

NATIONAL INSTITUTE OF ELECTRONICS AND INFORMATION TECHNOLOGY

DEEMED TO BE UNIVERSITY UNDER DISTINCT CATEGORY
(AN AUTONOMOUS INSTITUTION UNDER MINISTRY OF ELECTRONICS & IT, GOVT. OF INDIA)

Curriculum and Syllabi for M.Tech - Embedded Systems (2026-27 Scheme)



Main Campus at Ropar and Constituent Units at Aizawl, Agartala, Aurangabad, Calicut, Gorakhpur, Imphal, Itanagar, Kekri, Kohima, Patna and Srinagar

Vision

To prepare fresh graduates and upskill working professionals into proficient Embedded System Design Engineers by imparting advanced knowledge in both hardware and software domains. The program emphasizes industry-relevant topics aligned with current trends in embedded system development, enabling graduates to contribute effectively to industry or engage in application-oriented research in the embedded systems landscape.

Mission

To empower aspiring and working electronics engineers with industry-relevant education in embedded hardware and software design, transforming them into skilled Embedded System Professionals. The program bridges the gap between academic concepts and industrial requirements, fostering innovation, practical expertise, and career readiness for roles in embedded system development and application-driven research.

Program Education Objectives

PEO1: Professional Excellence

To equip fresh graduates and working professionals with the knowledge and skills required to become proficient Embedded System Designers.

PEO2: Industry Readiness

To prepare students for careers in industries involved in embedded systems through industry-relevant training.

PEO3: Research and Innovation

To build a strong foundation for students to pursue application-oriented research and innovation in the evolving domain of embedded systems.

Program Outcomes

Upon successful completion of the program, the learners will be able to:

PO1: Apply Engineering Knowledge

Demonstrate comprehensive understanding of hardware and software aspects of embedded system design.

PO2: Industry-Relevant Skills

Integrate practical and theoretical knowledge to solve real-world problems in embedded product development.

PO3: Design Proficiency

Design, develop, and test embedded products using current technologies and tools.

PO4: Lifelong Learning and Research Orientation

Exhibit readiness to engage in lifelong learning and pursue research or higher studies in advanced areas of embedded systems.

PO5: Problem Solving and Innovation

Apply analytical skills to design innovative solutions for embedded system applications in industrial contexts.

Program Specific Outcomes

PSO1: Embedded System Competence

Apply comprehensive knowledge of hardware and software to design and develop embedded systems for real-world applications.

PSO2: Industry-Aligned Skills

Demonstrate proficiency in using modern tools and technologies to solve practical problems in embedded product development.

PSO3: Design and Innovation

Design, implement, and evaluate embedded solutions with a focus on performance, reliability, and innovation.

PSO4: Research and Lifelong Learning

Pursue research, higher studies, or continuous learning in emerging areas of embedded systems and allied domains.

CATEGORY WISE CREDIT DISTRIBUTION

Category	Category Code	Credits
Open Elective Courses	OE	8
Audit Courses (without grade or credit)	AU	0
Skill / Employment Enhancement Courses (Project/Internship/Seminar/Dissertation/Research)	EE	36
Professional Elective Courses	PE	16
Program Core Courses	PC	20
Total Credits (Common track)		80

EVALUATION AND ASSESSMENT

1. Performance of a student in a semester shall be evaluated through continuous Class assessment, Tutorial/Lab assessment, Mid-Semester Examination (MSE) and End-Semester Examination (ESE). Both the MSE and ESE shall be the University examination and will be conducted as notified by the Controller of Examinations (CoE) of the University.
2. The continuous assessment shall be based on assignments, tutorials, paper presentation / quizzes/ viva-voce / flipped classes, lab work / projects / fieldwork and attendance, etc.
3. The MSE/ESE shall be comprising of written papers.
4. The overall assessment of the students will be done as per the following scheme:

S. No.	Assessment Type	Marks Weightage
1.	Mid Semester Examination	20
2.	End Semester Examination	40
3.	Continuous Assessment - Practical /Lab/ Tutorial	25
4.	Continuous Assessment - Theory	15
Total		100

For more details, please refer the applicable ordinance for this programme and Assessment SOPs.

CURRICULUM

Semester 1

Semester Code	Course Code	Course Title	L	T	P	Cr
PC-MTEEMS-101	DASH250002	Advanced Engineering Mathematics	3	1	0	4
PC-MTEEMS-102	DOEE250090	Embedded Programming	3	0	2	4
PC-MTEEMS-103	DOEE250005	Advanced Digital System Design	3	0	2	4
PE-MTEEMS-104	Elective	Program Elective				4
EE-MTEEMS-105	DASH250095	Research Methodology and IPR	3	1	0	4
AU-MTEEMS-106	Elective	Audit Elective				0

Semester 2

Semester Code	Course Code	Course Title	L	T	P	Cr
PC-MTEEMS-201	DOAI250002	Advanced Machine Learning	3	0	2	4
PC-MTEEMS-202	DOEE250088	Embedded OS and RTOS	3	0	2	4
PE-MTEEMS-203	Elective	Program Elective				4
PE-MTEEMS-204	Elective	Program Elective				4
OE-MTEEMS-205	Elective	Open Elective				4
AU-MTEEMS-206	Elective	Audit Elective				0

Semester 3

Semester Code	Course Code	Course Title	L	T	P	Cr
PE-MTEEMS-301	Elective	Program Elective				4
OE-MTEEMS-302	Elective	Open Elective				4
EE-MTEEMS-303	EE	DISSERTATION PHASE I				14

Semester 4

Semester Code	Course Code	Course Title	L	T	P	Cr
EE-MTEEMS-401	EE	DISSERTATION PHASE II				18

Elective Courses

Elective Courses for PE Category						
Course Code	Course Title	L	T	P	Cr	For Sem./Code
DOAI260001	AI (Industry)-Applied Ethics for AI	3	0	2	4	
DOAI260002	AI (Industry)-Introduction to Artificial Intelligence	3	0	2	4	
DOAI260003	AI (Industry)-Introduction to Generative AI	3	0	2	4	
DOAI260004	AI (Industry)-Introduction to Machine Learning	3	0	2	4	
DOEE250003	Advanced Data Communication and Networking	3	1	0	4	104
DOEE250181	Sensor Technologies and MEMS	3	1	0	4	104
DOEE250185	System Design Using Embedded Processors	3	0	2	4	104
DCSA250034	Information Security	3	0	2	4	203
DOEE250121	Internet of Things	3	0	2	4	203
DOEE250207	Wireless Technologies	3	1	0	4	203
DOEE250175	Reconfigurable Computing	3	0	2	4	204
DOEE250201	VLSI Signal Processing	3	0	2	4	204

Elective Courses for OE Category	
Students may opt courses under MOOC, NPTEL, SWAYAM, NSQF/NCVET aligned courses or other relevant technical subjects not included in their core curriculum. The exercise of option shall be subject to the Course Schedule of the respective Constituent Unit, the credit requirements and availability of seats. Guidelines for choosing MOOC/Online courses are given separately and shall have to be adhered to.	

Elective Courses for AU (Audit) Category						
Course Code	Course Title	L	T	P	Cr	
DASH240027	Disaster Management	2	0	0	0	
DASH240047	English for Research Paper Writing	2	0	0	0	
DASH240052	Environmental Science	3	0	0	0	
DASH240085	Pedagogy Studies	2	0	0	0	
DASH240086	Personality Development through Life Enlightenment Skills	2	0	0	0	
DASH240097	Sanskrit for Technical Knowledge	2	0	0	0	
DASH240103	Stress Management by Yoga	2	0	0	0	
DASH240104	Technical Presentation and Report Writing	0	0	2	0	
DASH240106	Value Education	2	0	0	0	
DASH240124	Constitution of India - AU	2	0	0	0	
DASH250023	Constitution of India	2	1	0	0	
DASH250027	Disaster Management	3	0	0	0	
DASH250034	Energy and Environmental Engineering	3	0	0	0	
DASH250047	English for Research Paper Writing	2	0	0	0	
DASH250054	Essence of Indian Knowledge and Tradition	2	0	0	0	
DASH250085	Pedagogy Studies	2	0	0	0	

DASH250086	Personality Development	2	0	0	0
DASH250097	Sanskrit for Technical Knowledge	3	0	0	0
DASH250103	Stress Management by Yoga	3	0	0	0
DASH250106	Value Education	2	0	0	0
DASH250117	Innovative Thinking and Entrepreneurship Skills	1	0	0	0
DASH250118	Intellectual Property Rights	2	0	0	0
DCSA240080	Training on Computer Networking	0	0	2	0
DCSA240304	Lab Based on Statistical Package	0	0	2	0
Any other Scheduled Course as per the Course Schedule of the respective Constituent Unit can also be chosen, subject to availability of seats. However, there shall be no assessment and grading for the course chosen as Audit Course.					

The choice of all type of Electives available shall be as per the Course Schedule of the respective Constituent Unit.

Guidelines for Massive Open Online Courses (MOOC) / approved Online Courses

1. Relevant Swayam, MOOC, NPTEL, NIELIT NSQF and any other online courses approved by UGC/AICTE shall also be allowed as Open Electives(OE).
2. One credit of MOOC course should be minimum of 30 hours.
3. A student can choose any approved online course as Open Elective, subject to minimum credit requirements.
4. The students willing to opt OE under MOOC in their next semester, will submit their request to the MOOC Coordinator at their respective campus.
5. Once approved, the campus shall display the list of accepted courses.
6. The student has to submit certificate issued by the institution offering the MOOCs course, along with the number of credits and grades, to get credits transferred into his/her marks certificate issued by NDU.
7. The transfer of credits shall be as adopted by NDU.

