2.
CO3	Understand the properties of Kalman filtering.	PO1, PO2, PO3, PO4, PO5, PO7, PO8, PO10, PO11, PO12, PEO1, PEO2.
CO4	Apply computer based simulation tools to understand the theoretical concepts of adaptive signal processing in various communication applications.	PO1, PO2, PO3, PO4, PO5, PO7, PO8, PO10, PO11, PO12, PEO1, PEO2.

DETAILED SYLLABUS:

Module No. 1	**Introduction**	**6 Hours**
Introduction: Adaptive systems, Definition and characteristics, areas of application, general properties, The filtering problem, Adaptive filters, linear filter structures, approaches to the development of linear adaptive filter algorithms, real and complex forms of adaptive filters, non linear adaptive filters, Applications, Open-loop and closed-loop adaptation, the adaptive linear combiner. Properties of the quadratic performance surface.		

Module No. 2	**Wiener Filters and Linear Prediction**	**12 Hours**
Wiener Filters: Linear optimum filtering problem statement, principle of orthogonality, minimum mean squared error, wiener- hopf equations, and error– performance surface. Linear Prediction: Forward Linear Prediction, backward Linear Prediction, Levinson-Durbin algorithm, properties of prediction error filters, Method of steepest descent: Steepest descent algorithm, stability of the steepest descent algorithm.		

Module No. 3	**LMS and RLS Alogrithm**	**8 Hours**
Least Mean Square (LMS) Algorithm: Over view of the structure and operation of the Least Mean square Algorithm, Least Mean square adaptation Algorithm, stability and performance analysis of the LMS algorithm. Normalized Least Mean Square (NLMS) Algorithm, Concept of method of least squares. Recursive Least Squares (RLS) Algorithm: The matrix inversion lemma, the exponentially weighted RLS algorithm, update recursion for the sum of weighted error squares. Convergence analysis of the RLS algorithm.		

Module No. 4	**Applications of adaptive signal processing**	**8 Hours**

Applications of adaptive signal processing, Design of Adaptive FIR & IIR filters, Adaptive modeling of a multipath communication channel, System identification using adaptive filters, inverse adaptive modeling, deconvolution and Channel equalization, adaptive noise cancellation, adaptive line enhancer.

Module No. 5	**Kalman Filters**	**6 Hours**
Kalman Filters: Recursive minimum mean square estimation for scalar random variables, statement of the Kalman filtering problem, the innovations process, estimation of the state using the innovations process, filtering, initial conditions, variants of the Kalman filter, extended Kalman filtering.		

COURSE DESCRIPTION: Digital Image Processing

Degree	B. Tech.
Level	Undergraduate
Branch	ECE (Electronics and Communication Engineering)
Semester	6th
Subject Name	Digital Image Processing
Course Type	Theory
Course Code	22EC6PE03T
Category	PEC
Credit Point	3

Time Commitment	Lecture	36 Hours
	Tutorial	08 Hours
	Practice	Nil
	Total	44 Hours
Recommended Background Knowledge	Signal Processing	
Subject Description	Digital image processing involves using algorithms to enhance, analyze and transform digital images. It includes techniques like filtering, segmentation and object recognition, with applications in fields like medicine, remote sensing and AI.	
Objectives and Outcomes	**Objectives:** The course should enable the students to: 1. Gain an insight into the various analytical methods and transforms used in image processing. 2. Familiarize with image enhancement and restoration techniques. 3. Mathematical modeling of different image compression techniques and their applications. 4. Understand the Concept of color image processing and morphological operations on gray image.	
	Outcomes: Upon completion of this course, the student will be able to: 1. Understand the need for different types of image transforms and their properties for processing of gray and color image data. 2. Implement the signal processing algorithms and techniques in image enhancement, image restoration, Morphology and Image Compression. 3. Implement basic image processing algorithms in MATLAB. 4. Understand practical scope of digital image processing for most of the work currently underway in this field.	

Assessment/ Evaluation	Mid-Term Examination	30 %
	Quiz Test-1	2.5 %
	Quiz-Test-2	2.5 %
	Surprise Test	5 %
	Assignment-1	2.5 %
	Assignment-2	2.5 %
	Attendance	5 %
	End-Term Examination	50 %
Prescribed Text Book(s)	1. R.C. Gonzalez, R.E. Woods, Digital Image Processing, 3rd Edition, Pearson Education, 2007, New Delhi. 2. S. Sridhar, Digital Image Processing, 2nd Edition, Oxford University Press, 2016, New Delhi.	
Reference Book(s)	1. Rafael C. Gonzalez, Richard E. Woods Digital Image Processing using MATLAB, Seventh Edition , Pearson Education, Inc, 2004, New Delhi. 2. William K. Pratt, Digital Image Processing, 4th Edition, Wiley, 2002, New York. 3. Anil K. Jain, ‘Fundamentals of Digital Image Processing', 1st Edition, Pearson 2019, New Delhi. 4. B. Chanda, Dutta D. Majumder, Digital Image Processing And Analysis, 2nd Edition ,PHI, 2011 , New Delhi.	
Digital Learning Resources	**Course Name**	DIGITAL IMAGE PROCESSING
	Course Link	https://nptel.ac.in/courses/117/105/117105135/
	Course Instructor	Prof. P.K. Biswas , Department of Electronics & Electrical Communication Engineering, I.I.T, Kharagpur

CO's Mapping with PO's and PEO's

Course Outcomes	Course Outcome Statement	PO's / PEO's

CO1	Understand the need for different types of image transforms and their properties for processing of gray and color image data.	
CO2	Implement the signal processing algorithms and techniques in image enhancement, image restoration, Morphology and Image Compression.	
CO3	Implement basic image processing algorithms in MATLAB.	
CO4	Understand practical scope of digital image processing for most of the work currently underway in this field.	

DETAILED SYLLABUS:

Module No. 1		**8 Hours**
Digital Image Fundamentals: Digital Image Processing: Introduction, Background of image processing, Fundamental steps in image processing, Elements of digital image processing systems. Digital image representation, Sampling and quantization, Relationship Between pixels, Imaging geometry: Translation, Rotation, Perspective Transformation. **Properties and Applications of Image Transforms:** Fourier Transform, Discrete Fourier Transform, Fast Fourier Transform, Discrete Cosine Transform, Walsh Transform, Hadamard Transform, Hotelling Transform, Fundamentals on wavelet transform.		

Module No. 2		**8 Hours**
Image Enhancement: Enhancement in spatial domain: Basic gray level transformations, Histogram processing, Smoothing and Sharpening of Spatial Filters. Enhancement in frequency domain: Introduction to filtering in frequency domain, Smoothing and Sharpening of frequency		

domain filters.

Module No. 3		**8 Hours**
Image Restoration and Reconstruction: Image restoration/degradation model, Noise models in image processing, Restoration in the presence of noise only, Periodic noise reduction by frequency domain filtering, Linear position invariant degradations, Estimating the degradation function, Inverse filtering, Wiener filtering, Constrained least squares restoration.		

Module No. 4		**6 Hours**
Image compression: Introduction and motivation, Fundamental concepts: Data redundancy (coding redundancy, inter pixel redundancy and psycho visual redundancy), Fidelity criteria, Image compression models, Image compression standards, Elements of information theory. Image compression methods: Huffman coding, Arithmetic coding, LZW coding, Run-Length Coding, Bit plane coding.		

Module No. 5		**6 Hours**
Color Image Processing: Color fundamentals, Conversion of color image to gray scale image, Color model (RGB, HSI, HSV, HLS, CMK, CMYK). **Morphological Image Processing:** Morphological Image Processing: Preliminaries, Erosion, Dilation, Opening and Closing, hit or Miss transformation, Boundary extraction, Hole filling, Extraction of connected components, Thinning, Thickening.		

