B.TECH IN ELECTRONICS AND COMMUNICATION ENGINEERING
III SEMESTER (2021-25 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	UE21EC251A	Analog Circuit Design	4	0	2	4	5	FC	Mentor Graphics Tanner Tools 2020.1 Version/ Cadence Virtuso
2	UE21EC252A	Computer Aided Digital Design	4	0	2	4	5	FC	Xilinx Vivado 2018 Version, Quartus Prime Lite
3	UE21EC241A	Mathematics for Electronics Engineers	4	0	0	4	4	FC	Matlab R2020a +
4	UE21EC242A	Network Analysis and Synthesis	4	0	0	4	4	FC	Matlab /PSPICE/ QUCS
5	UE21EC243A	Signals and Systems	4	0	0	4	4	FC	Matlab R2020a +
6	UE22MA101A	Bridge course Mathematics-I (Applicable to Lateral Entry Students)	2	1	0	2	0	AC	
		TOTAL	20 / 22	0 / 1	4	20/ 22	22		

IV SEMESTER (2021-25 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	UE21EC251B	Digital VLSI Design	4	0	2	4	5	CC	Mentor Graphics Tanner Tools 2020.0/Cadence Virtuso
2	UE21EC252B	Principles of Digital Signal Processing	4	0	2	4	5	CC	Matlab R2020a +/ Code Composer Studio
3	UE21EC241B	Control systems	4	0	0	4	4	CC	Matlab R2020a +
4	UE21EC242B	Digital Communication	4	0	0	4	4	CC	Matlab
5	UE21MA241B	Linear Algebra	4	0	0	4	4	FC	Matlab R2020a +
6	UE22MA101B	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 (2020-24 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	UE20EC301	Computer Communication Networks	4	0	2	4	5	CC	Wireshark, GNS3, Python
2	UE20EC302	RISC-V Architecture	4	0	2	4	5	CC	codasip
3	UE20EC303	Electromagnetic Field Theory	4	0	0	4	4	CC	Matlab R2020a +
Elective- I									
4	UE20EC311	Information Theory	4	0	0	4	4	EC	MATLAB

		and coding							
5	UE20EC312	Optical Fiber Communication	4	0	0	4	4	EC	MATLAB
6	UE20EC313	Digital System Design	4	0	0	4	4	EC	Cadence NcSim Version 2020.1
7	UE20EC314	Linear Integrated Circuits	4	0	0	4	4	EC	SPICE Package
8	UE20EC315	Electronic Device Automation – Verilog to Routing	4	0	0	4	4	EC	VTR, Vivado HLS, Open lane
9	UE20EC316	Chip level Photonics	4	0	0	4	4	EC	CST Tools
10	UE20EC317	Digital Image Processing-1	4	0	0	4	4	EC	Matlab R2020a +/ Scilab/Python
11	UE20EC318	Pattern classification	4	0	0	4	4	EC	Matlab R2020a +
12	UE20EC319	Statistical Signal Processing	4	0	0	4	4	EC	Matlab R2020a +
Elective – II									
13	UE20EC321	Wireless Communication	4	0	0	4	4	EC	MATLAB
14	UE20IE301	Operations Research	4	0	0	4	4	EC	MATLAB
15	UE20EC323	Real Time Operating Systems	4	0	0	4	4	EC	Free RTOS
16	UE20EC324	Quantum Entanglement and Quantum Computing	4	0	0	4	4	EC	Python (latest ed) and Comsol (ver 5 and above)
17	UE20EC325	Data Converters	4	0	0	4	4	EC	Cadence Virtuoso 2020.1
18	UE20EC326	Functional and Formal Verification of Digital Designs	4	0	0	4	4	EC	Cadence Jasper 2020.1 Version
19	UE20EC326 A	Verification of Digital Systems	4	0	0	4	4	EC	Cadence NcSim 2020.1 Version
20	UE20EC327	Artificial Neural Networks	4	0	0	4	4	EC	Matlab R2020a +/ Tensorflow
21	UE20EC328	Multirate System and Filter Banks	4	0	0	4	4	EC	Matlab R2020a +
22	UE20EC329	Linear Systems	4	0	0	4	4	EC	Matlab

									R2020a +
TOTAL			**20**	**0**	**4**	**20**	**22**		

ELECTIVES TO BE OPTED FOR SPECIALIZATION			
Sl. No.	**SPECIALIZATION**	**ELECTIVE – I**	**ELECTIVE – II**
A	Communication Systems	UE20EC311, UE20EC312	UE20EC321, UE20IE301, UE20EC327
B	VLSI Design	UE20EC313, UE20EC314 UE20EC315, UE20EC316	UE20EC323, UE20EC324, UE20EC325, UE20EC326, UE20EC326A
C	Signals and Systems	UE20EC317, UE20EC318 UE20EC319	UE20EC327, UE20EC328, UE20EC329
Note: Prerequisite course: Nil			

VI SEMESTER (2020-24 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	UE20EC351	Waveguides and Antennas	4	0	2	4	5	CC	Feko, Matlab
2	UE20EC352	Machine Learning and Applications	4	0	2	4	5	CC	Python,Matlab R2020a +
3	UE20EC353	Computer Architecture	4	0	0	4	4	CC	Cadence NcSim 2020.1 Version
4	UE20EC390A	Project Work-Phase-I	0	0	4	2	2	PW	
Elective – III									
5	UE20EC331	Networking Optimization	4	0	0	4	4	EC	CPLEX, CVXPY, Python
6	UE20EC332	Wireless Networking Fundamentals	4	0	0	4	4	EC	Matlab
7	UE20EC333	Memory Design and Testing	4	0	0	4	4	EC	Cadence Virtuoso 2020.1 Version
8	UE20EC334	Quantum Transport and Logic gates	4	0	0	4	4	EC	Python (latest ed) and Comsol (ver 5 and above)
9	UE20EC335	Synthesis,Physical	4	0	0	4	4	EC	Cadence EDA tools:

		design and Timing Analysis of Digital Circuits							Tempus, Genus 2020.1 Version
10	UE20EC336	RF Microelectronics	4	0	0	4	4	EC	Cadence Virtuoso 2020.1
11	UE20EC337	Speech processing	4	0	0	4	4	EC	Matlab R2020a +, Python
12	UE20EC338	Detection and Estimation	4	0	0	4	4	EC	Matlab R2020a +(SP, Com, Statistics and ML toolboxes), Python
13	UE20EC339	Robotic Systems	4	0	0	4	4	EC	ROS,Gazebo,MoveIt
Elective – IV									
14	UE20EC341	Cryptography	4	0	0	4	4	EC	MATLAB
15	UE20EC342	Mobile, Multimedia and Security	4	0	0	4	4	EC	Wireshark
16	UE20EC343	MIMO Communication	4	0	0	4	4	EC	MATLAB
17	UE20EC344	Testing of VLSI Circuits	4	0	0	4	4	EC	Cadence Modus Set 2020.1
18	UE20EC345	Low Power VLSI	4	0	0	4	4	EC	Cadence Low Power Tools Set 2020.1
19	UE20EC346	Architectures for Hardware Acceleration	4	0	0	4	4	EC	Xilinx Vivado/HLS 2018.1
20	UE20EC347	Analog and Digital Testing, Debug and Diagnosis	4	0	0	4	4	EC	Cadence
21	UE20EC347A	Non-linear Optics and Quantum technology	4	0	0	4	4	EC	Matlab
22	UE20EC348	Digital Image Processing-2	4	0	0	4	4	EC	Matlab R2020a +Scilab/Python
23	UE20EC349	Reinforcement Learning	4	0	0	4	4	EC	Matlab R2020a +
24	UE20EC349A	Adaptive Systems	4	0	0	4	4	EC	Matlab R2020a +
		TOTAL	**20**	**0**	**8**	**22**	**24**		

ELECTIVES TO BE OPTED FOR SPECIALIZATION

Sl. No.	SPECIALIZATION	ELECTIVE – III	ELECTIVE – IV

A	Communication Systems	UE20EC331, UE20EC332, UE20EC338	UE20EC341, UE20EC342, UE20EC343, UE20EC349
B	VLSI Design	UE20EC333, UE20EC334, UE20EC335, UE20EC336	UE20EC344, UE20EC345, UE20EC346, UE20EC347, UE20EC347A
C	Signals and Systems	UE20EC337, UE20EC338 UE20EC339	UE20EC348, UE20EC349, UE20EC349A
Note: Prerequisite course: Nil			

VII Semester (2019-23 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	UE20EC390B	Project Work-Phase-II	0	0	12	6	6	PW	
2	*	Special Topic/Swayam/MOOC	6	*	*	6	6	ST/SW/MC	
		Total	**6**	**0**	**12**	**12**	**12**		

VIII Semester (2019-23 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	UE20EC390C	Project Work-Phase-III	0	0	4	2	2	PW	
1	UE19EC491X/ UE19EC400X/ UE19EC400SX/ UE19EC400MX	Internship/Special Topic/ Swayam/Mooc/Study Abroad**	6	*	*	*	6	ST/SW/MC	
	Total		6	*	*	*	8		

Note:

1. 2 weeks of internship = 1 credit. UE19EC491A- 2-credit internship, UE19EC491B-4-Credit internship, UE19EC491C-6-credit internship.
2. The list of Courses Offered by Department /Swayam/Mooc courses will be notified by the department.

ELECTRONICS AND COMMUNICATION ENGINEERING

B. TECH. in Electronics and Communication Engineering

Program Educational Objectives

- Train and prepare students to be Electronics and Communication engineering professionals, strong and sound in fundamentals of science and engineering that facilitate innovative skills and strategies to help solve problems of industry and society.

- Facilitate students to be conversant in design, development, and implementation skills through application of technologies related to Electronics and Communication, in a sustained manner.

- Prepare graduates to pursue professional ethics in all their endeavours, adapt well to perform their roles as an individual, team-member, leader and possess good communicative skills that help foster sound inter-personal relationships in their engagement in industry and society.

- Motivate students in identifying various specialization available in the field of Electronics and Communication engineering and facilitate their further growth in the chosen domain with relevant elective modules.

- Orient students for graduate studies, pursue research-oriented career, entrepreneurship, and secure befitting placements in industries, with required competence.