Detailed Syllabus

Course Code	Course Name	L	T	P	Cr
DASH250002	Advanced Engineering Mathematics	3	1	0	4

Course Outcomes:

- CO1 : Model real-world uncertainty using probability theory and manipulate random variables in applied contexts.
- CO2 : Analyze convergence behavior of sequences of random variables and apply statistical limit theorems in AI/ML.
- CO3 : Solve abstract algebraic and vector space problems relevant to machine learning algorithmic design.
- CO4 : Perform linear transformations, change of basis, and analyze solvability of linear systems in data-centric applications.
- CO5 : Apply numerical methods such as interpolation, numerical differentiation, and integration in data approximation and machine learning tasks.

Module 1:

Probability Theory and Random Variables (9 Hours)

Axiomatic definition of probability, Bayes' theorem with applications, Random variables: discrete and continuous, Cumulative distribution function (CDF), Probability Mass Function (PMF), Probability Density Function (PDF), Conditional and joint distributions, independence of random variables.

Module 2:

Expectation, Moment Generating Functions, and Limit Theorems (9 Hours)

Expectation and fundamental properties, Moment generating functions (MGF) and characteristic functions (CF), Conditional expectation and covariance matrix, Uncorrelated random variables and joint Gaussian PDFs, Markov inequality, Chebyshev inequalities, Central Limit Theorem (CLT), weak and strong laws of large numbers, Modes of convergence of random variables. Random Process, Markov Process and Markov Chain.

Module 3:

Algebraic Structures and Vector Spaces (9 Hours)

Groups, rings, and fields (basic definitions and examples), Vector spaces and subspaces over a field, Linear independence, span, basis, and dimension, Direct sum of subspaces. System of Equations, Solving system of linear equations using Gaussian elimination.

Module 4:

Linear Transformations (9 Hours)

Linear transformations and their matrix representation, Four fundamental subspaces: null space, column space, row space, and left null space, Rank, Rank-Nullity Theorem, Solving systems of linear equations: existence and uniqueness, Transpose of a linear transformation. Orthogonality & Orthonormality, Orthogonalization, Eigen Value, Eigen Vector, Diagonalization of vectors.

Module 5:

Interpolation, Numerical Differentiation & Integration (9 Hours)

Lagrange's interpolation, Newton's divided difference interpolation, Newton's forward and backward difference interpolation, Approximation of derivatives using interpolation polynomials, Numerical integration using: Trapezoidal rule, Simpson's 1/3 rule.

Labs / Practicals:

N/A

References:

1. Gupta, S. C., and Kapoor, V. K., Fundamentals of Mathematical Statistics, Sultan Chand & Sons, New Delhi.
2. Goon, A. M., Gupta, M. K., and Dasgupta, B., An Outline of Statistical Theory, Vol. 1 & 2, World Press, Kolkata.
3. Hogg, R. V., McKean, J., and Craig, A. T., Introduction to Mathematical Statistics, Pearson Education.
4. Papoulis, A., and Pillai, S. U., Probability, Random Variables and Stochastic Processes, McGraw Hill Education.
5. Rao, C. R., Linear Statistical Inference and Its Applications, Wiley Eastern Limited.
6. Ramana, B. V., Higher Engineering Mathematics, Tata McGraw Hill Education.
7. Hoffman, K., and Kunze, R., Linear Algebra, Prentice Hall of India.
8. Jain, M. K., Iyengar, S. R. K., and Jain, R. K., Numerical Methods for Scientific and Engineering Computation, New Age International Publishers, New Delhi.
9. Kreyszig, E., Advanced Engineering Mathematics, Wiley India Edition.
10. Lipschutz, S., and Lipson, M., Linear Algebra, Schaum's Outline Series, McGraw Hill Education.

Course Code	Course Name	L	T	P	Cr
DOEE250090	Embedded Programming	3	0	2	4

Course Outcomes:

CO1: Understand fundamental concepts of programming, algorithms, flowcharts, and the basics of computation for effective problem-solving and logical thinking.

CO2: Apply C programming constructs including data types, operators, control statements, functions, arrays, and pointers to develop modular programs.

CO3: Develop and manipulate advanced C structures such as unions, linked lists, and other data structures, with applications in embedded system contexts.

CO4: Demonstrate object-oriented programming concepts using C++, including class hierarchies, templates, and exception handling for robust code development.

CO5: Analyze and apply embedded programming standards such as MISRA C/C++, use compiler directives, and perform code optimization and profiling for reliable and efficient embedded software development.

CO6: To understand Programming & algorithms for problem solving

CO7: To understand the Programming Concepts

CO8: Build Application using High level languages C/C++ Programming

Module 1:

Introduction to Programming & algorithms for problem solving

The Basic Model of Computation, Algorithms, Flow-charts, Programming Languages, Compilation, Linking and Loading, Testing and Debugging, Algorithms for Problem Solving: Decimal Base to Binary Base conversion, Reversing digits of an integer, GCD (Greatest Common Division), LCM etc. , Use case diagrams and UML.

Module 2:

C Programming Basics

GNU Tools: gcc, gdb, gprof, Makefiles, Basic data types, operations, and flow control (decision-making statements), Flow control (loops), typecasting, and computer logic, Switch-case, arrays, and the basics of strings, pointers, functions, storage class.

Module 3:

Advanced C programming for Embedded Systems

Structure and union, Linear and nonlinear data structures, Linked List

Module 4:

Object Oriented Programming concepts with C++

Overview of C++, , Fundamentals of the object-oriented approach, Class hierarchy, Advanced class concepts, Templates, Accessing data and dealing with exceptions.

Module 5:

Embedded Programming Coding standards & Concepts

Coding Standards For Compliance , ANSI C, C89, C95, C99, C11, MISRA C & C++, Profiling & Optimisation

techniques, Pragma , floating-point exceptions rounding multi-precision libraries (GMP, MPFR, MPIR), IEEE754, Static and dynamic Code analysis.

Labs / Practicals:

Develop algorithms/ Flow diagrams for any one from the following

1. Decimal Base to Binary Base conversion
2. Reversing digits of an integer
3. GCD Greatest Common Division)
4. LCM

Familiarisation of UML diagrams With the help of open source UML tools

1. Draw UML diagrams
2. Export diagrams
3. Share diagrams using Eclipse
4. Create new, custom UML elements
5. Build sequence and activity diagrams from plain text

C Programming using Linux platforms

1. Familiarisation of Linux Commands
2. Example usage of gcc compiler with sample C programs
3. C programming covering data types, operators, loops, strings

C Programming using Linux platforms

1. Examples using Pointers using C
2. Examples using functions, pass by value, pass by reference methods.
3. Examples covering the structure and union

Advanced C Programming for Embedded Systems (Linear & Nonlinear data structure implementation using C Language)

1. Write a c program to implement queue and its operations
2. Write a C Program to implement stack and its operation
3. Write a C program to implement singly linked list and its operations
4. Write a C program to implement circular linked lists and its operations.

Class hierarchy C++ programming

1. Write program to understand the class concepts in C++
2. Write C++ program to cover inheritance concepts in C++
3. Write C++ program to cover overloading concepts in C++.

Advanced class concepts using C++ programming

1. Write C++ program to cover virtual functions in C++.
2. Write C++ program to cover Templates, Accessing data and dealing with exceptions.

References:

Text Books

1. C Programming language, Kernighan, Brian W, Ritchie, Dennis M, Prentice Hall PTR
2. "Embedded C", Michael J. Pont, Addison Wesley Reference

Reference Books

1. The Complete Reference C++, Herbert Schildt, TMH
2. GNU C++ For Linux, Tom Swan , PrenticeHall India
3. Daniel W. Lewis, "Fundamentals of embedded software where C and assembly meet", Pearson Education, 2002.

Course Code	Course Name	L	T	P	Cr
DOEE250005	Advanced Digital System Design	3	0	2	4

Course Outcomes:

CO1: Understand and apply number systems, including two's complement and IEEE 754 floating-point formats, for performing basic and advanced arithmetic operations.

CO2: Design and analyze combinational logic circuits using functional blocks such as encoders, decoders, multiplexers, adders, and comparators, considering timing and hazard analysis.

CO3: Develop and optimize sequential logic systems using latches, flip-flops, and finite state machines (Mealy and Moore), with timing analysis and practical design examples.

CO4: Construct and implement digital subsystems including ALUs, shifters, pattern detectors, and arbiters, demonstrating knowledge of modular digital design.

CO5: Analyze and apply digital logic testing concepts such as fault modeling, fault simulation, test generation, and Design for Testability (DFT) and BIST strategies.

CO6: Simulate and implement combinational and sequential digital circuits using Verilog HDL, including multiplexers, counters, code converters, and flip-flops.

CO7: Design and test integrated digital components such as ALUs and counters in Verilog HDL, using simulation tools to verify functionality and timing behavior.

Module 1:

PROCESSOR ARITHMETIC

Two's Complement Number System – Arithmetic Operations Floating Point Number system – IEEE 754 format & POSIT, Basic binary codes.

Module 2:

COMBINATIONAL LOGIC DESIGN

Functional blocks – Decoders, Encoders, Three-state devices, Multiplexers, Parity circuits, Comparators, Adders, subtractor, carry look-ahead adder, timing analysis. Combinational multiplier structures, Timing hazards.

Module 3:

SEQUENTIAL LOGIC DESIGN

Latches and Flip-Flops, Sequential logic circuits – timing analysis (Set up and hold times) Synchronizers and metastability, State machines – Mealy & Moore machines, Analysis, FSM design using D Flip-Flops, FSM optimization and partitioning; FSM Design examples: Vending machine, Traffic light controller, Washing machine.