COURSE DESCRIPTION: FPGA Based Design

Degree	B. Tech.	
Level	Undergraduate	
Branch	ECE (Electronics and Communication Engineering)	
Semester	6th	
Subject Name	FPGA Based Design	
Course Type	Theory	
Course Code	22EC6PE04T	
Category	PEC	
Credit Point	3	
Time Commitment	Lecture	36 Hours
	Tutorial	08 Hours
	Practice	Nil
	Total	44 Hours
Recommended Background Knowledge	FPGA-Based Design involves creating configurable digital systems, requiring knowledge of digital electronics, logic design, and hardware description languages like Verilog or VHDL.	
Subject Description	FPGA-Based Design focuses on developing digital systems using Field Programmable Gate Arrays, emphasizing flexibility and high-speed performance. It covers topics like FPGA architecture, design methodologies, hardware description languages, and synthesis tools. The subject integrates theoretical concepts for applications in signal processing, embedded systems, and communication.	
Objectives and	**Objectives:** The course should enable the students to: 1. Provide insight to design low cost and high speed Digital systems	

<table>
<tr><td rowspan="2">Outcomes</td><td colspan="2">2. Gain inclusive knowledge about Verilog HDL
3. Understand the internal architecture of FPGA
4. Acquire the knowledge about FPGA design flow</td></tr>
<tr><td colspan="2">Outcomes:
Upon completion of this course, the student will be able to:
1. Acquire fundamental knowledge about Verilog HDL
2. Understand the basic building blocks of FPGA
3. Develop the concepts to design complex digital systems
4. Analyze the FPGA design flow</td></tr>
<tr><td rowspan="8">Assessment/ Evaluation</td><td>Mid-Term Examination</td><td>30 %</td></tr>
<tr><td>Quiz Test-1</td><td>2.5 %</td></tr>
<tr><td>Quiz-Test-2</td><td>2.5 %</td></tr>
<tr><td>Surprise Test</td><td>5 %</td></tr>
<tr><td>Assignment-1</td><td>2.5 %</td></tr>
<tr><td>Assignment-2</td><td>2.5 %</td></tr>
<tr><td>Attendance</td><td>5 %</td></tr>
<tr><td>End-Term Examination</td><td>50 %</td></tr>
<tr><td>Prescribed Text Book(s)</td><td colspan="2">1. Ian Grout , Digital Systems Design with FPGAs and CPLDs, 1st Edition, Newnes, 2008, UK
2. Michel D.Ciletti, Advanced Digital Design with verilog HDL, 2nd Edition, Pearson, 2017, New Delhi</td></tr>
<tr><td>Reference Book(s)</td><td colspan="2">1. ZainalabdienNavabi , Verilog Digital System Design, McGraw-Hill, 2nd Edition, 2017, New Delhi
2. Stephen Brown, ZvonkocVranesic, Fundamentals of Digital Logic with Verilog Design, McGraw-Hill, 2nd Edition, 2010, New Delhi</td></tr>
</table>

<table>
<tr><td></td><td colspan="2">3. Samir Palnitkar, Verilog HDL: A Guide to Digital Design and Synthesis, 2nd Edition, Prentice Hall PTR, USA</td></tr>
<tr><td rowspan="5">Digital Learning Resources</td><td>Course Name</td><td>Digital System Design with PLDs and FPGAs</td></tr>
<tr><td>Course Link</td><td>https://nptel.ac.in/courses/117/108/117108040/</td></tr>
<tr><td>Course Instructor</td><td>Prof. Kuruvilla Varghese
Centre for Electronics Design and Technology, IISc Bangalore</td></tr>
<tr><td>Course Name</td><td>FPGA Basic Flow</td></tr>
<tr><td>Course Link</td><td>https://www.xilinx.com/support/documentation/sw_manuals/xilinx10/isehelp/ise_c_basic_flow.htm</td></tr>
</table>

CO's Mapping with PO's and PEO's

Course Outcomes	Course Outcome Statement	PO's / PEO's
CO1	Acquire fundamental knowledge about Verilog HDL	PO1, PO2, PO3, PO4, PO5, PO6
CO2	Understand the basic building blocks of FPGA	PO1, PO2, PO3, PO4, PO5, PO6, PO7
CO3	Develop the concepts to design complex digital systems	PO1, PO2, PO3, PO4, PO5, PO6, PO7
CO4	Analyze the FPGA design flow	PO1, PO2, PO3, PO4, PO5, PO6, PO7

DETAILED SYLLABUS:

Module No. 1	**Introduction to HDL**	**8 Hours**
Introduction to Verilog HDL, Styles of description: Data flow, Behavioral, Structural.		

Module No. 2	**Synthesis and Simulation Constructs**	**-- Hours**
Conditional statements, Signal, Constant & Variable Declarations, and System Tasks & Functions. Clock Stimulus, Delays, Loops, System Tasks & Functions		

Module No. 3	**Components of FPGA**	**-- Hours**
LUTs, CLBs, Slices, Embedded RAM, Shift register, Adder, Multiplier, Hard microprocessor cores, Soft microprocessor cores		

Module No. 4	**Important Design Blocks in FPGA**	**6 Hours**
Clock trees and Clock managers, General purpose I/Os, Hard IP, Soft IP and Firm IP		

Module No. 5	**FPGA Design Flow**	**8 Hours**
FPGA based design flow: Design Entry(RTL), Functional Simulation, Synthesis, Translate, Map, Place & Route, Design Example of combinational and sequential circuits		

COURSE DESCRIPTION: 5G and Future Communications

Degree	B. Tech.	
Level	Undergraduate	
Branch	ECE (Electronics and Communication Engineering)	
Semester	6th	
Subject Name	5G and Future Communications	
Course Type	Theory	
Course Code	22EC6PE05T	
Category	PEC	
Credit Point	3	
Time Commitment	Lecture	36 Hours
	Tutorial	08 Hours
	Practice	Nil
	Total	44 Hours
Recommended Background Knowledge	Mobile Communication	
Subject Description	The "5G and Future Communication" course explores the evolution and technological advancements in cellular and wireless communication systems, emphasizing the progression from earlier generations to 5G. It provides a deep dive into networking fundamentals, mobility solutions, 5G spectrum strategies, MIMO techniques, and 5G radio access technologies. The course also covers cutting-edge topics like network slicing, SDN/NFV, and private 5G networks tailored for specific industries. The comprehensive approach enables students to analyze, design, and optimize communication systems for next-generation applications.	
	Objectives:	

<table>
<tr><td rowspan="2">Objectives and Outcomes</td><td colspan="2">The course should enable the students:
1. To provide a comprehensive understanding of the fundamentals of cellular communication, networking protocols, and IP mobility.
2. To examine the transition from 4G LTE to 5G, including spectrum access, channel modeling, and advanced access techniques.
3. To analyze the architecture, security, and innovative features of 5G networks, including SDN/NFV, network slicing, and edge cloud computing.
4. To explore the design and deployment of private 5G networks across various industries and applications.</td></tr>
<tr><td colspan="2">Outcomes:
Upon completion of this course, the student will be able to:
1. Demonstrate knowledge of cellular communication technologies and networking fundamentals, including 2G, 3G, and WiMAX.
2. Analyze the features of 4G LTE and transition techniques to 5G, including spectrum sharing and channel modeling.
3. Evaluate advanced 5G access methods, including MIMO techniques, SCMA, IDMA, and their applications in dense deployments and mMTC
4. Design and assess private 5G network architectures for diverse use cases such as healthcare, smart agriculture, and logistics.</td></tr>
<tr><td rowspan="7">Assessment/ Evaluation</td><td>Mid-Term Examination</td><td>30 %</td></tr>
<tr><td>Quiz Test-1</td><td>2.5 %</td></tr>
<tr><td>Quiz-Test-2</td><td>2.5 %</td></tr>
<tr><td>Surprise Test</td><td>5 %</td></tr>
<tr><td>Assignment-1</td><td>2.5 %</td></tr>
<tr><td>Assignment-2</td><td>2.5 %</td></tr>
<tr><td>Attendance</td><td>5 %</td></tr>
</table>

