B.TECH IN ELECTRONICS AND COMMUNICATION ENGINEERING

III SEMESTER (2023-27 BATCH)

Note: FC=Foundational Course, AC= Audit Course

Sl. No	Course Code	Course Title	Hours per week				Credits	Course Type	S/W / Tools
			L	T	P	S			
1	UE23EC251A	AnalogCircuit Design	4	0	2	4	5	FC	Mentor Graphics Tanner Tools 2020.1 Version/ Cadence Virtuso
2	UE23EC252A	Computer Aided Digital Design	4	0	2	4	5	FC	Xilinx Vivado 2018 Version, Quartus Prime Lite
3	UE23EC241A	Mathematics for Electronics Engineers	4	0	0	4	4	FC	MATLAB R2020a +
4	UE23EC242A	Network Analysis and Synthesis	4	0	0	4	4	FC	MATLAB /PSPICE/ QUCS
5	UE23EC243A	Signals and Systems	4	0	0	4	4	FC	MATLAB R2020a +
6	UE24MA101A	Bridge course Mathematics-I (ApplicabletoLateral Entry Students)	2	1	0	2	0	AC	
	TOTAL		20 / 22	0 / 1	4	20/ 22	22		

IV SEMESTER (2023-27 BATCH)

Note: CC= Core Course, FC=Foundational Course ,AC= Audit Course

Sl. No.	Course Code	Course Title	Hours per week				Credits	Course Type	S/W / Tools
			L	T	P	S			
1	UE23EC251B	Digital VLSI Design	4	0	2	4	5	CC	Mentor Graphics Tanner Tools 2020.0/Cadence Virtuso
2	UE23EC252B	Principles of Digital Signal Processing	4	0	2	4	5	CC	MATLAB R2020a +/ Code Composer Studio
3	UE23EC241B	Control systems	4	0	0	4	4	CC	MATLAB R2020a +
4	UE23EC242B	Digital Communication	4	0	0	4	4	CC	MATLAB
5	UE23MA241B	Linear Algebra	4	0	0	4	4	FC	MATLAB R2020a +
6	UE24MA101B	Bridge course Mathematics-II (Applicable to Lateral Entry Students)	2	1	0	2	0	AC	
	TOTAL		20 / 22	0 /1	4	20/ 22	22		

V SEMESTER (2022-26 BATCH)
Note: CC= Core Course, EC= Elective Course

Sl. No.	Course Code	Course Title	Hours per week				Credits	Course Type	S/W / Tools
			L	T	P	S			
1	UE22EC351A	Computer Communication Networks	4	0	2	4	5	CC	Wireshark, GNS3, Python
2	UE22EC352A	RISC-V Architecture	4	0	2	4	5	CC	Codasip
3	UE22EC341A	Electromagnetic Field Theory	4	0	0	4	4	CC	MATLAB R2020a +
Elective- I									
4	UE22EC342AA1	Wireless Mobile Systems	4	0	0	4	4	EC	MATLAB
5	UE22EC342AA2	Operations Research	4	0	0	4	4	EC	MATLAB
6	UE22EC342AA3	Wireless Communication	4	0	0	4	4	EC	MATLAB, LabView
7	UE22EC342AB1	Digital System Design	4	0	0	4	4	EC	Cadence NcSim Version 2020.1
8	UE22EC342AB2	Electronic design automation: Verilog to routing	4	0	0	4	4	EC	VTR, Vivado HLS, Open lane
9	UE22EC342AB3	Linear Integrated Circuits	4	0	0	4	4	EC	SPICE Package
10	UE22EC342AB4	Chip level Photonics	4	0	0	4	4	EC	CST Tools
11	UE22EC342AC1	Digital Image Processing	4	0	0	4	4	EC	MATLAB R2020a +/ Scilab/Python
12	UE22EC342AC2	Speech and Natural Language Processing	4	0	0	4	4	EC	MATLAB R2020a +
Elective – II									
13	UE22EC343AA1	Software Define Radio	4	0	0	4	4	EC	MATLAB
14	UE22EC343AA2	Networking and optimization	4	0	0	4	4	EC	MATLAB
15	UE22EC343AB1	Verification of Digital Systems	4	0	0	4	4	EC	Cadence NcSim 2020.1

									Version
16	UE22EC343AB 2	Real Time Operating Systems	4	0	0	4	4	EC	Free RTOS
17	UE22EC343AB 3	Quantum Entanglement and Quantum Computing	4	0	0	4	4	EC	Python (latest ed) and Comsol (ver 5 and above)
18	UE22EC343AB 4	Functional and Formal Verification of Digital Designs	4	0	0	4	4	EC	Cadence Jasper 2020.1 Version
19	UE22EC343AB 5	Data Converter Circuits and Systems	4	0	0	4	4	EC	Cadence Virtuoso 2020.1
20	UE22EC343AB 6	Machine Intelligence for Chip Security and HardwareTrust	4	0	0	4	4	EC	
21	UE22EC343AC 1	Artificial Neural Networks	4	0	0	4	4	EC	MATLAB R2020a +/ Tensorflow
22	UE22EC343AC 2	Intelligent Control Systems	4	0	0	4	4	EC	Matlab/Pytho n
TOTAL			**20**	**0**	**4**	**20**	**22**		

ELECTIVES TO BE OPTED FOR SPECIALIZATION			
Sl. No.	**SPECIALIZATION**	**ELECTIVE – I**	**ELECTIVE – II**
A	Communication Systems	UE22EC342AA 1, UE22EC342AA 2, UE22EC342AA 3	UE22EC343AA1, UE22EC343AA2
B	VLSI Design	UE22EC342AB 1, UE22EC342AB 2, UE22EC342AB 3, UE22EC342AB 4	UE22EC343AB1, UE22EC343AB2, UE22EC343AB3, UE22EC343AB4, UE22EC343AB5,UE22EC343AB6
C	Signals and Systems	UE22EC342AC 1, UE22EC342AC 2,	UE22EC343AC1, UE22EC343AC2

Note: Prerequisite course: Nil			

VI SEMESTER (2022-26 BATCH)
Note: CC= Core Course, EC= Elective Course, PW=Project Work

Sl. No.	Course Code	Course Title	Hours per week				Credits	Course Type	S/W / Tools
			L	T	P	S			
1	UE22EC351B	Waveguides and Antennas	4	0	2	4	5	CC	Feko, MATLAB
2	UE22EC352B	Machine Learning and Applications	4	0	2	4	5	CC	Python, MATLAB R2020a +
3	UE22EC341B	Computer Architecture	4	0	0	4	4	CC	Cadence NcSim 2020.1 Version
4	UE22EC321B	Project Work-Phase-I	0	0	4	2	2	PW	
Elective – III									
5	UE22EC342BA1	Cryptography	4	0	0	4	4	EC	CPLEX, CVXPY, Python
6	UE22EC342BA2	MIMO Communication	4	0	0	4	4	EC	MATLAB
7	UE22EC342BB1	Quantum Transport and Logic gates	4	0	0	4	4	EC	Python (latest ed) and Comsol (ver 5 and above
8	UE22EC342BB2	RF Microelectronics	4	0	0	4	4	EC	Cadence Virtuoso 2020.1
9	UE22EC342BB3	Architectures for Hardware Acceleration	4	0	0	4	4	EC	Xilinx Vivado/HLS 2018.1
10	UE22EC342BB4	Low Power VLSI	4	0	0	4	4	EC	Cadence Low Power
11	UE22EC342BC1	Computer Vision and Image Processing	4	0	0	4	4	EC	MATLAB R2020a +, Python
12	UE22EC342BC2	Reinforcement Learning	4	0	0	4	4	EC	MATLAB R2020a +(SP, Com,

									Statistics and ML toolboxes), Python
Elective – IV									
13	UE22EC343BA1	5G and 6G Technologies	4	0	0	4	4	EC	MATLAB,
14	UE22EC343BA2	Satellite Communication	4	0	0	4	4	EC	Matlab
15	UE22EC343BB1	Non-linear Optics and Quantum technology	4	0	0	4	4	EC	MATLAB
16	UE22EC343BB2	VLSI Circuit Testing and Testability	4	0	0	4	4	EC	Cadence Modus Set 2020.1
17	UE22EC343BB3	Analog and Digital Testing, Debug and Diagnosis	4	0	0	4	4	EC	Cadence
18	UE22EC343BB4	Semiconductor Devices and Fabrication	4	0	0	4	4	EC	MATLAB, Python
19	UE22EC343BB5	Memory Design and Testing	4	0	0	4	4	EC	Cadence Virtuoso 2020.1 Version
20	UE22EC343BC1	Deep Learning	4	0	0	4	4	EC	Python
21	UE22EC343BC2	Robotic Systems	4	0	0	4	4	EC	ROS,Gazebo,MoveIt
		TOTAL	**20**	**0**	**8**	**22**	**24**		

ELECTIVES TO BE OPTED FOR SPECIALIZATION

Sl. No.	SPECIALIZATION	ELECTIVE – III	ELECTIVE – IV
A	Communication Systems	UE22EC342BA1, UE22EC342BA2	UE22EC343BA1,UE22EC343BA2, UE22EC343BC2
B	VLSI Design	UE22EC342BB1, UE22EC342BB2, UE22EC342BB3, UE22EC342BB4	UE22EC343BB1, UE22EC343BB2, UE22EC343BB3, UE22EC343BB4, UE22EC343BB5
C	Signals and Systems	UE22EC342BC1, UE22EC342BC2,	UE22EC343BC1, UE22EC343BC2

Note: Prerequisite course: Nil			

VII Semester (2021-25 BATCH)

Note: ST=Special Topic, SW=Swayam Course, MC=MooC Course, PW=Project Work

Sl. No.	**Course Code**	**Course Title**	**Hours per week**				**Credits**	**Course Type**	**S/W / Tools**
			L	**T**	**P**	**S**			
1	UE21EC390B	Project Work-Phase-II	0	0	12	6	6	PW	
2	UE21EC491X/ UE21EC400X/ UE21EC400SX/ UE21EC400MX	Special Topic/Swayam/MOOC	6	*	*	6	6	ST/SW/MC	
		Total	**6**	*	*	**12**	**12**		

VIII Semester (2020-24 BATCH)

ST=Special Topic, SW=Swayam Course, MC=MooC Course, PW=Project Work

Sl. No.	**Course Code**	**Course Title**	**Hours per week**				**Credits**	**Course Type**	**S/W / Tools**
			L	**T**	**P**	**S**			
1	UE21EC390C	Project Work-Phase-III	0	0	4	2	4	PW	
2	UE21EC491X/ UE21EC400X/ UE21EC400SX/ UE21EC400MX	Internship/Special Topic/ Swayam/Mooc/Study Abroad**	4	*	*	*	4	ST/SW/MC	This is to be confirmed
	Total		**4**	*	*	*	**8**		
Note:									

UE24EC141A: Electronic Principles and Devices (4-0-0-4-4)

Course Description:

In this Course, Students will learn the working principles of Semiconductor Devices and Electronic circuits such as rectifiers, amplifiers, and other signal-conditioning circuits. Students will be able understand the basic digital logic circuits and fundamentals of Wireless communication & embedded systems.

Course Objectives:

- Impart understanding of working principles and applications of semiconductor devices in the design of electronic circuits.
- Introduce basic applications like rectifiers, amplifiers and other signal conditioning circuits with emphasis on practical design considerations.
- Provide brief introduction to fundamentals of Wireless communication.
- Introduce the fundamentals of embedded system design and its interfaces.
- To enhance the understanding of the topics in the curriculum, specific activities have been designed as conceptual and hands-on aid.

Course outcomes:

On successful completion of this course, the students will be able to:

- Analyze and appreciate the working of electronic circuits involving applications of diodes and transistors.
- Design combinational digital circuits to meet a given specification using digital ICs
- Comprehend working of basic communication systems.
- Understand the functioning of embedded system cores
- Develop simple projects based on the different devices studied in this course.

Course Content

Unit 1: Electronics and Semiconductor Devices:
Basic circuit elements: Resistor, Inductor, Capacitor, Semiconductor diode under forward and reverse bias, Shockley's equation, Zener and Avalanche breakdown, temperature effects, Ideal versus Practical diode, Diode resistances, Diode equivalent circuits, Zener diode characteristics, Series diode configurations; Parallel and Series- Parallel configurations and logical operations using diode. **Transistors:** Transistor construction, transistor operation, Transistor configurations - Common base and common emitter configurations – input and output characteristics. Transistor amplifying action. Enhancement-Type MOSFETs drain and transfer characteristics.
Demo: Active and passive components, Multi-meter, CRO.

16 Hours

Unit 2: Semiconductor diode applications:
Block diagram of regulated power supply, Half-wave, Centre Tap Full-wave and bridge rectifier, ripple factor, Peak inverse voltage derivations. Shunt capacitor filter- working, output waveform and ripple factor equation, Zener diode voltage regulator; Practical Applications: Battery charger, Controlled Battery-Powered Backup.

Demo: Pspice simulation of regulated power supply **12 Hours**

Unit 3: Digital Electronics:
Boolean Algebra, Logic gates, Basic Theorems and Properties of Boolean Algebra, Boolean Functions, Canonical and Standard Form, other Logical Operations. Combinational Logic Circuits:

Half Adder and Full adder, Multiplexer and De-multiplexer. Sequential Circuits: RS, D, T, JK Flip-Flops, SISO Register, 3 Bit Asynchronous UP/Down counters.

Demo: Using Digital Trainer kit: TT Verification of Logic Gates, Adders

14 Hours

Unit 4: Communication Systems and Core of Embedded Systems

Communication Systems: Electronic Communication systems, Modulation and Demodulation. Fundamental Concepts of Cellular Telephone, Frequency Reuse, Co-channel Interference, Roaming and hand- offs. **Core of Embedded Systems:** Definition, Block Diagram of Embedded System, Characteristics of Embedded Systems, General Purpose & domain specific processors, Applications of Embedded Systems. Memory, Sensors and Actuators, I/O Subsystems, LED, 7-Segment display, Opto-coupler, Stepper motor, Relay, Keyboard. Communication Interfaces, Design aspects of embedded systems: size, weight, power and thermal dissipation in embedded systems.
ARM Processor Fundamentals: ARM core dataflow model, Registers, Current Program Status Register;

Demo: Different Modulation Techniques, Simulation of Data Transfer and Arithmetic operations.

14 Hours

Text Books:

1. Robert. L. Boylestad and Louis Nashelsky, “Electronic Devices and circuit theory “, PHI, 10 th Edition, 2009

Reference books:

1. M Morris Mano, Michale D Ciletti, “Digital Design with an Introduction to Verilog HDL”, 5th Edition, Pearson 2013
2. Wayne Tomasi, “Electronic Communication Systems, Fundamentals through Advanced”, 5 th Edition, Pearson Education, 2004
3. Shibu K V, “Introduction to Embedded Systems”, Tata McGraw Hill, 2009.
4. Andrew N. Sloss, Dominic Symes, Chris Wright, “ARM System Developer’s Guide”, Elsevier,2004

UE23EC251A: Analog Circuit Design (4-0-2-4-5)

Course description:

An introductory course in analog circuits for microelectronic designers. Topics in this course include: Review of analog design basics, designing amplifiers and feedback concepts. Knowledge of Electronic Principles and Devices is required for this course.

Course Objectives:

- Provide basic understanding of the theoretical models of MOSFET.
- Impart understanding of single-stage CMOS amplifiers with emphasis on

practical design considerations.
- Introduce multistage amplifiers.
- Introduce feedback concepts and oscillator circuits

Course Outcomes:

At the end of this course, the student will be able to:

- Analyse CMOS analog circuits using models
- Comprehend the working of complex analog circuits.
- Understand and appreciate the working of CMOS amplifiers at high frequencies
- Design CMOS analog circuits against given specifications and implement the same using CAD tools.
- Design oscillators for given specifications

Course Content:

Unit 1: **14 slots**

Physics of MOS Transistor and MOSFET biasing: MOSFET Structure, MOS Symbols, MOS I/V Characteristics, Derivation of I/V Characteristics, MOS Transconductance, Second-Order Effects, MOS Device Capacitances, MOS Small Signal Model, MOS SPICE models, NMOS Versus PMOS, Devices General Considerations, Biasing, DC and Small – signal analysis, Operating point analysis and design

Unit 2: **14 slots**

Single – stage amplifiers, Frequency Response: Common-Source Stage with Resistive Load, CS Stage with Diode-Connected Load, CS Stage with Current-Source Load, CS Stage with Source Degeneration, Source Follower, Common-Gate Stage, Cascode Stage. Frequency Response: Miller Effect, Common source stage

Unit 3: **14 slots**

Differential Amplifiers and Current mirrors: Single-Ended and Differential Operation, Basic Differential Pair, MOS Differential Pair, Qualitative Analysis, Small-Signal Analysis, Common Mode Response, Differential Pair with Passive Load, Differential Pair with Active, Load- Small Signal Analysis. Basic Current Mirrors, Cascode Current Mirrors

Unit 4: **14 slots**

Feedback Amplifiers and Oscillators: Feedback: General considerations, properties of negative feedback, types of amplifiers, feedback topologies. Oscillators: General considerations, LC oscillators: Tank circuit and Cross – coupled oscillator, Crystal oscillators.

Textbooks:

1. Design of Analog CMOS integrated Circuits" ,BehzadRazavi, 2nd Edition, TMHPublisher, 2018

2. “Fundamentals of Microelectronics”, BehzadRazavi, 2nd Edition, TMH Publisher, 2013

Reference Books:

1. CMOS Analog Circuit Design " Allen and Holberg ,The Oxford Series in Electrical and Computer Engineering, 2016
2. Microelectronic Circuits: Theory And Applications: Seventh Edition, Adel S. Sedra , Kenneth C. Smith, 2017
3. Operational Amplifiers and Linear Integrated Circuits: Robert F Coughlin, Fredrick F Driscoll

UE22EC252A: Computer Aided Digital Design (4-0-2-4-5)

Course Description:

This course deals with the basic concepts of digital systems. It performs realization of combinational and sequential digital logic circuits and model them using Hardware description Language.

Course Objectives:

To understand the basic theoretical concepts of digital systems like the binary system.
To express real life problem in logic design terminology.
To design digital systems using combinational/sequential circuits.
To understand System Verilog HDL and modeling digital circuits in HDL.
To understand designing finite state machine (FSM) for a given application or logic.

Course Outcomes:

- Student will be able to perform realization of combinational and sequential digital logic circuit.
- Students will be able to design digital circuits and model them using HDL.

- FSM based digital system design
- Simulation of Digital Systems in FPGA and ASIC design tools
- Analysing the design for different tenets.

Course Contents:

Unit 1: Combinational Logic Design: Levels of abstraction for an electronic computing System. Number systems (decimal, binary, hexadecimal, signed and unsigned), Introduction, Multilevel Combinational Logic, X’s & Z’s, K-Maps, Combinational Building Blocks, HDL programming for Combinational Logic, Structural Modelling, Timing

14 Hours

Unit 2: Sequential Logic Design: Introduction, Latches & Flip Flops, Synchronous Logic Design, Finite State Machines, HDL programming for sequential circuits, Timing of Sequential Logic

.

14 Hours

Unit 3: Hardware Description Language: Sequential Logic, More Combinational Logic, HDL programming, Data Types, Parameterized Modules, Testbenches, Parallelism. 14 Hours

Unit 4: Digital Building Blocks: Introduction, Arithmetic Circuits, Number Systems (fixed and floating point), Sequential Building Blocks, Memory Arrays, Logic Arrays.
14 Hours
Text Book:
1. "Digital Design and Computer Architecture", David Money Harris and Sarah L Harris, Elsevier, 2nd Edition, 2019.

UE22EC241A: Mathematics for Electronics Engineers (4-0-0-4-4)

Course Description:

This course provides an introduction to the two well-used mathematical tools in electronics and communication engineering (ECE), namely, probability models and complex analysis. Probability models find their applications in several communications-related courses, while complex analysis is useful in control theory and signal processing-related courses. This course also highlights the importance of mathematical modelling and analysis, which is a key requirement in formulating and solving many modern day problems in the broad area of ECE.

Course Objectives:

- To develop strong background in mathematical analysis
- To understand basic concepts of series, residues and probability.
- To understand the concepts of continuous random variables.
- To understand the concepts of multiple random variables
- To understand random process.

Course Outcomes:

Students completing the course should be able to

- Solve complex analysis problems.
- Apply the probability and discrete random analysis.
- Analyze problems of continuous random variables.
- Apply multiple random variable concepts.
- Analyze random process.

Course Content:

Unit 1: Probability, Discrete and Continuous Random Variables: Basics of Probability, conditional probability and Bayes theorem, independent events and Bernoulli trials. Discrete Random variable: Definition, Probability mass function, Cumulative distribution, Geometric, Binomial, and Poisson distribution. Application problems. Continuous Random Variables:Introduction, distribution and density function of continuous random variable, Uniform, Rayleigh, Exponential and Gaussian distribution.

(12 Hours)

Unit 2: Properties of Single Random Variable and Multiple Random Variable: Single random variable: Expectation, moment and probability generating function. Characteristic function. Transformation of random variables, conditional density and distribution function. Multiple Random Variables: joint mass function and its properties, joint distribution and its properties; joint density and its properties; conditional distribution and density; statistical independence; Joint moments: correlation and covariance, distribution and density of a sum of random variables; central limit theorem. Vector random variables, jointly Gaussian random variables.

(16 Hours)

Unit 3: Random Processes: Stationarity and independence, ergodicity, correlation functions, power density spectrum and its properties: relationship between power spectrum and autocorrelation function, cross-power density spectrum and its properties, Gaussian random processes: Random signal response of linear systems; spectral characteristics of system response; spectral factorization; AR, MA and ARMA processes, noise bandwidth.

(12 Hours)

Unit 4: Calculus in Complex Plane: Introduction to Complex functions, Limit, continuity and Derivative of f(z). Analytic functions, Cauchy –Riemann equations in Cartesian and Polar forms (statement only), Harmonic Functions, Line integral in complex plane, Cauchy's integral theorem and consequences, Cauchy's integral formula and its generalization. Series of complex terms-Taylor's series and Laurent's series, Singularities, poles, Residues. Cauchy's Residue theorem and application problems.

(16 Hours)

Text Books:

1. *Erwin Kreyszig, "Advanced Engineering Mathematics", John Wiley & Sons, 10th Edition, Reprint 2019.*
2. Scott Miller and Donald Childers, *"Probability and Random Processes: With Applications to Signal Processing and Communication"*, 2nd Edition, Elsevier Inc., 2012.

Reference Book:

1. Signals, Systems and Inference " by Alan.V,oppenhiem , C.Vargees, Pearson Education, 30 Mar 2015

UE23EC242A: Network Analysis and Synthesis
(4-0-0-4-4)

Course Description:

This course deals with circuit analysis during transient state and steady state for both DC and AC circuits. It introduces various network theorems which simplify the analysis. The course also introduces two important topics namely two port networks and synthesis which are useful for courses related to areas such as Controls, VLSI circuits and Antennas. The hands-on teaching using circuit simulators and coding will strengthen the students' foundation in circuit theory. This course requires the knowledge of KVL and KCL.