Module 4:

DIGITAL SUBSYSTEMS

ALU, 4-bit combinational multiplier, Barrel shifter, Simple fixed point to floating point encoder, Dual Priority encoder, Cascading comparators .Pattern (sequence) detector, Programmable Up-down counter, Round robin arbiter with 3 requesters, Process Controller, FIFO.

Module 5:**DIGITAL LOGIC TESTING**

Introduction to digital logic testing, Fault modelling, fault collapsing, fault simulation, test generation ,Introduction to Design For Testability(DFT),DFT and Built-In-Self-Test(BIST).

Labs / Practicals:

Hands-on Sessions Featuring Simulations of Combinational and Sequential Circuits with Verilog HDL.

- Logic Gates
- Multiplexers/Demultiplexers: 2-to-1, 4-to-1,
- Encoders/Decoders: priority and nonpriority encoders, decoders.
- Adders/Subtractors: Building full adders, ripple carry adders, etc.
- Comparators: Creating magnitude comparators.
- ALUs
- Parity Generator & Checker
- Code Converters
- latch an flip-flop
- counters

References:**Text Books**

1. Digital Design by Frank,John Wiley and Sons Publishers.
2. Digital Computer Arithmetic Datapath Design Using Verilog HDL by James E. Stine, Springer
3. Essentials of Electronic Testing for Digital, Memory and Mixed-Signal VLSI Circuits by M. Bushnell ,Vishwani Agrawal, Springer.

Reference Books

1. Digital Design by M. Morris R. Mano and Michael D. Ciletti.,Pearson Education.
2. Gustafson and Yonemoto. 2017. Beating Floating Point at its Own Game: Posit Arithmetic. Supercomputing Frontiers and Innovations: an International Journal, Volume 4I, ssue 2, June 2017 , pp 71-86, <https://doi.org/10.14529/jsfi170206>.
3. Digital Design Principles and Practices by John F. Wakerly, Pearson Education.
4. An Introduction to Logic Circuit Testing by Parag K. Lala, Morgan & Claypool Publishers.
5. Digital Systems Testing and Testable Design by Melvin A. Breuer , Arthur D. Friedman, MironAbramovici, Wiley-IEEE Press

Course Code	Course Name	L	T	P	Cr
DASH250095	Research Methodology and IPR	3	1	0	4

Course Outcomes:

CO1: Understand the principles and process of research methodology.

CO2: Apply appropriate research design and data collection methods in computing projects.

CO3: Analyze and interpret qualitative and quantitative data using statistical tools.

CO4: Develop ethically sound, well-documented research or project reports conforming to academic and industrial standards.

CO5: Understand various forms of intellectual property and apply processes for protection and patent filing.

Module 1:

Introduction to Research and Research Ethics

Definition and objectives of research, types of research – fundamental, applied, exploratory, empirical, significance of research in computer applications, research ethics and integrity, plagiarism, citation styles (APA, IEEE), tools for plagiarism check.

Module 2:

Research Design and Data Collection

Research problem identification and formulation, hypothesis generation, literature review techniques, types of research design: experimental, descriptive, analytical, sampling techniques, primary and secondary data sources, survey design, case study design.

Module 3:

Data Analysis and Interpretation

Quantitative and qualitative data analysis, measures of central tendency and dispersion, t-test, ANOVA, correlation and regression, chi-square test, software tools: Excel, R, SPSS (demo-level), data visualization and result interpretation.

Module 4:

Technical Writing and Project Report Preparation

Structure of research papers and reports, abstract, introduction, literature review, methodology, results, and conclusions, referencing tools (Mendeley/Zotero), IEEE/ACM/SCI journal guidelines, thesis and dissertation formatting, proposal writing basics.

Module 5:

Intellectual Property Rights and Patent Process

Introduction to IPR: patents, copyrights, trademarks, industrial design, Indian and international patent systems (WIPO, TRIPS), criteria for patentability, patent filing process in India (IPINDIA portal), open-source licenses, patent drafting basics, IPR in software and AI innovations.

Labs / Practicals:

N/A

References:

1. C.R. Kothari & Gaurav Garg – Research Methodology: Methods and Techniques, New Age International.
2. Ranjit Kumar – Research Methodology – A Step-by-Step Guide, Sage Publications India.
3. P. Narayan – Intellectual Property Law, Eastern Book Company.
4. Neeraj Pandey & Khushdeep Dharni – Intellectual Property Rights, PHI Learning.
5. Yogesh Kumar Singh – Fundamentals of Research Methodology and Statistics, New Age International.
6. Bharat Bhushan – Research Methodology in Computer Science, Himalaya Publishing.
7. WIPO and IPIndia Manuals – Guidelines for Filing Patents in India.

Course Code	Course Name	L	T	P	Cr
DOAI250002	Advanced Machine Learning	3	0	2	4

Course Outcomes:

CO1: Understand the foundational concepts of machine learning, explore various learning paradigms and tasks, and apply essential data preprocessing and evaluation techniques.

CO2: Apply linear and logistic regression, regularization methods, and classification algorithms including SVM, Decision Trees, and Naïve Bayes for predictive modeling.

CO3: Analyze data using clustering algorithms and perform effective feature selection and dimensionality reduction to enhance machine learning model performance.

CO4: Gain knowledge of probabilistic graphical models and implement ensemble techniques to improve model robustness and accuracy.

CO5: Develop and apply deep learning models including CNNs, RNNs, LSTMs, and Transformers for advanced applications in vision, sequence processing, and natural language understanding.

Module 1:

Overview of machine learning: supervised, semi-supervised, unsupervised learning, reinforcement learning.

Types of Machine Learning Tasks: Classification, Regression, and Clustering.

Cross Validation.

Classifier and Regressor Performance Evaluation Measures, ROC Curves.

Cost functions: Definition and Types.

Bias-Variance trade off.

Data Preprocessing: Standardization, Normalization, Label Encoding, One-hot Encoding.

Module 2:

Linear Regression, Least Square Gradients.

Regularization: Ridge and Lasso Regression.

Classification Methods: K Nearest Neighbor, Logistic Regression.

Sigmoid function and differentiation.

Support Vector Machine (SVM): Optimal Separating Hyperplane, Kernel Trick, Kernel Functions.

Bayes Rule, Naïve Bayes Model.

Decision Tree – ID3.

Module 3:

Clustering Methods: K-means Clustering, Hierarchical Clustering Techniques, Density-Based Clustering

Feature Selection Techniques: Entropy, Correlation Coefficient, Chi-square Test, Forward and Backward Selection.

Dimensionality Reduction: PCA, LDA, t-SNE.

Maximum Likelihood Estimation Technique.

Module 4:

Basics of Graphical Models: Bayesian Networks, Hidden Markov Model.

Ensemble Methods: Boosting, Bagging, Random Forest, XGBoost

Module 5:

Neural Networks – Concept of Perceptron and Artificial Neuron.

Feed Forward Neural Network, Back Propagation Algorithm.

Convolutional Neural Networks (CNNs) for image classification and object detection.

Recurrent Neural Networks (RNNs), Long Short-Term Memory (LSTM) networks for sequential data processing, Autoencoders.

Transformer Models (BERT, GPT) for NLP applications.

Labs / Practicals:

1. Implement supervised, unsupervised, and semi-supervised learning on sample datasets and identify the type of machine learning task.
2. Apply cross-validation and evaluate classifier performance. Calculate accuracy, precision, recall, F1-score, and ROC-AUC metrics of models.
3. Perform data preprocessing using standardization, normalization, label encoding, and one-hot encoding and observe its effect on model accuracy.
4. Implement linear, Ridge, and Lasso regression models on a dataset and compare their performance using MSE.
5. Apply K-Nearest Neighbor, Logistic Regression, and SVM classifiers on a dataset and visualize decision boundaries.
6. Train and evaluate a Decision Tree using the ID3 algorithm and a Naïve Bayes classifier on a classification dataset.
7. Implement and compare K-means, hierarchical clustering, and DBSCAN on a dataset using visualization and silhouette scores.
8. Perform feature selection using entropy, correlation coefficient, and chi-square test, and evaluate model accuracy with selected features.
9. Apply PCA, LDA, and t-SNE for dimensionality reduction and visualize data in 2D space.
10. Build a Hidden Markov Model to predict sequences and evaluate performance using real or synthetic sequential data.
11. Train and compare Random Forest, Bagging, AdaBoost, and XGBoost models on a classification problem.
12. Implement a feedforward neural network with backpropagation to classify handwritten digits using the MNIST dataset.
13. Build a Convolutional Neural Network (CNN) for image classification using CIFAR-10 or MNIST and evaluate performance.
14. Train an LSTM model for time-series prediction and use a pre-trained BERT/GPT model for sentiment analysis in NLP.

References:

1. Ethem Alpaydin, Introduction to Machine Learning , MIT Press, 2014.
2. Kevin Murphy, Machine Learning: A Probabilistic Perspective (MLAPP), MIT Press, 2012.
3. Han, Jiawei, and Micheline Kamber. Data Mining: Concepts and Techniques. San Francisco: Morgan Kaufmann Publishers.
4. Christopher M. Bishop, "Pattern Recognition and Machine Learning", Springer, 2006.