	End-Term Examination	50 %
Prescribed Text Book(s)	1) *5G NR: The Next Generation Wireless Access Technology*: Erik Dahlman, Stefan Parkvall, and Johan Skold, 1st Edition, Elsevier, 2018. 2) *5G Mobile Networks*: Afif Osseiran, Jose F. Monserrat, and Patrick Marsch A Systems Approach" 1stedition, Cambridge University Press,2016. 3) *Wireless Communications & Networks*: William Stallings, 2nd edition, Pearson India.	
Reference Book(s)	1) *Fundamentals of 5G Communications: Connectivity for Enhanced Mobile Broadband and Beyond:* Wanshi Chen, Peter Gaal, Juan Montojo, Haris Zisimopoulos, 1st Edition, McGraw Hill, 2021. 2) *Wireless Communication and Networking, Essential Reading:* V K Garg, Morgan Kaufman Publishers, 2008, India.	
Digital Learning Resources	Course Name	5G Wireless Standard Design
	Course Link	https://www.youtube.com/watch?v=CJegkVLd3r8
	Course Instructor	Prof. Rohit Budhiraja , IIT Kanpur
	Course Name	Evolution of Air Interface towards 5G,
	Course Link	https://nptel.ac.in/courses/108105134
	Course Instructor	Suvra Sekhar Das, IIT Kharagpur

CO's Mapping with PO's and PEO's

Course Outcomes	Course Outcome Statement	PO's / PEO's
CO1	Demonstrate knowledge of cellular communication technologies and networking fundamentals, including 2G, 3G, and WiMAX.	PO1, PO2, PO3, PO4, PO5
CO2	Analyze the features of 4G LTE and transition techniques to 5G, including spectrum sharing and	PO1, PO2, PO3, PO5

	channel modeling.	
CO3	Evaluate advanced 5G access methods, including MIMO techniques, SCMA, IDMA, and their applications in dense deployments and mMTC.	PO1, PO2, PO3, PO4, PO5, PO6
CO4	Design and assess private 5G network architectures for diverse use cases such as healthcare, smart agriculture, and logistics.	PO1, PO2, PO3, PO4, PO5, PO6

DETAILED SYLLABUS:

Module No. 1	**Fundamentals of Networking and Cellular Communication**	**6Hours**
Introduction, Networking Fundamentals, Networking Protocols, Cellular Communication Background (2G, 3G, WiMAX), Inter-RAT Handover, Mobility Taxonomy (IP Mobility), Mobility Taxonomy (IP Mobility), Mobile IP, Hierarchical Mobility, Mobility Optimization		

Module No. 2	**4G LTE and the Transition to 5G**	**08 Hours**
4G (Long Term Evolution) - (RAN, EPC), Session Initiation Protocol (SIP), IMS (IP Multimedia Subsystem), 5G Spectrum Landscape, Spectrum Access Modes, and Sharing Scenarios, Understand and Explain the Channel Models of 5G.		

Module No. 3	**Advanced Access Techniques and MIMO in 5G**	**06Hours**
4G (Long Term Evolution) - (RAN, EPC), Session Initiation Protocol (SIP), IMS (IP Multimedia Subsystem), 5G Spectrum Landscape, Spectrum Access Modes, and Sharing Scenarios, Understand and Explain the Channel Models of 5G.		

Module No. 4	**5G Architecture and Network Innovations**	**10 Hours**
5G Architecture, Standards, Network Functions, Call Flows (3GPP), 5G Security Architecture, Orchestration, SDN/NFV, Edge Cloud, Network Slicing		

Module No. 5	**Private 5G Networks for Industry-Specific Applications**	**06 Hours**
Private Network Architectures of different Use-cases: Retail Store, Warehouse and Logistics, Oil, Gas and Mining, University Campuses, Healthcare, Smart Agriculture, Ship Ports		

COURSE DESCRIPTION: Wireless Sensor Networks

Degree	B. Tech.	
Level	Undergraduate	
Branch	ECE (Electronics and Communication Engineering)	
Semester	6th	
Subject Name	Wireless Sensor Networks	
Course Type	Theory	
Course Code	22EC6PE06T	
Category	PEC	
Credit Point	3	
Time Commitment	Lecture	36 Hours
	Tutorial	08 Hours
	Practice	Nil
	Total	44 Hours
Recommended Background Knowledge	Wireless Communication, Communication systems	
Subject	To understand the fundamentals of wireless sensor networks and its	

<table>
<tr><td>Description</td><td colspan="2">application to critical real time scenarios. To study the various protocols at various layers and its differences with traditional protocols.</td></tr>
<tr><td rowspan="2">Objectives and Outcomes</td><td colspan="2">Objectives:
The course should enable the students to:
1. Understand the basic WSN technology and supporting protocols
2. To learn various fundamental and emerging protocols of all layers
3. To study the design consideration of topology control and solution to the various problems.
4. Learn key routing protocols for sensor networks and main design issues.</td></tr>
<tr><td colspan="2">Outcomes:
Upon completion of this course, the student will be able to:
1. Understand and explain common wireless sensor node architectures.
2. Be able to carry out simple analysis and planning of WSNs.
3. To analyze routing and congestion algorithms
4. To design, develop , and carry out performance analysis of sensors on specific applications</td></tr>
<tr><td rowspan="7">Assessment/ Evaluation</td><td>Mid-Term Examination</td><td>30 %</td></tr>
<tr><td>Quiz Test-1</td><td>2.5 %</td></tr>
<tr><td>Quiz-Test-2</td><td>2.5 %</td></tr>
<tr><td>Surprise Test</td><td>5 %</td></tr>
<tr><td>Assignment-1</td><td>2.5 %</td></tr>
<tr><td>Assignment-2</td><td>2.5 %</td></tr>
<tr><td>Attendance</td><td>5 %</td></tr>
</table>

	End-Term Examination		50 %
Prescribed Text Book(s)	1. Waltenegus Dargie, Christian Poellabauer, "Fundamentals of Wireless Sensor Networks: Theory and Practice", Wiley 2010 2. Mohammad S. Obaidat, Sudip Misra, "Principles of Wireless Sensor Networks", Cambridge, 2014		
Reference Book(s)	1. Ian F. Akyildiz, Mehmet Can Vuran , "Wireless Sensor Networks", Wiley 2010 2. C S Raghavendra, K M Sivalingam, Taieb Znati, "Wireless Sensor Networks", Springer, 2010 3. C. Sivarm murthy & B.S. Manoj, "Adhoc Wireless Networks", PHI-2004 4. FEI HU., XIAOJUN CAO, "Wireless Sensor Networks", CRC Press, 2013 5. Feng ZHAO, L GUIBAS, " Wireless Sensor Networks", ELSEVIER , 2004		
Digital Learning Resources	**Course Name**	Wireless Ad Hoc and Sensor Network	
	Course Link	https://archive.nptel.ac.in/courses/106/105/106105160/	
	Course Instructor	Prof. Sudip Misra	

CO's Mapping with PO's and PEO's

Course Outcomes	Course Outcome Statement	PO's / PEO's
CO1	Understand and explain common wireless sensor node architectures.	
CO2	Be able to carry out simple analysis and planning of WSNs.	
CO3	To analyze routing and congestion algorithms	
CO4	To design, develop , and carry out performance analysis of sensors on specific applications	

DETAILED SYLLABUS:

Module No. 1		**8 Hours**
Components of a wireless sensor node, Motivation for a Network of Wireless Sensor Nodes, Classification of sensor networks, Characteristics of wireless sensor networks, Challenges of wireless sensor networks, Comparison between wireless sensor networks and conventional wireless networks, Limitations in wireless sensor networks, Design challenges, Hardware architecture and applications		

Module No. 2		**6 Hours**
Physical Layer, Basic Components, Source Encoding, Channel Encoding, Modulation Medium Access Control: Wireless MAC Protocols, Characteristics of MAC Protocols in Sensor Networks, Contention-Free MAC Protocols, Contention-Based MAC Protocols, Hybrid MAC Protocols.		