Course Objectives:

- To develop strong background in circuit concepts and network analysis
- To introduce network theorems which are applied to simplify complex circuits
- To provide the background to apply Laplace transform for solving integro-differential equations
- To represent and analyze circuits using the concepts of two port parameters
- To analyze the stability of circuits and synthesize a given transfer function

Course Outcomes:

Students completing the course should be able to

- Solve DC and AC electrical networks using nodal and mesh analysis
- Apply and verify the network theorems to simplify network analysis
- Analyze the transients and apply Laplace transform
- Calculate and verify the parameters of two port networks
- Demonstrate their knowledge of transfer functions and synthesize them

Course Content:

Unit 1: Electrical Circuit Analysis

(i) Basic conventions and Analysis: Reference directions for current and voltage, Independent and dependent sources, Source conversions, Mesh analysis, Nodal analysis, Bridge networks, Star-delta and Delta-star conversions; (ii) Dot convention and coupled circuits: Mutual inductance and Series connection of mutually coupled coils (iii) Superposition theorem, Thevenin's theorem, Norton's theorem.

14 Hours

Unit 2: Network theorems and Transients Analysis

(i) Maximum power transfer theorem, Millman's theorem, Substitution theorem and Reciprocity theorem, Application of Thevenin's theorem. (ii) RC transients: Storage cycle, Initial values, Instantaneous values, Application; (iii) RL transients: Storage cycle, Initial values, Instantaneous values, Application.

14 Hours

Unit 3: System Analysis

Circuit analysis in s-domain: Philosophy of Laplace transforms, Properties, Partial Fraction expansion, Initial value and final value, Transformed circuit, Configurations, Two port parameters – Impedance, Admittance, Hybrid, Transmission, and Relationship between parameters.

14 Hours

Unit 4: Network Synthesis:

(i) Interconnection of two port network (ii) Elements of realizability: Causality and stability, Hurwitz polynomial, positive real functions, elementary synthesis procedures; (iii) Elementary Synthesis procedure, Properties of LC immitance functions, Synthesis of LC driving point immittances, Properties of R-C impedances and R-L admittances, Synthesis of R-C impedances and R-L admittances, Properties of R-L impedances and R-C admittances, Synthesis of R-L impedances and R-C admittances.

14 Hours

Text Book:

1. Introductory Circuit Analysis, Robert L. Boylestad, 13th edition, Prentice Hall, 2015

Reference Books:

1. Network Analysis and Synthesis, Franklin F Kuo, Wiley India, 2nd Edition, 2006.
2. Engineering Circuit Analysis, W.H. Hayt, J.E. Kemmerly, S.M. Durbin, TMH, 9th Edition, 2021.
3. Network Analysis, M.E Van Valkenburg, Prentice Hall India, 3rd edition, 2006
4. Fundamentals of Electric Circuits, Charles.K.Alexander, Mathew.N.O.Sadiku, Fourth Edition, TMH, 2009

UE23EC243A: Signals and Systems (4-0-0-4-4)

Course Description:

This is one of the fundamental subjects, a thorough understanding of which is essential for proper appreciation and application of subjects like signal processing, communication and control systems. It introduces different types of signals and the basic operations performed on them. It discusses the important case of linear time invariant systems and their properties. This subject gives an insight into both continuous time and discrete time signals and systems, and their frequency domain representation.

Course Objectives:

- To familiarize different types of signals and systems typically encountered in Communication engineering.
- To expose students to different transformation techniques to apply and analyze different real-life periodic and aperiodic signals to systems (typically LTI).
- To provide valuable insights of complex systems/signals analyzed through different techniques learnt.
- To provide sufficient understanding of different types of signals and systems and transformation techniques for future courses in Signal Processing, Image processing and so on.

Course Outcomes:

Students completing the course should be able to

- Understand and represent signals and perform basic operations on signals.
- Determine Fourier representations for continuous-time and discrete-time signals.
- Understand LTI systems.
- Analyze and design signals and systems using transformation techniques.
- Use the unilateral Z transform.
- Apply the Fourier representation properties and z- transform properties to solve problems.

Course Content:

Unit 1: Signals and systems

Classification of signals, Continuous-time and discrete-time signals, Transformations of the independent variable, Exponential and sinusoidal signals, The unit impulse and unit step functions, Sa(x)/Sinc functions, Importance of sinc function, Continuous-time and discrete-time systems, Basic system properties. **Linear time-invariant systems:** Discrete-time LTI systems: The convolution sum, Continuous-time LTI systems: The convolution integral, Properties of LTI systems, Causal LTI systems described by difference equations (Natural, Forced, and Complete Response)

16 Hours

Unit 2: Representation of Periodic (Continuous Time & Discrete-Time) Signals Using Fourier Series

Explanation of Complex Exponentials, Response of LTI systems to complex exponentials, Trigonometric Fourier Series, Fourier series representation of continuous-time periodic signals, Convergence of the Fourier series (brief discussion only), Properties of continuous-time Fourier series (CTFS), Fourier series representation of discrete-time periodic signals, Properties of Discrete-time Fourier series (DTFS)

12 Hours

Unit- 3: Continuous-time Fourier transform

(i) Representation of aperiodic signals: the continuous-time Fourier transform (CTFT), The Fourier transform for periodic signals, Properties of continuous-time Fourier transform, Fourier transform pairs; (ii) Introduction to sampling: Sampling theorem, Nyquist frequency; (iii) The discrete-time Fourier transform: Representation of aperiodic signals: the discrete-time Fourier transform (DTFT), The Fourier transform for discrete periodic signals, Properties of discrete-time Fourier transform, Fourier transform pairs, Duality**.**

16 Hours

Unit 4: Z-transformation: The Z-transform, The region of convergence (ROC) for the Z-transform, The inverse Z-transform, Properties of the Z-transform, Z-transform pairs, Analysis and characterization of LTI systems using Z-transforms. The unilateral Z-transform and solution of difference equations.

12 Hours

Text Book:

1. “Signals and Systems”, V. Oppenheim and A. S. Willsky with S. H. Nawab, 2nd Edition,

Pearson Education, 1996.

Reference Books:

1. "Signal Processing and Linear Systems", B. P. Lathi, 1st Indian Edition, Oxford University Press, 2006.
2. "Signals and Systems", Simon Haykin and Barry Van Veen, 2nd Edition, Wiley India, 2004.
3. "Analog and Digital Signal Processing", Ashok Ambardar, Thomas Learning, 1999.
4. "Signal and Systems", S. K Mitra, Oxford University Press; 4th edition (21 June 2016).

UE23EC251B: Digital VLSI Design (4-0-2-4-5)

CourseDescription:

Thiscoursedealswith the analysisanddesignofdigitalCMOSintegratedcircuitsemphasizing fundamentals in addition to new models that students need to master as per industryrequirements and constraints. The course emphasizes the basic theory of digital circuits, designprinciples,andtechniquesfordigitaldesignblocksimplementedinCMOStechnology.Knowledgeof AnalogCircuitDesign and DigitalDesignusingHDLisrequiredforthiscourse.

- Thiscourse aimsto learn VLSI designmethodologiesandinverter characterizationwithdifferent loads.
- Layoutdesignfordifferentcircuitswillbeexplored.
- Tounderstandinterconnectsandtheircharacteristics
- Thiscoursewillalsocoverswitchingcharacteristicsofdigitalcircuitsalongwithdelayandpower estimation.
- UnderstandingtheCMOSsequentialcircuitsand memorydesignconcepts.

CourseOutcomes:

Studentscompletingthecourseshouldbeableto

- Understand the designingofcombinationandsequentialblocksusingMOSFET
- Understanddigitalfunctionalitiesusingdifferenttechnologieslike CMOS,BiCMOSetc.
- AppreciatetheimportanceofinterconnectsinVLSIlayouts.
- Drawlayoutswithdesignruleconstraintsandunderstandthestandardcellconcepts.

- Understand designing digital blocks with constraints such as propagation delay and dynamicpowerdissipation.

Course Contents:

Unit1:MOS Inverters(StaticCharacteristics):

VLSI design Methodologies and Design Flow, Introduction to inverters, Resistive-Load Inverter,Inverters with n-Type MOSFET Load and CMOS Inverter, Numericals, Introduction, BipolarJunctionTransistorStructureandOperation,BasicBiCMOSCircuits:StaticBehaviour,BiCMOSApplications. **14Hours**

Unit 2: Fabrication of MOSFETs with Layout Design and Switching Characteristics: Introduction, FabricationProcess Flow: Basic Steps, The CMOS nWell Process, Layout Design Rules, Full-Custom MaskLayoutDesign.CombinationalLogicCircuitsandLayout:NAND2gateandNOR2gate,Boolean functions of multiple input variables. Semi-custom and Full-Custom, MOSFET ScalingandSmallgeometryEffectsandScalingmodels.

Introduction,Delay-TimeDefinitions,CalculationofDelayTimes,InverterDesignwithDelay

Constraints. **14Hours**

Unit3:InterconnectEffects, Bi-stableelements and Dynamic Logic Circuits:

Estimation of Interconnect Parasitic, Calculation of Interconnect Delay, SwitchingPower Dissipation of CMOS Inverters. The behavior of Bi-stable Elements, The SR Latch Circuit,Clocked LatchandFlip-FlopCircuits,CMOS D-Latch,andEdge-TriggeredFlip-Flop.

Dynamic Logic Circuit: CMOS Transmission Gates (Pass Gates), Synchronous Dynamic CircuitTechniques,High-PerformanceCMOS Dynamic Circuits, DominoLogic.

13Hours

Unit4:SequentialMOSLogicCircuitsandMemories:

Sequencing static circuits, Sequencing Methods, Max-Delay Constraints, Min-Delay Constraints,Time Borrowing, Clock Skew, Problems on Max and Min Delay Constraints at the design level,

Semiconductor Memories: Introduction, Static Read-Write Memory (SRAM) Circuits, DynamicRead-WriteMemory(DRAM)Circuits.

15Hours

TextBook:

1. Sung-Mo(Steve)Kang,YusufLeblebigi,"CMOSDigitalIntegratedCircuitsAnalysisandDesign", TataMcGraw-Hill Education,2003.
2. NeilWesteandDavidHarris,"CMOSVLSIDesign",PearsonEducation,3rdEdition,2006.

UE22EC252B: Principles of Digital Signal Processing (4-0-2-4-5)

Course Description:

This subject Digital signal processing basically involves processing of discrete samples of data, the tools like Discrete Fourier transform and its properties are introduced, Fast Fourier transform algorithm implementation is also explained. Digital filters design concept with Butterworth and Chebyshev approximations are discussed in detail. Also design of IIR filters, FIR filters and realization forms gives the complete idea for the student to familiarize the different operations performed by the DSP processor.

Course Objectives:

- To understand discrete Fourier transform, its properties
- To introduce FFT and its applications
- To provide sufficient understanding of analog filter design
- To familiarize digital IIR design and realization
- To learn FIR filter design and realization

Course Outcomes:

Students completing the course should be able to

- Develop algorithms using Discrete Fourier transform (DFT) and Fast Fourier to process discrete samples
- Examine the properties of DFT
- Design and development of Analog Filters
- Design and development of digital IIR filters using Butterworth and Chebyshev approximations and realization forms
- Design and development of FIR filters and realization forms.

Course Content:

Unit 1: Discrete Fourier Transform (DFT)

Frequency domain sampling and reconstruction of discrete signals, DFT as a linear transformation, its relationship with other transforms, properties of DFT. Use of DFT in linear filtering: overlap-save and overlap-add methods.

16 Hours

Unit 2: Fast Fourier Transform (FFT)

Direct computation of DFT, need for FFT, Radix-2 FFT algorithm for computation of DFT and IDFT: decimation-in-time and decimation-in-frequency algorithms. Use of FFT in linear filtering: overlap-save and overlap-add methods.

12 Hours

Unit 3: Design of IIR Filters

Analog filter design:

Design of Butterworth and Chebyshev filters, analog to analog frequency transformations. Time and frequency domain aspects of ideal and non-ideal filters.

Mapping of transfer function:

Approximation of derivative: backward difference and bilinear transformation, impulse invariance, matched z-transform, verification for stability and linearity during mapping. Realization of IIR filters: direct form I and form II, cascade and parallel realizations, lattice realization.

16 Hours

Unit 4: Design of FIR filters:

Introduction to FIR filters, design of FIR filters using window functions: rectangular, Hamming, Bartlett and Kaiser, Hilbert transformer and FIR differentiator, FIR design using frequency sampling technique, linear phase, group delay. Realization of FIR filters: direct form, cascade and lattice realizations.

12 Hours

Text Book:

1. “Digital Signal Processing: Principles, Algorithms and Applications”, Proakis and

Manolakis, 4th Edition, Pearson Education, New Delhi, 2007.

Reference Books:

1. "Fundamentals of Digital Signal Processing", L. C. Ludeman, John Wiley and Sons, New York, 1986.
2. "Digital Signal Processing", S. K. Mitra, 4th Edition, TMH.
3. "Digital Signal Processing", Oppenheim and Schaffer, PHI, 2003.

UE22EC241B: CONTROL SYSTEMS (4-0-0-0-4)

Course Description:

This course provides an introduction to linear systems, transfer functions, feedback control systems. It covers stability concepts in both time domain and frequency domain.

Course Objectives:

The study of the subject should enable the student to learn:

• Mathematical modelling (transfer functions) of simple electrical, mechanical and electromechanical control systems

• The block diagram algebra and signal flow graph analysis.

• Characteristics of the time domain performance of feedback systems.

• Analyze the stability of feedback systems using various techniques.

• To design simple compensators in the frequency domain and controllers in the time domain.

Course Outcomes:

Students completing the course should be able to

• Apply Laplace transform to model dynamic systems.

• Analytically quantify the time and frequency domain behaviour of dynamic systems

• Specify steady state control system requirements and select prototype controller structures to achieve these requirements.

• Formulate dynamic feedback controller design specifications in the frequency domain

• Synthesise P, PD, PI & PID feedback controllers.

Course Content:

Unit 1: Mathematical Modelling and Analysis of Linear Systems: Introduction to control systems, Differential Equations of Physical Systems, Linear Approximations of Physical Systems, The Laplace Transform, The Transfer Function of Linear Systems, Block Diagram Models, Signal Flow Graph Model.

15 Hours

Unit 2: Performance & Characteristics of Feedback Control Systems: Error signal analysis, Sensitivity of Control Systems to Parameter Variations, Control of the Transient Response of Control Systems, Disturbance Signals in a Feedback Control System, Steady State Error Analysis, Test Input Signals, Performance of a Second Order System, Effects of a Third Pole and a Zero on the Second Order System Response, The s – Plane Root Location and the Transient Response, The Steady – State Error of Non unity Feedback Systems. **13 Hours**

Unit 3: The Stability of Linear Feedback Systems: The Concept of Stability, the Routh – Hurwitz Stability Criterion, The Relative Stability of Feedback Control Systems, The Root Locus Method, Concept and the Root Locus technique. Frequency Response methods: Introduction, Frequency Response Plots, Bode Diagram, and Performance Specifications in the Frequency Domain.
15 Hours

Unit 4: Stability in the Frequency Domain & design of compensators / controllers: Introduction, Mapping Contours in the s – Plane, the Nyquist Criterion, Relative Stability and the Nyquist Criterion. The Design of Feedback Control Systems: Introduction, Approaches to System Design, Cascade Compensation Networks, Phase – Lead Design Using the Bode Diagram, System Design Using Integration Networks, Phase-Lag Design Using Bode Diagram. Introduction to controllers, PD controller, PI and PID controllers. **13 Hours**

Text Books:

1. "*Modern Control Systems*", R.C. Dorf and R.H. Bishop, 12th Edition, Pearson, 2018 Impression.

Reference Books:

1. "*Control Systems Engineering*", I. J. Nagrath and M. Gopal, 6th Edition, New Age International Publications, 2018.
2. "*Modern Control Engineering*", K. Ogata, 5th Edition, Pearson Education Asia, 2019 Impression.
3. "*Control Systems Engineering*," N. Nise, Wiley India, 2018.
4. "*Control Systems – Principles and Design*", M. Gopal, 1st Edition, Tata McGraw Hill, 2013.
5. "*Automatic Control Systems*", Farid G, B. C. Kuo, 9th Edition, Wiley, 2017.

UE23EC242B: Digital Communication (4-0-0-4-4)

Course Description:

Digital communication is crucial for providing services in cellular networks, computer communication networks, IoT networks, etc. This course provides a comprehensive treatment for the design and analysis of digital communication over baseband channels and bandpass channels. In order to reliably transmit and receive digital data it is important to understand the properties of the channel. The design of the transmitter and the receiver in digital communication requires a good background in Fourier analysis and stochastic processes.

Course Objectives:

- Introduce analog to digital (bits) conversion and the motivation behind the different PCM versions
- Introduce the idea of baseband pulse shaping and its implications using Fourier analysis

- Understand the principles behind the design of digital communication systems for baseband and bandpass channels
- Build the idea of signal space which is crucial to the detection and decoding of transmitted symbols
- Introduce the concepts of information theory and its implications for digital data transmission

Course Outcomes:
Students completing the course should be able to
- Demonstrate and analyze pulse modulation techniques
- Understand and solve the requirements for baseband pulse shaping
- Apply methods to describe a transmitted/received signal in the form of vector and recover the symbols transmitted over noisy channels
- Analyze the different digital modulation techniques for passband transmission
- Understand the concepts such as source coding and channel coding for efficient and reliable data transmission

Course Content:

Unit 1: Information Theory
Introduction, Entropy, Source coding Theorem, Lossless Data compression algorithms, Discrete memoryless channel, Mutual information, Channel capacity, Channel coding theorem, Differential entropy and mutual information for continuous ensembles, Information capacity law and its implications, Rate distortion theory

14 hours

Unit 2: Digital Signal Generation
(i) Digital communication system: Communication process, Primary communication resources, Source of information, Communication networks, Communication channels, Modulation process, Analog and digital communication, (ii) Pulse modulation: Sampling theory, Pulse amplitude modulation (PAM), Quantization and its statistical characterization, Pulse code modulation (PCM), Time division multiplexing, Pros and cons of PCM, Prediction error filtering for redundancy reduction, Differential PCM, Delta modulation, (iii) Baseband signal (aka line codes or discrete PAM): Generation, waveform and power spectra of Unipolar NRZ, Polar NRZ, Bipolar NRZ, Unipolar RZ, Polar RZ, Bipolar RZ and Manchester Coding

14 hours

Unit 3: Band-limited Channels and Baseband Signal Transmission & Reception
(i) Transmission over band-limited channels: Intersymbol interference, Signal design for zero ISI, Ideal Nyquist pulse for distortionless baseband data transmission, Raised cosine spectrum, Eye-pattern, M-ary discrete PAM, (ii) Baseband signal analysis: Generic digital communication system, Geometric representation of signals, Conversion of the continuous AWGN channel into a vector channel, Likelihood functions, (ii) Optimum receivers using coherent detection: Correlation receiver, Matched filter, Probability of error

14 hours

Unit 4: Passband Signal Transmission, Reception and Analysis
(i) Bandpass signal analysis: Hilbert transform, Pre-envelopes, Complex envelopes of bandpass signals, Canonical representation of bandpass signals, (ii) Passband signals: Introduction, Passband transmission model, Coherent phase shift keying (BPSK, QPSK, M-ary PSK), M-ary quadrature amplitude

modulation, Coherent frequency shift keying, Non-coherent orthogonal modulation, Differential phase shift keying, Comparison of digital modulation schemes (in terms of BER and spectral efficiency)

14 hours

Text Book:

1. "Digital Communication Systems", Simon Haykin*, John Wiley & Sons, An Indian Adaptation,* 2021

Reference Book:

1. "Modern Digital And Analog Communication Systems", B. P. Lathi, Zhi Ding (Adapted by Hari Mohan Gupta), Oxford University Press, 4th Edition (South Asia Edition), 2017.
2. "Digital Communication", John G Proakis and Masoud Salehi, McGraw Hill Education, 5^{th} edition, 2014
3. "Communication Systems" A. Bruce Carlson and Paul B. Crilly, McGraw Hill Higher Education, 5^{th} edition, 2010
4. "Fundamentals of Digital Communication", Upamanyu Madhow, Cambridge University Press, 2008

UE22EC351A: Computer Communication Networks (4-0-2-4-5)

Course Description:

This course provides an in-depth overview of the Internet as architecture and as a service model. A top-down approach is followed in understanding the Packetization of transmission digital data and the performance of end-user applications as the data is exchanged over the internet. We explore the roles of network components (e.g., LAN switches, Routers, SDN). A hands-on approach is taken to enhance the understanding of the design and analysis of protocols and algorithms. The course introduces tools such as Wireshark, GNS3 and Python socket libraries.

Course Objectives:

- To provide an in-depth understanding of protocols and algorithms used in the Internet.
- To introduce the architecture and operating principles of different network components
- To enable the students to design simple computer networks.
- To provide tool based analysis for understanding packetization and data transmission
- To develop strong analytic and problem solving skills.

Course Outcomes:

At the end of the course, the student should be able to

- Understand the protocols related to the application layer, transport layer, network layer and link layer
- Design simple computer networks and analyze packet capture
- Implement routing algorithms, and write socket programs for client-server applications

- Solve numerical problems and logical problems arising in computer network design
- Apply networking concepts to the design of applications, protocols and systems

Course Content:

Unit 1: Internet architecture and applications: (i) Internet fundamentals: Terminology (services and protocols), Network edge (Access networks and PHY), Network core (Packet switching and Interconnection of ISPs), Performance measures (Delay, Loss, Throughput), Protocol layers and their service models, (ii) Application layer: Principles of network applications, Web and HTTP, DNS, Video streaming and CDN,Electronic mail, (iii) Transport layer: Services, sockets, multiplexing and de-multiplexing, UDP

14 Hours

Unit 2: Transmission control protocol and IP: (i) Principles of reliable data transfer: Stop and wait protocols, Pipelining, (ii) Connection oriented transport: TCP Connection, TCP Segment Structure, Round-Trip Time Estimation and Timeout, Reliable Data Transfer, Flow Control, TCP Connection Management, (iii) Congestion management: Principles of congestion control, Classic TCP congestion control (including Tahoe; Reno), (iv) Internet Protocol: IPv4 datagram format, IPv4 addressing (including DHCP), NAT, IPv6 (datagram and tunnelling), ICMP

14 Hours

Unit 3: Network layer: (i) Router and its operations: Internal organization, Functions of router (destination-based forwarding, switching, processing, scheduling), Generalized forwarding and SDN data plane (Match, Action, Openflow examples, Middleboxes), (ii) Routing algorithms: Introduction, LS algorithm, DV algorithm, (iii) Routing protocols: Intra-AS routing (OSPF),Inter-AS routing (BGP), Role of BGP, Advertising BGP route information, Determining the best routes, IP anycast, Routing policy, (iv) SDN control plane: Key features of SDN architecture, SDN controller and SDN network-control applications, Data plane and control plane interactions

14 Hours

Unit 4: Link Layer, LANs and WLANs: (i) Link layer: Services and implementation, Error detection and correction techniques (Parity check and CRC), Random access protocols (Slotted Aloha, CSMA, CSMA/CD), (ii) Switched LANs and Link virtualization: Link layer addressing and ARP, Ethernet, Link layer switches, Virtual Local Area Networking, MPLS (iii) Wireless networks: Basic architecture, Wireless link and network characteristics, WiFi (802.11) architecture, IEEE 802.11 protocol, 802.11 frame format

14 Hours

Textbook:

1. "Computer Networking: A Top-Down Approach", James F Kurose and Keith W Ross, 8th Edition, Pearson Education, 2022.