Program Outcomes

1. **Engineering knowledge:** Apply mathematical and theoretical principles in the modelling and design high-quality electronic systems using state-of-the-art technology.
2. **Problem analysis:** Conduct in-depth study of research literature in the area of Electronics & Communication and analyze problems in order to arrive at substantiated conclusions using first principles of math and allied sciences.
3. **Design/development of solutions:** Design, implement, and evaluate electronic systems and processes that meet partial/complete specifications with concern for society, environment, and culture.
4. **Conduct investigations of complex problems:** Design and conduct experiments, collect data, analyze and interpret the results to investigate complex engineering problems.
5. **Modern tool usage:** Apply state-of-the-art techniques and modern software and hardware tools in prediction, comparison and modelling of complex engineering activities
6. **The engineer and society:** Have sound understanding of professional, legal, security and social issues and responsibilities in Engineering actives
7. **Environment and sustainability:** Understand Societal and Environmental concerns and demonstrate responsibility in sustainable development of solutions
8. **Ethics:** Be aware of ethical and professional responsibilities in engineering situations; make informed judgments regarding intellectual property and rights in relation to technical solutions in global, economic, environmental, and societal contexts.
9. **Individual and team work:** Able to function effectively in teams to establish goals, plan tasks, meet deadlines, manage risk and produce high-quality technical solutions

10. **Communication:** Contribute and communicate effectively with the society, be able to write effective reports and design documents by adhering to appropriate standards, make effective presentations, give and receive clear instructions
11. **Project management and finance:** Apply skills in clear communication, responsible teamwork, and time management by, for example, managing a team or project and communicating with external stakeholders.
12. **Lifelong learning:** Recognize the need for and demonstrate an ability to engage in continuing professional development in its broadest sense

UE22EC141A: 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: Introduction to electronics and semiconductor diodes:
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.
Demo: Active and passive components, Multi-meter, CRO.

10 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 **11 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

12 Hours

Unit 4: 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;

Introduction to Communication Systems: Electronic Communication systems, Modulation and Demodulation. Fundamental Concepts of Cellular Telephone, Frequency Reuse, Co-channel Interference, Roaming and hand- offs;

Demo: Different Modulation Techniques.

12 Hours

Unit 5: 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 Interface.

ARM Processor Fundamentals: ARM core dataflow model, Registers, Current Program Status Register;

Demo: Simulation of Data Transfer and Arithmetic operations.

10 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

UE21EC251A: Analog Circuit Design (4-0-0-4-4)

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 applications of BJT amplifiers.
- 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

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.

Course Content:

Unit 1

Physics of MOS Transistor: 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

10Hours

Unit 2:

CMOS Amplifiers: General Considerations, 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

12 Hours

Unit 3:

CMOS Current Mirrors and CMOS Differential Amplifiers: Basic Current Mirrors, Cascode 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

12 Hours

Unit 4:

Frequency Response and Feedback Amplifiers: Frequency Response: Miller Effect, Common source stage; Feedback: General considerations, properties of negative feedback, types of amplifiers, feedback topologies **11 Hours**

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Unit 5:

Bipolar Amplifiers and Power amplifiers: Bipolar Amplifiers**:** General Considerations , Operating Point Analysis And Design**,** Bipolar Amplifier Topologies- Common-Emitter Topology**,** Power Amplifiers**:** General Considerations, Emitter Follower As Power Amplifier, Push-Pull Stage, Improved Push-Pull Stage. **10 Hours**

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

UE21EC252A: Computer Aided Digital Design (4-0-0-0-4)

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, Timing.

12 Hours

Unit 2: Hardware Description Language 1: Introduction, Data Types, Combinational Logic, Structural Modelling.

10 Hours

Unit 3: Sequential Logic Design: Introduction, Latches & Flip Flops, Synchronous Logic Design, Finite State Machines. Timing of Sequential Logic, Parallelism.

11 Hours

Unit 4: Hardware Description Language 2: Sequential Logic, More Combinational Logic, Finite State Machines, Parameterized Modules, Testbenches. 1

12 Hours

Unit 5: Digital Building Blocks: Introduction, Arithmetic Circuits, Number Systems (fixed and floating point), Sequential Building Blocks, Memory Arrays, Logic Arrays.

10 Hours

Text Book:

1. "Digital Design and Computer Architecture", David Money Harris and Sarah L Harris, Elsevier, 2 nd Edition, 2019.

UE21EC241A: 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.
- Analyse problems of continuous random variables.
- Apply multiple random variable concepts.
- Analyse random process.

Course Content:

Unit1: 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. **12 Hours**

Unit2: Series, Residues,Probability and Discrete Random Variables: Series of complex terms-Taylor's series and Laurent's series, Singularities, poles, Residues. Cauchy's Residue theorem and application problems. 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. **12Hours**

Unit3: Continuous Random Variables: Introduction, distribution and density function of continuous random variable, Uniform, Rayleigh, Exponential and Gaussian distribution. Expectation, moment and probability generating function. Characteristic function. Transformation of random variables, conditional density and distribution function.

10 Hours

Unit4: Multiple Random Variables: 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.

11 Hours

Unit5: Random Processes: Random processes: 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.

10 Hours

Text Books:

1. *Advanced Engineering Mathematics by Erwin Kreyszig, John Wiley & Sons, 10th Edition, 2015.*
2. Miller. S and Childers, “Probability and Random Processes: With Applications to Signal Processing and Communication”, 2nd Edition, Elsevier India.

UE21EC242A: 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: Introduction to 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

11 Hours

Unit 2: Network theorems

Superposition theorem, Thevenin's theorem, Norton's theorem, Maximum power transfer theorem, Millman's theorem, Substitution theorem and Reciprocity theorem, Applications

10 Hours

Unit 3: Transients analysis

(i) RC transients: Storage cycle, Initial values, Instantaneous values, Application; (ii) RL transients: Storage cycle, Initial values, Instantaneous values, Application; (iii) Circuit analysis in s-domain: Philosophy of Laplace transform, Properties, Partial Fraction expansion, Initial value and final value, Transformed circuit, Application of Thevenin's theorem

12 Hours

Unit 4: System analysis

Configurations, Two port parameters – Impedance, Admittance, Hybrid, Transmission, Relationship between parameters, Interconnection of two port networks

11 Hours

Unit 5: Synthesis

(i) Elements of realizability: Causality and stability, Hurwitz polynomial, positive real functions, elementary synthesis procedures; (ii) 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

11 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

UE21EC243A: 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 understand linear time invariant system.
- To provide visualization of Fourier series of periodic signals.
- To understand the basics concepts of Fourier transform
- To understand the existence of poles and zeros in z-domain

Course Outcomes:

Students completing the course should be able to

- Represent signals and perform basic operations on signals.
- Analyse LTI systems
- Determine Fourier representations for continuous-time and discrete-time signals.
- Analyse signals and systems using Fourier transformation techniques.
- Apply the unilateral Z transform .

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.

12 Hours

Unit 2: 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)

10 Hours

Unit 3: 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- 4: 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**.**

11 Hours

Unit 5: Z-transformation: The Z-transform, The region of convergence (ROC) for the Ztransform, 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.

10 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).

UE21EC251B: Digital VLSI Design (4-0-0-4-4)

Course Description:

This course deals with analysis and design of digital CMOS integrated circuits emphasizing fundamentals in addition to new models that students need to master as per industry requirements and constraints. The course emphasizes on basic theory of digital circuits, design principles and techniques for digital design blocks implemented in CMOS technology. Knowledge of Analog Circuit Design, Digital Design using HDL is required for this course.

- This course aims at learning VLSI design methodologies and inverter characterization with different loads.
- Layout design for different circuits will be explored.
- To understand interconnects and their characteristics
- This course will also cover switching characteristics of digital circuits along with delay and power estimation.
- Understanding the CMOS sequential circuits and memory design concepts.

Course Outcomes:
Students completing the course should be able to

- understand designing of combination and sequential blocks using MOSFET
- understand digital functionalities using different technologies like CMOS, BiCMOS etc.
- appreciate the importance of interconnects in VLSI layouts.
- construct Layout with design rule constraints and understand the standard cell concepts.
- understand designing digital blocks with design constraints such as propagation delay and dynamic power dissipation.

Course Content:

Unit 1: Introduction MOS Inverters (Static Characteristics):
VLSI design Methodologies and Design Flow, Introduction to inverters, Resistive-Load Inverter, Inverters with n-Type MOSFET Load and CMOS Inverter, Numerical,Introduction, Bipolar Junction Transistor Structure and Operation, Basic BiCMOS Circuits: Static Behaviour, BiCMOS Applications. **12 Hours**

Unit 2: Fabrication of MOSFETs and Layout Design Concepts: Introduction, Fabrication Process Flow: Basic Steps, The CMOS nWell Process, Layout Design Rules, Full-Custom Mask Layout Design. Combinational Logic Circuits and Layout: NAND2 gate and NOR2 gate, Boolean functions of multiple input variables. Semi-custom and Full-Custom, MOSFET Scaling and Small geometry Effects and Scaling models. **12 Hours**

Unit 3: Switching Characteristics and Interconnect Effects:
Introduction, Delay-Time Definitions, Calculation of Delay Times, Inverter Design with Delay Constraints, Estimation of Interconnect Parasitic, Calculation of Interconnect Delay, Switching Power Dissipation of CMOS Inverters. **10 Hours**

Unit 4: Sequential MOS Logic Circuits:
Introduction, Behaviour of Bi-stable Elements,The SR Latch Circuit, Clocked Latch and Flip-Flop

Circuits, CMOS D-Latch and Edge-Triggered Flip-Flop, Sequencing static circuits, Sequencing Methods, Max-Delay Constraints, Min-Delay Constraints, Time Borrowing, Clock Skew, Problems on Max and Min Delay Constraints at design level. **11 Hours**

Unit 5: Dynamic Logic Circuit:
CMOS Transmission Gates (Pass Gates), Synchronous Dynamic Circuit Techniques, High Performance CMOS Dynamic circuits, Domino Logic.
Semiconductor Memories:
Introduction, Static Read-Write Memory (SRAM) Circuits, Dynamic Read-Write Memory (DRAM) Circuits. **10 Hours**

Text Book:

1. Sung-Mo (Steve) Kang, Yusuf Leblebigi, "CMOS Digital Integrated Circuits Analysis and Design", Tata McGraw-Hill Education, 2003.
2. Neil Weste and David Harris," CMOS VLSI Design", Pearson Education, 3rd Edition, 2006.