Module No. 3		**8 Hours**
Routing Metrics, Flooding and Gossiping, Data-Centric Routing, Proactive Routing, On-Demand Routing, Hierarchical Routing, Location-Based Routing, QoS-Based Routing Protocols Node and Network Management: Power Management, Local Power Management aspects, Dynamic Power Management, Conceptual Architecture.		

Module No. 4		**8 Hours**
Clocks and the Synchronization Problem, Time Synchronization in Wireless Sensor Networks, Basics of Time Synchronization, Time Synchronization Protocols Localization: Ranging Techniques, Range-Based Localization, Range-Free Localization, Event Driven Localization.		

Module No. 5		**6 Hours**

Fundamentals of Network Security, Challenges of Security in Wireless Sensor Networks , Security Attacks in Sensor Networks, Protocols and Mechanisms for Security, IEEE 802.15.4 and Zig Bee Security.

COURSE DESCRIPTION: Satellite Communication

Degree	B. Tech.	
Level	Undergraduate	
Branch	ECE (Electronics and Communication Engineering)	
Semester	6th	
Subject Name	Satellite Communication	
Course Type	Theory	
Course Code	22EC6PE07T	
Category	PEC	
Credit Point	3	
Time Commitment	Lecture	36 Hours
	Tutorial	08 Hours
	Practice	Nil
	Total	44 Hours
Recommended Background Knowledge	Communication Engineering	
Subject Description	Satellite communication is a form of wireless communication that covers large area and long distance using satellites. In this course the students will get the basic technical knowledge of orbital dynamics, subsystems used in space segment and ground segment, power and bandwidth requirement, other impairments and techniques to mitigate them, regulatory aspect and standards.	

<table>
<tr><td rowspan="2">Objectives and Outcomes</td><td colspan="2">Objectives:
The course should enable the students to:
1. Educate students with a firm foundation in orbital mechanics and satellite launches.
2. Evaluate the impact of interference on the satellite communication and complete link design.
3. Comprehend multiple access techniques for satellite communication.
4. Design Earth Station antennas and educate them on a variety of useful satellite applications.</td></tr>
<tr><td colspan="2">Outcomes:
Upon completion of this course, the student will be able to:
1. Explain the basic concepts of orbit mechanics and satellite Launching.
2. Analyze and evaluate a satellite link and suggest enhancements to improve the link performance.
3. Classify various access methods and comprehend satellite link propagation impairments.
4. Explain the fundamentals of earth station technology and the role of satellites in various applications.</td></tr>
<tr><td rowspan="8">Assessment/ Evaluation</td><td>Mid-Term Examination</td><td>30 %</td></tr>
<tr><td>Quiz Test-1</td><td>2.5 %</td></tr>
<tr><td>Quiz-Test-2</td><td>2.5 %</td></tr>
<tr><td>Surprise Test</td><td>5 %</td></tr>
<tr><td>Assignment-1</td><td>2.5 %</td></tr>
<tr><td>Assignment-2</td><td>2.5 %</td></tr>
<tr><td>Attendance</td><td>5 %</td></tr>
<tr><td>End-Term Examination</td><td>50 %</td></tr>
<tr><td>Prescribed Text Book(s)</td><td colspan="2">1. T. Pratt, C. Bostian, Satellite Communication, 2nd Edition, John Wiley Co.,2003,India</td></tr>
</table>

	2. R.N.Mutagi, *Satellite Communication: Principles & Applications*, 1st Edition, Oxford University Press, 2016,India
Reference Book(s)	**1.** Dennis Roddy, *Satellite Communications*, 2nd Edition, McGraw Hill, 1996,India **2.** M. Richcharia, *Satellite Communications: Design Principles*, 2nd Edition, BSP, 2003,India **3.** Tri T. Ha, *Digital Satellite Communication*, Special Indian Edition, Tata McGraw- Hill, 2009, India

Digital Learning Resources	Course Name	Satellite Communication Systems
	Course Link	https://nptel.ac.in/courses/117/105/117105131/
	Course Instructor	Prof. Kalyankumar Bandyopadhyay

CO's Mapping with PO's and PEO's

Course Outcomes	**Course Outcome Statement**	**PO's / PEO's**
CO1	Explain the basic concepts of orbit mechanics and satellite Launching.	PO1, PO2, PO3, PO4, PO5, PO7, PO8, PO10, PO11, PO12, PEO1, PEO2.
CO2	Analyze and evaluate a satellite link and suggest enhancements to improve the link performance.	PO1, PO2, PO3, PO4, PO5, PO7, PO8, PO10, PO11, PO12, PEO1, PEO2.
CO3	Classify various access methods and comprehend satellite link propagation impairments.	PO1, PO2, PO3, PO4, PO5, PO7, PO8, PO10, PO11, PO12, PEO1, PEO2.
CO4	Explain the fundamentals of earth station technology and the role of satellites in various applications.	PO1, PO2, PO3, PO4, PO5, PO7, PO8, PO10, PO11, PO12, PEO1, PEO2.

DETAILED SYLLABUS:

Module No. 1		**10 Hours**
Introduction to satellite communication: Overview of satellite communications, General structure of satellite communication, Satellite frequency allocation and band spectrum, Satellite orbits – Performance characteristics of different altitude satellites (GEO, MEO and LEO satellite systems) **Orbital mechanics:** Introduction, Kepler's laws of planetary motion, Orbital parameters, look angle determination, Launches and Lunch vehicle, Orbital effects in communication system performance. **Satellite subsystem:** Attitude and Orbit Control System (AOCS), Telemetry, Tracking and Command System (TT&C), Power System, Satellite antennas, Communications subsystem, Transponders		

Module No. 2		**8 Hours**
Satellite Link Design: Basics of transmission theory, system noise temperature and G/T ratio, Uplink and Downlink design, design of satellite links for specified (C/N) performance.		

Module No. 3		**8 Hours**
Multiple Accesses: Multiplexing techniques for satellite links, Comprehensive study on FDMA, TDMA and CDMA; Spread Spectrum Transmission and Reception; Estimating Channel requirements, SPADE, Random access **Propagation on satellite:** Earth paths and influence on link design; Quantifying attenuation and depolarization, hydrometric & non hydrometric effects, ionosphere effects, rain and ice effects.		

Module No. 4		**8 Hours**
Satellite Antennas: Types of antenna and relationships; Basic Antennas Theory – linear, rectangular & circular aperture; Gain, pointing loss.		

Earth station Technology: Earth station design; Design of large antennas – Cassegrain antennas, optimizing gain of large antenna, antenna temperature, feed system for large cassegrain antennas.

Design of small earth station antennas: Front fed paraboloid reflector antennas, offset fed antennas, beam steering, Global Beam Antenna, equipment for earth station

Module No. 5		**6 Hours**
Application of Satellite communication: Overview of VSAT systems, Network architectures, direct broad casting TV. **Other Satellite services:** Fundamentals of mobile communication satellite.		