Reference Books:

1. "Data and Computer Communications", William Stallings, 10th Edition, Pearson Education, 2017.

Lab experiments :

1. Introduction to Wireshark: Packet capture procedure, Filters, Analysis
2. Analyze the downloading of embedded objects in a web-page using Wireshark
3. Analyze the DNS query and response using Wireshark
4. Analyze TCP connection and segmentation when downloading large file from a web-server using Wireshark
5. Socket programming and Wireshark analysis over LAN: UDP sockets and TCP sockets
6. Design simple 1-hop and 2-hop networks and configure IPv4 addresses and RIP using GNS3
7. Design a 1-hop network to demonstrate dynamic addressing using GNS3 and Wireshark
8. Design a 2-hop network to demonstrate dynamic addressing using GNS3 and Wireshark
9. Configure and analyze OSPF in a multihop network using GNS3
10. Design a 2-hop network to demonstrate static and dynamic NAT configurations using GNS3 and Wireshark
11. Design a switched LAN and analyze link layer addressing and ARP in GNS3 and Wireshark
12. Socket programming over WiFi hotspot and Wireshark analysis

UE22EC352A: RISC-V Architecture (4-0-2-0-5)

Course Description: This course gives the basic idea ofRISC-V architecture. It will give insight into parallelism and computer arithmetic. It also covers pipelining concepts.

Course Objectives:

- To make students know wider variety of issues, including factors such as power, reliability, cost of ownership, and scalability.
- To give the students good knowledge about “instruction set architecture” (ISA)
- To make students to understand RISC-V ISA
- To make students to understand how processors exploit implicit parallelism, Datapath and constructs a simple processor to implement an instruction set like RISC-V.

Course Outcomes:

- Students will broaden their knowledge of computer architectures.
- Students will increase their proficiency in Instruction Set Architecture (ISA).
- Students will get an idea of implementing an Instruction Set like RISC-V.
- Students will know the design principles of contemporary computers

- Students will acquire the knowledge about Arithmetic for Computer, Pipelining and parallelism.

Course Content

UNIT 1

Below your program,data flow model of RISC V Architecture.

Instructions: The Language of Computer: Introduction, Operations of Computer hardware,Operands of Computer hardware. Signed and Unsigned numbers, Representing Instruction in Computer, Logical operations, Instructions for making decisions, supporting procedures in Computer hardware. RISC-V Addressing for wide immediate and addresses **14 Hours**

UNIT 2

Instructions(contd) & The Processor:

Parallelism and Instructions: Synchronization, Translating and Starting Programs (Excluding DLL). A

C Sort Example to put it All together , Arrays verses Pointers, Advanced Material: Compiling C, The Rest of RISC-V Instructions

The processor: Introduction, Logic Design Conventions, building a Datapath, A Simple Implementation Scheme, an overview of pipelining, Pipelined Datapath and Control, Data Hazards, Exceptions, Parallelism via Instructions. **14 Hours**

UNIT 3

Arithmetic for Computer: Introduction, addition and Subtraction, Multiplication, Division, Floating Point, Parallelism and Computer Arithmetic.

RISC-V Interrupts and extension: Overview of RISC-V Interrupt, Introduction to the RISC-V Vector Extension**14 Hours**

UNIT 4

Computer Abstractions and Technology:

Computer Abstractions: Introduction, Eight Great Ideas in Computer Architecture, Technologies for building processors and Memory, Performance, The Power Wall, The Switching from uniprocessor to Multiprocessor, Benchmarking Intel i7, Fallacies and Pitfalls, Amdahl's Law and Concluding Remarks.

14 Hours

Text Books:

1. Computer Organization and Design- The Hardware/Software Interface: RISC-V Edition, David A. Patterson, John L. Hennessy, 2nd Edition

Reference Book:

1. Digital Design and Computer Architecture, RISC-V Edition by Sarah Harris, David Harris

UE22EC341A: ELECTROMAGNETIC FIELD THEORY (4-0-0-4-4)

Course Description:
This 4 Credits course lays an important foundation to the students to have a better appreciation of advanced courses such as Communication Engineering, Microwave Engineering, to name a few. To begin with, students are given a clear understanding into the concepts of Electrostatics and Magnetostatics and fundamentals of Wave Theory. Further, students are exposed to Maxwell's Equations governing EM fields. The course culminates while covering fundamental topics of Transmission Lines, Impedance matching and Smith Chart and its utility EM Theory.

Course Objectives:
- To introduce the concepts and laws related to static electric fields.
- To familiarise the concepts and laws related to static magnetic fields.
- To present Maxwell's equations related to EMF Theory.
- To acquaint Wave Theory and Wave propagation.
- To disseminate the basics of transmission lines and impedance matching.

Course Outcomes:
Students completing the course should be able to
- Calculate the electric field, scalar potential, stored energy, and capacitance associated with simple distributions of charge
- Calculate the magnetic field, stored energy, and inductance for simple distributions of current density.
- Use appropriate Maxwell's equations in integral and differential forms to time-varying field problems.
- Compute wave propagation in different media.
- Analyze and calculate basic transmission line parameters.

Pre-Requisites: Nil

Course Content:

Unit 1:Electrostatics: Coulomb's Law and field intensity, electric fields due to continuous charge distributions, electric flux density, Gauss's Law, Applications of Gauss's Law, Divergence of a vector and Divergence theorem, Electric potential, Gradient of a scalar quantity, Relationship between Electric field and potential. Continuity equation and relaxation time. Poisson's and Laplace's equation, one-dimensional solutions to Poisson's or Laplace's equation. Electric Boundary Conditions.
14 Hours

Unit 2:
Magnetostatics: Biot-Savart's Law, Ampere's circuital Law, applications of Ampere's Law, Curl of a vector and Stoke's theorem, magnetic flux density, Maxwell's equations for static fields, forces due to magnetic fields. Faraday's Law, transformer and motional electromotive forces, discrepancy in Ampere's Law, displacement current. Magnetic Boundary conditions.
14 Hours

Unit 3:
Maxwell's equations for time varying fields & Wave Theory: Maxwell's equations for time varying fields and for sinusoidal variations. Plane waves in free space, Wave propagation in lossy dielectrics: plane waves in lossless dielectrics, plane waves in good conductors, wave polarization.
14 Hours

Unit 4:
Transmission Lines & Impedance Matching: Equation of continuity and Kirchhoff's current law, equation of voltage and current, transmission line equations and solutions. Lossless lines, impedance transformation, reflection coefficient and standing wave ratio. Open-circuited and short-circuited lines. Impedance matching with quarter wave transformers. Stub matching. Smith chart, derivation of the Smith chart contours, single stub matching on Smith chart.
14Hours
Textbook:

1.'Principles of Electromagnetics", Matthew N. O. Sadiku, S. V. Kulkarni, 6^{th} Edition, Oxford University Press, 2007,Impression 2018.

Reference Books:

1."Microwave Devices and Circuits", Samuel L. Liao, Third Edition, Pearson, 2006, Impression 2019.

2."Electromagnetic waves and radiating systems", Edward C Jordan, Keith G Balmain, , 2ndEdition PHI, 2005.

3."Engineering Electromagnetics", William H Hayt Jr, J.A. Buck,8th Edition, Tata McGraw Hill, 2006, Special Indian Edition 2014.

4."Microwave Engineering"., David M. Pozar, Second Edition, John Wiley & Sons, 2004.

5."Electromagnetic Field Theory Fundamentals", Bhag Guru, H. Hiziroglu, Edition,Cambridge University Press, 2019.

6."Engineering Electromagnetics Essentials", B. N. Basu, Edition, Universities Press,2015.

UE22EC342AA1: WIRELESS MOBILE SYSTEMS (4-0-0-0-4)

UE22ECXXX: WIRELESS MOBILE SYSTEMS (4-0-0-0-4)

Course Description:
Today we rely on wireless mobile systems for a wide range of applications such as voice and multimedia applications, navigation, industrial process control, etc. The wireless mobile systems are undergoing structural changes to support the radio resource requirements and quality of service of emerging mobile

applications. The success of implementing the applications depends on a good understanding of the network architecture, spectrum usage, digital signal processing techniques and protocols. This course provides a strong foundation for designing wireless mobile systems. First, we look into the fundamentals of cellular systems followed and later focus exclusively on the 4G cellular system. Next we look at the IEEE wireless networks which are a counterpart of the cellular systems.

Course Objectives:

- To introduce concepts of cellular system and radio wave propagation
- To introduce the LTE system architecture and the design of LTE transceiver
- To introduce signal processing techniques such as OFDM, channel coding and MIMO
- To introduce the purpose of various LTE channels and radio resource management
- To introduce the link layer, network layer and transport layer for IEEE wireless systems

Course Outcomes:

Students completing the course should be able to

- Demonstrate, calculate and analyse fading in mobile wireless systems
- Understand and design OFDM, channel coding and MIMO techniques
- Understand the radio channels and radio resource management in LTE
- Understand LTE-Advanced concepts such as carrier aggregation, enhanced MIMO and CoMP
- Understand and analyse the link layer, network layer and transport layer in IEEE wireless systems

Course Content:

Unit 1: Cellular System and Mobile Radio Environment

(i) Cellular system: History, Carrier-to-Interference Ratio, Formation of Clusters, Sectorization, Frequency Allocation, Trunking Effect, Erlang Formulas, Erlang B Formula, (ii) Radio Propagation: Propagation Mechanisms, Free-Space Propagation, Propagation Models for Path Loss (Global Mean) Prediction, (iii) Mobile Radio Channel: Channel Characterization, Narrowband Flat Channel, Wideband Frequency Selective Channel, Doppler Shift, Fading, Shadowing/Slow Fading, Fast Fading/Rayleigh Fading, Diversity to Mitigate Multipath Fading, Space and Polarization Diversity, (iv) Radio Network Planning: Generic Link Budget, Receiver Sensitivity Level, Design Level, Rayleigh Fading Margin, Lognormal Fading Margin, Body Loss, Car Penetration Loss, Design Level, Building Penetration Loss, Outdoor-to-Indoor Design Level,
Power Link Budget, Power Balance

14 hours

Unit 2: 4G Long Term Evolution (LTE) System – Part I

(i) Architecture and Features: Introduction, Architecture of an Evolved Packet System, LTE Integration with Existing 2G/3G Network, E-UTRAN Interfaces, User Equipment, QoS in LTE, LTE Security, LTE Mobility, (ii) Transceiver Operations: LTE Radio Interface, Principle of OFDM, OFDM Implementation using IFFT/FFT Processing, Cyclic Prefix, Channel Estimation and Reference Symbols, OFDM Subcarrier Spacing, Output RF Spectrum Emissions, LTE Multiple-Access Scheme, OFDMA, Single-Carrier FDMA (SC-FDMA), OFDMA versus SC-FDMA Operation, SC-FDMA Receiver, User Multiplexing with DFTS-OFDM, MIMO Techniques

14 hours

Unit 3: 4G Long Term Evolution (LTE) System – Part II

(i) Channels and Their Roles: Radio Protocol Architecture, Downlink Physical Layer Processing, Downlink Control Channels, Mapping the Control Channels to Downlink Transmission Resources, Uplink Control Signalling, Uplink Reference Signals, Physical-Layer Procedures, LTE Radio

Dimensioning, Carrier Aggregation, Enhanced MIMO, Coordinated Multi-Point Operation (CoMP), Relay Nodes, Enhanced Physical Downlink Control Channel (E-PDCCH), Downlink Multiuser Superposition, MUST , Summary of LTE-A Features

14 hours

Unit 4: IEEE Wireless Systems:

(i) Wireless LAN: IEEE 802.11 Architecture, IEEE 802.11 Architecture and Services, IEEE 802.11 Physical Layer, Gigabit Wi-Fi, Other IEEE 802.11 Standards, IEEE 802.11I Wireless LAN Security, VANETs (ii) Wireless PAN: The Internet of Things, Bluetooth Motivation and Overview, Bluetooth Specifications, Bluetooth High Speed and Bluetooth Smart, IEEE 802.15, (iii) Mobility management: Mobile IP (Motivation, Agent discovery, Registration and Packet forwarding), Mobile Transport Layer (I-TCP, S-TCP and M-TCP)

14 hours

Text Book:

1. Alexander Kukushkin, "Introduction to Mobile Network Engineering: GSM, 3G-WCDMA, LTE and the Road to 5G", Wiley Telecom, 2018.
2. Cory Bread and William Stallings, "Wireless Communication Networks and Systems", 1st Edition, Pearson, 2015

Reference Book:

1. "From GSM to LTE-Advanced Pro and 5G: An Introduction to Mobile Networks and Mobile Broadband", Martin Sauter, Wiley 4th Edition, 2021
2. www.media.pearsoncmg.com/ph/esm/ecs_stallingsbeard_wcns_1/animations
3. www.corybeardwireless.com

UE22EC342AA2: Operations Research (4-0-0-4-4)

Course Description:

The purpose of this subject is to introduce the concept of operations research in their proper perspective and present the fundamentals necessary to grasp the features about the techniques and their tools. In this subject, the scope, characteristics, the different techniques and the models used in OR will be studied. The subject aims at combining the knowledge of various disciplines such as mathematics, statistics, economics engineering and psychology in making decisions in complex situations. The various techniques covered in this course include allocation problems, Assignments problems, Transportation problems, Waiting line problems, Network Analysis (PERT and CPM) and competitive problems.

Course Objectives:

- The purpose of this subject is to introduce the concept, scope and applications of operations research in business and industries and to expose the students to use of various Scientific tools and models.
- The subject aims at solving the Linear programming problems using appropriate optimization techniques, interpret the results obtained and translate solutions into directives for action.
- The subject helps the students to develop mathematical skills to analyse and solve the network models arising from a wide range of applications and to effectively communicate ideas, explain procedure and interpret results and solutions in simulation.
- The subject aims at combining the knowledge of various disciplines such as mathematics, statistics, economics engineering and psychology in making decisions in complex situations.
- The various techniques covered in this course include allocation problems, Assignments problems, Transportation problems, Waiting line problems, Network Analysis (PERT and CPM) and competitive problems.

Course Outcomes:

Students completing the course should be able to

- Get an insight into the fundamentals of Operations Research and to use some solution methods for solving the Linear optimization problems.
- Formulate the problem, construct its mathematical model and to develop a computer program to demonstrate how different Algorithm works.
- Use suitable appropriate methods to get feasible and optimal solutions and to develop Linear programming models for shortest path, minimum cost Transportation and Assignment problems.
- Identify and resolve Degenerate and special case problems and to use CPM/PERT techniques to plan, schedule and control project activities.
- Understand the usage of Game theory and simulation for solving complex Business and Industrial problems.

Course Content:

Unit 1: Simple OR problems & Simplex method

Definition, scope of operations research approach and limitations of OR models, characteristics and phases of OR. Mathematical formulation of LP problems, graphical solutions.The Simplex method-slack, surplus & artificial variables, problems, Degeneracy, procedure to resolve degenerate cases **14 Hours**

Unit 2: Linear programming and Game Theory

Simplex Method: Special case problems, Big-M method, Two-phase Simplex method, concept of duality, Dual Simplex method. Game Theory: Characteristics and formulation of games, two person-zero sum game, games with and without saddle point, principles of dominance, graphical solution for 2xn and mx2 games.

14 Hours

Unit 3: PERT-CPM techniques:

Steps in PERT/CPM techniques, Network construction, rules for drawing network diagram, labelling rule. Critical path and Floats in network, PERT time estimates and optimum duration. Cost analysis and crashing of networks, sensitivity analysis.

14 Hours

Unit 4: Transportation problems:

Formulation of transportation models, basic feasible solution using different methods, optimality by MODI method, unbalanced transportation problem, Degeneracy in transportation problems. Assignment problem: Formulation, Hungarian method, unbalanced assignment problem, variations in assignment problem, travelling salesman problem.

14 Hours

Text Book:

1. "Operations Research –An introduction", Hamdy A Taha, 10th edition, Prentice Hall of India, private Ltd, 2019

Reference Books:

1. "Operations Research", S.D. Sharma and KedarnathRamnath, , 15th revised edition, 2019.

UE22EC342AA3: Wireless Communication (4-0-0-4-4)

Course Description:
The course addresses the fundamentals of wireless communications and provides an overview of existing and emerging wireless communications systems and protocols. It covers radio propagation and fading models, fundamentals of cellular communications, multiple access technologies, CDMA and OFDM schemes in detail.

Course Objectives:
- Understand the working principle of current wireless systems.
- Determine the Path loss and cell coverage area in wireless systems.
- Understand the narrowband and wideband fading models of wireless channel and its importance in wireless system design.
- Understand different multiple access techniques.
- Understand the latest wireless transmission and reception techniques.

Course Outcomes:
Students completing the course should be able to
- Appreciate the challenges in designing a wireless communication system and network
- Analyze the statistical model of a wireless channel.
- Apply the different techniques learnt in this course to increase capacity of a wireless system and/or a network.
- Decide on a multiple access technology for a given application.
- Carry out Link Budget Analysis of a wireless system.

Course Content:
Unit 1: Signalling Over Wireless Channels:
Current Wireless Systems, Terrestrial Systems, Low Altitude Systems, Satellite Systems, Wireless Spectrum, Standards, Radio Wave Propagation Effects, Free-space path loss, Fading and Shadowing: Link Budget Analysis, Time varying channel impulse response, Jakes Model, Narrow band fading models, Wideband fading models, Outage Probability, Performance of various modulation schemes in flat fading, BER vs SNR curve with and without fading.

14 Hours

Unit 2: Wireless Transceiver & Cellular Network:
Block Diagram of transceiver of a wireless system, Channel Coding, Coding gain, Interleaver, Deinterleaver, LNA, Inter-symbol Interference, Equalizer, Interference Management techniques: Orthogonality in space, time, frequency, and coding. Cellular system fundamentals, channel reuse, handoff, SIR and user capacity, dynamic resource allocation, cell splitting, sectoring, zoning, Cell capacity.

14 Hours

Unit 3: Spread Spectrum Technique:
Capacity of AWGN channels, Capacity of Flat fading channels, capacity of Frequency selective channels, Spread Spectrum Techniques, Different types, FHSS, DSSS, differences, advantages

and disadvantages, CDMA, RAKE receiver, Multipath diversity in CDMA, Near-Far problem, Multiuser CDMA, Transmit and receive block diagram

14 Hours

Unit 4: Multicarrier Modulation:

Data transmission using multiple carriers, Multicarrier modulation with Overlapping sub channels, Discrete implementation of multicarrier modulation, The DFT and its properties, The cyclic prefix, orthogonal frequency-division multiplexing, matrix representation of OFDM, vector coding.

14 Hours

Text Book:

1. "Wireless Communications", Andrea Goldsmith, Cambridge University Press, 2012.
2. "Digital Communication Systems", Simon Haykin, John Wiley & Sons, 2014.
3. "Wireless Communications: Principles and Practices", T. S. Rappaport, 2nd Edition, Prentice Hall, 2002

Reference Books:

1. "Fundamentals of Wireless Communications", David Tse and Pramod Vishwanath, Cambridge University Press, 2012.

UE22EC342AB1: DIGITAL SYSTEM DESIGN (4-0-0-4-4)

Course Description:

This course includes advanced digital design concepts like FSM design, Global reset and reset management, Clock domain crossing, timing issues in design of digital circuits,

Course Objectives:

- The course intended to enhance the skill set of the students in RTL coding, FSM designusing Verilog.
- This course also equips the students to understand timing issues in design of digital circuits holistically.

Course Outcomes:

Students completing the course should be able to: -

- Good RTL design and FSM design using Verilog
- Understanding timing issues and designing Synchronizers in designing digital circuits
- Designing global signals: clock and resets
- Designing solutions to Clock Design Crossing

Pre-Requisite: Knowledge of Digital Design and Verilog HDL

Course Content:

Unit 1: RTL coding using Verilog HDL

RT level Combination Circuit, Regular Sequential circuit, two segment coding, Verilog RTL coding, FSM design, Moore and Mealy FSM, Circular FIFO, FSMD and examples,Testbench Simulation and Code coverage, Skew and Jitter analysis, Eye diagram. **14 Hours**

Unit 2: Clocks and Resets:

Theory of Metastability, Metastability Window, Calculating MTBF, Avoiding Metastability, Metastability Test Circuitry, Reset Design Strategy, Reset Synchronizer, Reset Glitch filtering, Asynchronous Reset Removal, Principles of PLL and DLL, Arbiter Design, Importance of DLL in FPGA, Standard Cell library design and Synthesis with constraints **14Hours**

Unit 3: ASIC Design flow

Gate level simulation, Equivalence Checking, Semi-custom layout, Placement, Routing and Clock tree synthesis and power analysis, Basics of STA, Limitations of STA, Timing models and Interconnect parasitics, Setup and Hold Measurements. **14 Hours**

Unit 4: **Static Timing Analysis and Synchronizer design:** Setup and Hold Measurement, Setup and Hold Measurement in the presence of Crosstalk and Noise, Robust Timing Verification and Statistical STA. Types of synchronizers, solutions to Clock domain crossing (CDC): Synchronous Clock Domain crossing, Handshake signalling method, Data transfer using synchronous FIFO, Asynchronous FIFO (or Dual Clock FIFO), Reset Domain Crossing, Case study: - Applications of CDC in Network on Chip (NoC) Design. **14 Hours**

Mandatory Experiments: -

Unit -1

1. Moore and Mealy simulation in NCSim
2. Circular FIFO design and simulation in NCSim
3. Experiment on Code Coverage in IMC

Unit -2

4. Simulation of skews and Jitters in Verilog. Jitter tolerance in digital circuits in NCsim

Unit -3

5. Synthesis with Constraints in Cadence Genus
6. Equivalence checking in Cadence Conformal
7. Semi-Custom Layout using Cadence Innovus

Unit -4

8. Simulation of Synchronous FIFO for solving CDC in NCSim
9. Simulation of Asynchronous FIFO for solving CDC in NCSim

Unit -5

10. Simulation of Metastability test circuitry and reset glitch filtering in NCSim
11. Simulation of Pipelined adder and multiplier in NCSim.

Text Books:

1. Pong P Chu, "FPGA Prototyping by Verilog Examples: Xilinx Sparta-3 Version", WileyBlackwell, ISBN-13: 978-0470185322, 2008.
2. William J Dally, John W Poulton, "Digital Systems Engineering", Cambridge University Press, ISBN-10: 052106175X.
3. Mohit Arora, "The Art of Hardwre Architecture: Design Methods and Techniques for Digital Circuits", Springer-2012, ISBN-13: 978-1461403968.
4. Static Timing Analysis for Nanometer Designs, A Practical Approach", J. Bhasker, Rakesh Chadha, 1st Edition, Springer-2009
5. Clifford E Cummings, Arturo Salz, "System Verilog Event Regions, Race Avoidance and Guidelines", Sunburst Design Inc White paper. http://www.sunburst-design.com/papers/CummingsSNUG2006Boston_SystemVerilog_Events.pdf.