UE21EC252B: Principles of Digital Signal Processing (4-0-0-4-4)

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.

12 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 DFT in linear filtering: overlap-save and overlap-add methods.

10 Hours

Unit 3: 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, linear phase, group delay.

10 Hours

Unit 4: 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.

11 Hours

Unit 5: 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. 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.

UE21EC241B: 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 and state space representation) 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 systems.
- To design simple compensators in the frequency domain and to design controller and observers in the state-space domain.

Course Outcomes:

Students completing the course should be able to

- Apply Laplace transform and state space techniques to model dynamic systems, and convert between these formulations
- 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 feedback controllers using root locus, Nyquist and Bode techniques

Course Content:

Unit 1:Mathematical Models of 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

12 Hours

Unit 2: Feedback Control System Characteristics: 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

10 Hours

Unit 3: The Performance of Feedback Control Systems: Introduction, 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, Introduction to controllers, PD controller, PI and PID controllers

10Hours

Unit 4: 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,Introduction, Concept and the Root Locus technique. Frequency Response methods:

Introduction, Frequency Response Plots, Bode Diagram, and Performance Specifications in the Frequency Domain. **11Hours**

Unit 5: Stability in the Frequency Domain: 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. **12Hours**

Text Books:

1. "Modern Control systems", R.C. Dorf and R.H. Bishop, 12th Edition, Prentice hall, 2011.

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, 2010.
3. "Control Systems Engineering," N. Nise, Wiley India, 2018.

UE21EC242B: Digital Communication (4-0-0-4-4)

Course Description:

This course provides a comprehensive treatment of the physical layer aspects of practical communication systems. It covers topics from analog communication that are prerequisites for digital communication. It also covers sampling, quantization, pulse shaping and modulation techniques.

Course Objectives:

- Understand the principles of amplitude and angle modulation
- Learn the different sampling techniques
- Understand the performance of different waveform coding techniques
- Understand the idea of signal space
- Learn the different digital modulation techniques

Course Outcomes:

Students completing the course should be able to

- Analyze the different analog modulation techniques
- Analyze the different sampling techniques
- Design quantization and pulse shaping systems
- Develop detection rules for the given transmission scheme
- Analyze the different coherent and non-coherent digital modulation techniques

Course Content:

Unit 1: Amplitude and Angle Modulation

Amplitude Modulation: Double Sideband Suppressed Carrier Modulation, Generation of DSBSC Waves, Coherent detection of DSBSC Wave, Standard Amplitude Modulation, Generation of AM waves, Detection of AM waves. Hilbert Transform, Canonical description of Bandpass Signals and Systems. Angle Modulation: Frequency and Phase Modulation, Single tone frequency modulation, Narrowband FM.

11 Hours

Unit 2: Frequency Modulation and Sampling

Spectrum analysis of sinusoidal FM Wave, Generation of FM Waves, Demodulation of FM Waves: Balanced Frequency Discriminator. Sampling: Sampling Theorem, Quadrature Sampling of Band Pass Signals, Practical aspects of sampling and signal recovery. Sample and Hold circuit for signal recovery, Time Division Multiplexing.

11Hours

Unit 3: Quantization and Pulse Shaping

Pulse Code Modulation: Pulse Code Modulation, Quantization Noise and Signal to Noise ratio. Robust Quantization, Differential Pulse Code Modulation, Delta Modulation. Pulse Shaping: Discrete PAM Signals, Power spectra of Discrete PAM Signals.

11 hours

Unit 4: Intersymbol Interference and Signal Space Representation

Inter Symbol Interference, Nyquist criterion for Distortion less Baseband Binary Transmission, Eye diagram, Gram-Schmidt Orthogonalization Procedure, Response of Bank of correlators to noisy input. Detection of known signals in Noise, Maximum-likelihood Detector.

11 Hours

Unit 5: Digital Modulation Techniques

Matched filter Receiver. Digital Modulation Schemes: Coherent Binary PSK, Coherent Binary FSK, Coherent QPSK, Differential Phase Shift Keying, Quadrature Amplitude Modulation. Power spectra and bandwidth efficiency of digital modulation schemes.

11 Hours

Text Book:

1. "Digital Communication", Simon Haykin, *John Wiley & Sons, 2010*

Reference Book:

2. "Communication Systems" ,SimonHaykin, *John Wiley & Sons, 4th Edition, 2001.*

UE20EC301: Computer Communication Networks (4-0-0-4-4)

Course Description:

This course provides an in-depth overview of the workings of the internet, application-level architecture and protocols. A top-down approach is followed in understanding the roles played by different network components (e.g., switches and routers) and the end-user applications as the data is exchanged over the internet. A hands-on experience is provided to enhance the understanding of the protocols and network performance.

Course Objectives:

- The objective of this course is to give the students an in-depth understanding and hands on experience of internet protocols and algorithms.
- This course aims to enable the students to design simple computer networks.
- The course begins with an introduction to the internet architecture and service models. A top-down approach is followed to explain the complex operation of sending data from one host to another.
- The standard application protocols, transmission protocols, networking protocols and MAC layer protocols are covered.
- Understand multi-protocol routing label switching, Forwarding and routing.

Course Outcomes:

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

- Analyze the internet protocols related to the application layer, transport layer, network layer and link layer
- Design simple computer networks using GNS3 and analyze packet capture using Wireshark
- Implement routing algorithms, client and server socket programs
- Solve numerical problems and logical problems in the design of computer networks
- Apply networking concepts to simple projects in the computer networks

Course Content:

Unit 1: Introduction: (i) Introduction: Network edge (architecture, ISP and ISP hierarchy), Network core (architecture and switching techniques), Performance parameters (delay, packet loss, throughput), Concept of layer based communication (protocols, protocol stack, process communication and its types), (ii) Application layer protocols: Web and HTTP, Electronic email in the internet, DNS, (iii) Delay Analysis: P2P file distribution, Web-caching, Numerical problems in packet switched networks, Numerical analysis of applications

10 Hours

Unit 2: Transport Layer:(i) Introduction: Services, Sockets and socket programming, (ii) Connectionless transport: UDP segment format, checksum calculation, (iii) Principles of reliable data transfer: Stop and wait protocols, Pipelining, GBN and SR, (iv) TCP Reliable data transfer: Segment structure, seq. numbers and ack. numbers, packet loss, connection establishment and closing, timeout estimation and control, duplicate ACKs and retransmission, (iv) Congestion management with TCP: Network congestion detection, congestion control algorithm, Tahoe and Reno, Congestion at receiver and flow control (v) Numerical problems in TCP

11Hours

Unit 3: Network layer/Routing: (i) Internal organization of router, Functions of router, (ii) IPv4: Datagram format, datagram fragmentation, Addressing, sub-netting and super-netting, DHCP, NAT, (iii) IPv6 and ICMP: Addressing, datargam format, dealing with IPv4 routers (iv) Intra-AS routing: Dijkstra algorithm, Bellman-Ford Algorithm, Concept of Autonomous Systems, RIP, OSPF (Concept of Areas, Types of LSAs and Types of Packets), (v) Inter-AS routing: The Role of BGP, Advertising BGP Route Information, Determining the Best Routes, Routing policy

12 Hours

Unit 4: Link Layer: (i) Introduction: Role and importance of Link Layer, Error detection techniques, Basic random access techniques, (ii) Switched local area networks: MAC address, ARP, forwarding frames, Ethernet protocol and frame format, Ethernet flavours, Link layer switches, Virtual Local Area Networking, (iii) IEEE 802.11 wireless networks: Hidden node problem, Active/Passive Scanning, Architecture and MAC protocol

12 Hours

Unit 5: Miscellaneous / Advanced topics: Broadcast algorithms, Multicast algorithms, Multi-Protocol Label Switching, Forwarding and Routing: Traditional versus SDN approach, Generalized forwarding and SDN, SDN Control Plane, Network security – overview with examples

10 hours

Textbook:

1. "Computer Networking: A Top Down Approach", James F Kurose and Keith W Ross, 7^{th} Edition, Pearson Education, 2017.

Reference Books:

1. "Computer Networking: A Top Down Approach", James F Kurose and Keith W Ross, 6^{th} Edition, Pearson Education, 2013.
2. "Computer Networks", Andrew S. Tanenbaum, 4th Edition, Prentice Hall, 2003.
3. "Data and Computer Communications", William Stallings, 8^{th} Edition, Prentice Hall, 2007.

UE20EC302: RISC-V Architecture (4-0-0-0-4)

Course Description: This course gives the basic idea of RISC-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 provide a bridge between computer languages structure and RISC-V instructions.
- 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: Computer Abstractions and Technology: 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, Concluding Remarks. **11 Hours**

Unit 2: 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, Communicating the people. **12 Hours**

Unit 3:
RISC-V Addressing for wide immediate and addresses, Parallelism and Instructions: Synchronization, Translating and Starting Programs, A C Sort Example to put it All together, Arrays verses Pointers, Advanced Material: Compiling C and Interpreting Java, Real Stuff: MIPS Instructions, x86 Instructions, The Rest of RISC-V Instructions, Fallacies and Pitfalls, Concluding Remarks, **12 Hours**

Unit 4: Arithmetic for Computer: Introduction, Addition and Subtraction, Multiplication, Division, Floating Point, Parallelism and Computer Arithmetic: Sub word parallelism, Real Stuff, Streaming SIMD Extensions, Advanced Vector Extensions in x86, Going Faster: Subword parallelism and Matrix Multiply, Fallacies and Pitfalls. **10 Hours**

Unit 5: 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, Real stuff: ARM –A53 and Intel Core i7 Pipelines, Going Faster: Instruction Level Parallelism and Matrix Multiply, Advanced Topic, Fallacies and Pitfalls, Concluding Remarks **10 Hours**

Text Books:

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

Reference Text Book

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

UE20EC303 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-requisite Courses:** 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. **12 Hours**

Unit 2: Electrostatics (contd.) and Magnetostatics: Poisson's and Laplace's equation, one-dimensional solutions to Poisson's or Laplace's equation. 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. **12 Hours**

Unit 3: Maxwell's equations for time varying fields: Faraday's Law, transformer and motional electromotive forces, discrepancy in Ampere's Law, displacement current, Maxwell's equations for time varying fields and for sinusoidal variations. Boundary conditions, plane waves in free space, Wave propagation in lossy dielectrics: plane waves in lossless dielectrics, plane waves in good conductors, wave polarization. **12 Hours**

Unit 4: Transmission Lines: 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. **9 Hours**

Unit 5: Impedance Matching with Transmission Lines: 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.