COURSE DESCRIPTION: Analog VLSI Design

Degree	B. Tech.	
Level	Undergraduate	
Branch	ECE (Electronics and Communication Engineering)	
Semester	6th	
Subject Name	Analog VLSI Design	
Course Type	Theory	
Course Code	22EC6PE08T	
Category	PEC	
Credit Point	3	
Time Commitment	Lecture	36 Hours
	Tutorial	08 Hours
	Practice	Nil

	Total	44 Hours
Recommended Background Knowledge	MOSFET Fundamentals, Circuit Theory, Analog Building Blocks, Frequency Response and Feedback	
Subject Description	**Analog VLSI Design** is a specialized field in electronics engineering focusing on the design, analysis, and implementation of analog circuits using CMOS technology. The subject covers essential building blocks such as operational amplifiers, differential amplifiers, current mirrors, voltage references, and oscillators. It delves into the principles of frequency response, feedback systems, and stability analysis to ensure robust circuit operation. A strong emphasis is placed on low-power design, noise reduction, and performance optimization to meet real-world constraints. Analog VLSI Design also explores ADC/DAC circuits, enabling seamless integration with digital systems. Students learn to apply simulation tools like SPICE for circuit verification and layout tools for physical design. The subject bridges the gap between device physics and system-level design, incorporating fabrication process knowledge. It finds applications in mixed-signal ICs, RF systems, and sensor interfaces. Through hands-on projects, students gain expertise in tackling challenges like process variations and parasitics. This field is critical for developing efficient and compact electronics in modern technology.	
Objectives and Outcomes	**Objectives:** The course should enable the students to: 1. Understand the concept of Robust Analog Design and Single-Stage Amplifiers. 2. Learn the concept of Differential Amplifier and Passive and Active Current Mirrors. 3. Learn the concept of Bandgap References and Operational Amplifier. 4. Understand the concept of Stability as well as Frequency Compensation and also learn the design methodology of amplifiers.	

<table>
<tr><td></td><td colspan="2">Outcomes:
Upon completion of this course, the student will be able to:
1. Analyze single stage amplifiers with different loads.
2. Acquire knowledge about differential amplifier with different loads and also analyze the concept of Passive and Active Current Mirrors.
3. Analyze the concept of Bandgap References and Operational Amplifier
4. Design and evaluate the performance of CMOS operational amplifiers with biasing as well as stability.</td></tr>
<tr><td rowspan="8">Assessment/ Evaluation</td><td>Mid-Term Examination</td><td>30 %</td></tr>
<tr><td>Quiz Test-1</td><td>2.5 %</td></tr>
<tr><td>Quiz-Test-2</td><td>2.5 %</td></tr>
<tr><td>Surprise Test</td><td>5 %</td></tr>
<tr><td>Assignment-1</td><td>2.5 %</td></tr>
<tr><td>Assignment-2</td><td>2.5 %</td></tr>
<tr><td>Attendance</td><td>5 %</td></tr>
<tr><td>End-Term Examination</td><td>50 %</td></tr>
<tr><td>Prescribed Text Book(s)</td><td colspan="2">1. Behzad Razavi, Design of Analog CMOS Integrated Circuits, 2nd Edition, Tata McGraw-Hill Publishing Company Limited, 2017.
2. Phillip E. Allen, Douglas R. Holberg, CMOS Analog Circuit Design, 3rd Edition, Oxford University Press, 2013.</td></tr>
<tr><td>Reference Book(s)</td><td colspan="2">1. David A Johns, Ken Martin, Analog Integrated Circuit Design, 2nd Edition, Wiley India Pvt. Limited, 2013.
2. Paul R Gray and R G Meyer, Analysis and design of analog integrated circuits, 6th Edition, Wiley, 2019</td></tr>
<tr><td rowspan="3">Digital Learning Resources</td><td>Course Name</td><td>Analog IC Design</td></tr>
<tr><td>Course Link</td><td>https://nptel.ac.in/courses/117/106/117106030/</td></tr>
<tr><td>Course Instructor</td><td>Prof. S. Aniruddhan| IIT Madras</td></tr>
</table>

	Course Name	CMOS Analog VLSI Design
	Course Link	https://nptel.ac.in/courses/117/101/117101105/
	Course Instructor	Prof. A.N. Chandorkar| IIT Bombay

CO's Mapping with PO's and PEO's

Course Outcomes	Course Outcome Statement	PO's / PEO's
CO1	Analyze single stage amplifiers with different loads.	PO1, PO2, PO3, PO4, PO5, PO7, PO8, PO10, PO11, PO12, PEO1, PEO2.
CO2	Acquire knowledge about differential amplifier with different loads and also analyze the concept of Passive and Active Current Mirrors.	PO1, PO2, PO3, PO4, PO5, PO7, PO8, PO10, PO11, PO12, PEO1, PEO2.
CO3	Analyze the concept of Bandgap References and Operational Amplifier	PO1, PO2, PO3, PO4, PO5, PO7, PO8, PO10, PO11, PO12, PEO1, PEO2.
CO4	Design and evaluate the performance of CMOS operational amplifiers with biasing as well as stability.	PO1, PO2, PO3, PO4, PO5, PO7, PO8, PO10, PO11, PO12, PEO1, PEO2.

DETAILED SYLLABUS:

Module No. 1		**10 Hours**
Introduction to 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.		

Module No. 2		**10 Hours**
Differential Amplifiers: Single-Ended and Differential Operation, Basic Differential Pair, Qualitative Analysis, Quantitative Analysis, Common-Mode Response, Differential Pair with MOS Loads. **Passive and Active Current Mirrors:** Basic Current Mirrors, Cascode Current Mirrors, Active Current Mirrors, Large-Signal Analysis, Small-Signal Analysis, Common-Mode Properties.		

Module No. 3		**06 Hours**
Bandgap References: General Considerations, Supply-Independent Biasing, Temperature-Independent References, Negative-TC Voltage,Positive-TC Voltage, Bandgap Reference, PTAT current generation.		

Module No. 4		**06 Hours**
Operational Amplifiers: General Considerations, Performance Parameters, One-Stage Op Amps, Two-Stage Op Amps, Gain Boosting, Slew Rate, Power Supply Rejection.		

Module No. 5		**04 Hours**
Design methodology of Amplifier: Design methodology with examples of Single Stage Amplifiers (CS) with resistive and MOS load, Differential Amplifier with resistive and active load, two stage operational Amplifier.		

COURSE DESCRIPTION: Fundamental of Satellite Communication

Degree	B. Tech.	
Level	Undergraduate	
Branch	ECE (Electronics and Communication Engineering)	
Semester	6th	
Subject Name	Fundamental of Satellite Communication	
Course Type	Theory	
Course Code	22EC6OE01T	
Category	OEC	
Credit Point	3	
Time Commitment	Lecture	36 Hours
	Tutorial	08 Hours
	Practice	Nil
	Total	44 Hours
Recommended Background Knowledge	Communication Engineering	
Subject Description	Satellite communication is a form of wireless communication that covers large area and long distance using satellites. In this course the students will get the basic technical knowledge of orbital dynamics, subsystems used in space segment and ground segment, power and bandwidth requirement, other impairments and techniques to mitigate them, regulatory aspect and standards.	
Objectives and Outcomes	**Objectives:** The course should enable the students to: 1. Make the students understand the basic concept in the field of Satellite Communication 2. Understand the design of satellite links 3. Gain knowledge about the Satellite Access schemes.	

	4. Comprehend the details of earth stations designand various useful satellite applications.	
	Outcomes: Upon completion of this course, the student will be able to: 1. Explain the basic concepts of orbit mechanics and satellite Launching 2. Analyze the design of satellite links for specified C/N with system design examples 3. Understand the various multiple access schemes for satellite communication systems, as well as the satellite link propagation impairments 4. Explain the fundamentals of earth station technology and the role of satellites in various applications.	
Assessment/ Evaluation	Mid-Term Examination	30 %
	Quiz Test-1	2.5 %
	Quiz-Test-2	2.5 %
	Surprise Test	5 %
	Assignment-1	2.5 %
	Assignment-2	2.5 %
	Attendance	5 %
	End-Term Examination	50 %
Prescribed Text Book(s)	1. T. Pratt, C. Bostian, *Satellite Communication*, 2nd Edition, John Wiley Co.,2003,India 2. R.N.Mutagi, *Satellite Communication: Principles & Applications*, 1st Edition, Oxford University Press, 2016,India	