6. Clifford E Cummings, “:Clock Domain Crossing (CDC) Design & Verification Techniques”, http://www.sunburstdesign.com/papers/CummingsSNUG2008Boston_CDC.

UE22EC342AB2: Electronic Design Automation- Verilog to Routing (4-0-0-4-4)

Course Description: In this course, students will learn about the design transformations in VLSI Design, viz., design entry, logic synthesis, technology mapping, floor-planning, placement and routing. Electronic design automation plays an important role in automating each of the phases. Using open-source tools, each of these phases and the impact on performance based on standard performance metrics such as, delay, area and power will be analysed. Standard cell and FPGA-based design flow will be studied and compared. This subject requires the knowledge of Digital Design Using HDL.

Course Objectives:

- To understand different stage in front-end and back-end VLSI design flows
- To appreciate the role of automation in the design and implementation of digital designs
- To obtain performance measurements in each of the design phases
- To understand multi-objective optimisations applied to meet the diverse performance goals
- Explore techniques to improve design time, compile time and runtime of digital designs

Course Outcomes:

At the end of this course, the student will be able to:

- Design and implement digital circuits using methods of electronic design automation
- Hands-on experience in the stages from the design-to-deployment of digital circuits
- Optimise digital design to meet performance goals like area, time and power
- Suggest trade-offs to improve design time and achieve performance goals
- Design, test and measure performance at every stage from design to deployment of digital designs.

Course Content:

Unit 1: Introduction to EDA& High-level Synthesis:

Moore’s law and growth of transistor densities, complexity, design and verification time. Role of automation in design, synthesis, placement, routing and verification of complex circuits.Use of high-level languages (C, OpenCL, etc.) to design circuits, transforming functionality to physical logic gates, heuristics to optimise the gate-level representation, performance objectives (such as area, time, power), pragmas for compiler transformations (such as loop-unrolling, pipelining).

16 Hours

Unit 2: Logic Synthesis:
Scheduling (ASAP, ALAP, List scheduling), resource allocation. Technology-independent logic optimisations, data-flow and control flow transformations.

15 Hours

Unit 3: Technology mapping:
Target technologies, such as standard cells, FPGA, structured ASICs, converting technology-independent netlist into technology-dependent representation, performance optimizations (gate-sizing, logic restructuring, remapping).

13 Hours

Unit 4: Floor planning, Placement and Routing:
Associating a physical location for modules in a design, heuristics for floor planning, placement and routing. Techniques for area minimisation, placement and routing quality estimation.

12 Hours

Text Book:

1. Synthesis and Optimization of Digital Circuits, Giovanni DeMicheli, McGraw-Hill, July 2017
2. Algorithms for VLSI Design Automation, SabihGerez
3. VLSI Physical design: From Graph partitioning to timing closure, Andrew B. Kahng, Jens Lienig, Igor L. Markov, Jin Hu

UE22EC342AB3: Linear Integrated Circuits (4-0-0-0-4)

Course Description:
This course covers basic construction of Operational Amplifier (Op-Amp) and its applications in instrumentation, signal processing and control systems. Op-Amp is a basic building block to design larger circuits which are widely used in all electronic systems like ADCs, DACs etc. This course introduce the Op-Amps based circuit and system design. For this course knowledge of Network Analysis**,** Analog Circuit Design is required.

Course Objectives:
The course objectives are

- Introducing theoretical & circuit aspects of Op-amp from Ideal model to practical model with noise.
- Making students familiar with Op-Amp based circuit design and system design
- Making students familiar with theory of nonlinear operational amplifiers.
- Making students familiar with theory and applications of voltage feedback
- Making students familiar with active filter design

Course Outcomes:

Students will be able

- To design OPAMP circuit for a linear equation.
- To simulate ideal and non-ideal characteristics of OPAMP
- To design and simulate applications of operational amplifiers including active filters
- To explore the change in parameters of OPAMP introducing a noise model.
- To simulate different OPAMP applications for given parameters on EDA tool

Course Content:

Unit 1:

Development of the Ideal OpAmpEquations: Ideal Op Amp Assumptions, The Noninverting Op Amp, The Inverting Op Amp, The Adder, The Differential Amplifier, Complex Feedback Networks, Impedance matching amplifiers
Single Supply Op Amp Design Techniques**,** DC Coupled Single Supply Op Amp Design Techniques**,** Circuit Analysis, Simultaneous Equations

14 Hours

Unit 2:

A Continuum of Applications, Noninverting Attenuator with Zero Offset, Positive Offset and Negative offset, Inverting Attenuation with Zero Offset, Positive Offset and Negative Offset Development of the Nonideal Op Amp Equations:Introduction, Review of the Canonical Equations, Noninverting Op Amps, Inverting Op Amps, and Differential Op AmpsVoltage Feedback Op Amp Compensation**:** Introduction, Internal Compensation, External Compensation, Stability and Performance, Dominant Pole Compensation, Gain Compensation, Lead Compensation, Compensated Attenuator Applied to Op Amp, Lead/Lag Compensation, Comparison of Compensation Schemes

14 Hours

Unit 3:

Current Feedback Op Amp Analysis: Introduction, CFA Model, Development of the Stability Equation, The Noninverting CFA, The Inverting CFA, Stability Analysis, Selection of the Feedback Resistor, Stability and Input Capacitance, Stability and Feedback Capacitance, Compensation of C_F and C_G Voltage and Current Feedback Op Amp Comparison, Fully Differential Op Amps**:** Differential Gain Stages, Single Ended to Differential Conversion, Working with Terminated Inputs, Conceptualizing the V_{OCM} Input, Instrumentation, Op Amp Noise Theory

14Hours

Unit 4:

Active Filter Design Techniques: Introduction, Fundamentals of low pass filters, low pass filter design, high pass filter design, band pass filter design, band reject filter design, all pass filter design, practical design hints, Fast simple filter design, Fast practical filter design, design of filter, low pass filter and high pass filter.

14 Hours

Text Books:

1. Op Amps for Everyone, Bruce Carter, Ron Mancini · 2017 Edition

Reference Books :

1. Linear Circuit Design Handbook, By Analog Devices Inc., Engineer · 2011Edition
2. Operational amplifiers and linear ICs by James M Fiore 2016

UE22EC342AB4: Chip-level Photonics (4-0-0-4-4)

Course Description:

Faster communication, ultra-secure hardware and application, high fidelity measurements and sensing, ultra-wide bandwidth, etc., all that are required for today's demand off technology, are to be addressed by light. Today, tech-giants like Intel, Microsoft, Google etc., and most countries of the world are investing heavily in photonic technology, in order to reform the computing technology in the form of light. A huge demand for Photonic scientists and professionals, in the form of integrated photonics technologists or quantum technologists have emerged lately. The present course has been tailored to provide the basics to develop photonic chips for optical processors, at an undergraduate level.

Course Objectives:

The present course is so designed as to:

- Provide students an introduction to basic photonic waveguide designs;
- To provide students with basic knowledge of photonic computation;
- To educate students on photonic sensor activities;
- To introduce students to VLSI photonics;
- To integrate the needs for smart cities technologically.

Course Outcomes:

Students who successfully complete the course will be able to:

- Perform simple photonic computations;
- Understand the design basics in Photonic planar structures;
- Appreciate the related material properties;
- Understand a relevant layer of smart city concept,
- Look into more sophisticated application in comparison with electronics.

Course Content:

Unit 1: Concepts in Photonics: Basic design principles of optical waveguides, essential mode recognition and other photonic circuit components, essential maxwell equations and relation to electronics. Basic FDTD and FDBPM techniques

14 Hours

Unit2: Computational photonics:.1D and 2D programming introduction, usage of diffraction and other relevant python packages; **I**ntroduction to coupled mode theory, directional couplers, interferometers and resonators.

14 Hours

Unit3: VLSI Photonics: Building blocksof VLSI photonics**:** Micro-resonators; Coupled resonators, planar and fiber waveguide combination, photonic crystal basics: 1D and 2D photonic crystals, Photonic bandgap devices, metasurfaces.

14 Hours

Unit4: Case -studies (adaptable with time): Silicon photonics, glass photonics, multifunctional materials for wearable optics, integrated photonic sensors for wearables, wearable electronics and photonics comparison, wearable photonics in healthcare, review of current commercial players.

14 Hours

Text Book:

1. José Capmany, Daniel Pérez, *Programmable Integrated Photonics*, Oxford University Press, 2020, ISBN13: 9780192582775

Reference Books:

1. Keigo Lizuka, Elements of Photonics, Volume I: In Free Space and Special Media: 41 (Wiley Series in Pure and Applied Optics), ed. Bahaa E. A. Saleh, 2002, Wiley Interscience 1st Edition, ISBN10: 0471839388, ISBN13: 978-0471839385

2. VLSI MICRO- and NANOPHOTONICS Science, Technology, and Applications, eds. El-Hang Lee, Louay A. Eldada, Manijeh Razeghi, Chennupati Jagadish, Taylor and Francis pubs., 2011, ISBN3: 978-1-4200-1790-8

UE22EC342AC1: Digital Image Processing (4-0-0-4-4)

Course Description:

This course provides an introduction to the essential concepts for digital image processing with reference to enhancing the image quality. This course also introduces colour image processing. It will cover the transforms for DIP and the methods for image enhancement, filtering and restoration.For this course knowledge of Principles of Digital Signal Processing is required.

Course Objectives:

- To introduce basic concepts of digital image processing
- To understand important image transforms
- To learn image enhancement methods

- To familiarize withimage restoration and colour image processing concepts

Course Outcomes:

Students completing the course should be able to

- Describe the required fundamental transforms
- Explain the different image processing algorithms
- Use different techniques in image enhancement and image restoration for improving image quality
- Investigate the best algorithm for enhancing an image
- Design image processing algorithms for different applications

Course Content:

Unit 1: Digital Image Fundamentals:
What is digital Image Processing, Fundamental Steps in Digital Image Processing, Components of an Image Processing System, Introduction to computer vision, Elements of Visual Perception. Light and Color and Sensors, Some Basic Relationships between Pixels, Linear and Nonlinear operations.

14Hours

Unit 2: Image Transforms:
2-D orthogonal and Unitary transforms, 1-D and 2-D DFT, Cosine, Sine, Hadamard, Haar, singular value Decomposition.

14 Hours

Unit 3: Image Enhancement in Spatial and frequency domains:
Basic Gray Level transformations, histogram processing, Enhancement using ALU operations, Basics of spatial filtering. Image Enhancement in Frequency domain: Ideal low pass filters, Butterworth low pass filters, Gaussian low pass filters. **Image filtering and Restoration:** Image observation models, Noise Models, Restoration in the presence of noise only-Spatial Filtering, Periodic noise reduction by frequency domain filtering.

14 Hours

Unit 4: Morphological Image Processing: Preliminaries, Dilation and Erosion, Opening and Closing, The Hit-or-Miss Transformation, Some Morphological Algorithms.

14Hours

Text Book:

1. “Digital Image Processing”, R. C. Gonzalez and R. E. Woods, 4th Edition, Pearson Education Limited ,2018.
2. “Computer Vision: Algorithms and Applications”, RichardSzeliski, Springer Science & Business Media, 2010.

Reference Books:

1. “Fundamentals of Digital Image Processing,’ Anil K Jain, Pearson Education Pvt. Ltd., 2004.
2. “Digital Image Processing”, S Jayaraman, S Esakkirajan and T Veerakumar, Mc Graw

Hill, 2009.

UE22EC342AC2: Speech and Natural Language Processing

Speech and Natural Language Processing

Course Description:

This subject will introduce students to the mechanism of speech production, time domain and frequency domain analysis of speech and recognition of speech and several other applications. It also introduces to major topics in Natural Language Processing and relevant related topics (traditional and neural-network based methods to, e.g., language modeling, classification, sequence processing). This course requires the knowledge of Principles of Digital Signal Processing, Mathematics for Electronics Engineers.

Course Objectives:

- To teach the basics of speech signal processing, analysis and modelling of speech signals driven by ever demanding applications to cater to present needs.
- To provide an understanding of discrete-time speech signal processing techniques that are motivated by speech model building
- To understand frequency-domain representations of speech production and aspects of speech perception.
- To introduce applications such as speech recognition, speaker recognition, enhancement etc.
- To introduce the field of natural language processing which is concerned with practical and theoretical issues that arise in getting computers to perform various tasks with human languages. The course allows that kind of interaction so that non-programmers can obtain useful information from computing systems.

Course Outcomes:

Students completing the course should be able to

- Characterize speech signal in relation to production and hearing of speech by humans.
- Design few basic algorithms for speech analysis
- Construct/develop speech recognition, synthesis and coding
- Illustrate practical aspects of speech algorithms and its implementation
- Design a simple system for speech processing (speech activity detector, recognizer of limited number of isolated words)
- Develop a comprehensive understanding of fundamental concepts and techniques in Natural Language Processing (NLP), including regular expressions, word tokenization, normalization, lemmatization, stemming, and sentence segmentation.
- Acquire practical skills in evaluating and building language models, including proficiency in using N-gram models, assessing model performance through perplexity

scores, and implementing advanced smoothing techniques such as Kneser-Ney Smoothing.

Unit 1: Digital Models for the Speech Signals:
Introduction, The Process of Speech production, The acoustic theory of the speech, acoustic phonetics, prosody, speech perception, Loss less tube models, Digital model for speech signals.

10 Hours

Unit-2: Speech Analysis: Time dependent processing of speech, Short time energy and average magnitude, Short time average zero crossing rate, Speech vs silence discrimination using energy & zero crossings, Pitch period estimation, Short time autocorrelation function, Short time average magnitude difference function, Pitch period estimation using autocorrelation function. Frequency Domain Methods for Speech Processing: Short Time Fourier Analysis: Fourier transform and Linear Filtering interpretation, Filter banksummation method, Overlap addition method, Design of digital filter banks, Implementation using FFT, Spectrographic displays, Pitch detection.

18 Hours

Unit 3: Homomorphic Speech Processing and LPC: Homomorphic systems for convolution-Computational consideration, Complex cepstrum of speech, Pitch detection, Formant estimation, Mel Frequency Cepstral Coefficients, Homomorphic vocoder, Linear Predictive Coding of Speech: Basic principles of linear predictive analysis, Solution of LPC equations, Prediction error signal.
Applications of speech processing: Pitch and formant detection using LPC, Voice response systems, speech enhancement, speaker recognition and verification, Hidden Markov Models, isolated word recognizer using HMM, Automatic Speech recognition, ASR using HMM, Introduction to speech synthesis.

14 Hours

Unit-4: Introduction to NLP: Introduction, Regular Expressions, Words, Corpora, Simple Unix Tools for Word Tokenization, Word Tokenization, Word Normalization, Lemmatization and Stemming, Sentence Segmentation, Minimum Edit Distance, **N-gram Language Models:** N-Grams, Evaluating Language Models: Training and Test Sets, Evaluating Language Models: Perplexity, Sampling sentences from a language model, Generalization and Zeros, Smoothing, Huge Language Models and Stupid Backoff, Advanced: Kneser-Ney Smoothing, Advanced: Perplexity's Relation to Entropy.

14 Hours

Text Book (s):

1. "Digital Processing of Speech Signals", L. R. Rabiner and R. W. Schafer, Pearson Education (Asia) Pvt. Ltd., 2004.

2. “Speech and Natural Language Processing”, Daniel Jurafsky and James H. Martin, 3rd edition online,2023. (https://web.stanford.edu/~jurafsky/slp3/ed3bookfeb3_2024.pdf)

Reference Book(s):

1. “Theory and Applications of Digital Speech Processing”, L. R. Rabiner and R. W. Schafer, Pearson Education Pvt. Ltd., 1st Edition, 2010
2. “Discrete-Time Processing of Speech Signals”, J. R. Deller, Jr., J. H. L. Hansen and J. G. Proakis, IEEE Press, 2000.
3. “Discrete-time Speech Signal Processing: Principles and Practice”, Thomas F. Quatieri, Pearson Education (Singapore) Pvt. Ltd., 2002.
4. Speech Communications: Human and Machine”, D. O’Shaughnessy, Universities Press, 2001.
5. “Introduction to Natural Language Processing”, Jacob Eisenstein, MIT Press, Adaptive computation and Machine Learning series, 18th October, 2019.
6. The open source softcopy is available at githubhttps://github.com/jacobeisenstein/gt-nlp class/blob/master/notes/eisenstein-nlp-notes.pdf.

UE22EC343AA1: Software Defined Radio(4-0-0-4-4)

Course Description:

Software-defined radio (SDR), an RF communication technology that is used for countless applications in numerous industriesand one of the inherent parts of the modern communication system, where many processes, which used to be implemented in hardware, are defined in the software domain for flexibility and configurability. This course describes various components of software-defined-radios with the understanding of their limitation and application of ‘software-defined-solutions’ to overcome such limitations.

Course Objective

- This course describes the fundamental radio components and how these components are implemented in software.
- The principles of software architecture to support the SDR will be developed.
- Policy and cooperation mechanisms that enable SDR to interoperate will be developed.

- In this course you will study and build SDR and investigate their role in future communication systems.

Course outcomes

Students who successfully complete this course will have

- An ability to make system-level decisions for software-defined radio technology and products
- Knowledge of software development methods for embedded wireless systems
- Knowledge of digital hardware architectures and understanding of development methods
- An understanding of middleware in SDR,

Understanding GNU Radio and applications of SDR

Course content:
Unit 1: SDR Architecture

Introduction to Software Radio, The need for Software Radios, Characteristics and benefits of a Software Radio, Introduction to MATLAB Simulink and GNU Radio, Design principles of Software Radio.Radio frequency implementation issues: The purpose of the RF Front-End, Dynamic range: The principal challenge of receiver design. RF receiver front-end topologies, Enhanced flexibility of the RF Chain with Software Radios, Importance of the components to overall performance, Transmitter architectures and their Issues, noise and distortion in the RF Chain, ADC and DAC distortion. Flexible RF Systems using Microelectromechanical Systems

Hands on1. Installation of GNU Radio software 2.Introduction to MATLAB Simulink

14 Hours

Unit 2 : SDR Hardware

Key hardware elements, DSP processors, Components of a Communication System, Components of an SDR,Analog to digital and digital to analog conversion: Parameters of ideal data converters, Parameters of practical data converters, Techniques to improve data converter performance, Common ADC and DAC architectures.Application of Software defined radio: Cognitive Radio, Vehicular Networking

Hands on1.Introduction to USRP Hardware N210, RTL SDR 2.Installation of USRP Software

14 Hours

Unit 3 : GNU Radio

What is GNU Radio? Radio, Flowgraph Fundamentals, Python, Variables in Flowgraphs ,Runtime Updating Variables, Signal Data Types, Converting Data Types ,Packing BitsStreams and Vectors, Heir Blocks and Parameters,. DSP Blocks: Low Pass Filter Example, Designing Filter Taps, Sample Rate Change, RTL-SDR

Hands on1. Introduction of GNU Radio

14 Hours

Unit 4 :Using GNU Radio with SDRs.

Modulation and Demodulation, FM Receiver, Live aircraft tracking with Mode-s Transponder using USRP or RTL-SDR, Ship tracking using USRP based on Automatic Identification system (AIS), GSM Signal Sniffing. RFID card Reader, ZIGBEE Receiver (Decoder). Temperature Sensor Interrogation with USRP Radar applications using USRP (Real Time Implementation of FMCW Radar for Target Detection using GNU Radio and USRP), Setting up a Base Station

Hands on1.FM Receiver 2. Live aircraft tracking

14 Hours

Text Book:

1. "Software Radio-A Modern Approach to Radio Engineering ", J.H. Reed **,** Prentice Hall PTR, 2002

Reference Books:

1. "Software-Defined Radio for Engineers ", Travis F. Collins, Robin Getz, Di Pu, Alexander M. Wyglinski, Artech House,2018
2. https://wiki.gnuradio.org/index.php/Tutorials

UE22EC343AA2: Networking Optimization (4-0-0-4-4)

Course Description:

Optimization is one of the mature forms of mathematically modelling of networked systems (e.g., IoT, communication networks, smart grids, financial systems). This course provides an understanding of the underlying properties, complexity and solution methods for different types of optimization problems. This course also provides some ground rules for mathematical modelling of networked systems. Combined with hands-on training, this course enables students to take up research in networking. For this course Knowledge of Linear Algebra is required.

Course Objectives:

- Introduce the students to a variety of optimization problems using case studies spreading across domains such as communications, smart grids, finance, planning, etc.
- Enabling the students to formulate optimization problems
- Enable students to identify the structure of the problem
- To develop background into applying different solution methods
- To make students solve the optimization problems using open source optimization software.

Course Outcomes:

At the end of the course, students should be able to

- Understand and identify the structure of various classes of optimization problems
- Formulate and solve optimization problems
- Analyze the structure of the formulation and apply suitable solution method
- Apply decomposition and approximation techniques to optimization problem.
- Run simulations using software such as CVX and CPLEX

Course Content:

Unit 1: Unconstrained problems and linear programs:
(i) Overview: Network design, Role of networking, Mathematical models, Steps for Network design, Optimization problem structure, types and complexity, (ii) Unconstrained optimization problems: single variable and multivariable solution methods, (iii) Linear programs: Standard form of LP, structural properties, Simplex method, Duality and Economic interpretation, Formulating and coding LP problems, Introduction to solvers: CVXPY/CVX and CPLEX,

14 Hours

Unit 2: Integer Programs and Convex programs:

(i) Integer programs: Structure and Types, Formulating and coding IP problems, Branch and bound methods, Cutting plane method, MINLP to MILP conversion, Benders Decomposition, (ii) Convex Optimization: Convexity, convex geometry, Convex functions, Lagrangian relaxation (LR and ALR) and Duality, KKT conditions, Formulating convex problems; Multi-objective problems

14 Hours

Unit 3: Convex relaxations and Stochastic Programs:

(i) Convex relaxations: Semidefinite programming: Convex and Non-convex relaxations, Geometric programming, Interior point method,(ii) Stochastic programs: Representing uncertainty, Deterministic LP versus stochastic LP, Two stage SLP, Recourse formulations and interpretations, Formulating stochastic problems (Two-stage SLP, Robust LP and CCP), Node variable and scenario variable formulations, EVPI and VSS

14 Hours

Unit 4: Solving SLP and MDP:

(i) SLP solution methods: L-shaped method, PH algorithm and ADMM, (ii) MDP: Markov chains and MDP, Formulating MDP, Bellman's optimality condition, Finite horizon problems: Dynamic programming, Infinite horizon problems: Value iteration and Policy iteration

14 Hours

Text Books:

1. "Linear and Convex Optimization: A Mathematical Approach" Michael H. Veatch, 1st edition, Wiley, 2021
2. "Practical Mathematical Optimization", Jan A. Synman and Daniel N Wilkie, 2nd Edition, Springer, 2018
3. *"Reinforcement Learning*: An Introduction", *Richard* S. *Sutton* and Andrew G. Barto, 2nd edition, MIT Press , 2015

Reference Books:

2. "Convex Optimization", Stephen Boyd and L. Vandenberghe, 1st Edition, Cambridge University Press, 2004.
1. "Introduction to Stochastic Programming", J. R. Birge and F. Louveaux, 2ndEdition, Springer Series in Operations Research and Financial Planning, 2011.
3. "Operations Research –An introduction", Hamdy A Taha, 10th edition, Prentice Hall of India, private Ltd, 2019

UE22EC343AB1: VERIFICATION OF DIGITAL SYSTEMS (4-0-0-0-4)

Course Description: Verification of Digital Systems will impart training in understanding the complexities of digital system verification and the importance of hardware verification languages (HVLs). The course describes the lexical elements of the system Verilog and equips the students to create the layered test benches for modern-day complex digital designs in SystemVerilog. Digital Design & Computer Organization is required for this course as a prerequisite.