10 Hours

Textbook:

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

Reference Books:

1. "Microwave Devices and Circuits", Samuel L. Liao, Third Edition, Pearson, 2006, **16th Impression 2019**.
2. "Electromagnetic waves and radiating systems", Edward C Jordan, Keith G Balmain, , 2nd Edition PHI, 2005.
3. "Engineering Electromagnetics", William H Hayt Jr, J.A. Buck, 8th Edition, Tata Mc Graw 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, 2nd Edition, Cambridge University Press, **2019**.
6. "Engineering Electromagnetics Essentials", B. N. Basu, 1st Edition, Universities Press, **2015**.

UE20EC311: Information Theory and Coding (4-0-0-0-4)

Course Description

This course covers the essential aspects of information theory and coding. Basic ideas of entropy and information, source coding and channel capacity are covered, with emphasis on intuitive understanding of the concepts. In coding theory, block codes, cyclic codes and convolutional codes are covered, along with the currently popular coding schemes like LDPC codes, rateless codes and polar codes.For this course knowledge of Digital Communication is required.

Course objectives

- Understand the idea of entropy and source coding

- Understand channel capacity
- Understand linear block codes
- Understand convolutional codes
- Understand advanced codes like LDPC codes, rateless codes and polar codes

Course Outcomes:

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

- Analyze a given source in terms of its information content
- Apply the theorems to find the capacity of practical channels
- Analyze the performance of linear block codes
- Analyze the performance of convolutional codes
- Analyze the performance of advanced codes

Course Content:

Unit 1: Basic Information theory:

Uncertainty, Information and Entropy, Joint Entropy, Conditional Entropy and Mutual Information. Source Coding: Kraft Inequality, Source Coding Theorem, Shannon-Fano Coding, Huffman coding.

12 Hours

Unit 2: Channel Capacity:

Discrete Memoryless channels, Channel Capacity, Channel Coding Theorem, Differential entropy and Mutual Information for Continuous Ensembles. Channel Capacity Theorem, Spectral efficiency.

11 Hours

Unit 3: Linear Block Codes:

Introduction to algebra. Methods of controlling errors, types of codes, types of errors. Linear Block Codes: Matrix description, Syndrome, minimum distance, error detection and error correction. Decoding using the Standard arrays; Cyclic codes: Encoding using an (n-k) bit shift register. Syndrome calculation, error detection and correction.

11 Hours

Unit 4: Convolutional Codes:

Time domain approach. Transform domain approach, Tree and Trellis diagrams, Maximum – Likelihood decoding of convolutional codes, The Viterbi Algorithm. Turbo codes.

11 Hours

Unit 5: Advanced Coding Techniques:

LDPC codes: General Description, Characteristics, Encoding and Decoding.Rateless codes: Raptor codes, coding for data storage. Polar codes.

10 Hours

Text Books:

1. “Channel Coding Techniques for Wireless Communications”, K. Deergha Rao, Springer, 2020

Reference Books:

1. “Error Control Coding”, Shu Lin & Daniel J. Costello, Second Edition, Pearson / Prentice Hall, 2004.
2. “Elements of Information Theory,” T. M. Cover and J. A. Thomas, Wiley Student Edition, Wiley India (P) Ltd., 2011.

UE20EC312: Optical Fiber Communication (4-0-0-4-4)

Course Description:

Optical fiber communication (OFC) has taken over trunk lines in established telephony for over a decade. Be it domestic telephone cables or trans-Atlantic communication for miles under-water, OFC has established its importance. Thus, the knowledge of today's communication technologists is incomplete without knowing OFC. The present course is designed to equip the student with details of light sources that generate the data in OFC, the analytical features of the fibers deployed and how digital communication thrives in the THz frequency zone. Further, knowing the networking strategies involved, the students will learn how communication is going beyond 5G with this phenomenal technology of 5G, providing a huge bandwidth to consumers. For this course knowledge of Engineering Physics is required.

Course Objectives:

- Understand why and how fibre optic communication is different from wired and/or wireless communication.
- Understand different optical sources
- Understand different optical detectors
- Understand operation of different optical receivers
- Learn to carry out Link Budget Analysis

Course Outcomes:

Students completing the course should be able to

- Identify the basic elements of optical fibre transmission.
- Able to choose an optical source for a given application
- Capable of deciding on an optical detector for a given application
- Analyse and select an optical receiver architecture for a given application
- Design an optical communication link

Course Content:

Unit 1: Overview of Optical Fiber Communication

Motivations for Lightwave Communications, Block Diagram of an Optical Communication System, Bit Rate, Bandwidth, Total Internal Reflection, Single Mode, Multimode Fiber Numerical Aperture, Acceptance Angle, Mode Theory of Optical Fibers, Cut Off Wavelength V Number, Material Dispersion, Waveguide Dispersion, Intermodal Dispersion, Pulse Spreading, Transmission bit rate/ transmission distance limitation due to dispersion, Fiber Losses **10 Hours**

Unit 2: Optical Sources

Parameters of a light source suitable for optical fiber communication, Direct Band gap material Indirect Band gap material, Heterostructures, Internal Quantum Efficiency, Materials used for LED, Emission Spectra, Fiber Coupling Efficiency, Semiconductor LASER, LASER Gain expression, how to guarantee temporal coherence, spatial coherence, Derivation of conditions for sustained oscillation, Fabry Perot Cavity spectrum, FSR, Ruby LASER, He-Ne LASER, Semiconductor LASER, L-I characteristic of LED, LASER, Biasing a LASER, Delay in LASER Relaxation Oscillation in LASER, Modulation Bandwidth of LED, LASER, Electrical Bandwidth, Optical Bandwidth. **11 Hours**

Unit 3: Optical Detectors & Optical Receiver Operation

Photodetector Parameters, Responsivity, Quantum Efficiency, PiN diode, APD, Current gain of APD, Sensitivity of Photodetector, Noise in Photodetector – shot noise, dark current noise, thermal noise, SNR calculation, Photodetector Response Time, Depletion width vs Response time tradeoff BER Calculation, Q value, Thermal Noise dominated regime, Shot Noise dominated regime, Scaling of SNR with incident optical power, Scaling of (PD) receiver sensitivity with supported bit rate, Derivation of shot noise variance, Quantum Limit. **12 Hours**

Unit 4: External Modulation & Coherent Receivers

LASER Receiver, Switch-On delay, Delay & bias point tradeoff, Relaxation Oscillation, RIN, Single Frequency LASER, DFB LASER, Phase Noise, Frequency Chirp, Coherent Communication, Direct Modulation, External Modulation, MZM Modulator, Generation of PSK, QAM symbols, Detector for PSK, QAM Symbols, Thermal Noise dominated regime, Shot Noise dominated regime, Coherent Receiver, SNR Analysis of homodyne receiver, SNR Analysis of heterodyne receiver. **12 Hours**

Unit 5: Optical Networks & Link Budget Analysis

Optical Coupler, Optical Amplifier Types, EDFA, Band Diagram, Basic applications and types of Optical amplifiers, Semiconductor Optical Amplifiers. Erbium doped fiber amplifiers, EDFA Small Signal Gain, ASE Noise, NF, NF for a cascade of EDFAs, Loss Budget, Rise Time Budget, Numerical, PON, Optical Networks: SONET / SDH, High speed light wave links, Optical Add/Drop multiplexing, optical switching, WDM Network examples. **10 Hours**

Text Book:

1. "Fiber – Optic Communication Systems", Govind P. Agarwal, 5th Edition, John Wiley and Sons, 2021.

Reference Books:

1. “Optical Fiber Communications”, Gerd Keiser , 4th Edition, TMH, 2008.
2. “Optical Fiber Communication”, John M. Senior, 2nd Edition, PHI, 1993.

UE20EC313: 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 design using Verilog.
- This course also equips the students to understand timing issues in design of digital circuits holistically.
- This course covers the ASIC design flow holistically
- This course intends students to understand clock domain crossing
- This course intends students to understand resets, metastability and pipelining.

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
- Understanding of ASIC design flow

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. **12 Hours**

Unit 2: Timing Conventions:
Skew and Jitter analysis, allowable clock rate, considerations in timing design, Timing Nomenclature, timing properties of delay elements, timing properties of combinational logic, timing properties of clocked storage elements, eye diagram, encoding aperiodic events, encoding periodic signals, On-chip clock distribution, Selected Topics in Verilog. **12 hours**

Unit 3: ASIC Design flow
Synthesis with constraints, Gate level simulation, Equivalence Checking, Semi-custom layout creation, timing and power analysis. **10 Hours**

Unit 4: Synchronizer Design
Mesochronous synchronizers, plesiochronous synchronizers, Periodic asynchronous synchronizers, General purpose asynchronous synchronizers, stoppable clocks, asynchronous

signalling protocols, Solutions to Clock domain crossing (CDC): Synchronous Clock Domain crossing, Handshake signalling method, Data transfer using synchronous FIFO, Asynchronous FIFO (or Dual Clock FIFO) **12 Hours**

Unit 5: **Resets and pipelining:**
Theory of Metastability, Metastability Window, Calculating MTBF, Avoiding Metastability, Metastability Test Circuitry, Reset Design Strategy, Reset Synchronizer, Reset Glitch filtering, Asynchronous Reset Removal, Pipelining, Performance Increase from pipelining. **9 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", Wiley Blackwell, ISBN-13: 978-0470185322, 2008.