Reference Book(s)	1. Dennis Roddy, *Satellite Communications*, 2nd Edition, McGraw Hill, 1996,India 2. M. Richcharia, *Satellite Communications: Design Principles*, 2nd Edition, BSP, 2003,India 3. Tri T. Ha, *Digital Satellite Communication*, Special Indian Edition, Tata McGraw- Hill, 2009, India	
Digital Learning Resources	Course Name	Satellite Communication Systems
	Course Link	https://nptel.ac.in/courses/117/105/117105131/
	Course Instructor	Prof. Kalyan kumar Bandyopadhyay

CO's Mapping with PO's and PEO's

Course Outcomes	Course Outcome Statement	PO's / PEO's
CO1	Explain the basic concepts of orbit mechanics and satellite Launching	PO1, PO2, PO3, PO4, PO5, PO7, PO8, PO10, PO11, PO12, PEO1, PEO2.
CO2	Analyze the design of satellite links for specified C/N with system design examples	PO1, PO2, PO3, PO4, PO5, PO7, PO8, PO10, PO11, PO12, PEO1, PEO2.
CO3	Understand the various multiple access schemes for satellite communication systems, as well as the satellite link propagation impairments	PO1, PO2, PO3, PO4, PO5, PO7, PO8, PO10, PO11, PO12, PEO1, PEO2.
CO4	Explain the fundamentals of earth station technology and the role of satellites in various applications.	PO1, PO2, PO3, PO4, PO5, PO7, PO8, PO10, PO11, PO12, PEO1, PEO2.

DETAILED SYLLABUS:

Module No. 1		**10 Hours**
Introduction to satellite communication: Overview of satellite communications, General structure of satellite communication, Satellite frequency allocation and band spectrum, Satellite orbits – Performance characteristics of different altitude satellites (GEO, MEO and LEO satellite systems) **Orbital mechanics:** Introduction, Kepler's laws of planetary motion, Orbital parameters, look angle determination, Launches and Lunch vehicle, Orbital effects in communication system performance. **Satellite subsystem:** Attitude and Orbit Control System (AOCS), Telemetry, Tracking and Command System (TT&C), Power System, Satellite antennas, Communications subsystem, Transponders.		

Module No. 2		**8 Hours**
Satellite Link Design: Basics of transmission theory, system noise temperature and G/T ratio, Uplink and Downlink design, design of satellite links for specified (C/N) performance.		

Module No. 3		**8 Hours**
Multiple Accesses: Multiplexing techniques for satellite links, Comprehensive study on FDMA, TDMA and CDMA; Spread Spectrum Transmission and Reception **Propagation on satellite:** Earth paths and influence on link design; Quantifying attenuation and depolarization, hydrometric & non hydrometric effects, ionosphere effects, rain and ice effects.		

Module No. 4		**8 Hours**
Satellite Antennas: Types of antenna and relationships; Basic Antennas Theory – linear, rectangular & circular aperture; Gain, pointing loss. **Earth station Technology:** Earth station design; Design of large antennas – Cassegrain antennas		

Module No. 5		6 Hours
Application of Satellite communication: Overview of VSAT systems, Network architectures, direct broad casting TV. **Other Satellite services:** Fundamentals of mobile communication satellite.		

COURSE DESCRIPTION: Introduction to Digital VLSI Design

Degree	B. Tech.	
Level	Undergraduate	
Branch	ECE (Electronics and Communication Engineering)	
Semester	6th	
Subject Name	Introduction to Digital VLSI Design	
Course Type	Theory	
Course Code	22EC6OE02T	
Category	OEC	
Credit Point	3	
Time Commitment	Lecture	36 Hours
	Tutorial	08 Hours
	Practice	Nil
	Total	44 Hours
Recommended Background Knowledge	A solid understanding of Digital Electronics (logic gates, sequential circuits), CMOS fundamentals (MOSFET operation, fabrication, and scaling), and Basic Circuit Design is essential. Familiarity with SPICE simulations, and testing methodologies will enhance learning.	

<table>
<tr><td>Subject Description</td><td colspan="2">The subject Introduction to Digital VLSI Design focuses on the principles and methodologies for designing high-performance digital integrated circuits. It covers topics like CMOS technology, fabrication processes, and MOSFET characteristics, emphasizing logic circuit design and optimization. Students learn to design combinational and sequential circuits, analyze power dissipation, and address timing issues. Advanced topics include layout techniques, clock strategies, and design-for-testability (DFT) methodologies to enhance circuit reliability and manufacturability.</td></tr>
<tr><td rowspan="2">Objectives and Outcomes</td><td colspan="2">Objectives:
The course should enable the students to:
1. Introduce VLSI design fundamentals, including IC technology, design flow, and modular principles.
2. Explore CMOS fabrication processes and MOSFET characteristics, including scaling and modeling.
3. Develop skills to design and analyze CMOS combinational and sequential logic circuits.
4. Analyze circuit performance, focusing on delay constraints, interconnect effects, and power dissipation.</td></tr>
<tr><td colspan="2">Outcomes:
Upon completion of this course, the student will be able to:
1. Explain VLSI design concepts, including IC technology, design hierarchy, and layout rules.
2. Analyze MOSFET operation, current-voltage characteristics, and scaling effects in digital circuits.
3. Design and optimize CMOS combinational and sequential circuits for performance and power efficiency.
4. Apply timing analysis, interconnect effects, and power dissipation considerations to digital circuit design.</td></tr>
<tr><td>Assessment/ Evaluation</td><td>Mid-Term Examination</td><td>30 %</td></tr>
</table>

	Quiz Test-1	2.5 %
	Quiz-Test-2	2.5 %
	Surprise Test	5 %
	Assignment-1	2.5 %
	Assignment-2	2.5 %
	Attendance	5 %
	End-Term Examination	50 %
Prescribed Text Book(s)	1. Sung-Mo Kang, Yusuf Leblebici and Chul Woo Kim, *CMOS Digital Integrated Circuits: Analysis and Design*, 4th Edition, Tata McGraw-Hill Publishing Company Limited, 2015. 2. Debaprasad Das, *VLSI Design*, 2nd Edition, Oxford University Press, 2015, New Delhi.	
Reference Book(s)	1. Neil h. e. weste, David harris and Ayan Banerjee, *CMOS VLSI design a circuits and systems perspective*, 4th Edition, Pearson Education, 2015. **2.** Jan M. Rabaey, Anantha Chandrakasan and Borivoje Nikolic, *Digital Integrated Circuits – A Design Perspective,* 2nd Edition , PHI Learning, 2016, New Delhi.. **3.** Wayne Wolf, *Modern VLSI Design System on Chip Design*, 3rd Edition, PHI Learning Publisher, 2016, New Delhi. **4.** John P. Uyemura, *CMOS Logic Circuit Design*, 1st Edition, Springer, 2007, US.	

Digital Learning Resources	**Course Name**	Digital VLSI Design
	Course Link	https://nptel.ac.in/courses/108/103/108103108/
	Course Instructor	Prof. Chandan Karfa | IIT Guwahati
	Course Name	CMOS Digital VLSI Design
	Course Link	https://nptel.ac.in/courses/108/107/108107129/
	Course Instructor	Prof. Sudeb Dasgupta | IIT Roorkee

CO's Mapping with PO's and PEO's

Course Outcomes	Course Outcome Statement	PO's / PEO's
CO1	Explain VLSI design concepts, including IC technology, design hierarchy, and layout rules.	PO1, PO2, PO4, PO5, PO7, PO10, PO11, PO12, PEO1, PEO2.
CO2	Analyze MOSFET operation, current-voltage characteristics, and scaling effects in digital circuits.	PO1, PO2, PO3, PO4, PO7, PO8, PO10, PO12, PEO1, PEO2.
CO3	Design and optimize CMOS combinational and sequential circuits for performance and power efficiency.	PO1, PO2, PO4, PO5, PO8, PO10, PO11, PEO1, PEO2.
CO4	Apply timing analysis, interconnect effects, and power dissipation considerations to digital circuit design.	PO1, PO2, PO3, PO4, PO7, PO8, PO10, PO11, PO12, PEO1, PEO2.