Course Objectives:

- Understanding the complexity of Digital verification
- Understanding the OOPS in System Verilog
- Understand and use the SystemVerilog RTL design and synthesis features, including new data types, literals, procedural blocks, statements, and operators, relaxation of Verilog language rules, fixes for synthesis issues, enhancements to tasks and functions, new hierarchy and connectivity features, and interfaces.
- Appreciate and apply the SystemVerilog verification features, including classes, constrained random stimulus, coverage, strings, queues, and dynamic arrays, and learn how to utilize these features for more effective and efficient verification.
- Understanding of complete layered testbench of System Verilog

Course Outcomes:

Students completing the course should be able to

- Understand the necessity of Verification
- Understand the complexity of Verification: directed testbench and layered testbench.
- Students will be able to write system Verilog code for both design and verification.
- Understand the constraints for verification and other constructs like interface, clocking etc.
- Students using System Verilog constructs will be able to achieve better functional coverage.

Course Content:

Unit 1: Introduction&Connecting The Testbench: Verification Guidelines: The Verification Process, Basic Test bench Functionality, Directed Testing, Methodology Basics, Constrained-Random Stimulus Data Types: Built-In Data Types, Fixed-Size Array, Dynamic Arrays, Associative Arrays,Array Methods, Choosing a Storage Type, Creating New Types with typedef, Creating User-Defined Structures, Type conversion,

Constants, Strings Procedural Statements And Routines: Procedural Statements, Tasks, Functions, Void Functions, Task and Function Overview, Routine Arguments, Returning from a Routine, Local Data Storage, Time Values.
Separating the Testbench and Design,The Interface Construct,Stimulus Timing,Interface Driving, and Sampling, Connecting It All Together, Top-Level Scope, Program - Module Interactions,System Verilog Assertions, The Four-Port ATM Router, and The ref Port Direction. **15 Hours**

Unit 2: Basic OOP & Randomization:
Basic OOP: Where to Define a Class, OOP Terminology, Creating New Objects, Object Deallocation, Using Objects,Static Variables vs. Global Variables, Class Methods,Detining Methods Outside of the Class, Scoping Rules, Using One Class Inside another,Understanding Dynamic Objects, Copying Objects, Public vs. Local, Straying Off Course,Building a Testbench.
Introduction, What to Randomize, Randomization in System Verilog, Constraint Details, Solution Probabilities, Controlling Multiple Constraint Blocks, Valid Constraints, In-line Constraints, The pre_randomize and post_randomize Functions, Random Number Functions, Constraints Tips and Techniques, Common Randomization Problems, Iterative, and Array Constraints, Atomic Stimulus Generation vs. Scenario Generation, Random Control, Random Number Generators, Random Device Configuration, Conclusion Threads and Interprocess Communication: Working with Threads, Interprocess Communication, Events, Semaphores, Mailboxes, Building a Testbench with Threads and IPC.**15 Hours**

Unit 3: Functional Coverage: Coverage Types, Functional Coverage Strategies, Simple Functional Coverage Example, Anatomy of a Cover Group, Triggering a Cover Group, Data Sampling,Cross Coverage, Generic Cover Groups, Coverage Options, Analyzing Coverage Data, Measuring Coverage Statistics During Simulation, Conclusion. **12 Hours**

Unit 4: Advanced Interfaces: Virtual Interfaces with the ATM Router, Connecting to Multiple Design Configurations, Procedural Code in an Interface.
A Complete System Verilog Testbench: Design Blocks, Testbench Blocks, Alternate Tests.
Interfacing with C: Passing Simple Values, Connecting to a Simple C Routine, Connecting to C++, Simple Array Sharing, Open arrays, Sharing Composite Types, Pure and Context Imported Methods, Communicating from C to System Verilog**14 Hours**

Text Books:

1. "SystemVerilog for Verification: A Guide to Learning the Testbench Language Features", Chris Spear, Greg Tumbush, Springer Publication, ISBN-13: 9781489995001, 2014

Reference Books:

1. "System Verilog For Design Second Edition: A Guide To Using SystemVerilog For Hardware Design And Modeling", Peter Flake, Simon Davidmann, Stuart Sutherland, Springer, 2010, ISBN: 9781441941251.

UE22EC343AB2: Real Time Operating Systems (4-0-0-4-4)

Course Description:

The goal of this course is to meet the basics of real time systems and to provide thorough discussion of the fundamentals of Operating system design and to relate these to contemporary design issues and to current directions in the development of operating systems

Course Objectives:

- To understand basics of Operating System
- To understand the process states, creation and to perform inter process communication
- To understand necessary and sufficient conditions of real time tasks and scheduling algorithms
- To understand memory management systems
- To understand key characteristics of RTOS and hands on using Free RTX

Course Outcomes:

Students completing the course should be able to understand

- Difference between General Operating system and Real time operating system
- The multitasking techniques in real time systems.
- Real time scheduling policies in applications.
- Memory management in RTOS
- Design embedded applications using RTOS.

Course Content:

Unit 1: Operating Systems:

Introduction, Goals of an OS,Operation of an OS,Principles of OS,Key features of classes of OS,System performance and user services,Structure of an OS,Layered design of OS,Kernel and microkernel based OS.

14 Hours

Unit 2: Process :

Process concepts, PCB, 5 state model, Processscheduling,Operations on Processes,Threads. IPC-shared memory system, message passing system, pipe and fifo, Process synchronization: semaphore,priority inversion, mutex .

14 Hours

Unit 3: Scheduling:

scheduler, Types – preemptive and Nonpreemptive scheduling, RR, SJF, FCFS, Priority, Rate Monotonic least upper bound, Necessary and Sufficient feasibility, Deadline -Monotonic Policy, Dynamic priority policies; I/O Resources: Worst-case Execution time, Intermediate I/O, Execution efficiency, I/O Architecture. Multi processor scheduling, Multilevel Queue scheduling.

14 Hours

Unit 4: Memory & Real Time Systems:
Memory management Requirements,Memorypartitioning,paging ,segmentation.Virtual Memory, Hardware and control structures.
Key characteristics of an RTOS, implementing Real time Operating systems, Lab related to free RTX(semaphore, message queues, Multithreaded applications)

14 Hours

Text Book:

1. "Real-Time Concepts for Embedded Systems" ,Qing Li and Carolyn, 1st Edition, CRC Press, 2003.

Reference Books:

1. Operating Systems, William Stallings,Pearson Publications,2018
2. "Operating System Concepts", Silberschatz , Galvin, Gagne,John Wiley & Sons
3. "Computer Architecture and Organisation", J.P. Hayes, Second edition, Tata McGraw-Hill, 1988.
4. "Real-Time Embedded Systems and Components", Sam Siewert, Cengage Learning India Edition, 2007

UE22EC343AB3:
Quantum Entanglement and Quantum Computing (4-0-0-4-4)

Course Description:

Quantum entanglement is the physical bedrock of the surging quantum computing. Various by-products as Machine learning etc., are merging towards the same goal. The students will be equipped to a convenient introduction to optical entanglement physics leading to quantum computing aspects. Related computational modelling and programming will provide enjoyment and working knowledge simultaneously. This subject requires the knowledge of Linear Algebra.

Course Objectives:

- The students will be equipped to a convenient introduction to entanglement phenomenon leading to quantum computing aspects.
- To provide a comprehensive introduction to quantum state vectors and their relation with linear algebra.

- To clarify the differences between Quantum information and Quantum computing principles.
- To introduce the basic quantum computing algorithms after vivid basics.
- To introduce students to real quantum computing problems via project-based learning.

Course Outcomes:

Students completing the course should be able to

- Understand the basic mathematics in quantum theory;
- Understand the physics of quantum entanglement.
- Understand the reversible computing in classical and quantum Gates;
- Understand the development of Quantum algorithms used in search, sort, etc.
- Apply the ideas in quantum computing.

Course Content:

Unit 1: Basics of Quantum Tech:

Quantum and classical physics, Example, Double slit Experiment with bullets and waves, Double slit Experiment with electrons and concept of probability density, Dirac Notation, State of a quantum system, Hilbert Space representation, Quantum Mathematics, (linearity of states and operators) Discrete and continuous base representations, Basic postulates of Quantum Mechanics, Matrix representation of state vectors, Geometry of Probability distributions:uptoBloch sphere Representations, Python implementation of some of the basic quantum examples/ tutorial

14 Hours

Unit 2: Quantum States Algebra:

Pure and mixed states, Ensemble and density matrix, space of density matrices, Cbits and Qbits, EPR paradox, Density matrices and entropies, Superposition of States, Distinguishable and Indistinguishable states and consequences, Quantum logic gates, Introduction to IBM/Microsoft Quantum computer environment, Simulation of Quantum circuits on IBM Quantum environment

14 Hours

Unit 3: Entanglement and Quantum information:

Quantum Entanglement, Quantum Entanglement examples, Sources of Entangled photons, Time, momentum and polarization entanglement, introduction to classical information theory, Entropy and information; Consequences of entanglement on Quantum computation and Quantum information, Quantum measurement, Quantum circuits, Quantum error correction, Introduction to quantum information, No cloning theorem, Quantum dense coding,Quantum teleportation and protocol, Implementation of Quantum entanglement and circuits on Qiskit, Examples.

14 Hours

Unit 4: Quantum computing:

Classical Vs Quantum computers, P,NP,QBP domains, Quantum Algorithms: Deustch- Jozsa, Berstein-Vazirani algorithm, Simon's algorithm, Quantum phase estimation, Shor's, Grover's,Grover-Radhakrishnan (partial Grover's) Algorithms, Quantum Fourier transform, Implementation using Qiskit, Examples implementing entanglement and Quantum Fourier transform on FPGA (From Photonics and Quantum Technology Lab).

14 Hours

Textbooks:

1. "Quantum Computing: An Applied Approach," Jack D. Hidary, 2^{nd}. Ed., Springer, 2021;
2. "Quantum Entanglement Engineering and Applications," F J Duarte and T S Taylor, IOP Publishing Ltd., 2021.

Reference Books:

1. "Entanglement, information, and the interpretation of quantum mechanics", Gregg Jaeger, Springer-Verlag Berlin Heidelberg, 2009.
2. "Quantum Computation and Quantum Information," Michael A. Nielsen & Isaac L. Chuang Cambridge university press, 2010;
3. "The mathematical language of quantum theory: from uncertainty to entanglement", Teiko Heinosaari, MárioZiman, Cambridge university Press, 2012.
4. "Foundations of Quantum Programming", Morgan Kaufmann Publishers, Mingsheng Ying, 2016.
5. "Geometry of Quantum States: An Introduction to Quantum Entanglement", Ingemar Bengtsson, Karol Życzkowski, Cambridge university Press, 2017.

UE22EC343AB4: Functional and Formal Verification of Digital Designs (4-0-0-4-4)

Course Description:

This course deals with formal and functional verification (FV) of digital designs in an ASIC design flow. FormalVerification is important and mandatory process in chip design flow and this course deals withbasics of mathematical algorithms used in FV tools and developing properties applying on thedigital designs.

Course Objectives:

- To learn the need and applications of functional and formal verification of Digital VLSI design.
- To learn methods for formal analysis of combinational and sequential digital circuits.
- Analysis of the constraining functional and formal properties.
- To learn holistic formal verification of hardware designs.

Course Outcomes:

Students completing the course should be able to:

- Development of formal properties for different types of hardware designs like processor andcommunication controllers.
- Able to write and apply the formal properties and constraints and analyze the designsimulations on CAD tools.
- Learn formal verification algorithms to gain full coverage without exhaustive simulation.
- Understand functional and formal verification tools and how they differ from simulation tools.
- Create instant test benches to gain insight into how models work and find initial bugs

Pre-Requisites: Digital Design

Course contents:

Unit 1: Introduction to Functional Verification: Complexity of Verification, Necessity of Hardware Verification Languages (HVL), Directed Verification and Constrained Random Verification, Layered testbench architecture, System Verilog Datatypes: logic and other data types, Different types of arrays, queues, linked lists. Definitions and importance of code coverage and functional coverage. Achieving functional coverage using assertions and covergroups. **13 Hours**

Unit -1 Experiments:

1. Simulation of Counter for Code Coverage
2. Simulation of FSM for FSM coverage
3. Simulation for Covergroup and functional coverage
4. Simulation to demonstrate the system Verilog datatypes: logic, arrays, queues, etc

Unit 2: Object Oriented Programming in System Verilog and Randomization:
Class, Objects, static and global variables, class methods, copying objects, dynamic objects, methods outside of the class, Pubic vs local variables. Randomization in System Verilog, constraints in randomization, controlling multiple constraint blocks, Valid and in-line constraints, pre-randomize and post randomize, Atomic and scenario generation, Revisiting the code coverage and functional coverage with randomization. **15 Hours**

Unit -2 Experiments:

5. Simulation to demonstrate the class and variable
6. Simulations to improve Functional Coverage using Randomization
7. Simulation of pre-randomize and post randomization
8. Design Verification using assertions with randomization

Unit 3: System Verilog Assertions and formal verification: Introduction to system Verilog assertions, Basic Assertion Concepts, Immediate Assertions, Sequences, Properties, and Concurrent Assertions, Assertion based functional coverage. Difference between functional and formal verification, developing assertions for formal verification, formal verification apps, Vacuity and handling complexity issues in formal verification **14 Hours**

Unit -3 Experiments:

1. Simulation of immediate assertions
2. Simulation of Concurrent assertions
3. Simulation of Concurrent assertions: sequences and properties
4. Simulation of functional coverage using assertions
5. Formal verification with examples: elevator, FIFO, etc

Unit 4: Constructs for Automating the System Verilog Testbench and UVM: Building agents, drivers for stimulus, scoreboard and monitors, interfaces, modport, clocking block, connecting the testbench and design, interprocess communication and threads. Building complete layered system Verilog testbenches, Introduction to UVM testbenches, UVM constructs and UVM layers. **14 Hours**

Unit-4: Experiments:

6. Simulation to demonstrate complete layered testbench using SV constructs
7. Simulation to demonstrate the functioning of different constructs like clocking block,

modport and interfaces.
8. UVM example

Text Book:
1. "System Verilog for Verification" by Chris Spear, Springer Publications, 2nd Edition.

Reference Book:
1. Ashok Mehta "System Verilog Assertions and Functional Coverage: Guide to language,methodology and applications", Springer, ISBN-13: 978-1461473237, 2013.
2. "Formal Verification, An essential toolkit for modern VLSI design", Erik Seligman, TomSchubert, M. V Achutha Kiran Kumar, 1st Edition, Morgan Kaufmann, August-2015

UE22EC343AB5: Data Converter Circuits and Systems (4-0-0-0-4)

Course Description:
This course deals with theory of data conversion and data converter circuit design. Discuss the basic principles underlying in converting the data from analog to digital and vice versa. Along with principles on data conversion, the circuit also include the different topologies of ADCs and DACs and describing their trade-offs.This course requires the knowledge of ACD and Digital VLSI

Course Objectives:
- Impart understanding of different data conversion principles and systems
- Introduce performance metrics of both digital to analog and analog to digital converters
- To put forward design tradeoffs in selection of data converter architectures

Course outcomes:
On successful completion of this course, the students will be able to:
1. Understand concept behind digital to analog and analog to digital conversion system
2. Understand various architectures used in digital to analog and analog digital converters
3. Compare various architectures in data converters
4. Understand performance metrics used in data converters

Course Content:

Unit-1:

Basic Sampling Circuits: General Considerations, Performance metrics, MOS Switches, Diode Switches, Comparison and MOS and Diode switches, Improvement in MOS switch performance.
Sample and Hold Architectures : Conventional open loop architecture, Conventional closed loop architecture**14 Hours**

Unit-2:

Sample and Hold Architectures : Open loop architecture with miller capacitance, Recycling architecture, Switched Capacitor architecture, Current mode architecture.
Basic Principles of Digital to Analog Conversion: General considerations, performance metrics, Reference multiplication and division, voltage, current and charge,

14 Hours

Unit-3:

Basic Principles of Digital to Analog Conversion: switching functions in resistor ladder DACs, switching functions in current steering DACs, switching functions in capacitor DACs, Binary and thermal code conversion.
Digital to Analog Converter Architectures: Resistor Ladder DAC architecture, ladder architecture with switched subdivider, intermeshed ladder architecture, current steering architectures, R-2R network-based architectures, segmented architectures.

14 Hours

Unit-4: Analog to Digital Converter Architectures: General considerations, performance metrics, flash architectures, two step architectures, interpolative and folding architectures, pipelined architectures, successive approximation architectures.Interleaved architecture**s**

14 Hours

Text Books:

1. R Jacob Baker, "CMOS Mixed Signal Circuit Design" John Wiley and Sons, Fouth edition 2019
2. Behzad Razavi, "Principles of Data Conversion System Design" IEEE Press 1995

Reference Books:

1 . Tony Chan Carusone, David a Johns and Ken Martin. "Analog Integrated Circuit Design" Second edition, John Wiley and Sons, second edition 2012

UE22EC343AB6:Machine Intelligence for Chip Security and

HardwareTrust

Course Description:
This course investigates recent technology developments for the design and evaluation of integrated circuits and systems. Hardware security and trust techniques are required to ensure that chips remains secure and trustworthy during its entire lifecycle from design to manufacturing, deployment, and service. Fundamentals of hardware security and trust for cryptographic hardware, invasive and non-invasive attacks, side-channel attacks, physically unclonable functions (PUFs), true random number generation (TRNG), FPGA security, counterfeit ICs, hardware Trojans detection in IP cores and ICs are covered in this course.

Course Objectives:
This course provides a comprehensive survey of state-of-the-art technology and practices.

- Learning the state-of-the-art security methods and primitives
- Integration of security as a design metric, not as an afterthought
- Better understanding of attacks and providing countermeasures against them
- A hands-on learning approach, via projects, home works, and review assignments

Course Outcomes:
Students completing the course should be able to:

- Understand the hardware Trojan attacks and countermeasures
- Develop various hardware security primitives and analyze.
- Apply machine intelligence for hardware security.
- Design for trust schemes and their implementation.
- Design of Cryptographic hardware and side channel analysis.

Course Content:
Unit 1: Hardware Trojans
Hardware Trojan Nomenclature and Operating Modes, Trojan taxonomy - Case study, HT Attacks and Countermeasures, Classification of Trojan detection, Logic Testing based HT Detection, Side-channel Analysis based Techniques for Trojan Detection, Challenges in Trojan detection, Machine Intelligence based HT Detection.**14 Hours**
Unit 2: Hardware Security Primitives
True Random Number Generator, Physically Unclonable Functions (PUFs), PUF Implementations, PUF Quality Evaluation, Design Techniques to Increase PUF Response Quality, Artificial Intelligence – PUF**14 Hours**
Unit 3: Cryptographic Hardware Security
Cryptographic Hardware and their Implementation, Optimization of Cryptographic Hardware, Side-channel Attacks on Cryptographic Hardware, Design Techniques to Prevent Side-channel Attacks, Improved Side-channel Attack Algorithms and Prevention using Machine Intelligence
14 Hours
Unit 4: Design for hardware trust:
Delay-based methods – Shadow registers – Ring oscillators - Dummy scan Flip-Flop insertion - Trojan activation time analysis - Trojan detection and isolation flow – Architectural approaches,

Machine Intelligence for Design Protection.

14 Hours

Textbooks

1. Emerging Topics in Hardware Security , by Tehranipoor, Mark (Editor), ISBN-13: 978-3030644475 ISBN-10: 3030644472., 1 May 2021, Springer Nature.

2. Tehranipoor, Mohammad, and Cliff Wang, eds. Introduction to hardware security and trust. Springer Science & Business Media, 2012.

3. D. Mukhopadhyay and R. S. Chakraborty, "Hardware Security: Design, Threats and Safeguards", CRC Press, First Edition , 2014

References

1. Mohammad Tehranipoor, Hassan Salmani and Xuehui Zhang, "Integrated Circuit Authentication - Hardware Trojans and Counterfeit Detection", Springer International Publishing, Switzerland 2014.

2. Nicolas Sklavos, Ricardo Chaves, Giorgio De Natale, Francesco Regazzoni (Eds), "Hardware Security and Trust: Design and Deployment of Integrated Circuits in a Threatened Environment", Springer, 2017.

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UE22EC343AC1: Artificial Neural Networks (4-0-0-4-4)

Course Description:

This course introduces students to the basic concepts of Artificial Neural Network likesupervised and unsupervised learning algorithms. This will help them in understanding howANN can be employed in solving real-world problems. Knowledge of Linear Algebra,Mathematics for Electronics Engineers is required.

Course Objectives:

- Expose the fundamentals of artificial neural networks and learning, and their role in engineering;
- To understand the fundamental unit perceptron and single layer network.
- To understand radial basis function networks.
- Provide knowledge of supervised learning and unsupervised learning
- To understand self-organizing maps and to provide applications of neural networks.

Course Outcomes:

Students completing the course should be able to

- Describe the basic neuronal models
- Analyse the perceptron and single layer network.
- Analyse the significance of radial basis function networks.
- Analysedifferent learning process.
- Evaluate the practical considerations in applying neural networks in applications.

Course Content:

Unit 1: Basics of Neural network

Introduction to neural network,Human brain; models of a neuron; neural networks as directed graphs; feedback; network architectures; Learning Processes: Error-correction learning; memory-based learning; Hebbian learning; competitive learning; Boltzmann learning; learning with and without a teacher

Linear Neuron: Adaptive filtering problem; unconstrained optimization techniques; linear least-squares filters; gradient descent algorithm; least-mean-square algorithm; Newton's method. Implementation of various activation function, and ADLINE

14 Hours

Unit-2: Single and Multi-layer perceptron

Single layer networks: Linear separability; Perceptron; perceptron convergence theorem; Multilayer layer network: Preliminaries; back-propagation algorithm; XOR problem; heuristics for making the BPA perform better; advantages and disadvantages of BPA. Implementation of single layer and multilayer feedforward neural network; Hessian matrix; generalization; approximation of functions; cross-validation; network pruning techniques; virtues and limitation of back-propagation learning.

14 Hours

Unit 3:Radial-Basis Function Networks

Cover's theorem on the separability of patterns, interpolation problem, supervised learning as an ill-posed hyper-surface reconstruction problem, regularization theory, regularization networks, generalized radial-basis function networks, XOR problem revisited, comparison of RBF networks and multilayer perceptron. Implementation of RBF neural network.