References:

1. William J Dally, John W Poulton, "Digital Systems Engineering", Cambridge University Press, ISBN-10: 052106175X.
2. Mohit Arora, "The Art of Hardwre Architecture: Design Methods and Techniques for Digital Circuits", Springer-2012, ISBN-13: 978-1461403968.
3. 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.
4. Clifford E Cummings, ":Clock Domain Crossing (CDC) Design & Verification Techniques", http://www.sunburstdesign.com/papers/CummingsSNUG2008Boston_CDC.

UE20EC314: 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 Noise and Differential amplifier.

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.
- 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, Video Amplifiers, Low pass filter, High pass filter

10 Hours

Unit 2:

Single Supply Op Amp Design Techniques: Single Supply versus Dual Supply, Circuit Analysis, Simultaneous Equations, A Continuum of Applications, Noninverting Attenuator with Zero Offset, Positive Offset and Negative offset, Inverting Attenuation with Zero Offset, Positive Offset and Negative Offset **12 Hours**

Unit 3:

Development of the Nonideal Op Amp Equations: Introduction, Review of the Canonical Equations, Noninverting Op Amps, Inverting Op Amps, Differential Op Amps

Voltage 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 **12 Hours**

Unit 4:

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: Introduction, Precision, Bandwidth, Stability, Impedance, Equation Comparison **11Hours**
Unit 5:
Fully Differential Op Amps: Introduction, What Does Fully Differential Mean?,How Is the Second Output Used?, Differential Gain Stages, Single Ended to Differential Conversion, Working with Terminated Inputs, Conceptualizing the V_{OCM} Input, Instrumentation, Filter Circuits
Op Amp Noise Theory and Applications: Introduction, Types of Noise, Op Amp Noise **10 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

UE20EC315: 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 :
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.

10 Hours

Unit 2: High-level Synthesis:
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).

12 Hours

Unit 3: Logic Synthesis:
Scheduling (ASAP, ALAP, List scheduling), resource allocation. Technology-independent logic optimisations, data-flow and control flow transformations.

11 Hours

Unit 4: 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).

11 Hours

Unit 5: 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.

11 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

UE20EC316: 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: Introduction to Photonic basics : Basic design principles of optical waveguides, essential mode recognition and other photonic circuit components, essential maxwell equations and relation to electronics.

11 Hours

Unit2: Computational photonics: Basic FDTD and FDBPM techniques, 1D and 2D programming introduction, usage of diffraction and other relevant python packages.

12 Hours

Unit3: Introduction to planar components: Introduction to coupled mode theory, directional couplers, interferometers and resonators.

12 Hours

Unit4: Introduction to VLSI Photonics: Microresonators and metamaterials in VLSI photonic circuits.

10 Hours

Unit5: Wearable photonics – case study (adaptable with time): Multifunctional materials for wearable optics, integrated photonic sensors for wearables, wearable electronics and photonics comparison, wearable photonics in healthcare, review of current commercial players.

10 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

UE20EC317: Digital Image Processing-1 (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 with image restoration
- To understand color 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, Elements of Visual Perception. Image Sensing and Acquisition, Image Sampling and Quantization, Some Basic Relationships between Pixels, Linear and Nonlinear operations.

11Hours

Unit 2: Image Transforms:

2-D orthogonal and Unitary transforms, 1-D and 2-d DFT, Cosine, Sine, Hadamard, Haar, Slant, Karhunen-loeve, singular value Decomposition.

12 Hours

Unit 3: Image Enhancement in Spatial and frequency domains:

Basic Gray Level transformations, histogram processing, Enhancement using ALU operations, Basics of spatial filtering, smoothing spatial filters sharpening spatial filters. Image Enhancement in Frequency domain: Ideal low pass filters, Butterworth low pass filters, Gaussian low pass filters, Sharpening filters, Unsharp masking, High boost filtering, Notch filters, Homomorphic filtering.

12 Hours

Unit 4: 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, inverse and Wiener filtering, least square filters.

10Hours

Unit 5: Color image processing:
Color Fundamentals, Color Models, Pseudocolor Image Processing, Basics of Full-Color Image Processing, Color Transformations, Smoothing and Sharpening, Noise in Color Images.

10 Hours

Text Book:

1. "Digital Image Processing", R. C. Gonzalez and R. E. Woods, 4th Edition, Pearson Education Limited ,2018.

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.

UE20EC318: Pattern Classification (4-0-0-4-4)

Course Description:

This subject will introduce students to the fundamentals of Pattern Recognition and Pattern Classification. For this course knowledge of Linear Algebra, Mathematics for Electronics Engineers is required.

Course Objectives:

- To introduce the fundamentals of pattern recognition and classification.
- To understand parametric techniques.
- To understand different Non parametric techniques.
- To give knowledge on linear discriminant functions
- To understand unsupervised learning and clustering.

Course Outcomes:

Students completing the course should be able to

- Analyze the major concepts and techniques in pattern recognition.
- Acquire abilities to solve problems using parametric techniques.
- Analyze different non parametric techniques.
- Design models using different linear discriminant functions.

- Analyze unsupervised learning and clustering.

- Capable of designing pattern recognition systems and QAM

Course Content:

Unit 1: Introduction: Machine perception; example; pattern recognition systems; the design cycle; learning and adaptation.
Bayesian Decision Theory: Introduction; Bayesian decision theory – continuous features; minimum-error-rate classification; classifiers, discriminant functions, normal density; discriminant functions for the normal density; Bayesian decision theory – discrete features; missing and noisy features. **11 Hours**

Unit-2: Parametric Techniques: Maximum-likelihood estimation; Bayesian estimation; Bayesian parameter estimation: Gaussian case and general theory; problems of dimensionality; component analysis and discriminants; Hidden Markov models.
11 Hours

Unit 3: Non-parametric Techniques:
Density estimation; Parzen windows; kn-nearest-neighbour estimation; nearest-neighbour rule; metrics and nearest-neighbour classification; approximation by series expansions;
11 Hours

Unit 4: Linear Discriminant Functions:
Linear discriminant functions and decision surfaces; generalized linear discriminant functions; two-category linearly separable case; minimizing the perceptron criterion function; relaxation procedures; non separable behaviour; minimum squared-error procedures; Ho-Kashyap procedures; linear programming algorithms; support vector machines; multicategory generalizations;
12 Hours

Unit 5: Unsupervised Learning and Clustering:
Mixture densities and identifiability; maximum-likelihood estimates; application to normal mixtures; unsupervised Bayesian learning; data description and clustering; criterion functions for clustering; hierarchical clustering; on-line clustering; component analysis; low-dimensional representation and multidimensional scaling.
10 Hours

Textbook:

1. "Pattern Classification", Richard O. Duda, Peter E. Hart and David G. Stork, 2nd Edition, John Wiley, 2001.

Reference Books:

1. "Pattern Recognition and Image Analysis", EartGose, Richard Johnsonburg and Steve Joust, Prentice-Hall of India, 2003.
2. "Pattern Recognition and Machine Learning", Christopher M. Bishop, 3rd Edition, Springer, 2007.
3. "Statistical Pattern Recognition", Andrew R. Webb, 2nd Edition, John Wiley, 2002.

UE20EC319: Statistical Signal Processing (4-0-0-4-4)

Course Description: This subject introduces random processes, signal modelling techniques and adaptive filters. In addition, it introduces several methods for spectrum estimation and array processing. Knowledge of Principles of Digital Signal Processing, Mathematics for Electronics Engineers is required. For this course Knowledge of Principles of Digital Signal Processing, Mathematics for Electronics Engineers is required.

Course Objectives:

- To introduce the fundamentals of statistical signal processing.
- To understand the signal modelling.
- To give knowledge about Weiner filtering.
- To familiarize different approaches of spectrum estimation and
- To understand basics of array processing.

Course Outcomes:

Students completing the course should be able to

- Analyze problems in statistical signal processing
- Analyze the signal modelling techniques
- Implement Weiner filter and adaptive filters to suit specific requirements for specific applications.
- Compare the parametric and non-parametric methods of spectrum estimation
- Analyze array processing methods

Course Content:

Unit 1: Discrete-time Random Processes:
Random variables and processes, filtering random processes, spectral factorization, ARMA, AR and MA and harmonic processes.

10 Hours

Unit 2: Signal Modeling:
Least squares method, Pade approximation, Prony's method, finite data records, stochastic models. Levinson-Durbin recursion.

12 Hours

Unit 3: Wiener Filters:
FIR and IIR Wiener filters; discrete Kalman filter. **Adaptive Filters:** FIR adaptive filters (steepest descent and LMS)

12 Hours

Unit 4: Spectrum Estimation: Nonparametric methods, minimum-variance spectrum estimation, maximum entropy method, parametric methods, frequency estimation, principal components spectrum estimation.

11 Hours

Unit 5: Array Processing:
Array fundamentals, beamforming, optimum array processing, performance considerations, adaptive beamforming, linearly constrained minimum-variance beamformers, sidelobe cancellers, angle estimation, space-time adaptive processing.

10 Hours

Textbook:

1. “Statistical Digital Signal Processing and Modeling", Monson H. Hayes, John Wiley & Sons (Asia) Pvt. Ltd., 2002.

Reference Books:

1. "Statistical and Adaptive Signal Processing: Spectral Estimation, Signal Modeling, Adaptive Filtering and Array Processing", Dimitris G. Manolakis, Vinay K. Ingle, and Stephen M. Kogon, McGraw-Hill International Edition, 2000.

2. "Algorithms for Statistical Signal Processing", J.G. Proakis, C.M. Rader, F. Ling, C.L. Nikias, M. Moonen and I.K. Proudler, Pearson Education (Asia) Pvt.. Ltd, 2002.

3. "Adaptive Signal Processing", Bernard Widrow and Samuel D. Stearns, Pearson Education (Asia) Pvt. Ltd., 2001.

4. "Adaptive Filters", Simon Haykin, , 4th Edition ,Pearson Education (Asia) Pvt. Ltd, 2002.

UE20EC321: 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 networks. It covers radio propagation and fading models, fundamentals of cellular communications, multiple access technologies and various wireless networks, OFDM.

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 ta 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: Overview of Wireless Communication:
History, Wireless Vision, Technical Issues, Current Wireless Systems, Wireless Spectrum, Standards; Path loss and Shadowing: Radio Wave Propagation, Transmit and Receive signal models, Free-space path loss, Ray tracing, Emphericalpathloss models, Simplified path loss model, Outage probability under pathloss shadowing, Cell cover area.