Course Code	Course Name	L	T	P	Cr
DOEE250088	Embedded OS and RTOS	3	0	2	4

Course Outcomes:

- CO 1 Attain comprehensive understanding of Embedded OS (Linux) fundamentals
- CO 2 Attain comprehensive understanding of Embedded Processor and its software
- CO 3 Attain comprehensive understanding of Embedded Linux Drivers
- CO 4 Attain comprehensive understanding of basics of real-time concepts
- CO 5 Attain comprehensive understanding of incorporating RTOS in an embedded system
- CO 6 Attain comprehensive understanding of applying the knowledge for developing practical applications of modern real-time systems
- CO 7 Get knowledge in Embedded OS (Linux) fundamentals
- CO 8 Understand Embedded Linux Internal programming
- CO 9 Comprehend Embedded Linux Drivers
- CO 10 Learn about the basics of real-time OS Programming concepts

Module 1:

Introduction to Embedded Linux

Overview of Linux OS, Directory structures, basic Linux shell commands, Overview of Systems Calls, Classification of system Calls, Inter Process Communication, Multithreading and Thread Management

Module 2:

Embedded Linux Driver Development

Linux Kernel Module Programming, Character device driver development, USB device driver development, Block, Network and PCI device driver development

Module 3:

Building and Customisation of Linux for Embedded systems

Linux booting procedure, Bootloader, hypervisor, opensbi, qemu, Linux build tools - Buildroot and Yocto

Module 4:

Overview of Real Time OS

Basics of RTOS: Real-time concepts, Hard Real time and Soft Real-time, Differences between General Purpose OS & RTOS, Basic architecture of an RTOS, Scheduling Systems, RTOS Issues – Selecting a Real Time Operating System

Module 5:

RTOS for Embedded Applications

FreeRTOS, Thread creation & Management, Inter thread Communication, Mutual Exclusion, MbedOS, Other real time OS (VxWorks, Azure RTOS, SAFERTOS etc.)

Labs / Practicals:

Embedded Linux shell commands
Embedded Linux System Call programming
Embedded Linux Interprocess Communication
Development of Multithreaded application in Linux
Performing Thread Synchronization and resource protection (Mutex) based applications in Linux
Develop simple Kernel Module Programming
Develop basic character Device driver in Linux
Familiarization of FreeRTOS, Thread creation, synchronization - Port to FreeRTOS to ARM Cortex M4 development board

References:

1. GNU/LINUX Application Programming, Jones, M Tims
2. Sreekrishnan Venkateswaran Essential Linux Device Drivers, Prentice Hall 2008
3. Embedded/Real Time Systems Concepts, Design and Programming Black Book, Prasad, KVK
4. Software Design for Real-Time Systems: Cooling, J E Proceedings of 17th IEEE Real-Time Systems Symposium December 4-6, 1996 Washington, DC: IEEE Computer Society
5. FreeRTOS Reference Manual

Course Code	Course Name	L	T	P	Cr
DOAI260001	AI (Industry)-Applied Ethics for AI	3	0	2	4

Course Outcomes:

CO1. Understand and be able to define and explain the terms 'AI for good' and 'responsible AI'. Describe the significance of responsible AI and recognize the potential benefits of AI in society.

CO2. Discuss and examine the impact of ethics on AI decision-making processes. Identify common ethical pitfalls in AI development and deployment. Explore methods for ethical AI practices.

CO3. Understand to apply an ethics-first approach to AI project planning and development. Compare different approaches to ethical AI design which include design of rules based on ethics and virtues. Identify factors influencing ethical decisions in AI development.

CO4. Apply Utilitarian and Kantian ethical principles to AI case studies, scenarios, and dilemmas. Explain the purpose and benefits of AI ethics codes. Develop a code of ethics for AI within an organization.

CO5. Identify the importance of interpretability in AI models. Evaluate the strengths and weaknesses of three different explainable AI tools: SHAP, LIME, and Tree Interpreter.

CO6. Conduct impact assessments for AI solutions. Apply ethical considerations in designing an AI system or solution. Implement measures to mitigate ethical risks and challenges post deployment.

Module 1:

Introduction to AI Ethics – meaning and importance, Role of Ethics in Responsible AI – defining 'AI for good' and 'responsible AI', significance of responsible AI in society, Common Ethical Pitfalls in AI – bias, fairness, accountability, transparency issues in AI development and deployment, Principles of Ethical AI – core principles guiding ethical AI, methods for ethical AI practices in development and deployment.

Module 2:

Ethics-First Approach in the AI Project Cycle – applying ethics at every stage of AI project planning and development, Approaches for Designing Ethical AI – rules-based ethics, values-based design, Introduction to Ethical Frameworks – overview of major ethical frameworks applied to AI, Virtue-Based Ethics – virtue ethics principles and the 4-box method for analysing ethical dilemmas, Applying Bio-Ethics Framework in AI – bioethical principles applied to AI in healthcare and biotechnology.

Module 3:

Utilitarianism for Ethical AI – utilitarian principles applied to AI case studies and dilemmas, Kantianism for Ethical AI – Kantian ethical principles applied to AI scenarios, Code of AI Ethics for Organizations – purpose, benefits and development of an organizational AI code of ethics, Data Protection and AI – risks of data breaches, privacy violations, responsible data handling.

Module 4:

Explainable AI – importance of interpretability in AI models, Intel XAI Toolkit, impact of explainability on decision-making and trust, Explainable AI in Practice – SHAP, LIME and Tree Interpreter tools: strengths, weaknesses and methods for applying them to analyze and interpret AI applications.

Module 5:

Impact Assessment of AI Solutions – conducting impact assessments for AI systems, Mitigating Ethical Issues Post Deployment – strategies to identify and resolve ethical risks after deployment, Project Creation – creating an AI startup with data card, model card, code of ethics, explainability report, impact self-assessment and transparency report.

Labs / Practicals:

1. Develop comprehensive Data Cards for datasets, as outlined in the Data Cards Playbook by Google, to ensure transparency and accountability in AI training data.
2. Design Responsible AI Best Practices.

3. Apply Human-Centered AI Canvas to design AI systems that address user needs and ethical considerations.
4. Learn to use The Box to embed AI principles into organizational workflows and operations.
5. Apply bio-ethics principles to AI case studies, scenarios, and dilemmas; evaluate the impact of virtue-based ethics on AI systems.
6. Develop AI ethics cards for given AI scenarios. Analyse a variety of ethical dilemmas by following the 4-box method from Virtue Ethics.
7. Analyse a variety of ethical dilemmas by walking through the ethical frameworks: Virtue Ethics, Bioethics, Utilitarian, Kantian, and Moral System Agnostic.
8. Develop an AI Code of Ethics for a fictitious company.
9. Use the UXAI Toolkit to brainstorm and plan different explainable interfaces for AI applications. Use the explainable AI library SHAP to create an explainability report for income prediction on the standard adult census income dataset.
10. Conduct impact assessments for AI solutions; create your own AI startup, develop business documents, write documentation (data card, model card, code of ethics, explainability report, impact self-assessment) and create and analyze transparency report.

References:

1. Intel AI for Future Workforce – Applied Ethics for AI Course Content, Intel Digital Readiness Program.
2. Virginia Eubanks – Automating Inequality: How High-Tech Tools Profile, Police, and Punish the Poor, St. Martin's Press.
3. Cathy O'Neil – Weapons of Math Destruction, Crown Publishers.
4. Kate Crawford – Atlas of AI: Power, Politics, and the Planetary Costs of Artificial Intelligence, Yale University Press.
5. Google Data Cards Playbook – <https://pair-code.github.io/datacardsplaybook/>

Course Code	Course Name	L	T	P	Cr
DOAI260002	AI (Industry)-Introduction to Artificial Intelligence	3	0	2	4

Course Outcomes:

- CO1. Describe what AI is and what it is not. Appreciate the history of AI and its evolution over time.
- CO2. Identify and analyze current trends in AI by correlating them with other technologies like IoT, Big Data and 5G.
- CO3. Identify 3 common domains of AI – Natural Language Processing, Computer Vision and Statistical Data – based on the type of underlying data.
- CO4. Examine and appreciate typical steps involved in an AI Project through the AI Project Cycle.
- CO5. Examine the immediate impacts of AI practices on society and appreciate the ethical concerns of AI applications.
- CO6. Classify Supervised Learning, Unsupervised Learning and Reinforcement Learning with the help of examples. Discuss the roles played by different key stakeholders in a typical AI team.

Module 1:

Demystification of AI – what AI is and what it is not, History and Evolution of AI, Current trends in AI, AI and Technology convergence, Industry 4.0 and Digitalization, Role of IoT, Big Data and 5G in AI, Domains of AI – Natural Language Processing, Computer Vision and Statistical Data.

Module 2:

AI Project Cycle-I – Problem Scoping and Data Acquisition, AI Project Cycle-II – Modelling and Evaluation, Societal Impact of AI – ethical concerns and responsible practices, Elements of ML – Supervised Learning, Unsupervised Learning and Reinforcement Learning with examples.

Module 3:

Elements of AI – types and characteristics, Data as Fuel for AI – structured and unstructured data, methods of data mining and data storage, AI/Data Science Team – roles and responsibilities of key stakeholders.

Module 4:

Tools to implement AI – No-Code tools (Teachable Machine, Orange, Roboflow, Chatfuel) and Code-based tools, Introduction to Neural Networks – working of simple Neural Networks, difference between common Deep Learning models with examples and applications.

Module 5:

AI Project-I – Natural Language Processing use case using no-code tool Chatfuel, AI Project-II – Statistical Data use case using no-code tool Orange Data Mining, AI Project-III – Computer Vision use case using no-code tool Roboflow, Future Possibilities of AI – emerging software and hardware technology trends and their direct impact on development of AI.

Labs / Practicals:

1. Familiarize with AI tools and techniques, including statistical data analysis using raw graphs, computer vision applications like Vision API, and generative AI tools such as DALL·E, Stable Diffusion, Gemini, and ChatGPT.
2. Apply the AI Project Cycle to real-world scenarios by identifying problems, collecting data, developing models, and evaluating their effectiveness to propose impactful AI-based solutions.
3. Deconstruct the working behind simple Neural Networks and outline the difference between some common DL models with the help of examples and applications.
4. Explore and utilize no-code tools, such as Teachable Machine, to build AI projects.
5. Project Building using No-code tool – Orange Data Mining for Statistical Data Use cases.
6. Project Building using No-code tool – Roboflow for Computer Vision Use cases.
7. Project Building using No-code tool – Chatfuel for Natural Language Processing Use cases.
8. Classify the type of data into structured and unstructured and evaluate data quality using real datasets.