14 Hours

Unit 4: Unsupervised Learning Algorithms

Principal Component Analysis: Some intuitive principles of self-organization; principal components analysis; Hebbian-based maximum eigen filter; Hebbian-based principal components analysisFeature-mapping models (no proof); self-organizing map; properties of the feature map; learning vector quantization; Applications of Neural Networks in Forecasting, image processing and compression, and control. Implementation of Principal component analysis, and Self Organization mapping

14 Hours

Text Book:

1. "Neural Networks: A Comprehensive Foundation," S. Haykin, 2 nd Edition, Prentice Hall of India, 2003.

Reference Books:

1. "Neural Networks and Learning Machines", S. Haykin, 3rd Edition, Prentice Hall of India, 2009.
2. "Applications of Neural Networks", Alan Murray, Springer Science+Business Media, New York. 1995.
3. "Neural Network Design", T. Hagan, H. B. Demuth and M. Beale, Thomson Learning, 2002.
4. "Static and Dynamic Neural Networks: From Fundamentals to Advanced Theory", M. M.Gupta, L. Jin and N. Homma, John Wiley-IEEE Press, 2003.
5. "Introduction To Neural Networks With Matlab 6.0", S Sivanandam, S Sumathi and S N Deepa, Mcgraw Hill Education,2017

UE22EC343AC2 - INTELLIGENT CONTROL SYSTEMS (4-0-0-0-4)

Course Description: This course provides an insight into the concept of State Space Analysis, followed by understanding of Adaptive Control techniques. Modelling of dynamical systems using Neural Networks is dealt in detail and the course culminates in the design of control strategies for dynamical systems using Neural Networks.

Course Objectives: Students undergoing this course will learn;

- State Space descriptions and analysis.
- Stability Theory and Adaptive Control strategies.
- Concept of Neural Networks and Modelling of dynamical systems using Neural Networks.
- Design of control strategies using Neural Networks.

Course Outcomes: Students having undergone this course should be able to;

- Design the State Space model of a system and the associated controllers.
- Design and apply Adaptive Control Techniques for dynamical systems.
- Model, design and train Neural Networks.
- Identify and design the appropriate Neural Networks based control strategies to control a dynamical system.

Unit -1: State Space Descriptions: Concept of State Space; Modelling in State Space; State Space representation of LTI Continuous-time and Discrete-time systems – Canonical Forms; Eigen Values; Controllability and Observability; Pole placement; Design of controllers using State feedback; tracking controller.**14 Hours**

Unit – 2: Adaptive Control Techniques: Lyapunov Stability Theory, Introduction to adaptive control - Direct and indirect adaptive control - Model reference adaptive control: Control design using MIT Rules and Lyapunov Theory -. Singularity regions, Lyapunov redesign.**14 Hours**

Unit – 3: Modelling using Neural Networks : Introduction to Intelligent System: Need for intelligent modelling - Architecture for intelligent control - Concept of Artificial Neural Networks and its basic mathematical model - Feed forward Multilayer Perceptron - Learning and Training the neural network.**14 Hours**

Unit – 4: Neural Networks based Control: RBF networks - Recurrent networks. Modelling using Neural Networks: System identification using Neural networks – NNARMAXmodelCase studies*: Identification and control of nonlinear dynamic systems using simulation tools
14 Hours

Textbooks:

1. “Modern Control Engineering”, K. Ogata, PHI, 5th Edition,2010.
2. “Discrete Time Control Systems”, K. Ogata, Pearson, 2nd Edition, 2015.
3. “Adaptive Control: Stability, Convergence and Robustness”, Shankar Sastry, Marc Bodson, Dover Publications Inc, 2011.
4. “Neural Networks for Modelling and Control of Dynamic Systems, A Practitioner’s Handbook”, M. Norgaard, O. Ravn, N.K. Poulsen, L.K. Hansen, Springer; 2nd ed., 2012.

*K. S. Narendra and K. Parthasarathy, "Identification and control of dynamical systems using neural networks," in *IEEE Transactions on Neural Networks*, vol. 1, no. 1, pp. 4-27, March 1990, doi: 10.1109/72.80202.

References:

1.“Linear Systems”, T. Kailath, Prentice-Hall, 1980.
2. “Stable Adaptive Systems”, K. Narendra, Anuradha A, Dover Books in Electrical

Engineering, Courier Corporation, 2012.
3. “Linear System Theory and Design”, Chi-Tsong Chen, 3rd edition, Oxford University Press, 1998.
4. “Intelligent Systems and Control”, Laxmidhar Behera, Indrani Kar, 5th edition, Oxford University Press, 2009.

5. “Adaptive Control”, K.J. Astrom and B. Wittenmark, Dover, 2nd edition, 2008.

UE22EC351B: WAVEGUIDES AND ANTENNAS (4-0-2-4-5)

Course Objectives:

- The main objective of the course is to make the students understand the fundamental concepts of electromagnetic wave propagation inside the waveguides and radiation through antennas.
- This course will help the students to apply the basic electromagnetic concepts to design microwave components, such as waveguides and antennas.
- This course aims to give an in-depth understanding of the fundamentals of antennas.
- This course is expected to help the students to apply the concepts of antenna design and perform simple experiments.

Course Outcomes:
Students completing the course should be able to

1. Analyse waveguides, eg determine their cutoff frequency, propagating modes and other parameters.
2. Analyse cavities, eg determine their resonance frequency and other parameters.
3. Get an insight into the fundamentals of antennas.
4. Select the appropriate kind of antenna from the radiation pattern and other characteristics / specifications.
5. Select / design the appropriate kind of dipole antennas.
6. Decide the type of array required for a given application.
7. Analyse and design special antennas.

Course Content:

Unit 1: Waveguides, cavities, and radiation from point source: Waveguide propagation: Solutions of wave equations in rectangular co-ordinates, TE and TM modes in Rectangular Waveguides, Poynting vector, Power transmission and Power losses in rectangular waveguides, Excitation of waveguides. Microwave Cavities: rectangular cavity resonator. Magnetic vector potential, retarded potentials, relation between vector and scalar potential: Lorentz condition. Solution for inhomogeneous vector potential wave equation due to point source. (16 hours)

Unit 2: Wire antennas and radiation parameters: Infinitesimal current element or Hertzian dipole, short dipole, half-wavelength dipole: current distribution, radiated fields, power density, power radiated, radiation resistance. Finite length dipole: current distribution, radiated fields, and power density. Definitions of antenna parameters: radiation intensity, radiation pattern, directivity, gain, effective aperture, half-power beam width, input impedance, and polarization. (12 hours)

Unit 3: Friis transmission formula and antenna arrays: derivation of Friis transmission formula for matched and unmatched conditions. Field regions: near field region, intermediate field region, and far field region. Linear array, pattern multiplication, and array factor. Two-element array: broadside array and endfire array. Array factor of uniform linear array of N elements. Main lobe and grating lobes. Antenna array with uniform spacing and non-uniform amplitude (binomial array) and its array factor. Comparison of uniform linear array and binomial array. (16 hours)

Unit 4: Special Antennas: Horn Antennas, Reflector Antennas, Yagi Uda Array, Helical Antennas, Log Periodic Dipole Array, Microstrip Patch Antenna, Aperture Antenna: Radiation Pattern as Fourier Transform of Current Distribution. (12 hours)

Pre-requisite Course: Electromagnetic Field Theory.

Reference Books:

1. "Microwave Engineering", David M. Pozar, Fourth Edition, 2012, John Wiley & Sons, New Jersey.
2. "Antennas and Wave Propagation", A.R.Harish and M.Sachidananda, First Edition 2007, Third impression 2008, Oxford University Press, New Delhi.

UE21EC352B: Machine Learning and Applications (4-0-0-4-4)

Course Description:

The course aims to provide an introduction to fundamental techniques in machine learning, like supervised learning-based regression and classification models. It also introduces clustering and dimensionality reduction. For this course Knowledge of Linear Algebra, MEE is required.

Course Objectives:

- Develop an appreciation of what is involved in learning from data.
- To give knowledge on parametric classification.
- To give elaborate idea on non-parametric classification.
- To give a platform for kernel machines
- To give knowledge about unsupervised learning

Course Outcomes:

Students completing the course should be able to

- Use effective machine learning techniques for various applications.
- Understand different parameters in parametric classification.
- Analyse different non parametric classification.
- Analyse different kernel machine problems.
- Understand the concepts of unsupervised learning

Course Content:

Unit 1: Foundation of Machine Learning: Introduction to Classification and Regression, Design and Analysis of Machine Learning Experiments: Factors, Response, and Strategy of Experimentation, Response Surface Design, Randomization, Replication, and Blocking, Guidelines for Machine Learning Experiments, Cross-Validation and Resampling Methods, Measuring Classifier Performance, Interval Estimation, Hypothesis Testing

12 Hours

Unit 2: Supervised Learning- parametric methods: Learning a Class from Examples, Vapnik-Chervonenkis Dimension, Probably Approximately Correct Learning, Noise, Learning Multiple Classes, Regression, Model Selection and Generalization, Dimensions of a Supervised Machine Learning Algorithm. Parametric Classification, Regression, Tuning Model Complexity: Bias/Variance Dilemma, Model Selection Procedures. Gradient Descent, Logistic Discrimination. Multivariate Data, Parameter Estimation, Estimation of Missing Values, Multivariate Normal Distribution, Multivariate Classification, Tuning Complexity, Discrete Features, Multivariate Regression.

16 Hours

Unit 3: Supervised Learning- Nonparametric Methods: Nonparametric Density Estimation, Generalization to Multivariate Data, Nonparametric Classification, Condensed Nearest Neighbor Distance-Based Classification, Outlier Detection, Nonparametric Regression.
Decision Trees: Introduction, Univariate Trees, Classification Trees, Regression Trees, Pruning, Rule Extraction from Trees, Learning Rules from Data.
Kernel Machines: Introduction, Optimal Separating Hyperplane, The Nonseparable Case: Soft Margin Hyperplane, ν-SVM, Kernel Trick, Vectorial Kernels, Defining Kernels, Multiple Kernel Learning, Kernel Machines for Regression, One-Class Kernel Machines, Kernel Dimensionality Reduction

16 Hours

Unit 4:
Clustering and Dimensionality Reduction: Clustering: Introduction, Mixture Densities, k-Means Clustering, Expectation-Maximization Algorithm, Mixtures of Latent Variable Models, Supervised Learning after Clustering, Spectral Clustering, Hierarchical Clustering, Choosing the Number of Clusters.
Dimensionality Reduction: Principal Component Analysis, Singular Value Decomposition, Linear Discriminant Analysis.

12 Hours

Text Book:

1. "Introduction to Machine Learning", EthemAlpaydin , 4th Edition, MIT Press, 2020.

Reference Books:

1. "An Introduction to Statistical Learning", Gareth James, Daniela Witten, Trevor Hastie , Robert Tibshirani, 2023.
2. "Pattern Recognition and Machine Learning", Christopher M. Bishop, Springer, 2006.
3. "Machine Learning: A Probabilistic Perspective", Kevin P. Murphy, MIT Press, 2012.
4. "Pattern Classification", Richard O. Duda, Peter E. Hart and David G. Stork, 2nd Edition, John Wiley, 2001.

UE22EC341B: Computer Architecture (4-0-0-0-4)

Course Description:

This course gives an idea of computer architecture. It covers memoryhierarchy design. It gives an insight into different types of parallelism such as instruction levelparallelism, data level parallelism and thread level parallelism.

Course Objectives:

- To make students know about the Parallelism concepts in Programming
- To give the students an elaborate idea about the different memory systems and buses.
- To introduce the advanced processor architectures to the students.
- Important architectures as GPU etc., to be introduced.
- To make the students know about the importance of multiprocessor and

- multicomputer.

Course Outcomes:

- Students will increase their proficiency in the performance evaluation of processors.
- Students will get an idea of the computer memory hierarchy.
- Students will know the design principles of contemporary computers.
- Students will acquire the background for understanding next-generation CPUs.
- Students will learn about Parallel Organizations –Parallel Processing and Multi-
- Core Computers.

Course Content:

Unit 1:“
Fundamentals of Quantitative Design and Analysis: Defining Computer Architecture, Dependability, Quantitative Principles of Computer Design, Basics of Cache, Fully Associative mapping, Set Associative mapping, Mapping numerical, Cache Performance Measurement, Performance of multilevel caches, Cache Write Policies, Cache replacement Algorithm-LRU, Numerical
Memory Hierarchy Design: Six Basic Cache Optimization

14 Hours

Unit 2:
Memory Hierarchy Design: Ten AdvancedOptimizations of Cache Performance, Memory Technology and Optimizations,Protection: Virtual Memory – Page table ,page fault,TLB(From Text 2-5.7)and VirtualMachines, The Design of Memory Hierarchies,
Instruction-Level Parallelism and Its Exploitation: Instruction-LevelParallelism: Concepts and Challenges, Basic Compiler Techniques for Exposing ILP,Reducing Branch Costs with Advanced Branch Prediction

14 Hours

Unit 3:
Instruction-Level Parallelism and Its Exploitation:Overcoming Data Hazards with Dynamic Scheduling, Dynamic Scheduling: Examples and the Algorithm, Hardware-Based Speculation, Exploiting ILP Using Multiple Issue and Static Scheduling, Exploiting ILP Using Dynamic Scheduling, Multiple Issue, and Speculation, Advanced Techniques for Instruction Delivery and Speculation, Multithreading: Exploiting Thread-Level Parallelism to Improve Uniprocessor Throughput
Data-Level Parallelism. Introduction, Vector Architecture, Instruction Set Extensions for Multimedia **14 Hours**

Unit 4:
Data-Level Parallelism.Graphics Processing Units, Detecting and Enhancing Loop-Level Parallelism,
Thread-Level Parallelism: Introduction, Centralized Shared-Memory Architectures, Performance of Symmetric Shared-Memory Multiprocessors, Distributed Shared-Memory and Directory-Based Coherence, Synchronization: The Basics, Models of Memory Consistency: **14 Hours**

Text Books:

1. Computer Architecture: A Quantitative Approach by Hennessy and Patterson, 6th Edition
2. Computer Organization and Design David A. Patterson, John L. Hennessy, fifth edition Elsevier
3. Computer Organization and Architecture: Themes and variations", Alan Clements 2013

Reference Books:

1. "Digital Design and Computer Architecture" ,Harris and Harris, 2020 edition

UE22EC342BA1 : Cryptography(4-0-0-4-4)

Course Description:

The Course Cryptography give the basic foundation aspects of number theory applied to cryptography and information security, describes about various network security protocols based on standard cryptographic primitives such as symmetric key cryptography, asymmetric key cryptography and one-way hash functions and illustrates the different kinds of attacks on information systems, and techniques to prevent them or mitigate their effects.

Course Objectives :

- Understand the different kinds of attacks on information systems and techniques to prevent them or mitigate their effects.
- Learn the Concepts of Mathematics related to Cryptography
- Provide basic understanding to design standard symmetric key cryptographic Algorithms.
- Provide insight Knowledge on Cryptography protocols based on standard Asymmetric key cryptography Methods.
- To introduce the network protocols that are used in Design of secure communication systems.

Course Outcomes:

On successful completion of this Course, the students would be able to:

- Perform a security analysis of an information system to determine the required security attributes.

- Illustrate different kinds of attacks on information systems, and design techniques to prevent them or mitigate their effects.
- Demonstrate aspects of number theory applied to cryptography and information security.
- Explain the internal construction and performance overheads of cryptographic primitives based on Symmetric Key Cryptography (SKC), Asymmetric Key Cryptography (AKC), and One-Way Hash (OWH) functions.
- Design network security protocols using the cryptographic primitives, and analyse their weaknesses.

Course Content:

Unit 1: Principles of Security and Mathematics for Cryptography

Information systems, Attacks on information systems by adversaries. Threat analysis: Adversarial models and Security attributes or security goals. Trade-offs between security and user convenience and user privacy. Notions of trust. Common-sense principles in security design. Introduction to cryptography, cryptanalysis, and Steganography; Prime numbers, Euclid's greatest common divisor algorithm, Additive inverse and multiplicative inverse, extended Euclid's algorithm, Algebraic structures: Groups, Rings, Fields, Subgroups, Cyclic groups and cyclic sub-groups Chinese remainder theorem.

14 Hours

Unit 2: Symmetric Key Cryptography (SKC) and Message Authentication

Kerckhoff's principle: Key Domain, Entropy of key. Substitution cipher and Transposition cipher, Block ciphers and Stream ciphers. Product ciphers, Shannon's principles of confusion and diffusion, Data Encryption Standard (DES): DES Structure, Multiple DES, DES Security Analysis, Advanced Encryption Standard (AES): Transformations, Key expansion, AES Security analysis. Techniques (ECB, CBC, CFB,OFB, CTR) to use block ciphers to encrypt large files; Characterization of properties one-way hash functions (pre-image resistance, second-preimage resistance and collision-resistance) via birthday theorems; Message authentication via Message Authentication Codes (MAC): HMAC, NMAC, CMAC.

14 Hours

Unit 3: Asymmetric Key Cryptography and Digital Signature

Euler's theorem, and Fermat's theorem; Asymmetric Key Cryptography (AKC): Computational hardness of integer factorization and Discrete Logarithm Problem (DLP). RSA crypto-system. El-Gamal crypto-system. Digital Signatures, Digital signature algorithms (RSA, El-Gamal, Schnorr, Digital Signature Algorithm), Digital signatures via One Time Signatures (OTS); Digital Certificate, Certifying Authority (CA), Certificate Revocation List (CRL) Applications of digital signatures, attacks on digital signatures;

14 Hours

Unit 4: Network Security Protocols

Internal structure of OWH functions: Compression functions, SHA-512, Applications of OWH functions: Message integrity, Password maintenance, Message authentication Entity authentication via Smart-cards, Passwords, and Biometrics. Challenge-response protocols, zero-knowledge protocols, 2-factor authentication via One Time Passwords (OTPs), Authenticated Key Exchange Protocols: Diffie-Hellman Key Exchange, Station To Station (STS) protocol, Key Management in the Kerberos system, Secure Sockets Layer (SSL) protocol. Secret splitting techniques; Attacks and Defence mechanisms on Internet-based systems: Topics to be selected by instructor; Systems Security: Topics to be selected by instructor.

14 Hours

Text Books:

1. "Cryptography and Network Security", Behrouz A. Forouzan and Debdeep Mukhopadhyay, 3rd Edition, Tata McGraw-Hill, 2010.

Reference Books:

1. "Cryptography and Network Security", William Stalling, Pearson Education, 7th Edition, 2017.
2. "Computer Networking: A Top Down Approach", James Kurose and Keith Ross, 5th Edition, Pearson, 2012.
3. "Cryptography and Network Security", AtulKahate, TMH, 2003.
4. "A Computational Introduction to Number Theory and Algebra", Cambridge University Press, Victor Shoup, 2005.
5. "Handbook of Applied Cryptography, CRC Press", Alfred Menezes, Paul, Oorschot, and Scott Vanstone, 1996.

UE22EC342BA2:MIMO Communication (4-0-0-4-4)

Course Description:

This course provides an overview of Multiple Input Multiple Output systems and the advantages and complexities a MIMO architecture brings into a wireless transceiver design.
Single User MIMO as well as Multi User MIMO are being taught in detail. Capacity of MIMO channels, different Diversity techniques and beamforming concept are learnt here. Analysis of Massive MIMO, one of the key enabling technologies for modern broadband wireless systems is done too. This course requires the knowledge of Digital Communication.

Course Objectives:

- Understand wireless channel impairments and the resulting challenges.
- Appreciate the advantages of MIMO.
- Learn how MIMO can be used to improve performance of a wireless system.

- Understand how a wireless transceiver and network design gets complicated by introducing MIMO.
- Understand how MIMO concept is used in latest wireless communication standards.

Course Outcomes:

At the end of the course, students should be able to

- Analyse the wireless system design issues.
- Realize why multiple antennas are needed in all modern wireless systems.
- Realize the problems associated with using multiple antennas.
- Apply MIMO concepts for future research project.
- Apply the above learnt concepts and to design next generation wireless systems and networks.

Course Contents:

Unit 1– Wireless propagation and MIMO basics

Evolution of Wireless systems from 1G to 5G, building blocks of a digital communication transceiver, what is SISO, MISO, SIMO, MIMO, Time Selectivity & Frequency Selectivity of wireless channel, Interplay of bit rate, power, bandwidth, Small scale propagation envelope distribution, Performance of AWGN Channel, performance of wireless channel, Interference, Degradation in performance due to interference, why we need MIMO, Numerical.

14 Hours

Unit 2 - Single User MIMO - I

Expression for MIMO channel, MIMO channel characteristics, statistical properties of MIMO channel matrix, Spatial Diversity, Multiplexing, Receive Diversity Techniques, Selection Combining, Maximal Ratio combining, Transmit Diversity Techniques, Transmit diversity without channel known at transmitter, Alamouti Coding, Diversity-Multiplexing Tradeoff, Capacity of SISO system, Capacity of MIMO system, Ergodic Capacity, Outage Capacity, Numerical. **14 Hours**

Unit 3 - Single User MIMO – II

Capacity when channel is unknown at Transmitter, Capacity when channel is known at transmitter, Single User MIMOPrecoder Design Principles, Linear Receivers for single user MIMO, ZF receiver, MMSE receiver, What is Massive MIMO, Advantages & Disadvantages, Numerical. **14 Hours**

Unit 4 – Multiuser MIMO& Massive MIMO

Multi user communication prelude, Spectral Efficiency, Orthogonal Channel sharing, Non-Orthogonal Channel Sharing, Broadcast Channel, Multiple Access Channel, Duality between Multiple Access & Broadcast Channel, Multi User MIMO with Optimum Transceiver, Massive MIMO Issues, Pilot contamination, Mitigation of pilot contamination, Channel hardening, Machine Learning aided MIMO Communication.

14 Hours

Text Books

1. Foundations of MIMO Communication by Robert W. Heath Jr., Angel Lozano, Cambridge University Press, 2018.

Reference Books:

1. Fundamentals of Wireless Communication, by David Tse, PramodViswanath, Cambridge University Press, 2012.
2. Wireless Communications by A. Goldsmith, Cambridge University Press, 2012.
3. MIMO Wireless Communications by EzioBiglieri, Robert Calderbank et al, Cambridge University Press, 2010.
4. Fundamentals of MIMO Wireless Communications by Rakhesh Singh Kshetrimayum, Cambridge University Press, 2017.

UE22EC342BB1: Quantum Transport and Logic Gates (4-0-0-4-4)

Course Description:

This course is designed for those students who has the device level curiosity as to how a quantum computer or its units will look like. This is for those minds who think how nanoelectronics passed down to nano-optics and resulted in the quantum era. Overall, how the quantum transport effect established itself in the domains of nanoelectronics and quantum-optics. The basic phenomena that guide the development of quantum electronic or optical devices needs to be known by budding engineers. Also, the course ensures that they have some fun with the same by producing codes to visualize few of the phenomena. For this course Knowledge of Digital Design Using HDL and Linear Algebra is required.

Course Objectives:

- The students will be taught the device level quantum transport phenomena for practical thinking.
- Students will be introduced to fundamental usage of Green’s function and Density Functional theory.
- The students will learn atomic level transport phenomena and their relevance to Qubits;
- The students will know the background of device level simulation for electronic and quantum-optical devices;
- Quantum teleportation and cryptography will be introduced and practiced at elementary level.