12 Hours

Unit 2: Multipath models:
Time varying channel impulse response, Narrow band fading models, Wideband fading models

12 Hours

Unit 3: Access Techniques:
Multi-User DSSS systems, Multi-user FHSS systems; Multiuser Systems: Multiuser channels: uplink and downlink, Multiple Access: FDMA, TDMA, CDMA, SDMA, hybrid techniques

11 Hours

Unit 4: Cellular systems and Infrastructure based wireless networks:
Cellular system fundamentals, channel reuse, SIR and user capacity, Interference reduction techniques, dynamic resource allocation, Fundamentals and rate limits; Capacity of wireless channels: Capacity of AWGN, Capacity of Flat fading models, Capacity Vs Receiver diversity; Diversity: Realization of independent fading paths, Receiver diversity, Transmitter diversity

10 Hours

Unit 5: 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.

10Hours

Text Book:

1. "Introduction to Wireless Communications & Networks: A Practical Perspective", by K. Raghunandan, Springer, 2022
2. "Wireless Communications", Andrea Goldsmith, Cambridge University Press, 2011.

Reference Books:

1. "Wireless Communications: Principles and Practices", T. S. Rappaport, 2nd Edition, Prentice Hall, 2002.
2. "Fundamentals of Wireless Communications", David Tse and PramodVishwanath, Cambridge University Press, 2009.

UE20IE301: 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: Introduction:

Definition, scope of operations research approach and limitations of OR models, characteristics and phases of OR. Mathematical formulation of LP problems, graphical solutions.

11 Hours

Unit 2: Linear programming:

The Simplex method-slack, surplus & artificial variables, problems, Degeneracy, procedure to resolve degenerate cases, special case problems, Big-M method, concept of duality, Dual Simplex method.

12 Hours

Unit 3: Game theory and Queuing 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. Queuing system and their characteristics, M/M/I Queuing system, M/M/C Queuing model (numerical only, no derivation of relationship).

10 Hours

Unit 4: 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.

10 Hours

Unit 5: 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.

12 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, 2009-10

UE20EC323: 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: Introduction:
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.

10 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 .

12 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.

11 Hours

Unit 4: Memory:
Memory management Requirements,Memorypartitioning,paging ,segmentation.Virtual Memory, Hardware and control structures.

12 Hours

Unit 5: Real Time Systems:
Key characteristics of an RTOS, implementing Real time Operating systems, Lab related to free RTX(semaphore, message queues, Multithreaded applications)

10 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

UE20EC324:
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: Introduction to Quantum Tech:

Quantum and classical physics, Quantum mathematics: Hilbert space and wave functions, Dirac notations and Operators, Discrete and continuous base representations, Matrix form and wave mechanics, Basic postulates of Quantum Mechanics, implementation using Python (adaptable with time).

12 Hours

Unit 2: Quantum Entanglement background:

Geometry of probability distributions, spheres, complex projective spaces, coherent states and group action, space of density matrices, purification of mixed quantum states, Quantum operations, Duality; introduction to IBM/Microsoft Quantum computer environment (Bloch spheres)

10 Hours

Unit 3: Entanglement:

Discrete structures in Hilbert space, Density matrices and entropies, distinguishability measures, monotone metrics and measures, quantum entanglement; introduction to Qiskit and new Python Quantum libraries.

11 Hours

Unit 4: Quantum information:

Superposition, limits of local causality, Quantum measurement, probability, logic, interpretations of quantum mechanics, introduction to quantum information; implementation of quantum computing and studying Bloch spheres on Qiskit and Quantum computers.

12 Hours

Unit 5:Introduction to quantum computing:

Quantum search algorithms: Deustch- Jozsa, Berstein-Vazirani, Simon's, Quantum phase estimation, Shor's, Grover's, Grover-Radhakrishnan (partial Grover's), implementing entanglement and Quantum Fourier transform on FPGA (From Bhowmick Lab).

10 Hours

Textbooks:

1. "The mathematical language of quantum theory : from uncertainty to entanglement", TeikoHeinosaari, MárioZiman, Cambridge university Press, 2012.
2. "Geometry of Quantum States: An Introduction to Quantum Entanglement", Ingemar Bengtsson, Karol Życzkowski, Cambridge university Press, 2017.

Reference Books:

1. "Entanglement, information, and the interpretation of quantum mechanics", Gregg Jaeger, Springer-Verlag Berlin Heidelberg, 2009.
2. "Foundations of Quantum Programming", Morgan Kaufmann Publishers,MingshengYing, 2016.
3. "Coding Theory - Algorithms, Architectures, and Applications", Andre Neubauer, Jurgen Freudenberger, Volker Kuhn, Wiley-Interscience, 2007.

UE20EC325: Data Converters (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:

- Understanding the necessity of Data converters for different applications
- 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
- Introduction to Low Power ADCs

Course outcomes:

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

- Understand concept behind digital to analog and analog to digital conversion system
- Understand various architectures used in digital to analog and analog digital converters
- Compare various architectures in data converters
- Designing and simulation of data converters.

- 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. **10 Hours**

Unit-2 :**Sample and Hold Architectures :** Conventional open loop architecture, Conventional closed loop architecture, Open loop architecture with miller capacitance, Recycling architecture, Swichted Capacitor architecture, Current mode architecture. **12 Hours**

Unit-3:Basic Principles of Digital to Analog Conversion: General considerations, performance metrics, Reference multiplication and division, voltage, current and charge, switching functions in resistor ladder DACs, switching functions in current steering DACs, switching functions in capacitor DACs, Binary and thermal code conversion. **12 Hours**

Unit-4: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. **11 Hours**

Unit-5: Analog to Digital Converter Architectures : General considerations, performance metrics, flash architectures, two step architectures, interpolative and folding architectures, pipelined architectures, successive approximation architectures. **10 Hours**

Text Books:

1. 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

2. R Jacob Baker, "CMOS Mixed Signal Circuit Design" John Wiley and Sons

UE20EC326: 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. Formal Verification is important and mandatory process in chip design flow and this course deals with basics of mathematical algorithms used in FV tools and developing properties applying on the digital designs.

Course Objectives:

- To learn the need and applications of functional and formal verification of Digital VLSI design.
- To develop system Verilog Assertions.
- 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 and communication controllers.
- Able to write and apply the formal properties and constraints and analyze the design simulations 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: Knowledge of Digital Design is required.

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.

12 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:

Class, Objects, static and global variables, class methods, copying objects, dynamic objects, methods outside of the class, Pubic vs local variables. **11 Hours**

Unit -2 Experiments:

5. Simulation to demonstrate the class and variables

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 **12 Hours**

Unit -3 Experiments:

6. Simulation of immediate assertions
7. Simulation of Concurrent assertions
8. Simulation of Concurrent assertions: sequences and properties
9. Simulation of functional coverage using assertions

10. Formal verification with examples: elevator, FIFO, etc

Unit 4: Randomization: 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. **10 Hours**

Unit -4: Experiments

11. Simulations to improve Functional Coverage using Randomization
12. Simulation of pre-randomize and post randomization
13. Design Verification using assertions with randomization

Unit 5: Constructs for Automating the System Verilog Testbench: 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. **10 Hours**

Unit-5: Experiments:

14. Simulation to demonstrate complete layered testbench using SV constructs
15. Simulation to demonstrate the functioning of different constructs like clocking block, modport and interfaces.

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, Tom Schubert, M. V Achutha Kiran Kumar, 1st Edition, Morgan Kaufmann, August-2015

UE20EC326A: 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 importance of hardware verification languages (HVLs). The course describes the lexical elements of system Verilog and equip the students to create the layered testbenches for modern day complex digital designs in system Verilog.For this course knowledge of C-Programming, Digital Design & Computer Organization is required.

Course Objectives:

- Understanding the complexity of Digital verification
- Understanding the OOPS in System Verilog
- Understand and use the System Verilog 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 System Verilog 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: 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. and Void Functions, Task and Function Overview, Routine Arguments, Returning from a Routine, Local Data Storage, Time Values

12 Hours

Unit 2: Connecting The Test bench : 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, The ref Port Direction.
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

9 Hours

Unit 3:Randomization: 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.

10 Hours

Unit 4: 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 5: 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

12 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.

UE20EC327: Artificial Neural Networks (4-0-0-4-4)

Course Description:

This course introduces students to the basic concepts of Artificial Neural Network like supervised and unsupervised learning algorithms. This will help them in understanding how ANN 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
- Analyze the perceptron and single layer network.
- Analyze the significance of radial basis function networks.
- Analyze different learning process.
- Evaluate the practical considerations in applying neural networks in applications.

Course Content:

Unit 1: Introduction:

What is a neural network? Human brain; models of a neuron; neural networks as directed graphs; feedback; network architectures; knowledge representation. Linear Neuron: Adaptive filtering problem; unconstrained optimization techniques; linear least-squares filters; least-mean-square algorithm; learning curves; learning rate annealing techniques.

12 Hours

Unit 2: Perceptron: Single Layer:

Perceptron; perceptron convergence theorem; relation between perceptron and Bayes' classifier for a Gaussian environment. Multilayer: Preliminaries; back-propagation algorithm; XOR problem; heuristics for making the BPA perform better; output representation and decision rule; feature detection; back-propagation and differentiation; Hessian matrix; generalization; approximation of functions; cross-validation; network pruning techniques; virtues and limitation of back-propagation learning; accelerated convergence of back-propagation learning; supervised learning as an optimization problem.

12 Hours

Unit 3: Radial-Basis Function Networks:

Cover's theorem on the separability of patterns, interpolation problem, supervised learning as an ill-posed hyersurface reconstruction problem, regularization theory, regularization networks, generalized radial-basis function networks, XOR problem revisited, estimation of the regularization parameter, approximation properties of RBF networks, comparison of RBF networks and multilayer perceptrons; learning strategies.

12 Hours

Unit 4: Learning Processes:

Error-correction learning; memory-based learning; Hebbian learning; competitive learning; Boltzmann learning; credit-assignment problem; learning with and without a teacher. Principal Component Analysis: Some intuitive principles of self-organization; principal components analysis; Hebbian-based maximum eigenfilter; Hebbian-based principal components analysis.