DETAILED SYLLABUS:

Module No. 1	Introduction to Digital VLSI Design	08 Hours
Introduction: IC technology an overview, Classification of IC technology, VLSI Design challenges, VLSI Design Flow, Design Hierarchy, Concept of Regularity, Modularity and Locality, VLSI Design Styles. Fabrication Processes Flow–Basic Concepts, the CMOS n-Well and p-well Process, Layout Design Rules, Stick Diagrams, Mask Layout Design.		

Module No. 2	MOS Transistor	10 Hours
MOS Transistor: The MOS System under External Bias, Structure and Operation of MOS Transistor (MOSFET), MOSFET Current-Voltage Characteristics, SPICE models for MOS transistor, MOSFET Scaling, MOSFET Capacitance.		

Module No. 3	**Static Characteristics and MOS Inverters– Switching Characteristics and Interconnect Effects**	**14 Hours**
Static Characteristics: Introduction, Resistive-Load Inverters, Enhancement-Load nMOS Inverter, Depletion-LoadnMOS Inverter, CMOS Inverter. **MOS Inverters– Switching Characteristics and Interconnect Effects:** Introduction, Delay-Time Definitions, Calculation of Delay-Times, Inverter Design with Delay Constraints, Switching Power Dissipation of CMOS Inverters		

Module No. 4	**Combinational MOS Logic Circuits**	**06 Hours**
Combinational MOS Logic Circuits: CMOS Logic Circuits, Complex Logic Circuits, Layout of Complex CMOS Logic Gates, AOI and OAI Gates, Pseudo-nMOS Gate, CMOS Full-Adder Circuit, CMOS Transmission Gates (Pass Gates), Pass Transistor Circuits, Complementary Pass-TransistorLogic (CPL), Power dissipation.		

Module No. 5	**Sequential MOS Logic Circuits**	**06 Hours**
Sequential MOS Logic Circuits: Static and Dynamic Latches and Registers, Timing issues, pipelines, clock strategies, Clocked Latch and Flip-Flop Circuits and CMOS D-Latch.		

COURSE DESCRIPTION: Microwave Engineering Lab

Degree	B. Tech.
Level	Undergraduate
Branch	ECE (Electronics and Communication Engineering)
Semester	6th

Subject Name	Microwave Engineering	
Course Type	Laboratory	
Course Code	22EC6PC02L	
Category	PCC	
Credit Point	1	
Time Commitment	Lecture	05 Hours
	Tutorial	Nil
	Practice	20 Hours
	Total	25 Hours
Recommended Background Knowledge	Microwave Engineering Lab involves hands-on experiments with microwave components and systems, requiring prior knowledge of electromagnetic theory, transmission lines, and network analysis.	
Subject Description	The Microwave Engineering Lab provides practical exposure to the design, testing, and characterization of microwave components and systems. Students perform experiments on waveguides, antennas, transmission lines, and devices like circulators and directional couplers. The lab emphasizes understanding microwave measurement techniques and analyzing real-world applications in communication and radar systems.	
Objectives and Outcomes	**Objectives:** The course should enable the students to: 1. To provide hands-on experience in analyzing and measuring the performance of microwave components and devices. 2. To determine the performance parameters of microwave junctions and directional couplers through experiments. 3. To introduce simulation-based design and analysis of various passive microwave devices using electromagnetic simulation tools. 4. To analyze the radiation pattern characteristics and performance of horn antennas and microstrip patch antennas using simulations.	

	Outcomes: Upon completion of this course, the student will be able to: 1. Analyze the characteristics and performance of microwave components and instruments through practical experiments, including Gunn diode operation. 2. Evaluate the performance and applications of microwave tubes, such as reflex klystrons, through experimental observation. 3. Design and analyze E-plane, H-plane, and magic tees to study their scattering parameters and functionality in microwave systems. 4. Design and simulate horn antennas and microstrip patch antennas based on given specifications using advanced simulation tools, and interpret their radiation characteristics.	
Assessment/ Evaluation	Lab Experiments	20%
	Record Writing	10%
	Behavior/ Attitude	05%
	Quiz	10%
	Attendance	05%
	Final Lab Test	30%
	Final Viva/ Final Lab Quiz Test	20%
	Lab Experiments	20%

CO's Mapping with PO's and PEO's

Course Outcomes	Course Outcome Statement	PO's / PEO's
CO1	Analyze the characteristics and performance of microwave components and instruments through practical experiments, including Gunn diode operation.	
CO2	Evaluate the performance and applications of microwave tubes, such as reflex klystrons, through experimental observation.	

CO3	Design and analyze E-plane, H-plane, and magic tees to study their scattering parameters and functionality in microwave systems.	
CO4	Design and simulate horn antennas and microstrip patch antennas based on given specifications using advanced simulation tools, and interpret their radiation characteristics.	

Sl. No.	**Name of Experiments**	**Duration in Hrs**
	(Any Ten of the following experiments are to be performed with X-band/S-band/Ku-band Microwave components)	
1	Study of Microwave components and Instruments	2
2	Measurement of Reflex Klystron Characteristics	2
3	Study of V-I characteristics of Gunn Diode	2
4	Measurement of Directional coupler characteristics	2
5	Calibration of the attenuation constant of an Attenuator	2
6	Measurement of Voltage Standing Wave Ratio (VSWR) and reflection Coefficient	2
7	To measure an unknown impedance using smith chart	2
8	Impedance, Wavelength and Frequency Measurement	2
9	To study the isolator and circulator.	2
10	Design of a Rectangular waveguide and determination of cutoff frequency of the dominant mode.	2
11	Design and analysis of microstrip Patch antenna.	2
12	Design of a pyramidal Horn Antenna and study its radiation characteristics.	2
13	Design and analysis of E plane Tee and H plane Tee.	2
14	Design and analysis of Magic Tee.	

COURSE DESCRIPTION: Digital VLSI Design

Degree	B. Tech.	
Level	Undergraduate	
Branch	ECE (Electronics and Communication Engineering)	
Semester	6th	
Subject Name	Digital VLSI Design	
Course Type	Laboratory	
Course Code	22EC6PC03L	
Category	PCC	
Credit Point	1	
Time Commitment	Lecture	10 Hours
	Tutorial	Nil
	Practice	20 Hours
	Total	30 Hours
Recommended Background Knowledge	Basic Electronics and Circuits, Digital Logic Design, Semiconductor Fundamentals, Programming Knowledge, Hardware Description Languages, Mathematical Foundations, Electronics Laboratory Experience, Basic Knowledge of EDA Tools (Optional)	
Subject Description	The **Digital VLSI Design Lab** provides practical exposure to the design, simulation, and implementation of digital circuits using CMOS technology. It equips students with the skills to model, synthesize, and analyze digital systems using hardware description languages (HDLs) such as Verilog or VHDL. Students gain hands-on experience with Electronic Design Automation (EDA) tools to design and simulate CMOS logic gates, combinational and sequential circuits, and memory elements. The lab emphasizes the principles of low-power, high-performance digital circuit design while exploring layout	

	techniques and physical design processes.
Objectives and Outcomes	**Objectives:** The course should enable the students to: 1. Equip students with the knowledge and skills to model and simulate digital circuits using hardware description languages (HDLs) such as Verilog or VHDL. 2. Provide hands-on experience in designing and analyzing CMOS-based digital circuits, focusing on concepts like combinational and sequential logic, power efficiency, and performance optimization. 3. Train students in designing CMOS logic gates and their corresponding physical layouts using EDA tools. 4. Prepare students for careers in semiconductor design, embedded systems, and related research areas by familiarizing them with industry-standard tools and processes.
	Outcomes: Upon completion of this course, the student will be able to: 1. Design and simulate digital circuits using Verilog or VHDL for a variety of applications. 2. Analyze and implement digital circuits based on CMOS technology, focusing on power, performance, and area optimization. 3. Use industry-standard EDA tools to simulate and verify the functionality and timing of digital designs. 4. Create combinational and sequential logic modules and optimize them for efficiency. 5. Synthesize, implement, and test digital logic designs on FPGA platforms, bridging the gap between design and hardware realization