Course Outcomes:

Students who successfully complete the course will be able to:

- Understand the physics of quantum transport and computational tools related to it;
- Understand the working fundamentals of Green's Function and Density Functional theory.
- Understand the concept of Qubits
- Do basic computation
- To be able to use computational skills for quantum computation at a demonstrable level.

Course Content:

Unit 1: Quantum basics:

Quantum mathematics basics: Bra-ket algebra, Matrix form of state vectors, Bloch sphere, superposition quantum state decomposition, Quantum potential well calculations in 1D and 2D, Green's function, Interaction of representation, role of temperature, Quantum devices, Introduction to Density Functional Theory free software tools and usage working with IBM quantum computer and Qiskit

14 Hours

Unit 2: Quantum transport:

Quantum transport: methods, MOSFET, Quantum confinement effects in transport, Density of states, Surface states & band bending, Metal semiconductor contacts Semiconductor heterostructures; 2D electron systems, Quantum confinement by electrostatic shaping; 2D systems: Flux quantization, Shubnikov-de Haas oscillations & Quantum Hall effect; 2D systems: Weak-localization, Universal conductance fluctuations, Aharonov-Bohm effect.

14 Hours

Unit 3: Computational Quantum theory:

2D layered systems, Spin-Orbit coupling, topological insulators; 1D systems: Quantum point contacts, Nanowires; 1D systems: atomic point contacts, charge sensing techniques; 0D systems: Gated Quantum dots, artificial atoms, Coulomb blockade, Single electron

Charging; 0D systems: Shell filling, single electron states, Coupled quantum dots, spin-qubits; Mesoscopic superconductivity: Josephson junctions, AC and DC Josephson effects.

14 Hours

Unit 4: Computational Quantum Gates and Circuits:

Solving Schrodinger equation using Python in 1D, 2D: Basic statistical python, FDTD and utilization in quantum programming. Qubits, single Qubit Gates, many single-Qubit gates, Basic quantum circuit diagrams, Quantum transport and spin qubits., solving problems using Quantum computers.

14 Hours

Textbook:

1. "Quantum Transport South Asia Edition: Atom to Transistor," Supriyo Datta, Cambridge University Press, 2023, Asia Edition.

2. “An Introduction to Quantum Transport in Semiconductors”, David K. Ferry, Taylor and Francis, 2018.

Reference Books:

1. “A First Introduction to Quantum Computing and Information”,BernardZygelman, Springer, 2018.
2. “Quantum Computing Explained”, David McMahon, Wiley, 2007.
3. “Mathematics of Quantum Computation and Quantum Technology”, Goong Chen Louis Kauffman Samuel J. Lomonaco, Chapman and Hall, 2007.

UE22EC342BB2: RF Microelectronics (4-0-0-4-4)

Course Description:

This course covers the basic concepts of Radio frequency microelectronics using CMOS technology. Course imparts training in designing RF transmitters, RF receivers, Low noise amplifiers and Power management circuits. Students apply these concepts to design RF circuits with different topologies to meet the design specifications.Knowledge of CMOS Analog VLSI Design is required.

Course Objectives:

- To impart training in Radio Frequency communication fundamentals
- To impart RF Circuit Design
- To impart training in RF Amplifier design
- Introduce RF circuit design parameters and simulation.
- To put forward RF circuit design blocks for system integration and simulation.

Course outcomes:

On successful completion of this course, the students will be able to:

- Differentiate the Technologies for RFIC
- Identify the Design Constraints and Remedies for some RFIC Design
- RF Transceiver and Receiver design.
- Design Amplifiers, Mixers,
- Understanding design of power amplifiers and Oscillators.

Course Content:

Unit1:

Basic Concepts in RF Design: Introduction to RF design and Wireless technology, General Considerations, Effects of Nonlinearity, Noise, Sensitivity and Dynamic Range, Passive impedance transformation. **13 Hours**

Unit2:

Transceiver Architectures: General considerations**,** Receiver architectures, Basic Heterodyne receiver and direct conversion receivers Transmitter
Architectures, General considerations, direct conversion transmitters and heterodyne transmitters
Low Noise Amplifiers: General considerations, LNA topologies,
15 Hours

Unit3:

Low Noise Amplifiers: Gain switching, Band switching, High IP2 –LNAs, Non linear calculations
Mixers: General Considerations, Passive down conversion mixers,
Active down conversion mixers,Up conversion mixers, **14 Hours**

Unit 4:

Oscillators: Performance parameters**,** Basic principles, cross coupled oscillators, voltage-controlled oscillators, LC VCOs with wide tuning range, Phase noise, Basic concepts and effect of phase noise
Power Amplifiers General considerations, Classification of power amplifiers, high frequency power amplifiers,
14 Hours

Textbooks:

1. Behzad Razavi, "RF Microelectronics" 2nd Edition Prentice Hall 2012

Reference Books:

1. Thomas H. Lee "Design of CMOS RF Integrated Circuits" 2nd edition, Cambridge University press 2003.

UE22EC342BB3: Architectures for Hardware Acceleration (4-0-0-4-4)

Course Description:

As Moore's Law slows down, there is increasing interest in the use of hardware accelerators, especially for big data AI/ML workloads. Examples include Google's Tensor Processing Units and the recent Inferentia from Amazon. This course provides a big picture overview of the hardware accelerator landscape and clear, in-depth and insightful coverage of design techniques for hardware accelerators (like those mentioned above) and the state-of-the-art in programmable logic-based implementation of hardware acceleration.

Course Objectives

The objectives of this course are to provide a sound understanding of:

- The motivations for the increasing trend of hardware acceleration
- The architecture of modern programmable logic devices
- Efficiencies obtained over software by direct implementation of computation in hardware

- Modern industry standard development tools

Course Outcomes

At the end of the course, the student will be able to:

- Comprehend the rationale behind and adapt to the shift towards hardware acceleration in mainstream computing
- Build efficient computation structures to accelerate computation
- Use industry standard tools to implement accelerator logic
- Design and implement accelerator logic to speed up an application

Pre-requisites: Knowledge of Digital Design and Computer Organization

Course Content:

Unit 1:Introduction: Business and technical motivations for custom architectures, End of Moore's law, Dennard Scaling, Amdahl's law, Gustfson-Barsis's law. Necessity and Importance of hardware accelerators and custom architectures, computational requirements of ML and data centers. Introduction to High level synthesis and FPGA Architecture, Floating Point Arithmetic, IEEE floating point formats, Floating point adders and multipliers. **13 hours**

Unit 2:Basic Building Blocks of Accelerator Logic: Systolic Arrays, Matrix multiplication using Systolic arrays, Convolution architecture, FIR and Parallel FIR architecture, CORDIC architecture, Sorting Architectures**.** **13 Hours**

Unit 3:Hardware Implementations of Cryptographic Algorithms and Network on Chips: Finite field arithmetic, Galois fields, AES Algorithm, Hardware Implementation of AES, Key generation techniques using Physical Unclonable Functions and TRNG and cryptographic applications.

Network on Chips (NoC): Overview of an NoC, Message Transmission, Routing, Router design and performance aspects. **15 Hours**

Unit 4: GPU, NPU and Hardware Accelerators for Machine Learning: -

GPUs: Traditional GPUs, Programming GPGPUs, Programming GPGPUs, Architecture of a GPU

Hardware Accelerators for ML: Convolutional Neural Networks, Design of CNN, Intra PE parallelism, Memory interface to Accelerators

Neural Processing Unit (NPU): Introduction to Generative AI, Necessity of the NPUs, Tensor Accelerators, Applications on NPU with CNN accelerator and Tensor accelerator.**15 Hours**

Text Book:

1. "Advanced Computer Architecture", by Smruti R Sarangi, Mc Graw Hill, 1st Edition, -

2021.

2. “Artificial Intelligence and Hardware Accelerators”, by Ashutosh Mishra, et al, 1st Edition, Springer Publications-2023.

UE22EC342BB4: LOW POWER VLSI (4-0-0-4-4)

Course Description:
This course deals with low voltage device modelling, low voltage, low power VLSI CMOS circuit design and low power architectures.

Course Objective:

- To understand importance of low power design.
- Learn about the various techniques used in modern chip design industry to achieve low power.
- To develop knowledge and understanding of developing design intent using UPF and using low power tools (lab component)

Course Outcome:
At the end of the course, the student should be able to:

- Evaluate performance of different standard structured low power techniques with respect to various parameters.
- Designing IP cores with low power.
- Hands on learning and skill for developing end to end low power solutions in chip design.

Pre-Requisite: Digital VLSI

Course content:

Unit 1: Low Power Design and Power Analysis
Low power, Power vs Energy, Dynamic power, Conflict between dynamic and static power, Reasons for power consumption, Modelling power in core logic, Modelling of power in I/O's and Macro Blocks.Switching Activity, Power consumption for basic cells and macros, Specifying activity at the block or chip level, power analysis of chip level. **15 Hours**

Unit 2: Design Intent and Architectural Techniques for Low Power: Power Management Requirements, Power Domains, Special Cells for Power Management, Variable Frequency, Dynamic Voltage Scaling, Dynamic Voltage and Frequency Scaling, Reducing VDD, Architectural Clock Gating, Multi-voltage, Optimizing Memory Power Operand Isolation, Operating Modes of Design, RTL Techniques
15 Hours

Unit 3 : Power gating and circuit level design for low power :
Power Gating overview, Switching Fabric Design, Signal Isolation, State Retention and Restoration Methods, Architectural Issues for power Gating, Leakage Modes Supported for SALT processor, Design Partitioninglow power very fast dynamic logic circuits, Circuit Technology-Independent Power Reduction, Circuit Technology-Dependent Power Reduction, Circuit parallelization, TSPC 15 Hours

Unit 4: Low power implementation Techniques: Technology Node and Library Trade-Offs, Library Selection, Clock Gating, Timing Impact Due to Clock Gating, Gate-Level Power Optimization Techniques, Power Optimization for Sleep Modes, Adaptive Process Monitor, Decoupling Capacitances and Leakage. UPF power specification. **13 Hours**

Mandatory Demo Sessions:

1. Reporting power during synthesis in Cadence Genus
2. Developing UPF for synthesis
3. Clock gating demonstration
4. Power gating demonstration
5. Developing UPF for layout

Text Books:

1. David Flynn, Rob Aitken, et al, "Low Power Methodology Manual: For SoC Design, First Edition," Springer-2007, ASIN: B0016PZT90.
2. "Low-Power CMOS Circuits: Technology, Logic Design and CAD Tools" by Christian Piguet, CRC Press, ISBN-10: 028493953723.
3. **Rakesh Chadha, J. Bhasker, An ASIC Low Power Primer: Analysis, Techniques and Specification"** Springer Science & Business Media, 5 Dec 2012

UE22EC342BA1:Computer Vision and Image Processing (4-0-0-4-4)

Course Description:

This course provides an introduction to computer vision including motion geometry, image and texture segmentation, symbolic representation, advanced segmentation, vision transformers and object recognition. This course requires the knowledge of Principles of Digital Signal Processing and Digital Image Processing.

Course Objectives:

- Toexpose students to advanced concepts of image processing.
- Toinvestigate current representations and methods in image processing such as wavelets and morphology.
- To understand algorithms for advanced image analysis like image compression, image reconstruction, image segmentation.
- To understand image processing based on Wavelets.
- To understand different approaches of object recognition.

Course Outcomes:

Students completing the course should be able to

- Compare and use different tools for image analysis in a transformed domain (wavelet vs. Fourier transform).
- Recognize and describe both the theoretical and practical aspects of computing with images. Connect issues from Computer Vision to Human Vision.
- Get exposures to advanced concepts leading to object recognition and vision transformers.
- Show how higher-level image concepts such as edge detection, segmentation, representation can be implemented and used.

Course Content:

Unit 1: Motion Geometry: 2D transformations, 3D transformations, 3D rotations, 3D to 2D projections, Lens Distortions, Camera Calibration, Introduction to stereo Imaging, Epipolar Geometry, Structure from Motion, Stereo matching

14 Hrs

Unit 2: Image segmentation: Introduction, Classification of image Segmentation techniques, Region approach-segmentation, Clustering techniques, Segmentation based on thresholding, Watershed transformation, Edge based segmentation, Classification of edges, Edge detection, Edge Linking, Hough Transform, Shape representation.

14 Hrs

Unit 3: Wavelets and Wavelet based Compression: Introduction, Evolution of wavelet transform, 2D continuous wavelet transform, discrete wavelet transform, Multi resolution analysis, Examples of wavelets, Wavelet based image compression.

14 Hrs

Unit 4: Applications of Computer Vision and Image Processing: Object Recognition-Approaches to object recognition,Vision transformers:Case Study – Paper1: Attention is all you need, Paper 2: An image is worth 16x16 words: Transformers for image recognition at scale, basics of video processing and applications

14 Hrs

Textbook:

1. "Computer Vision: Algorithms and Applications", RichardSzeliski, Springer Science & Business Media, 2010.
2. "Digital Image Processing", R. C. Gonzalez and R. E. Woods, 4th Edition, Pearson Education Limited,2018.

Reference Books:

1. "Feature Extraction & image Processing for Computer Vision", Mark S. Nixon, Alberto S. Aguado, Elsevier.
2. "Computer Vision & Image Processing – Fundamentals and Applications", Manas Kamal

Bhuyan, CRC Press, 2020.
3. “Digital Image Processing”, S Jayaraman, S Esakkirajan and T Veerakumar, Mc Graw Hill, 2009.
4. “Digital Image Compression Techniques”, M. Rabbani and P W Jones, SPIE Press, 1991.
5. “A Wavelet Tour of Signal Processing”, S Mallat, Second Edition, Academic Press.
6. Dosovitskiy, A., “An Image is Worth 16x16 Words: Transformers for Image Recognition at Scale”, <i>arXiv e-prints</i>, 2020. doi:10.48550/arXiv.2010.11929.
7. Ashish Vaswani, Noam Shazeer, Niki Parmar, Jakob Uszkoreit, Llion Jones, Aidan N. Gomez, Łukasz Kaiser, and Illia Polosukhin, “Attention is all you need”, *In Proceedings of the 31st International Conference on Neural Information Processing Systems (NIPS'17)*, Curran Associates Inc., Red Hook, NY, USA, 6000–6010, 2017.

UE22EC342BC2: Reinforcement Learning (4-0-0-4-4)

Course Description:

This course aims to provide an introduction to reinforcement learning including the foundational Markov Decision Process and dynamic programming. The primary focus is on approximation methods for practical situations wherein no models are available. These include Monte Carlo, temporal-difference, Sarsa and Q-learning. For even larger spaces, value function and policy approximations are dealt with. This course requires the knowledge of Random Variables, and Random Processes.

Course Objectives:

- Formalise problems as Markov Decision Processes.
- Understand dynamic programming for problems.
- Understand model free tabular solution methods
- Understand different basic model free tabular solution method.
- Understand different approaches for model free tabular solution methods

Course Outcomes:

On successful completion of this Course, the students would be able to:

- Distinguish between RL from AI and other non-interactive learning.
- Formulate as a RL/ADP problem given an application.
- Design both model-based and model-free RL
- Implement algorithms for RL/ADP
- Describe the exploration versus exploitation aspect of RL.

Course Content:

Unit 1:

Finite Markov Decision Process: Agent-environment interface, Goals and rewards, Returns, Episodic Tasks, Markov Property, Markov Decision Process, Value Functions, Optimal Value Functions, Optimality and approximation, Bellman Equation, Examples

Dynamic Programming: Policy**,** Policy Evaluation, Policy Improvement and iteration, Value iteration, Asynchronous dynamic programming, Generalised policy iteration, Efficiency of dynamic programming, Examples.

8 + 8 = 16 Hours

Unit 2:

Monte Carlo-Method: Monte Carlo prediction, Monte Carlo estimation of Action Values, Monte Carlo Control, Examples.

Temporal Difference Learning: Temporal-difference prediction, Advantages of TD Prediction, Optimality of TD (0), Sarsa: On-Policy TD Control, Q-learning: Off-Policy TD Control
n-step TD prediction, Examples, Python Code for SARSA & Q Learning.

6 + 6 = 12 Hours

Unit 3:

Approximate Solution Methods: Value Prediction with Function Approximation, Gradient Descent Methods, Linear Methods, Control with Function Approximation, Actor Critic Methods, Python Coding, Introduction to Deep Reinforcement Learning using Python coding.

Multi-Arm Bandit: n-arm Bandit, Exploration vs Exploitation, Upper Confidence Bound, Thompson sampling, Examples.

8 + 6 = 14 Hours

Unit 4:

Formulation of an RL Problem: An asset selling problem, Adaptive market planning, Stochastic shortest path problems Static, Stochastic shortest path problems Dynamic, Ad-click optimization, Revenue management for hotels.

14 Hours

Text books:

1. R.S. Sutton and A. G. Barto (2018), Reinforcement Learning: An Introduction, MIT Press, 2nd edition.
2. Warren B. Powell, *Sequential Decision Analytics and Modeling: Modeling with Python* , now, 2022.

Reference books:

1. W. B. Powell (2011), Approximate Dynamic Programming: Solving the Curses of Dimensionality, Wiley Series in Probability and Statistics, John Wiley & Sons.

2. C. Szespesvari (2010), Algorithms for Reinforcement Learning,Morgan and Claypool, 2010.
3. D. P. Bertsekas (2012), Dynamic Programming and Optimal Control, Vol 2: Approximate Dynamic Programming, 4th edition, Athena Scientific.

UE22EC343BA1: 5G & 6G Technologies (4-0-0-0-4)

Course Description:
A development of the fifth generation of mobile networks can be regarded as a mix of evolutionary advances in 4G LTE through LTE-A and new radio technology likely operating in newly allocated spectrum bands. It is pertinent to understand the 5G cellular concepts as the widespread implementation has already begun. As a new generation of cellular technology typically appears every 8–10 years, 6G can be expected around 2030. 6G could offer high-fidelity holograms, multisensory communications, Terahertz (THz) communications, and pervasive artificial intelligence. The idea of this syllabus is to explore the evolution from 5G towards 6G from a service, air interface, and network perspective.

Course Objectives:
- To introduce concepts of 5G with respect to Release 15
- To introduce the technologies that enhance the 5G Radio and Network Architectures
- To introduce 6G use cases and its enabling technologies
- To introduce the advanced concepts related to 6G technologies

Course Outcomes:
Students completing the course should be able to
- Understand the 5G technology and its components
- Understand the advanced technologies used in the 5G Radio Interface
- Understand the need for 6G for future use cases
- Understand the intersection of next generation technologies with 6G

Course Content:

Unit 1: Fifth Generation Cellular Communication – Major usage scenarios of 5G system – Device Requirements – Capabilities of 5G – Spectrum Consideration - 5G Technology Components -Technologies to Enhance the Radio Interface – Advanced MCS, NOMA, 3D Beamforming, MU-MIMO, Massive MIMO, Wireless Self-backhauling -Technologies to Enhance Network Architectures- SDN, Cloud RAN**,** Network Slicing, SON

14 hours

Unit 2: 5G Systems -

5G System Architecture **–** 5G Standalone System Architecture – Network Slicing Support, 5G NR - System Architecture (Release 15) – Network Interfaces – Radio Protocol Architecture– 5G NR Frame structure, Physical resources, Frames and Sub-Frames, Physical Resources, NR Dual connectivity - E-UTRA and NR MR-DC

14 hours

Unit 3: 6G Part I

6G Use cases, requirements, metrics - Emerging applications of 6 G – KPI Targets of 6G – Performance Metrics 6G Enabling Technologies –- Challenges in Physical Layer Design – Reconfigurable Intelligent Surfaces (qualitative treatment only) - Challenges in Transport Layer Design—Resource Allocation in 6G Optical Wireless systems

14 hours

Unit 4: 6G Part II

Millimetre wave and Tera Hertz Spectrum for 6G – Propagation impairments – Beamforming and Antenna Patterns (mm wave) – Channel Models - Machine Type Communications in 6G – Edge Intelligence in 6G – Cloudified RAN in 6G – Federated Learning in 6G networks – BlockChain & 6G – Open Issues of 6G

14 hours

Text Book:

1. Alexander Kukushkin, "Introduction to Mobile Network Engineering: GSM, 3G-WCDMA, LTE and the Road to 5G", Wiley Telecom, 2018.

2. Yulei Wu,Sukhdeep Singh,Tarik Taleb,Abhishek Roy,Harpreet S. Dhillon, Madhan Raj Kanagarathinam Aloknath De, “6G Mobile Wireless Networks” Springer

Reference Book:

1. TBA

UE22EC343BA2: Satellite Communication(4-0-0-0-4)

Course Description:

Satellite Communication finds application in fixed point-to-point, broadcasting, mobile, radio navigation, data relay, computer communication systems. The rapid growth in satellite communication has created a need for accurate information on satellite communication system engineering, and impact of atmosphere on satellite link design and system performance. This course aims at addressing the above need.

Course Objectives:

- Understand different satellite orbits and the related challenges
- Understand the satellite segment and earth segment
- To be aware of different satellite networks and applications
- Understand the steps involved in launching and maintenance of a satellite

Course Outcomes:

Students completing the course should be able to

- Appreciate the challenges associated with different types of satellites
- Understand the satellite transmission impairments
- Perform link budget analysis
- Enumerate the steps involved in developing a new application of satellite

Course Content:

Unit-I: Orbital Mechanics & Satellite Systems:

Kepler's Laws, Newton's Law, Orbital Parameters, Orbital Perturbations, Station Keeping, Geo Stationary and Non Geo-Stationary Orbits – Look Angle Determination - Limits of Visibility – Eclipse - Sub Satellite Point – Sun Transit Outage - Launching Procedures - Launch Vehicles and Propulsion, INTELSAT Series, INSAT, VSAT, Mobile Satellite Services: GSM, GPS, INMARSAT, LEO, MEO, Satellite Navigational System. GPS Position Location Principles, Differential GPS, Direct Broadcast satellites (DBS/DTH).

14 hours

Unit 2: Space Segment& Propagation Effects:

Spacecraft Technology - Structure, Primary Power, Attitude and Orbit Control, Thermal Control and Propulsion, Communication Payload and Supporting Subsystems, Telemetry, Tracking and Command – Transponders - The Antenna Subsystem, Atmospheric Absorption, Cloud Attenuation, Tropospheric and Ionospheric Scintillation and Low angle fading, Rain Induced attenuation, rain induced cross polarization interference.

14 hours

Unit 3: Earth Station & Link Budget Analysis:

Transmitters, Receivers, Antennas, Tracking systems, Terrestrial Interface, Power Test methods, Lower Orbit Considerations, Altitude and orbit control system, TT&C Sub-System, Altitude control Sub-System, Power Systems, Communication Subsystems, Satellite antenna Equipment, Basic transmission theory, system noise temperature and G/T ratio, Basic Link Analysis, Interference Analysis, Design of satellite links for specified C/N, (with and without frequency Re-use), Link Budget Calculation.

14
hours

Unit 4: Multiple Access & Packet Communication:
Frequency Division Multiple Access(FDMA), Intermodulation, Calculation of C/N. Time Division Multiple Access(TDMA), Frame structure, Burst structure, Satellite Switched TDMA Onboard processing, Demand Assignment Multiple Access (DAMA) – Types of Demand Assignment, Characteristics, CDMA Spread Spectrum Transmission and Reception. Message Transmission by FDMA: M/G/1 Queue, Message Transmission by TDMA, PURE ALOHA-Satellite Packet Switching, Slotted Aloha, Packet Reservation, Tree Algorithm. Low Throughput Systems and Small Satellites, NGSO Satellite Systems, Direct Broadcast Satellite Television and Radio.