9. Explore various AI domains by running Vision API experiments and comparing outcomes from NLP, CV, and Statistical Data use cases.
10. Demonstrate the AI Project Cycle on a chosen real-world problem from an industrial or social impact perspective and present findings.

References:

1. Intel AI for Future Workforce – Introduction to AI Course Content, Intel Digital Readiness Program.
2. Stuart Russell and Peter Norvig – Artificial Intelligence: A Modern Approach, Pearson Education.
3. Andreas Mueller and Sarah Guido – Introduction to Machine Learning with Python, O'Reilly Media.
4. Ian Goodfellow, Yoshua Bengio, and Aaron Courville – Deep Learning, MIT Press.
5. Aurélien Géron – Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow, O'Reilly Media.

Course Code	Course Name	L	T	P	Cr
DOAI260003	AI (Industry)-Introduction to Generative AI	3	0	2	4

Course Outcomes:

CO1. Define Gen AI and distinguish its role in the broader context of AI. Describe how the basic model of Gen AI works. Discuss the wider societal impact of Gen AI.

CO2. Understand how NLP has evolved over time and the shift from Traditional AI to Gen AI. Understand Prompt Engineering and its impact on the output of NLP tasks.

CO3. Learn the limitations of current AI generation tools for video and audio. Recognize the challenges in ethical considerations and responsibilities when using generative AI tools.

CO4. Describe the stages of a generative AI project and learn to select and use appropriate AI tools for development.

CO5. Understand the basic structure of neural networks, architecture of transformer models, workings of diffusion models, and the pre-training process for generative AI models.

CO6. Learn to fine-tune generative AI models, understand RLHF, prototype Gen AI applications, and apply principles of responsible and ethical use of LLMs.

Module 1:

Introduction to Gen AI – definition and scope, role of Gen AI in the broader context of AI, how the basic model of Gen AI works, societal impact of Gen AI, Demystifying Gen AI Models – types of generative models (GANs, VAEs, Diffusion Models, LLMs), evolution of NLP to Gen AI, shift from Traditional AI to Gen AI.

Module 2:

Prompt Engineering-I – introduction to prompt engineering, basic applications and impact on NLP task outputs, text generation and conversation initiation, Prompt Engineering-II – advanced prompt engineering techniques for diverse NLP applications, real-world examples such as Mint Mobile Commercial, Basics of Video and Audio for Generation using Gen AI for Productivity-I – introduction to video generation tools (Runway ML, Genmo), text-to-video and image-to-video generation, limitations of current AI generation tools for video and audio.

Module 3:

Basics of Video and Audio for Generation using Gen AI for Productivity-II – audio and music generation using AIVA, code generation using Codeium, text generation using ChatGPT, Gemini and Perplexity, Generative AI-Ethics – ethical considerations, responsibilities and challenges when using generative AI tools, Generative AI Project Lifecycle – stages of a Gen AI project, selection of appropriate AI tools, Gen AI Tools for Development – open-source tools such as Stable Diffusion XL, proprietary tools such as Bing Image Creator powered by DALLE3.

Module 4:

Neural Network Fundamentals – basic structure and functioning of neural networks, how neural networks process data to make predictions, Transformers and the Evaluation of LLMs – architecture of transformer models, methods to evaluate large language models for performance and reliability, walkthrough of OpenAI Playground and parameter exploration, Diffusion Models and the Evaluation of Text to Image Generation – workings of diffusion models, evaluation of quality of text-to-image generation, Pre-Training Gen AI Models-I – pre-training process for generative AI models, importance of pre-training in building effective AI systems, modifying classification labels of Cohere datasets and its impact on fine-tuning and model confidence.

Module 5:

Fine-Tuning Gen AI Models – techniques for fine-tuning generative AI models to adapt them for specific tasks and applications, RLHF – Evaluating and Optimizing Gen AI Models: reinforcement learning with human feedback, evaluation and improvement of performance of generative AI models, Prototyping Gen AI Applications – skills to design, develop and test prototypes of generative AI applications, LangChain components – LLM, Agents, Prompts, Chains, Document loaders and utils with code-based implementation, LLM Application and Responsible use of AI – practical applications of large language models, ethical and responsible use of LLMs, building an AI

Tutor using open-source models such as Dolly 3B and Intel Neural Chat 7B.

Labs / Practicals:

1. Apply prompt engineering skills in basic NLP tasks, such as text generation, conversation initiation, and simple problem-solving.
2. Develop advanced prompt engineering skills for diverse NLP applications. Examine real-world prompt engineering examples, such as the Mint Mobile Commercial, to discern its role in marketing.
3. Explore cutting-edge Gen AI tools, their features, and capabilities for content generation including video and audio.
4. Explore open-source models such as Stable Diffusion XL and proprietary tools such as Bing Image Creator (powered by DALL-E3) for image generation.
5. Text-to-video generation and image-to-video generation using tools like Runway ML and Genmo. Generate audio and music files using the tool AIVA.
6. Generate code by prompts using the tool Codeium. Generate text using tools like ChatGPT, Gemini, and Perplexity.
7. Walkthrough of OpenAI Playground. Explore how changing parameters can affect responses generated by different models.
8. Explore how modifying classification labels of Cohere datasets impacts fine-tuning and model confidence.
9. Explore basic components of LangChain like LLM, Agents, Prompts, Chains, and Document loaders and utils, along with a code-based implementation.
10. Utilize open-source text generation models such as Dolly 3B and Intel Neural Chat 7B for building an AI Tutor application.

References:

1. Intel AI for Future Workforce – Introduction to Generative AI Course Content, Intel Digital Readiness Program.
2. Antony Hagiwara – Generative Deep Learning: Teaching Machines to Paint, Write, Compose, and Play, O'Reilly Media.
3. Ashish Vaswani et al. – Attention is All You Need, Advances in Neural Information Processing Systems.
4. OpenAI – GPT-4 Technical Report, OpenAI.
5. Harrison Chase – LangChain Documentation – <https://docs.langchain.com/>

Course Code	Course Name	L	T	P	Cr
DOAI260004	AI (Industry)-Introduction to Machine Learning	3	0	2	4

Course Outcomes:

- CO1. Describe Machine Learning and how Deep Learning is a subset of the wider field of Machine Learning.
- CO2. Understand the importance of dashboards and discuss various applications of dashboards across different industries.
- CO3. Explain the mathematical working behind different ML models. Implement different classification and regression ML models using Python.
- CO4. Outline the difference between supervised, unsupervised and reinforcement learning algorithms. Examine the working of different reinforcement learning models.
- CO5. Describe the working of Neural Networks and contrast it with biological Neurons. Describe various applications of neural networks. Outline different methods to overcome variance and bias in DL models.
- CO6. Discuss and interpret the future of ML based on current and upcoming trends. Develop Python-based AI Projects incorporating Supervised Learning, Unsupervised Learning and Deep Neural Networks.

Module 1:

Introduction to Machine Learning – definition, types and applications, Relationship between AI, ML and Deep Learning, Tools to Implement AI (Python & Mathematics) – I: Python basics for ML, NumPy, Pandas, data manipulation.

Module 2:

Tools to Implement AI (Python & Mathematics) – II: mathematical foundations – linear algebra, statistics and probability, No-Code tool for Data Exploration – Tableau dashboard creation, data visualization techniques, statistical concepts implementation using no-code visualization tools.

Module 3:

AI (Modeling) Supervised Learning-I – Linear Regression, Logistic Regression, mathematical working behind models, classification and regression using Python, AI (Modeling) Supervised Learning-II – SVM, Decision Tree, industrial applications of ML models, AI (Modeling) Unsupervised Learning-I – K-Means Clustering, mathematics of clustering algorithms, AI (Modeling) Unsupervised Learning-II – Recommendation Systems, mathematics behind recommendation system, applications of recommendation systems.

Module 4:

Reinforcement Learning – definition, difference from supervised and unsupervised learning, working of reinforcement learning models with applications, Neural Network and Deep Learning-I – biological vs artificial Neurons, working of Neural Networks, applications of neural networks, Deep Learning-II – Convolutional Neural Networks, Recurrent Neural Networks, methods to overcome variance and bias in DL models, implementation using Python and deep learning frameworks, exploring OpenAI's Gym for reinforcement learning.

Module 5:

ML Project – Supervised Learning AI models: end-to-end Python project using classification/regression, ML Project – Unsupervised Learning AI models: end-to-end Python project using clustering, ML Project – Deep Neural Networks: building and training DNN in Python, Future of Machine Learning and Deep Learning – current and upcoming trends in ML and DL.

Labs / Practicals:

1. Interpret and understand the basic tools required for building ML Projects through a selected list of topics from Mathematics and Python Programming.
2. Develop and create a simple dashboard for visualizing data through Tableau.
3. Implement statistical concepts using the no-code visualization tool and create your own dashboard with the help of a no-code visualization tool.

4. Implement supervised machine learning algorithms, such as SVM and Decision Tree, using Python to develop a deeper understanding of their practical applications.
5. Implement unsupervised machine learning algorithms, such as K-Means, using Python to develop a deeper understanding of their practical applications.
6. Implement neural networks and create simple generative AI models using Python and deep learning frameworks, including exploring OpenAI's Gym for hands-on experience with AI and reinforcement learning.
7. Develop Python-based use cases and AI Projects incorporating Supervised Learning methods.
8. Develop Python-based use cases and AI Projects incorporating Unsupervised Learning methods.
9. Develop Python-based use cases and AI Projects incorporating Deep Neural Networks.
10. Implement a recommendation system using Python and evaluate its performance on a real-world dataset.