9Hours

Unit 5: Self-Organizing Maps:

Feature-mapping models; self-organizing map; properties of the feature map; learning vector quantization; Recurrent Networks: Recurrent network architectures; state-space model; nonlinear autoregressive with exogenous inputs model; computational power of recurrent networks; learning algorithms; back-propagation through time; real-time recurrent learning. Applications of Neural Networks in Engineering.

10 Hours

Text Book:

1. "Neural Networks: A Comprehensive Foundation," S. Haykin, 2nd 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.

UE20EC328: Multi rate Systems and Filter Banks (4-0-0-4-4)

Course Description:

This subject introduces the basic concepts of multirate systems and filter banks. Here, students will get to learn digital filter design and multistage implementation of filters. DFT filter banks, quadrature mirror filter banks are also discussed in detail. This subject helps students in understanding the application of fundamental DSP concepts**.** Knowledge of Principles of Digital Signal Processing is required.

Course Objectives:

- To introduce design of digital filter
- To understand the fundamentals of multirate systems such as, interpolation and decimation.
- To learn the concepts of QMF filter banks.
- To understand maximally decimated filter banks.
- To familiarize with the para unitary perfect reconstruction filter banks.

Course Outcomes:

Students completing the course should be able to

- Design and development of digital FIR and IIR filters
- Design of interpolators and decimators
- Analyze QMF bank.
- Design and implementation of filters using multi-stage concept
- Explain the concepts of Filter Banks and Trans multiplexers

Course Content:

Unit 1: Digital Filters:

Specifications; FIR and IIR filter designs; all pass filters, special types of filters; IIR filters based on all pass filters

12 Hours

Unit 2: Fundamentals of Multirate Systems:

Basic multirate operations, interconnection of building blocks, polyphase representation, multistage implementation, special filters and filter banks; Interpolated FIR Filter Design.

12 Hours

Unit 3: QMF Filter Banks:

Errors created in the QMF bank, alias-free QMF system, power symmetric QMF banks

11 Hours

Unit 4: Maximally Decimated Filter Banks:

M-channel filter banks, polyphase representation, perfect reconstruction systems, alias-free filter banks, tree structured filter banks, transmultiplexers

10 Hours

Unit 5: Paraunitary Perfect Reconstruction Filter Banks:

Lossless transfer matrices, filter bank properties induced by paraunitariness, two channel paraunitary lattice, M-channel FIR paraunitaryQMF banks. Transform coding.

10 Hours

Text Book:

1. "Multirate Systems and Filter Banks", P.P. Vaidyanathan, Pearson Education. 2004.

Reference Books:

1. "Modern Digital Signal Processing", R. Cristi, Thomson Learning2004.
2. "Digital Signal Processing", Proakis and Manolakis, 4th Edition, Prentice Hall, 1996.
3. "Digital Signal Processing: A Computer Based Approach", S.K. Mitra, 4th Edition, Tata McGraw Hill, India.
4. "Wavelets and Filter Banks", G. Strang and T. Nguyen, Wellesley-Cambridge. 1996.
5. "Multirate Digital Signal Processing", N.J. Fliege, John Wiley, 2000.

UE20EC329 : LINEAR SYSTEMS (4-0-0-4-4)

Course Description:

This 4-credit course aims to expose the undergrad students into the field of Linear Systems from control system design perspective. The course starts with concept of State Space representation of LTI systems, both Continuous and Discrete time, followed by their analysis. Concepts of Controllability and Observability are also explained. The course culminates in the design of Controllers and Observers for such LTI systems for regulation and tracking.

Course Objectives:

- To familiarise the concepts of state variables and state-space representation for both continuous- and discrete-time linear systems.
- To understand Lyapunov Stability theorem
- To formulate state-variable representations of dynamical systems.
- Stability, controllability, observability of state-space realisations.
- To design state-variable feedback controllers, full-order and reduced-order observers, and observer-based compensators.

Course outcomes:

Students completing the course should be able to:

- Find state-space representations for both linear continuous- and discrete-time systems.
- Predict the controllability and observability properties of the different canonical forms.
- Use Lyapunov analysis to investigate the stability of state-space representations of dynamical systems.
- Evaluate the conditions for designing controllers.
- Design state-variable feedback controllers, full-order and reduced-order observers, and observer-based compensators.

Course content:

1. State Space Descriptions (Continuous-time and Discrete-time):

Concept of State Space; Modelling in State Space; State Space representation of LTI Continuous-time and Discrete-time systems – Canonical Forms; Transfer Functions / Pulse Transfer Functions from State Space Models.

12 Hours

2. **State Space Analysis (Continuous-time and Discrete-time):**

Eigen Values; Solution of State Space Equations; State Transition Matrix; Cayley – Hamilton Theorem; Discretization of Continuous-time State Space Equations; Lyapunov Stability Analysis.

12 Hours

3. **Controllability and Observability (Continuous-time and Discrete-time):**

Controllability and Observability; stabilisability and Detectability; Principle of Duality; Effects of discretisation of Continuous-time systems on controllability and observability.

12 Hours

4. **Control Systems design in State Space - 1 (Continuous-time and Discrete-time):**

Pole placement; Design of controllers using State feedback; State Observers; Full-order Observer; Separation Principle; Minimum / Reduced-order Observers; combined Controller – Observer structures.

10 Hours

5. **Control Systems design in State Space - 2 (Continuous-time and Discrete-time):**

Design of Servo Systems; Design of Regulator Systems; Design of Tracking Systems; Design of Quadratic Optimal Regulators

9 Hours

Pre-requisite: A fair knowledge of Signals & Systems, Control Systems and Linear Algebra.

Text Books:

1. "Modern Control Engineering", K. Ogata, PHI, 5th Edition,2010.
2. "Discrete Time Control Systems", K. Ogata, Pearson, 2nd Edition, 2015.

Reference Books:

1. "Linear Systems", T. Kailath, Prentice-Hall, 1980.
2. "Modern Control Systems Theory", M. Gopal, New Age International Publishers, 1993.
3. "Linear System Theory and Design", Chi-Tsong Chen, 2nd edition Holt, Rinehart and Winston, 1984.
4. "Linear Systems", Panos J. Antsaklis and Anthony N. Michel, Birkhauser, 2006.
5. "Modern Control Theory", William T. Brogan, 3rd Edition, Prentice-Hall, 1990.
6. "Linear System Theory", Wilson J. Rugh, 2nd Edition, Prentice-Hall, 1996.

UE20EC351: WAVEGUIDES AND ANTENNAS (4-0-0-4-4)

Course Description: This course deals with wave guides and gives an insight of wave propagation. It also delas with antenna which is essential element in the communication. For this course knowledge of Electromagnetic Fields and Transmission lines is required.

Course Objectives:

- The main objective of the course is to make the students to understand the fundamental concept of propagation and guiding of electromagnetic wave in wave guides and cavities.
- This course will help the students to apply the basic electromagnetic concepts to design basis antennas such as hertzian dipole.
- This course aims to give an in-depth understanding of different dipoles.
- Ability to understand the concepts and design different types of antenna arrays.
- This course is expected to help the students to apply the concepts of antenna design and perform simple experiments using Hardware/software.

Course Outcomes:
Students completing the course should be able to

- Analyse waveguides& cavities e.g., determine their cut-off frequency, resonance frequency, propagating modes and other
- Select the appropriate kind antenna from the radiation pattern and other characteristics, specifications.
- Design the appropriate kind of dipole antennas from the given requirements.
- Decide the type of array required for a given application.
- Analyse and design special antennas.

Pre-requisite- Nil
Course Content:

Unit 1: Waveguides and cavities

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, Characteristics of Standard rectangular Waveguides. Microwave Cavities: rectangular cavity resonator, Q factor of a cavity resonator.

12Hours

Unit 2: Hertzian Dipole

Magnetic vector potential, retarded potentials, relation between vector and scalar potential: Lorentz condition. Solution for inhomogeneous vector potential wave equation. Far field radiation. Infinitesimal current element (or Hertzian dipole): radiated fields, power density, radiation resistance, near field region, and intermediate field region, far field region.

10 Hours

Unit 3: Antenna parameters and finite length Dipole

Definitions of antenna parameters; radiation intensity, radiation pattern, directivity, gain, half-power beam width, input impedance. Friis transmission equation, Radiation integrals. Small dipole: region separation. Finite length dipole: current distribution, radiated fields, power density, radiation intensity and radiation resistance, directivity, input resistance, far field approximations. Half wavelength dipole.

10 Hours

Unit 4: Antenna Arrays

2 element array, pattern multiplication, N' element linear array: Array factor, uniform amplitude and spacing, broadside array, ordinary end-fire array, phased array N element linear array: uniform spacing and non- uniform amplitude, Array factor. Rectangular planar array: array factor. Grating lobes.

12 Hours

Unit 5: Special Antennas

Aperture Antennas: field equivalence principle, Sheet Current Distribution in free space, Radiation Pattern as Fourier Transform of Current Distribution, Microstrip Antenna, Horn Antennas, Reflector Antennas, Yagi Uda Array, Helical Antennas, Log Periodic Dipole Array.

11 Hours

Text Books:

1. “Electromagnetic Waves”, R.K.Shevgaonkar, 1st Edition, Tata McGraw Hill, 2006.

Reference Books:

1. “Antenna Theory Analysis and Design”, C.A.Balanis, 2nd Edition, John Wiley & Sons, 2000.
2. ”Antennas and Propagation”, A.R.Harish and M.Sachidananda, 1st Edition, Oxford University Press, 2007.

UE20EC352: 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 machine learning**,** review of mathematics for ML: Probability and Linear Algebra, 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, Assessing a Classification Algorithm's Performance, Comparing Two Classification Algorithms, Comparing Multiple Algorithms: Analysis of Variance, Comparison over Multiple Datasets, Multivariate Tests.

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.

12 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.

12 Hours

Unit 4: Kernel Machines: Introduction, Optimal Separating Hyperplane, The Nonseparable Case: Soft Margin Hyperplane, ν-SVM, Kernel Trick, Vectorial Kernels, Defining Kernels, Multiple Kernel Learning, Multiclass Kernel Machines, Kernel Machines for Regression, Kernel Machines for Ranking, One-Class Kernel Machines, Large Margin Nearest Neighbor Classifier, Kernel Dimensionality Reduction

9 Hours

Unit 5: 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.