14
hours

Text Book:

1. Gerard Maral, Michel Bousquet, et al., "Satellite Communication Systems: Systems, Techniques and Technology", 6th Edition, Wiley, 2020, ISBN-13: 978-1119382089
2. Timothy Pratt, and Jeremy Allnutt, "Satellite Communications", 3rd Edition, Wiley, 2019, ISBN-13: 978-1119482178

UE22EC343BB1: Non-linear Optics and Quantum technology

Course Description:
The progress of Optical science gave rise to the vast field of photonics, which in turn has today facilitated the growth of the superset of electronics and photonics, i.e., quantum technology. Photonics can be broadly classified as linear and non-linear. Non-linearity in optics started as a vice, but ended up producing many marvels. Are Qubits, the basic units of Quantum technology related to Non-linear optics? The present course can give an answer to the intuitive question.

Course Objectives:
The present course is so designed as to:

- Provide students an introduction to non-linear optics principles;
- To understand basic waveguide interactions through coupled wave analyses;
- To understand parametric optical applications;
- To introduce students to relevant computation;
- To introduce students to the qubits and related application in light of non-linear optics.

Course Outcomes:
Students who successfully complete the course will be able to:

- Have a good understanding of the contemporary optical non-linearity with computing basis;
- Understand the design basics in coupled wave analyses;
- Understand the transition of parametric device design;
- Understand how Qubits relate to Optical Non-linearity.
- Understand Quantum computing in light of recent research in non-linear optics.

Course Content:

Unit-1: Non-linear Optics: Linear and non-linear refractive-index, Dispersion, optical susceptibility, second and third order harmonic generation, non-linear optical combination effects, problem solving and computations.

14 Hours

Unit-2: Coupled Wave Analyses: Coupled wave theory, computation for simple optical guiding, parametric and non-parametric interactions, non-linearity in coupled mode analyses, simple problems and computations.
14 Hours

Unit-3: Optical phase and frequency conversion: Phase matching geometry, birefringent phase matching, Quasi-phase matching, waveguide phase matching, second harmonic generation in waveguide, Optical parametric amplification, frequency conversion, four-wave mixing.
14 Hours

Unit-4: Optical Non-linearity and Qubits: introduction to Qubits, Qubits generation by second order nonlinearity, Qubit limit of cavity non-linear optics, optical non-linearity in quantum entanglement, basic computations.Linear optical computing, Non-linear optics quantum computing with circuit QED.
14 Hours

Text Book:

Jia-Ming Liu, 2022, “Non-linear photonics,” Cambridge University Press.

References

- Published SCI journal papers

UE22EC343BB2: VLSI Circuit Testing and Testability (4-0-0-4-4)

Course Description:

This course deals with digital VLSI Circuit testing, which is an integral part of IC design andmanufacturing. The topics discussed are: Importance of VLSI Testing, Test process and AutomaticTest Equipment, Defects versus Fault Models, Fault Simulation, Logic Simulation, CombinationalCircuit Testing, Sequential Circuit Testing, Memory Testing, and Design-for-Testability, Scan Design,Boundary Scan, Built-in-Self Test and Delay Test. This course requires the knowledge of Digital Design using HDL.

Course Objectives:

- This course aims at demonstrating the concepts of Digital Testing and applying the various teststrategies to VLSI circuits.
- Introducing the Automatic Test Pattern Generation (ATPG) Algorithms
- The theory connected with memory testing, scan testing and other topics will be explored.
- This course will cover VLSI testing techniques such as VLSI fault modelling (stuck-at-fault,delay fault), automatic test generation, memory testing, and design for testability (DFT).
- VLSI scan testing and built-in self-test (BIST) will also be covered. Students will learnvarious VLSI testing strategies and how to design a testable VLSI circuit.

Course Outcomes:

Students completing the course should be able to:

- Apply various VLSI testing methodologies for digital circuit and develop fault models/ testing strategies
- Develop various ATPG Algorithms for Stuck at fault and Delay fault.
- Design for testability (DFT) circuits and taxonomy of DFT circuits.
- Built-in self-test (BIST) both logic BIST and Memory Testing with BIST.
- Boundary scan and Low-power Testing using test compression and response compaction

Course Content:

Unit 1: Introduction to Testing and Verification and ATPG:
Introduction to testing: need for testing, Testing Philosophy, Role of Testing,
Fault Modelling: Defects, Errors, Faults Functional Versus Structural Testing,Levels of Fault Models, A Glossary of Fault Models, Single Stuck-at Fault, and Fault Equivalence,Equivalence of Single Stuck-at Faults Fault Collapsing, Fault Dominance and Checkpoint Theorem.
Definition of Automatic Test-Pattern Generator: Search Space Abstractions, Algorithm Completeness, ATPG Algebras, Algorithm Types, and Redundancy Identification (RID), Boolean Difference Method. **15 Hours**

Unit 2: Combinational,Sequential ATPG, and Delay Test:
Combinational ATPG Algorithms: D-Calculus and D-Algorithm, PODEM. ATPG for Single-Clock Synchronous Circuits, A Simplified Problem Time-Frame Expansion Method, Use of Nine-Valued Logic, Development of Time-Frame Expansion Methods, Approximate Methods, Implementation of Time-Frame Expansion Methods, Complexity of Sequential ATPG.
Delay Test Problem: Path-Delay Test, Test Generation for Combinational Circuits, Number of Paths in a Circuit, Transition Faults, Delay Test Methodologies. **15 Hours**

Unit 3: DFT – Logic Built – In Self –Test &Memory Testing:
Design for Testability: DFT Architectures, BIST Design Rules, Test Pattern Generation, Output Response Analysis,Logic BIST Architecture.
Memory Testing: RAM Functional Fault Models and Test Algorithm, RAM Fault Simulation and Test Algorithm Generation, Memory Built-In Self-Test **14 Hours**

Unit 4: Low Power Test – Test Compression & Boundary Scan:
Low-power Testing: Test Stimulus Compression, Test Response Compaction, Industry Practices Introduction to boundary scan: Digital Boundary Scan (IEEE Std. 1149.1)**12 Hours**

Mandatory Experimental Demos:

1. ATPG generation for combinational logic using Modus or Tessent
2. DFT insertion for sequential logic using Modus or Tessent
3. ATPG generation for sequential logic using Modus or Tessent
4. JTAG FSM functional simulation using NcSim or Questasim
5. ATPG generation for Delay test

Text Book:

1. "Essentials of Electronic Testing for Digital, Memory, and Mixed-Signal VLSI Circuits", M.Bushnell and V. D. Agrawal, Kluwer Academic Publishers, 2005.
2. "VLSI Test Principles and Architectures", L T Wang, Cheng Wen Hu and Xiaoqing Wen, Morgan Kaufmann Publisher, 2006.

Reference Books:

1. "VLSI Testing: Digital and Mixed analogue/digital techniques", by Stanley L Hurst, Institution of Engineering and Technology, ISBN-10: 0852969015.
2. "Digital Systems Testing and Testable Design", M. Abramovici, M. A. Breuer and A. D. Friedman, IEEE Press, 1990.
3. "Digital Circuit Testing and Testability", P. K. Lala, Academic Press, 1997.

UE22EC343BB3: Analog and Digital Testing, Debug and Diagnosis (4-0-0-4-4)

Course Description:
This course deals with digital systems testing, which is an integral part of IC design andmanufacturing. The topics discussed are: Importance of VLSI Testing, Test process and AutomaticTest Equipment, Defects versus Fault Models, Fault Simulation, Logic Simulation, CombinationalCircuit Testing, Sequential Circuit Testing, Memory Testing, Design-for-

Testability, Scan Design,Boundary Scan, Built-in-Self Test and Delay Test.

Course Objectives:

- This course aims at demonstrating the concepts of Testing and applying the various teststrategies to VLSI circuits.
- The theories of memory testing, scan testing and other topics will be explored.
- This course will cover VLSI testing techniques such as VLSI fault modelling (stuck-at-fault,delay fault), automatic test generation, memory testing, design for testability (DFT).
- VLSI scan testing and built-in self-test (BIST) will also be covered. Students will learnvarious VLSI testing strategies and how to design a testable VLSI circuit.

Course Outcomes:

Students completing the course should be able to:

- Apply various VLSI testing methodologies for any digital circuit.
- Develop fault models, testing strategies for combinational/sequential circuits and memorycircuits.
- Perform delay testing, design for testability (DFT), built-in self-test (BIST) and boundary scan,effectively use the concepts for testing VLSI systems using existing test methodologies, toolsand equipment.

Pre - Requisite: Knowledge of Digital Design using HDL

Course Content:

Unit 1: Introduction to VLSI Testing and Basics of ATPG: The need for testing, Problems of digital, analog and mixed analogue/digital testing, economics of test, faults in digital circuits, controllability and observability, fault models. Test pattern generation for combinational logic circuits, Pseudorandom test pattern generation. **14 Hours**

Unit 2: Delay Test, Design for Testability and BIST: Basics of DFT, Scan cell designs, Scan architectures, Scan Design rules, Scan Design flows. Test pattern generation for sequential circuits, Exhaustive, non-exhaustive and pseudorandom test pattern generation, IDDQ and CMOS testing, Delay fault testing.

Logic BIST: BIST Design rules, Test pattern generation, Output response analysis, Logic BIST architectures. **15 Hours**

Unit 3: Analog Test: Introduction to Analog and Mixed signal circuits testing, Fault models of ADC and DAC, Calculation of INL and DNL, Amplifier testing, Amplifier fault models and testing. **13 Hours**

Unit 4: Test Compression and Test standards: Test Stimulus compression, Test response compaction, Introduction to Logic diagnosis. Industry practices: Mentor Graphics EDT and Synopsys Z-Scan, Test Standards: JTAG 1149.1 standard, IEEE 1500 SoC testing standard and IEEE 1687 on chip instrumentation standard or Internal JTAG (IJTAG),

Advances in Chip testing: Streaming Scan Networks, Silent Data Corruption, trade off between security and testing **14 Hours**

Mandatory Experimental Demos: -

1. ATPG generation for combinational logic using Modus or Tessent
2. DFT insertion for sequential logic using Modus or Tessent
3. MUX based Scan methods experiment.
4. LSSD based Scan method experiment
5. ATPG generation for sequential logic using Modus or Tessent
6. JTAG FSM functional simulation using NcSim or Questasim
7. ATPG generation for Delay test
8. Test Compression using Mentor Graphics Tessent Kompress
9. Test Compression -EDT.
10. Analog test pattern generation using Verilog AMS

Text Book:

1. "Essentials of Electronic Testing for Digital, Memory and Mixed-Signal VLSI Circuits", M.Bushnell and V. D. Agrawal, Kluwer Academic Publishers, 2005.

Reference Books:

2. "VLSI Testing: Digital and Mixed analogue/digital techniques", by Stanley L Hurst, Institution of Engineering and Technology, ISBN-10: 0852969015.
2. "VLSI Test Principles and Architectures, Design for Testability", Wang, Wu and Wen, Elsevier Publications-2011.

UE22EC343BB4: Semiconductor Devices and Fabrication (4-0-0-4-4)

Course Description: The course aims to equip ECE graduates with a solid foundation in semiconductor device fundamentals and device fabrication. Indian initiative in the semiconductor fab process is expected to generate a lot of opportunities for semiconductor and fabrication professionals. In this regard, it is expected that an ECE graduate be aware of the processes involved in semiconductor device fabrication.

Course Objective:

The course aims to:

- Introduce the students to the basics of semiconductor physics.
- The foundation on the governing equations of basic and common devices like pn junction, and BJT.
- Lays a strong foundation on the size effects and consequences
- Introduces the modelling of novel semiconductor devices and a strong sense of fabrication processes.

Course Outcomes:

Upon completion of this course, students should be able to:

- To understand clearly the basic principles of semiconductor devices
- To understand the properties of electrons in semiconductor devices.
- To understand various processes in device fabrication.

- To understand electronic and optoelectronic applications of semiconductor materials.
- To understand and implement device modelling using governing equations.

Course Contents:

Unit 1:Semiconductor Basics and Carrier Transport:
Charge carriers in semiconductors, Dopant atoms, and energy levels, Extrinsic semiconductors, statistics of donors and acceptors, Charge neutrality, and the position of Fermi level, Carrier Drift, Drift Current Density, Mobility Effects, Carrier Diffusion, Graded Impurity Distribution,The Hall Effect, Carrier Generation and Recombination, Characteristics of Excess Carriers,

14 Hours

Unit 2:The pn-junction:
Structure of pn junction, unbiased, forward and reverse biasing, small signal model, generation and recombination current, Schottky barrier diode, Metal-semiconductor ohmic contact, Heterojunctions, Solar and photodiodes. BJT-Basic operations and modes, Transistor effect, gain, and switching

14 Hours

Unit 3:Device simulation:
Classical device simulation based on Monte Carlo, Boltzmann transport equation; drift-diffusion, etc. Small size effects on transport in devices; Quantum Transport Models, NEGF, Scattering Matrixwith examples, Use of Comsol and other software tools for the device simulation (uses of these tools to solve the monte carlo, transport, and diffusion equation hands-on experience).

14 Hours

Unit 4: Fabrication Processes:
oxidation, diffusion ion implantation, lithography, and thin film deposition techniques Device fabrication examples: pn junction, MOSFET fabrication, and IC process flow. Wafer Technology, Deposition, Fabrication, Etching, Packaging, Fab Processing, Hands-on session with PCB as the substrate.

14 Hours

Textbook:

1. Semiconductor physics and devices, Donald A Neaman McGraw-Hill 4^{th} edition, 2012
2. Semiconductor device fundamentals, Robert F Pierret, Pearson, 1996

Reference books:

1. Advanced Theory of Semiconductor devices, Karl Hess, PHI, 2000
2. Transport in Nanostructures, Ferry Goodnick and Bird 2^{nd} Edition, Cambridge UP, 2009
3. Semiconductor device physics and design, Umesh Mishra and Jasprit Singh, Springer 2008
4. VLSI Fabrication Principles S K Gandhi, John Wiley and sons,

UE22EC343BB5: Memory Design and Testing (4-0-0-4-4)

Course Objectives:

- Impart an understanding of the working principles of conventional semiconductor memories in the design of electronic circuits.
- Introduce various non-conventional memories and their working
- Provide a basic understanding of memory faults and testing
- Introduce the concepts of built-in-self test for embedded memories

Course Outcomes:

At the end of the course, students should be able to

- Analyze and comprehend the research work currently being done in this area.
- Design and implement memory arrays using different types of memory cells.
- Implement and develop new testing algorithms
- Develop projects based on the different concepts studied in this course.

Course Content:

Unit1: Semiconductor Memory Technologies Overview: Introduction to Memory Hierarchy, Data Explosion to Zetta-scale, Memory Hierarchy in the Memory Sub-system, Introduction to Memory Array Architecture, Generic Memory Array Diagram, Memory Cell Size and Equivalent Bit Area, Memory Array's Area Efficiency, Peripheral Circuits: Decoder, MUX, and Driver, Sense Amplifier, Industry Technology Scaling Trend
Static Random Access Memory (SRAM): 6T SRAM Cell Operation, SRAM Stability Analysis
14 Hours

Unit2: Static Random Access Memory (SRAM): SRAM's Leakage, Variability and Reliability, SRAM Layout and Scaling Trend, **CAM:** CAM topology, Binary CAM, Ternary CAM
In Memory Computing: What is In-Memory Computing, Simple Logic gate Implementation using 6T SRAM
14 Hours

Unit 3: Dynamic Random Access Memory (DRAM): DRAM Overview, 1T1C DRAM Cell Operation, DRAM Technology, DRAM Scaling Trend, Stacked DRAM, Embedded DRAM. Simple Logic gate Implementation using 1T1C DRAM
Flash Memory: Flash Overview, Flash Device Physics, Flash Array Architectures
Emerging Non-volatile Memories: eNVM Overview, Phase Change Memory (PCM), Resistive Random Access Memory (RRAM), Magnetic Random Access Memory (MRAM), Ferroelectric Memories
14 Hours

Unit4: Memory Testing: Memory Faults: General Fault Modelling, Read Disturb Fault Model, Precharge Faults, False Write Through, Data Retention Faults, Decoder Faults; Memory Patterns: Zero-one, Exhaustive Test, Walking, Marching and Galloping, Common Array Patterns, Common March Patterns, CAM Patterns.
Design for Test: Weak Write Test Mode, Bit Line Contact Resistance, PFET Test, Shadow Write and Shadow Read.
Memory Self-Test: BIST Concepts: The memory boundary, Deterministic BIST, Pseudo-

random BIST; BIST and Redundancy- Redundancy types, Hard and Soft Redundancy, Redundancy calculation. BIST using BILBO; Memory Error Detection and Correction Techniques. Memory reliability; Power dissipation in Memories. **14 Hours**

Text Books:

1. **"**Semiconductor Memory Devices and Circuits" **", Shimeng Yu, 1st Edition., CRC Press 2022.**
2. **"High-Performance Memory Testing: Design Principles, Fault Modeling and Self Test", R.Dean Adams, Kluwer Academic Publishers, 2003.**
3. **"DRAM Circuit Design: Fundamental and High-Speed Topics",Brent Keeth, R. Jacob Baker, Brian Johnson, Feng Lin 2E, Wiley - IEEE Press, 2007.**

Reference books:

1. "Semiconductor Memories- Technology, Testing and Reliability", Ashok K. Sharma, PHI, 2004.

UE22EC343BC1: Deep Learning (4-0-0-4-4)

Course Description: This course gives a conceptual introduction to Machine Learning and Deep Learning. It covers majorly topics in neural networks.

Course Objectives:

- To make students know an in depth understanding of neural networks along with the mathematical notions associated with deep learning.
- To give the students a perspective into deep learning applications.
- To give students a perspective into modelling a deep network.
- To make students understand the difference between using deep learning libraries as a black box versus the theory behind such networks.

Course Outcomes:

- Students will get a mathematical background of deep learning.
- Students will appreciate the difference between programming and theory.
- Students will be able to apply different algorithms to practical scenarios.
- Students will understand the need for theoretical knowledge.
-

Course Content:

Unit 1: Deep Feedforward Networks and Convolutional Networks: Introduction**,** Architecture Design, Back Propagation and Other Differentiation Algorithms, The Neuroscientific Basis for Convolutional Networks, Invariance and Equivariance, The Convolution Operation, Motivation, Pooling, Convolutional Networks for 1D inputs, Convolutional Networks for 2D inputs, Downsampling and Upsampling.

14 Hours

Unit 2: Regularization for Deep Learning: .Parameter Norm Penalties, Dataset Augmentation, Noise Robustness, Semi-Supervised Learning, Early Stopping, Sparse Representations, Bagging and Other Ensemble Methods, Dropout.

14 Hours

Unit 3: Recurrent Neural Networks and Autoencoders: Recurrent Neural Networks, Deep Recurrent Networks, The Long Short-Term Memory and other Gated RNNs, Undercomplete Autoencoders, Regularized Autoencoders, Representational Power, Layer Size and Depth, Stochastic Encoder and Decoders, Denoising Autoencoders, Applications of Autoencoders.

14 Hours

Unit 4: Applications of Deep Learning: Large scale deep learning, Computer vision, speech recognition, Natural Language processing, Other applications.

14 Hours

Text Books:

1. Goodfellow, Ian, Yoshua Bengio, and Aaron Courville. *Deep learning*. MIT press, 2016.

2. Simon J.D. Prince, Understanding Deep Learning. MIT press 2023.

Reference Text Book

1. Bishop, Christopher M. *Pattern recognition and machine learning*. Vol. 4. No. 4. New York: springer, 2006.

UE22EC342BC2: Robotic Systems (4-0-0-4-4)

This course covers the robot mechanics, kinematics, trajectory planning and interfaces of robotic systems in a formal mathematical framework. Beginning with the representation of rotational and rigid body motions, topics range from forward and inverse kinematics to the path and trajectory planning of manipulators and mobile robots, and includes the study of sensors, actuators and various application of robotic systems.
The Robot Operation Systems (ROS) will be the platform used for practical understanding and will be taught during AHP sessions. Gazebo, Moveit, RVIZ etc will be introduced.

Course Objectives:

- Develop skills in performing spatial transformations associated with rigid body motions.
- Understand kinematic analysis of manipulators.
- Understand the path and trajectory planning of robots
- Understand use of sensors and actuators as robotic system interfaces
- Understand mobile robots, their perception, locomotion, kinematic analysis, localization and navigation

Course Outcomes:

On successful completion of this Course, the students would be able to:

- Apply spatial transformation to describe the kinematics.
- Evaluate the inverse kinematics of manipulators.

- Explain the principles of path planning and design of trajectory tracking
- Understand the working of sensors and actuators in the design of Robotic motion
- To understand difference between manipulators and Mobile Robots

Course Content:

Unit 1: Robot Mechanics
Modeling of robots, Robot Configuration Space, classification of robotic manipulators, Robotic system, accuracy and repeatability, wrists and end effectors, kinematic arrangement of manipulators, point and vector representation in 2D and 3D coordinate system, Two- link planar robot

13 Hours

Unit 2: Manipulator Kinematics

Rigid Body Motion – translational and rotational matrices, Euler Angles, Homogeneous transformations, Forward kinematics: DH parameters, Assigning coordinate frames, inverse kinematics, kinematic decoupling, Manipulator Jacobian

15Hours

Unit 3: Path and Trajectory Planning and Interfaces
Path and trajectory planning, Joint Space Trajectory Planning, Cartesian Space Trajectory Planning, Point to point planning, Continuous path generation and curve fitting
Interfaces: Actuators - Hydraulic & Electric Actuators, Sensors - Encoders, Tactile Sensors, Visual Sensors, Sonic Sensors, Gyros, GPS

15 Hours

Unit 4: Mobile Robots
Locomotion, Kinematics, perception, Localization and SLAM, Kalman Filter for SLAM, Visual SLAM, navigation and path planning

13 Hours

Text Book:

1. M. W. Spong, S. Hutchinson and M. Vidyasagar (2020), *Robot Modeling and Control,* 2nd edition, John Wiley.
2. Roland Siegwart, Illah R. Nourbakhsh, and Davide Scaramuzza (2011), *Introduction to Autonomous Mobile Robots,* 2nd edition, The MIT Press Cambridge, Massachusetts London, England

Reference Books:

1. Saeed B Niku (2020), *Introduction to Robotics: Analysis, Control and Applications,* 3rd edition, John Wiley
2. Gerald Cook, Feitian Zhang (2020), Mobile Robots: Navigation, Control and Sensing, Surface Robots and AUVs, Second Ed., Wiley-IEEE Press.
3. John Craig, Introduction to Robotics: Mechanics and Control, ISBN-13: 978-0133489798, Pearson; 4th edition, 2017.

4. Robot Operating System (ROS): http://wiki.ros.org/ROS/Tutorials
5. ROS2 tutorials: https://docs.ros.org/en/foxy/Tutorials.html