References:

1. Intel AI for Future Workforce – Introduction to Machine Learning Course Content, Intel Digital Readiness Program.
2. Andreas Mueller and Sarah Guido – Introduction to Machine Learning with Python, O'Reilly Media.
3. Ian Goodfellow, Yoshua Bengio, and Aaron Courville – Deep Learning, MIT Press.
4. Aurélien Géron – Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow, O'Reilly Media.
5. Christopher Bishop – Pattern Recognition and Machine Learning, Springer.

Course Code	Course Name	L	T	P	Cr
DOEE250003	Advanced Data Communication and Networking	3	1	0	4

Course Outcomes:

- CO 1 To provide understanding of advanced concepts of data communication
- CO 2 To understand the concepts and technologies used in data communication domain
- CO 3 To understand protocols used in data communication applications
- CO 4 To get knowledge about latest trends in data communication and networks
- CO 5 To be exposed to TCP/IP protocol suite
- CO 6 To be familiar with various types of computer networks

Module 1:

Fundamentals of Data Communication and Networks

Data Communications, Networks and Network Types, Internet History, Standards and Administration, Protocol Layering, TCP/IP protocol suite, OSI Model, Digital Data Transmission, DTE-DCE interface, Data Link Layer: Introduction, Data Link Layer, Nodes and Links, Services, Categories of Links, sub layers, Link Layer Addressing, Address Resolution Protocol.

Module 2:

Error Detection and Correction

Types of Errors, Redundancy, detection versus correction, Coding Block Coding: Error Detection, Vertical redundancy checks, longitudinal redundancy checks.

Error Correction: Error correction single bit, Hamming code.

Cyclic Codes: Cyclic Redundancy Check, Polynomials, Cyclic Code Encoder Using Polynomials, Cyclic Code Analysis, Advantage of Cyclic Codes.

Checksum Data Link Control: DLC Services, Data Link Layer Protocols, HDLC, Point to Point Protocol.

Module 3:

Switching and Multiplexing

Switching: Introduction to Switching, Circuit Switched Networks, Packet Switching, Structure of switch.

Multiplexing : Multiplexing, Frequency Division Multiplexing, Time Division Multiplexing.

Connecting devices: Passive Hubs, Repeaters, Active Hubs, Bridges, Two Layer Switches, Routers, Three Layer Switches, Gateway, Backbone Networks

Wired LANS: Ethernet Protocol, Standard Ethernet, Fast Ethernet, Gigabit Ethernet, 10 Gigabit Ethernet

Module 4:

Media Access Control (MAC)

Media Access Control (MAC) Sub Layer Random Access, ALOHA, Carrier Sense Multiple Access (CSMA), Carrier Sense Multiple Access with Collision Detection (CSMA/CD), Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA), Controlled Access- Reservation, Polling- Token Passing, Channelization, Frequency Division Multiple Access (FDMA), Time - Division Multiple Access (TDMA), Code - Division Multiple Access (CDMA), Spectrum Spreading: Spread Spectrum-Frequency Hopping Spread Spectrum and Direct Sequence Spread Spectrum.

Module 5:

Networks Layer

Packetizing, Routing and Forwarding, Packet Switching, Network Layer Performance, IPv4 Address, Address Space, Classful Addressing, Classless Addressing, Dynamic Host Configuration Protocol (DHCP), Network Address Resolution (NATF), Forwarding of IP Packets, Forwarding based on Destination Address, Forwarding based on Label, Routing as Packet Switches, Unicast Routing : Introduction, Routing Algorithms-Distance Vector Routing, Link State Routing, Path Vector Routing, Unicast Routing Protocols- Routing Information Protocol(RIP), Open Short Path First Version 4.

Labs / Practicals:

N/A

References:

1. B. A. Forouzan, "Data Communications and Networking", 5th, 2013, TMH.
2. William Stallings, "Data and Computer Communications", 8th ed., 2007, PHI.
3. Prakash C. Gupta, "Data Communications and Computer Networks", 2006, PHI.
4. B. A. Forouzan, "Data Communications and Networking", 2nd, 2013, TMH.

Course Code	Course Name	L	T	P	Cr
DOEE250181	Sensor Technologies and MEMS	3	1	0	4

Course Outcomes:

CO 1 Study the fundamentals of the sensor.

CO 2 Apply varied parameters in the design of industrial classified sensor

CO 3 Evaluate the standards and calibrations of sensors with test and measurements

CO 4 Study the mems in sensor technology

CO 5 Create the unique application-based testing and standards for qualification by performing the failure analysis

Module 1:

Sensor Fundamentals

Basic Sensor Technologies, Sensor System, Sensor Characteristics, System Characteristics, Instrument Selection, Data Acquisition, Measurement Issues, Sensor Signal Conditioning: Conditioning Bridge Circuits, Amplifiers for signal conditioning, Usage of ADC, Signal Conditioning High Impedance Sensors. Basic Types of Sensors-Acceleration, Shock, Vibration Sensors, Biosensors, Chemical Sensors.

Module 2:

Industrial Classified Sensors

Capacitive, Inductive Displacement Sensors, Flow and Level Sensors, Force Load and Weight Sensors, Humidity Sensors, Machinery Vibration Monitoring sensors, Optical and Radiation Sensors, Position and Motion sensors, Pressure Sensors, Sensors for mechanical shock, Temperature sensors, nanotechnology enabled sensors.

Module 3:

Test and Measurements

Example of Microphone, Characteristics, types of microphones, Formation of frequency response, limitations of measurements range, effects of environmental conditions, standards and calibrations, manufactures of test equipments and usage, strain gauge-based measurements and standards, applications of wireless sensor networks in measurement and cyber physical systems, materials used in sensor technology-types, composition, properties and performances.

Module 4:

MEMS in Sensor Technology

Microelectromechanical systems design and modelling, materials, microfabrication process, simulation, micro actuators: design and technology, micro reaction chambers, resonant frequency response of smart microelectromechanical systems vibrating structures, quality factor and the loss coefficient of smart microelectromechanical systems vibrating structures. MEMS accelerometers, MEMS gyroscope, MEMS magnetometer, electrohydrodynamic printing applications.

Module 5:

MEMS Sensor Applications and Reliability

Photovoltaic and fuel cells in power microelectromechanical systems for smart energy management MEMS for smart communication systems and future 5G applications, smart acoustic sensor array system for real time sound processing applications, Failure modes and mechanisms: Failure modes and mechanisms in MEMS, In Use Failures, Root Cause and Failure Analysis. Testing and Standards for Qualification, continuous improvement: tools and techniques for reliability improvement.

Labs / Practicals:

N/A.

References:

Text Book

1. Jon S Wilson, Sensor Technology Handbook, Newnes, 2005
2. S Nihtianov, A. Luque, Smart Sensors and MEMS, Woodhead Publishing, 2013

Reference Books

1. Horst czihos, Measurement, Testing and Sensor Technology, Springer, 2011
2. Allyson L Hartzell, Mark G dasilva, Herbert R. Shea, MEMS Reliability, Springer, 2011
3. Tina L. Lamers, Beth L. Pruitt (auth.), Reza Ghodssi, Pinyen Lin (eds.), MEMS Materials and Processes Handbook, Springer, 2011
4. Brand Fedder, System level modelling of MEMS, Wiley-VCH, 2013
5. Sergey Y. Yurish, Maria Teresa S. R. Gomes, Smart Sensors and MEMS, Springer, 2004

Course Code	Course Name	L	T	P	Cr
DOEE250185	System Design Using Embedded Processors	3	0	2	4

Course Outcomes:

CO 1 Comprehend Embedded Processor and its software
 CO 2 Design an Embedded system with ARM microcontrollers
 CO 3 Design an Embedded system using processors, memory I/O devices and communication network within realistic constraints
 CO 4 Comprehend ARM Cortex M4 microcontrollers
 CO 5 Comprehend the peripheral programming of ARM cortex M4 Microcontrollers
 CO 6 Comprehend advanced Embedded Controllers, Features and case studies
 CO 7 Perform ARM Cortex M4 Microcontroller configuration for various applications using peripheral devices
 CO 8 Demonstrate an embedded system on ARM Cortex M4 Microcontroller development board

Module 1:

Introduction to Embedded Systems
 Overview of embedded system architecture, Development and debugging Tools for Embedded Systems, Overview ARM Architecture - Architecture Versions, Instruction Set Development, Thumb-2 and Instruction Set Architecture, AMBA, AXI bus overview. Overview of the ARM Cortex-Mx Processor Architectures.

Module 2:

ARM Cortex M4 Microcontroller System
 ARM Cortex M4 Core, Interconnect Matrix in ARM Cortex M4 Microcontroller, System configuration Controller, NVIC, External Interrupt Controllers, DMA, Reset and Clock Control, Clock Recovery System, Power Control.

Module 3:

ARM Cortex M4 Microcontroller Peripheral Overview
 Introduction to ARM Cortex-M4 Programming, overview of CMSIS, GPIO, ADC, DAC, Communication & Peripherals - USART, UART, I2C, SPI, USB, CAN
 Watchdogs and Timers, PWM.

Module 4:

Memory, Safety and Security in ARM Cortex Microcontroller
 Flash, Quad SPI Interface, Flexible Memory controller, CRC, Random Number Generator, memory protections, Advanced Encryption Standard HW Accelerator (AES), Safety support.

Module 5:

Advanced Embedded Controllers, Features and case studies
 Programming for Power-Efficient Computing - High Level and low level Techniques, Cortex M7, M23 and M33 Controllers and Features, Overview of mbed platform, Embedded Systems case studies - Consumer, Medical, Automotive.