Assessment/ Evaluation	Lab Experiments	20%
	Record Writing	10%
	Behavior/ Attitude	05%
	Quiz	10%
	Attendance	05%

	Final Lab Test	30%
	Final Viva/ Final Lab Quiz Test	20%
	Lab Experiments	20%
Prescribed Text Book(s)	1. "CMOS VLSI Design: A Circuits and Systems Perspective"Neil H. E. Weste, David Harris, Pearson. 2. "Verilog HDL: A Guide to Digital Design and Synthesis", Samir Palnitkar, Pearson Education 3. "Principles of CMOS VLSI Design", Neil H. E. Weste, Kamran Eshraghian Addison-Wesley 4. **"Fundamentals of Digital Logic with Verilog Design"** Stephen Brown, Zvonko Vranesic McGraw-Hill	

Digital Learning Resources	Course Name	**Architectural Design of Digital Integrated Circuits**
	Course Link	https://onlinecourses.nptel.ac.in/noc20_ee37/preview
	Course Instructor	**Architectural Design of Digital Integrated Circuits** Instructor: Prof. Indranil Hatai, IIEST Shibpur
	Course Name	**CMOS Digital VLSI Design**
	Course Link	https://onlinecourses.nptel.ac.in/noc22_ee08/preview
	Course Instructor	Instructor: Prof. Sudeb Dasgupta, IIT Roorkee

CO's Mapping with PO's and PEO's

Course Outcomes	**Course Outcome Statement**	**PO's / PEO's**
CO1	Develop digital circuits using Verilog HDL with gate-level, dataflow, and behavioral modeling techniques.	PO1, PO2, PO3, PO4, PO5
CO2	Realize fundamental digital components like logic gates, multiplexers, encoders, decoders, flip-flops, and finite state machines using	PO1, PO2, PO3, PO5

	Verilog HDL	
CO3	Model and optimize combinational and sequential circuits such as full adders, binary-to-gray code converters, and state machines.	PO1, PO2, PO3, PO4, PO5, PO6
CO4	Use Tanner EDA tools to design, simulate, and analyze CMOS circuits, including inverters, logic gates, transmission gates, and oscillators.	PO1, PO2, PO3, PO4, PO5, PO6

LABUS (EXPERIMENTS):

Sl. No.	Name of Experiments	Durations
1	Design and verification of a Full Adder Using Structural, Dataflow, and Behavioral Modeling in Verilog.	2h
2	**a)** Design and verification of a 3-Bit Comparator Using Verilog. **b)** Design and verification of a 4-bit Binary to Gray Code Converter Using Verilog.	2h
3	Design and Functional Verification of Combinational Circuits: 2:4 Decoder, 8:3 Encoder, and 8:1 MUX/DeMUX Using Verilog.	2h
4	Design, Simulation, and Synthesis Analysis of SR, JK, T, and D Flip-Flops Using Verilog, find out Gate-Level Netlist, Area Analysis, Power Consumption, and Timing Analysis.	2h
5	Design, Verification, and Synthesis Analysis of Finite State Machines (Mealy/Moore) for Sequence Generation Using Verilog.	2h
6	Design, Layout, and Analysis of CMOS Inverter Using Tanner EDA: Switching Characteristics, Functional Behavior, and Layout Verification.	2h
7	Design, Layout, and Analysis of Transmission Gate Using Tanner EDA: Switching Characteristics, Functional Behavior, and Layout Verification.	2h
8	Design, Layout, and Analysis of NAND Gate Using Tanner EDA: Switching Characteristics, Functional Behavior, and Layout	2h

	Verification.	
9	Design, Layout, and Analysis of 2:1 MUX Using Tanner EDA: Switching Characteristics, Functional Behavior, and Layout Verification.	2h
10	Design, Layout, and Analysis of Ring Oscillator(3 Inverter) Using Tanner EDA: Switching Characteristics, Functional Behavior, and Layout Verification.	2h

COURSE DESCRIPTION: Research and Lab-Based Project

Degree	B. Tech.	
Level	Undergraduate	
Branch	ECE (Electronics and Communication Engineering)	
Semester	6th	
Subject Name	Research and Lab-Based Project	
Course Type	Laboratory	
Course Code	22CM6PS01L	
Category	PSI	
Credit Point	2	
Time Commitment	Lecture	10 Hours
	Tutorial	Nil
	Practice	20 Hours
	Total	30 Hours
Recommended Background Knowledge	Research and Lab-Based Projects involve conducting in-depth studies and experiments on advanced topics, requiring knowledge of research methodologies, experimental design, and relevant subject matter expertise.	
Subject Description	The Research and Lab-Based Project subject involves applying theoretical knowledge to solve real-world engineering problems through independent research and practical experimentation. Students design and execute projects, often in collaboration with faculty or industry, to address challenges in various engineering fields. The subject emphasizes innovation, critical thinking, and hands-on experience in developing prototypes, models, or systems.	
Objectives and	**Objectives:** The course should enable the students to: 1. Enable students to apply theoretical concepts to solve practical	

<table>
<tr><td rowspan="2">Outcomes</td><td colspan="2">engineering problems through independent research and experimentation.
2. Develop critical thinking, problem-solving, and analytical skills by designing and conducting research projects.
3. Foster collaboration and communication skills by working with faculty, peers, or industry experts on real-world projects.
4. Enhance students' ability to design, prototype, and test engineering systems or solutions using modern tools and methodologies.</td></tr>
<tr><td colspan="2">Outcomes:
Upon completion of this course, the student will be able to:
1. Gain hands-on experience in conducting research and experiments, addressing complex engineering problems.
2. Develop the ability to analyze data, evaluate outcomes, and propose solutions based on research findings.
3. Demonstrate the ability to work independently or in teams, showcasing effective time management and project coordination skills
4. Improve their communication skills, presenting their research findings clearly through reports, presentations, or publications.</td></tr>
<tr><td rowspan="4">Assessment/ Evaluation</td><td>Project Work</td><td>40%</td></tr>
<tr><td>Report Writing</td><td>20%</td></tr>
<tr><td>Attendance</td><td>10%</td></tr>
<tr><td>PPT presentation</td><td>30%</td></tr>
</table>

CO's Mapping with PO's and PEO's

Course Outcomes	Course Outcome Statement	PO's / PEO's
CO1	Gain hands-on experience in conducting research and experiments, addressing complex engineering problems.	PO1, PO2, PO3, PO4, PO5

CO2	Develop the ability to analyze data, evaluate outcomes, and propose solutions based on research findings.	PO1, PO2, PO3, PO5
CO3	Demonstrate the ability to work independently or in teams, showcasing effective time management and project coordination skills	PO1, PO2, PO3, PO4, PO5, PO6
CO4	Improve their communication skills, presenting their research findings clearly through reports, presentations, or publications.	PO1, PO2, PO3, PO4, PO5, PO6

DETAILED SYLLABUS :

Carry out a project on one of the latest emerging technologies approved by the Department Committee.

Sl. No.	Name of Projects	Durations
1	Implementation of the project in Embedded system with IoT.	
2	Carry out projects on Analog and Digital VLSI using the EDA tool.	
3	Carry out project on Communication, signal/image processing using MATLAB/SCILAB	
4	Carry out project on RF and Microwave Engineering using CST studio / HFSS / Microwave office	
5	Carry out project on Wireless Communication using WiCOMM-T/MATLAB	
6	Carry out project on FPGA Based Embedded System.	
7	Carry out project on Nano-Electronics.	
8	Undertake projects in Artificial Intelligence, Machine Learning, Deep Learning, Computer Vision, and Natural Language Processing, leveraging the power of Python programming.	