Labs / Practicals:

Embedded C Programming on ARM Cortex M4 Microcontroller with CMSIS/HAL libraries, Embedded C Programming - Peripheral Programming - GPIO, ADC, DAC, USART, Timers and PWM, Design of a real-time data acquisition & control system using the ARM Cortex M4 Microcontroller

References:

1. Yiu J. The Definitive Guide to ARM Cortex M3 and Cortex M4 Processors, 3rd Edition, Elsevier
2. Andrew N Sloss, Dominic Symes, Chris Wright, "ARM System Developer's Guide - Designing and Optimizing System Software", 2006, Elsevier

3. Steve Furber, "ARM System-on-Chip Architecture", 2nd Edition, Pearson Education
4. Raj Kamal, "Microcontroller - Architecture Programming Interfacing and System Design" 1st Edition, Pearson Education
5. P.S Manoharan, P.S. Kannan, "Microcontroller based System Design", 1st Edition, Scitech Publications
6. Cortex-M4 Technical Reference Manual (TRM)
7. STMicroelectronics Nucleo-G4xx development board user manual

Course Code	Course Name	L	T	P	Cr
DCSA250034	Information Security	3	0	2	4

Course Outcomes:

CO 1 Learn fundamentals of cryptography and its application to network security

CO 2 Understand network security threats, security services, and countermeasures.

CO 3 Understand vulnerability analysis of network security

CO 4 Acquire background on hash functions; authentication; firewalls; intrusion detection techniques

CO 5 Gain hands-on experience with programming and simulation techniques for security protocols

CO 6 Obtain background for original research in network security, especially wireless network and MANET security

CO 7 Understand the tradeoffs and criteria/concerns for security countermeasure development

CO 8 Apply methods for authentication, access control, intrusion detection and prevention

CO 9 Identify and mitigate software security vulnerabilities in existing systems

Module 1:

Introduction to Information Security

Attacks, Vulnerability, Security Goals, Security Services and mechanisms.

Module 2:

Conventional Cryptographic Techniques

Conventional substitution and transposition ciphers, One-time Pad, Block cipher and Stream Cipher, Steganography.

Module 3:

Symmetric and Asymmetric Cryptographic Techniques, Authentication and Digital Signatures

DES, AES, RSA algorithm, Use of Cryptography for authentication, Secure Hash function, Key management – Kerberos.

Module 4:

Program Security

Nonmalicious Program errors, Buffer overflow, Incomplete mediation, Time-of-check to Time-of-use Errors, Viruses, Trapdoors, Salami attack, Man-in-the-middle attacks, Covert channels.

Module 5:

Security in Networks

Threats in networks, Network Security Controls – Architecture, Encryption, Content Integrity, Strong Authentication, Access Controls, Wireless Security, Honeypots, Traffic flow security, Firewalls – Design and Types of Firewalls, Personal Firewalls, IDS, Email Security – PGP, S/MIME

Labs / Practicals:

1. Identifying Security Goals and Threats in a Web-Based System
2. Vulnerability Scanning
3. Implementing Substitution and Transposition Ciphers
4. Hiding Text in Images using Steganography
5. File Encryption and Decryption using AES
6. Implementing Digital Signatures using RSA
7. Demonstration of Buffer Overflow
8. Simulate a Salami Attack
9. Packet Sniffing and Analysis
10. Firewall Rule Configuration

References:

- [1] W. Stallings, Cryptography and Network Security: Principles and Practice, 7th ed., Pearson, 2017.
- [2] C. P. Pfleeger and S. L. Pfleeger, Security in Computing, 5th ed., Pearson, 2015.
- [3] B. A. Forouzan and D. Mukhopadhyay, Cryptography and Network Security, 2nd ed., McGraw-Hill, 2010.
- [4] M. Bishop, Computer Security: Art and Science, 2nd ed., Addison-Wesley, 2018.
- [5] R. Shirey, "Internet Security Glossary, Version 2," RFC 2828, May 2000. [Online]. Available: <https://datatracker.ietf.org/doc/html/rfc2828>
- [6] M. E. Whitman and H. J. Mattord, Principles of Information Security, 6th ed., Cengage Learning, 2018.
- [7] B. Schneier, Applied Cryptography: Protocols, Algorithms, and Source Code in C, 2nd ed., Wiley, 1996.

Course Code	Course Name	L	T	P	Cr
DOEE250121	Internet of Things	3	0	2	4

Course Outcomes:

- CO 1 Explain the concept of IoT
- CO 2 Networking basics for IoT application development
- CO 3 Analyze various protocols for IoT
- CO 4 Design a PoC of an IoT system using various hardware platforms
- CO 5 Apply data analytics and use cloud offerings related to IoT
- CO 6 Analyze applications of IoT in real time scenario

Module 1:

Overview of IoT

Introduction to the Internet of Things, IoT system architecture and standards, Networking Basics - TCP/IP, Networking Basics - IP addressing basics (IPv4 and IPv6), Optimizing IP for IoT: From 6LoWPAN to 6Lo, Routing over Low Power and Lossy Networks.

Module 2:

IoT hardware Platforms

IoT Design Methodology – Embedded computing logic – Microcontroller-System on Chips, Hardware platforms for prototyping IoT node- Arduino, Raspberry Pi, NodeMCU, ESP32, ARM Cortex Microcontrollers, IoT mote hardware platforms, Swadeshi RISC V based solutions, Interfacing sensors and actuators with hardware platforms, Developing IoT applications using Raspberry Pi with Python Programming.

Module 3:

IoT connectivity & Protocols

IoT Access Technologies: WiFi, Zigbee, Zwave, Bluetooth, UWB, sub1GHz, LoRaWAN, Sigfox and NB-IoT, Topology and Security of IEEE 802.15.4, 802.15.4g, 802.15.4e, 1901.2a, 802.11ah and LoRaWAN, IoT application level protocols: MQTT, CoAP, XMPP, HTTP/Rest Services, WebSockets.

Module 4:

Data analytics, Cloud and IoT Security

No SQL Databases Vs SQL Databases, Apache web servers, JSON, Open and commercial Cloud solutions for IoT, Python Web Application Frameworks for IoT, IoT data visualisation tools, IoT Security - Need for encryption, standard encryption protocol, lightweight cryptography, Trust models for IoT, ARM Cortex Microcontroller Security, Root Security Services (RSS).

Module 5:

IoT Case studies

Smart Lighting, Smart home, Smart Agriculture, Smart farming, IoT for health care & patient monitoring, Smart and Connected Cities, Building end-to-end smart applications with TinyML.

Labs / Practicals:

Hands-on Sessions on IoT Application Development using IoT Hardware Kits (ESP32/STM32/Rpi etc.)

- IPv4 and IPv6 Implementation
- 6LoWPAN Network Implementation
- Interfacing multiple sensors and actuators with Processor Hardware using different communication protocols and develop an integrated monitoring system.
- Implementation of different IoT connectivity technologies including WiFi, Bluetooth, and BLE for various application scenarios.
- Implementation of MQTT protocol for IoT device communication
- Implementation of CoAP for resource-constrained IoT devices
- Integration of IoT devices with cloud platforms for data analytics

References:

Reference Books

1. David Hanes, Gonzalo Salgueiro, Patrick Grossetete, Rob Barton and Jerome Henry, —IoT Fundamentals: Networking Technologies, Protocols and Use Cases for Internet of Things, Cisco Press, 2017
2. Alessandro Bassi, Martin Bauer, Martin Fiedler, Thorsten Kramp, Rob van Kranenburg, Sebastian Lange, Stefan Meissner, “Enabling things to talk – Designing IoT solutions with the IoT Architecture Reference Model”, Springer Open, 2016
3. VijayMadiseti , ArshdeepBahga, Adrian McEwen (Author), Hakim Cassimally “Internet of Things: A Hands-on-Approach” ArshdeepBahga& Vijay Madiseti, 2014.
4. Gian Marco Iodice, TinyML Cookbook: Combine artificial intelligence and ultralow-power embedded devices to make the world smarter
5. Olivier Hersent, David Boswarthick, Omar Elloumi , —The Internet of Things – Key applications and Protocols, Wiley, 2012

Course Code	Course Name	L	T	P	Cr
DOEE250207	Wireless Technologies	3	1	0	4

Course Outcomes:

CO 1 Understand the different wireless technologies available today

CO 2 An understanding on the functioning of wireless communication systems and evolution of different wireless communication systems and standards

CO 3 An ability to compare recent technologies used for wireless and Mobile communication

CO 4 An ability to explain the architecture, functioning, protocols, capabilities and application of various wireless communication networks

CO 5 An ability to evaluate design challenges, constraints and security issues associated with Ad-hoc wireless networks

CO 6 An ability to explain the Wireless Sensor Networks and Wireless Personal Area Network Technologies

Module 1:

Wireless Communication Fundamentals

RF Basics: Radio Frequency (RF) Fundamentals: Introduction to RF & Wireless Communications Systems, Units of RF measurements, SNR, ISI, Analog & Digital Modulation techniques for Mobile communication, Multiple access techniques, Wireless Antenna basics, OFDM, MIMO.

Module 2:

Cellular & Mobile technologies

The cellular concept - system design issues, Cellular carriers and Frequencies, Channel allocation, Cell coverage, Cell Splitting, Microcells, Picocells, Handoff and outage, Improving coverage and system capacity, Cellular Systems (1G, 2G, 3G, 4G, 5G and beyond 5G), NBIoT, Mobile IP, 6G overview, Software Defined Networking (SDN), Virtual RAN & Open RAN (VRAN & ORAN).

Module 3:

Mobile Radio Propagation

Reflection, Diffraction, Fading, Multipath Propagation, Channel modeling, Diversity Schemes and Combining Techniques, Wireless Channel Models.

Module 4:

Wireless LAN

Wi-Fi Organizations and Standards: Regulatory Bodies, IEEE, Wi-Fi Alliance, WLAN Connectivity, WLAN QoS & Power-Save, IEEE 802.11 Standards, 802.11-2007, 802.11a/b/g, 802.11e/h/l, 802.11n, 802.11AC, Wi-Fi Hardware & Software: Access Points, WLAN Routers, WLAN Bridges, WLAN Repeaters, WLAN Controllers/Switches, Wireless Topologies, PoE Infrastructure, Wireless signalling, WiFi6, WiFi Security standards.

Module 5:

WSN and WPAN

Wireless Sensor Network (WSN) & Wireless Personal Area Network (WPAN): Introduction to WSN, WSN IEEE standards, WSN Topologies, WSN - Routing protocols, Low Power Lossy networks, RPL, TSCH and 6TiSCH,

Zigbee, Zwave, Thread, Bluetooth 1.0 to 6.0, LoRA&LoRA WAN, WiMaX, 6lowPAN,s igfox.

Labs / Practicals:

N/A.

References:

1. Theodore S. Rappaport, "Wireless Communications: Principles and Practice", Second Edition, 2002, Pearson Education Asia.
2. David Tse and Pramod Viswanath, Fundamentals of wireless communications, Cambridge University Press, First Edition, 2012.
3. Henrik Schulz And Christian L'uders, Theory and Applications of OFDM and CDMA Wideband Wireless Communications, , John Wily & Sons, First Edition, 2005.
4. Bluetooth Revealed; By: Miller, Brent A, Bisdikian, Chatschik; Addison Wesley Longman Pte Ltd., Delhi.
5. Wilson , "Sensor Technology hand book," Elsevier publications 2005.
6. Andrea Goldsmith, "Wireless Communications," Cambridge University Press, 2005.
7. Mobile and Personal Communications Services and Systems; 1 st Edition; By: Raj Pandya; PHI, New Delhi.
8. Mobile Communications; By: Schiller, Jochen H; Addison Wesley Longman Pte Ltd., Delhi
9. 3G Networks: Architecture, protocols and procedures based on 3GPP specifications for UMTS WCDMA networks, By Katera, Sumit, Narang, and Nishit, TATA MGH, New Delhi.
10. Wireless Sensor Networks: information processing by approach, ZHAO, FENG, GUIBAS and LEONIDAS J, ELSEVIER, New Delhi.
11. Holger Karl and Andreas Wiilig, "Protocols and Architectures for Wireless Sensor Networks" John Wiley & Sons Limited 2008.
12. Wireless Communications and Networking, VijayGarg, Elsevier.

Course Code	Course Name	L	T	P	Cr
DOEE250175	Reconfigurable Computing	3	0	2	4

Course Outcomes:

- CO 1: Able to select suitable hardware for an application
 CO 2: Able to understand the design methodology of micro-processor system on Chip (SoC) buses, memory peripherals on FPGA
 CO 3: Build reconfigurable system using FPGAs
 CO 4: Able to evaluate hardware accelerator and achieve acceleration factor for a specific application.
 CO 5: Perform partial reconfiguration for various applications using peripheral devices.
 CO 6: Demonstrate an embedded system on FPGA using IP blocks.

Module 1:

Introduction to Reconfigurable Computing
 Reconfigurable Architectures: Classification of Reconfigurable Architectures. FPGA Technology and Architectures, LUT devices and Mapping, Placement and Partitioning. Programming Technology: HDL Based Programming and High level Synthesis using C, Partial Reconfiguration. Intellectual Property Based Design: Soft core, Firm core and Hard Core, Software tools.

Module 2:

System on chip (SoC) system in FPGA devices
 Embedded computer organization and methodology of System on chip (SoC) system in FPGA devices. Design challenges and Differences GPP, DSP, ASIC and FPGA based System on Chip platforms. Application profiling and partitioning, FPGAs vs. Multi-core processor architectures. Xilinx Zynq 7000 family programmable SoC (system on chip) in particular - hybrid device with ARM + FPGA architecture.

Module 3:

Overview of AXI Bus protocol
 Design of Master and Slave Bus protocols based IPs. Design Metrics, General purpose peripherals (interrupt, timer, clock, DMA etc.) and special purpose peripherals Serial Transmission protocols & Standards, and advanced high speed buses. Debugging methodologies.

Module 4:

Emulating SoC Architectures on FPGAs
 Emphasis on different embedded processors and multiprocessor and architectures. Coprocessor creation, hardware design for System-On-a-Chip. Memory and peripheral interfacing. System level design Tradeoffs, Power, Energy, Performance and Area.

Module 5:

High level synthesis and system modeling
 Overview of high level synthesis (HLS). Exploration of HLS tools, System Modeling. Models of Computation and System Specification Languages, High Level Computation/Behavioral Synthesis. Application case study like FFT, JPEG.

Labs / Practicals:

Hands-on Sessions on FPGA development board.

1. To design and implement various combinational logic circuits on an FPGA development board

- Basic logic gates, 2x1 Mux, 4x1 Mux, 3 bit Comparators, Half adder, 3 bit Full adder, Ripple Carry adder using Structural Modelling
 - Code converters – 4 bit BCD, Gray Code, Gray to Excess-3 code
 - Encoders and Decoders
2. To design and implement various sequential logic circuits on an FPGA development board
 - D Flip-flop with Reset
 - Up, Down, Up-down Counter
 - Ring & Johnson Counter
 - Traffic Light Controller implementation with FSM
 - IP CORE - Binary Counter
 - IPCORE - Adder/Subtractor
 3. System on chip (SoC) implementation on FPGA Devices : Zynq 7000
 - GPIO configuration and control of LEDs on Zynq Board
 - Configuration and data transmission with UART on Zynq Board
 4. System Modelling with High Level Synthesis
 - Matrix multiplication using the concept of HLS. Tool used : Vivado HLS
 - FFT process using concept of HLS. Tool used : Vivado HLS
 5. Demonstration of debugging methodologies
 - Capture and display internal signal waveforms in real-time on the FPGA using Integrated Logic Analyzer & Virtual Input Output IP Cores

References:

Text Books

1. R. Sass and A. G. Schmidt. Embedded Systems Design with Platform FPGAs Principles and Practices. Elsevier Inc, USA, 2010.
2. The Zynq Book: Embedded Processing with the Arm Cortex-A9 on the Xilinx Zynq-7000 All Programmable SoC, Strathclyde Academic Media , UK ,2014.

Reference Books

1. S. Hauck and A. DeHon, Reconfigurable Computing: The Theory and Practice of FPGA-Based Computing, Morgan Kaufmann, 2008.
2. Cardoso, João M. P.; Hübner, Michael (Eds.), Reconfigurable Computing: From FPGAs to Hardware/Software Codesign, Springer, 2011.

Course Code	Course Name	L	T	P	Cr
DOEE250201	VLSI Signal Processing	3	0	2	4

Course Outcomes:

CO1: Understand the fundamentals of signal processing algorithms and their mathematical representations, including discrete-time signals and systems, linear time-invariant (LTI) systems, and Fourier analysis.

CO2: Gain proficiency in using hardware description languages (HDLs) such as Verilog and VHDL for modeling, simulating, and synthesizing digital signal processing (DSP) algorithms for VLSI implementation.

CO3: Develop critical thinking and problem-solving skills through analysis of existing VLSI signal processing architectures, identifying design trade-offs, and proposing innovative solutions to improve performance and efficiency.

Module 1:

Introduction to VLSI Signal processing:

Graphical representation of DSP algorithms. Dataflow and control flow. Parallel pipelined design of DSP Algorithms. Retiming.

Module 2:

Unfolding and Folding:

Properties of unfolding, unfolding and retiming, Folding Transformation, Register Minimization Techniques.

Module 3:

VLSI Architectures for Digital Signal Processing:

Architectural Design at Register Transfer Level, Design of data path and control path units, Verilog RTL implementation.

Module 4:

VLSI implementation of Filter and Transform structures:

FIR and IIR architectures. Serial and parallel implementation of DIT-FFT algorithm.

Module 5:

VLSI array signal processing:

Overview of spatial filters. VLSI implementation of a delay and sum (DAS) spatial filter.

Labs / Practicals:

1. Fold 4-bit parallel adder using 1 bit adder. Design control circuitry for proper scheduling of input and output data. Verify the operation with proper scheduling.
2. Perform the Verilog RTL implementation for a radix-2 FFT butterfly structure.
3. Given the following DSP System $y(n) = a \cdot x(n) + b \cdot y(n-1)$, with multiplier delay 9ns and adder delay 7nsec. Develop RTL description of the system using Verilog HDL Coding. Perform timing analysis.
4. Implement a 3-tap FIR filter using Verilog HDL and demonstrate the pipe-line operation.
5. Perform Verilog RTL implementation of a 6 tap FIR data broad cast structure.
6. Design and simulate an 8-channel delay and sum spatial filter.
7. Verilog RTL Implementation of a 16-point Radix-2 Decimation-in-Time FFT
8. Design and Verification of a Direct Form II IIR Filter
9. Implementation of a Systolic Array for Matrix Multiplication
10. Design and Simulation of a CORDIC Processor for Sine and Cosine Computation

References:

1. VLSI Signal Processing Systems - Keshab K Parhi, John Wiley and Son's, NY 1999.
2. Architectures for Digital Signal Processing - Peter Prissch, John Wiley and Son's NY 1998.

In addition, manufacturers Device data sheets and application notes are to be referred to get practical and application-oriented information.