10 Hours

Text Book:

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

Reference Books:

1. "Machine Learning", Tom M. Mitchell, McGraw Hill, 1997.
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.

UE20EC353: Computer Architecture (4-0-0-0-4)

Course Description: This course gives an idea of computer architecture. It covers memory hierarchy design. It gives an insight into different types of parallelism such as instruction level parallelism, 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: Introduction, Classes of Computers, Defining Computer Architecture, Trends in Technology, Trends in Power and Energy in Integrated Circuits, Trends in Cost, Dependability, Measuring, Reporting, and Summarizing Performance, Quantitative Principles of Computer Design, Putting It All Together: Performance, Price, and Power, Fallacies and Pitfalls

12 Hours

Unit 2: Memory Hierarchy Design: Introduction, Ten Advanced Optimizations of Cache Performance, Memory Technology and Optimizations, Protection: Virtual Memory and Virtual Machines, Crosscutting Issues: The Design of Memory Hierarchies, Putting It All Together: Memory Hierarchies in the ARM Cortex-A8 and Intel Core i7.

12 Hours

Unit 3: Instruction-Level Parallelism and Its Exploitation: Instruction-Level Parallelism: Concepts and Challenges, Basic Compiler Techniques for Exposing,Reducing Branch Costs with Advanced Branch Prediction, 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 Speculation2023.10Studies of the Limitations of ILP, Cross-Cutting Issues: ILP Approaches and the Memory System, Multithreading: Exploiting Thread-Level Parallelism to Improve Uniprocessor Throughput

11 Hours

Unit 4: Data-Level Parallelism in Vector, SIMD, and GPU Architectures .1Introduction, Vector Architecture, Instruction Set Extensions for Multimedia, Graphics Processing Units, Detecting and Enhancing Loop-Level Parallelism, Crosscutting Issues, Putting It All Together: Mobile versus Server GPUs and Tesla versus Core i7.

10 Hours

Unit5: 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: An Introduction, Crosscutting Issues, Putting It All Together: Multicore Processors and Their Performance

10 Hours

Text Books:

1. Computer Architecture: A Quantitative Approach by Hennessy and Patterson, 5th Edition

Reference Books:

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

UE20EC331 : 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: Introduction:
Review of linear algebra, Network design, Role of networking, Mathematical models, Steps for Network design, Optimization problem structure, types and complexity, Unconstrained optimization problems: single variable and multivariable solution methods, Introduction to solvers: CVXPY/CVX and CPLEX.

10 Hours

Unit 2: Linear and Integer Programming:
Standard form of LP, structural properties, Simplex method, Duality and Economic interpretation, Formulating and coding LP problems, Integer programming: Structure and Types, Formulating and coding IP problems, Branch and bound methods, Cutting plane method, MINLP to MILP conversion, Benders Decomposition.

12 Hours

Unit 3: Convex Optimization: Convexity, convex geometry, Convex functions, Lagrangian relaxation (LR and ALR) and Duality, KKT conditions, Formulating convex problems; Multi-objective problems; Convex relaxations: Semidefinite programming: Convex and Non-convex relaxations, Geometric programming, Interior point method

12 Hours

Unit 4: Stochastic Programming:
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, Solution methods - L-shaped method, PH algorithm and ADMM

11 Hours

Unit 5: Markov Decision Process:
Markov chains and Markov Decision processes, Formulating MDP, Bellman's optimality condition, Finite horizon problems: Dynamic programming, Infinite horizon problems: Value iteration and Policy iteration

10 Hours

Text Books:

1. "Convex Optimization", Stephen Boyd and L. Vandenberghe, 1st Edition, Cambridge University Press, 2004.

Reference Books:

1. "Introduction to Stochastic Programming", J. R. Birge and F. Louveaux, 2ndEdition, Springer Series in Operations Research and Financial Planning, 2011.

2. *"Reinforcement Learning:* An Introduction", *Richard S. Sutton* and Andrew G. Barto, 2nd edition, MIT Press , 2015
3. "Introduction to Applied Optimization", Urmila Diwekar, 2nd Edition, Springer, 2008
4. "Linear Algebra", Paul Dawkins, Lamar University, 2007.
5. "Operations Research –An introduction", Hamdy A Taha, 10th edition, Prentice Hall of India, private Ltd, 2019

UE20EC332: Wireless Networking Fundamentals (4-0-0-4-4)

Course Description: This course deals with concepts and challenges related to wireless communications and wireless networking. Various multiple access mechanisms used in different types of wireless communications and their comparison are covered for appreciating their suitability and relative merits. The course covers in-depth different IEEE 802.11 family of wireless local area networks standards and their chronological growth. Other wireless networking systems like Bluetooth, WiMAX and Zigbee are briefly introduced. Different generations of Cellular networks including a brief coverage of the 5G mobile communication systems are covered for understanding the incorporation of new technologies in every higher generation. The concept of Mobile IP and Mobile TCP to handle packet traffic in wide-area networks with mobility of nodes is discussed. Satellite-based wireless systems are unique in their characteristics due to the very nature of the satellite communication. The multiple access, latency, routing etc are covered in this course. Few software tools like Netspot, Wireshark, G-predict are familiarised to the students for reinforcing the understanding of the subject.

Course Objectives:

- To introduce important concepts and challenges of wireless channels, wireless networks, and wireless standards.
- To understand the various multiple access mechanisms used in different wireless networks and their need & relative merits/demerits.
- To familiarize physical and datalink layer of wireless local area networks and to appreciate the importance of functional block-diagram of mobile communication systems
- To study and understand the need and challenges of Mobile IP & Mobile TCP
- To understand and appreciate the characteristics and types of satellite communication systems

Course Outcomes:

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

- Appreciate the characteristics and challenges in designing a wireless communication system and network
- Appreciate the need, significance and difference between different multiple access mechanisms
- Analyze different wireless local area network standards and compute data rates
- Analyze the components of a satellite communication link
- Identify the improvements in different generations of mobile communication systems

Course Content:

Unit 1: Wireless Communication Technology: Antennas, Spectrum Considerations, Line-of-Sight Transmission, Fading in the Mobile Environment, Channel Correction Mechanisms, Digital Signal Encoding Techniques, OFDM, OFDMA, Single-Carrier FDMA, The Concept of Spread Spectrum, Frequency Hopping Spread Spectrum, Direct Sequence Spread Spectrum, Code Division Multiple Access
Tools:Matlab/Python

12 Hours

Unit 2: Wireless Local and Personal Area Networks: (i) IEEE 802.11 Architecture, IEEE 802.11 Architecture and Services, IEEE 802.11 Medium Access Control, IEEE 802.11 Physical Layer, Gigabit Wi-Fi, Other IEEE 802.11 Standards, IEEE 802.11I Wireless LAN Security, (ii) The Internet of Things, Bluetooth Motivation and Overview, Bluetooth Specifications, Bluetooth High Speed and Bluetooth Smart, IEEE 802.15
Tools: Wireshark and Netspot

10 Hours

Unit 3: Wireless Mobile Networks: (i) Principles of Cellular Networks, Second- Generation TDMA, Third Generation Systems, (ii) Purpose, Motivation, and Approach to 4G, LTE Architecture, Evolved Packet Core, LTE Resource Management, LTE Channel Structure and Protocols, LTE Radio Access Network, LTE-Advanced, (iii) Selected Topics in 5G

12 Hours

Unit 4: Mobile Network and Transport Layers: Mobile IP (Motivation, Agent discovery, Registration and Packet forwarding), Mobile Ad-hoc Networks: Architecture and Routing, Sensor Networks: Architecture and Routing, Mobile Transport Layer (I-TCP, S-TCP and M-TCP)

11 Hours

Unit 5: Satellite Systems: Satellite Parameters and Configurations, Access Techniques (DAMA, PRMA, rTDMA), Link Capacity Allocation, Routing, Localization and Handover, Satellite Applications, Satellite Tracking Software (G-Predict)

10Hours

TextBook:

1. Cory Bread and William Stallings, "Wireless Communication Networks and Systems", 1st Edition, Pearson, 2015

Reference Books:

1. Jochen H. Schiller, "Mobile Communications", 2nd Edition, Addison-Wesley, 2003.
2. "From GSM to LTE-Advanced Pro and 5G: An Introduction to Mobile Networks and Mobile Broadband", Martin Sauter, Wiley 4th Edition, 2021
3. Lecture notes on WSN

www.media.pearsoncmg.com/ph/esm/ecs_stallingsbeard_wcns_1/animations

UE20EC333: Memory Design and Testing (4-0-0-4-4)

Course Description:

Memory Design and test are considered jointly in this course since knowledge of one without the other is insufficient for the task of having high quality memories. Knowledge of memory design is required to understand test. An understanding of test is required to have effective built-in self-test implementations. A poor job can be done on any of these pieces resulting in a memory that passes test but which is not actually good. In the first 3 units, an overview of the various memory designs is provided, of which the first 2 units deal with volatile memories, namely, SRAM and DRAM. Unit 3 deals with design of non-volatile memories including the future memories such as MRAM and FeRAM. Units 4 and 5 deal with memory testing. Unit 4 details the different faults that can occur in memories and the algorithms used to test the faults. Unit 5 which is the last Unit will detail the key factors in implementing good self-test practices.This course requires the knowledge of Digital VLSI Design.

Course Objectives:

- Impart understanding of working principles of conventional semiconductor memories in the design of electronic circuits.
- Designing peripheral circuits for memory access
- Introducing Dynamic and Static Memories
- Provide 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.
- Simulating the memory and peripheral circuits using SPICE Tools.

Course Content:

Unit 1: Introduction:

Overview of semiconductor memory types, Memory architectures and building blocks; S**tatic RAM:** Various configurations of CMOS SRAM Cell, Read/Write operation of 6-T SRAM Cell; SRAM Peripheral Circuitry: Pre-charge circuitry, Isolation circuitry, Sense Amplifier, Write driver circuit, Decoder circuitry; C**AM:** CAM topology, Binary CAM, Ternary CAM

12 Hours

Unit 2: Dynamic Random Access Memory:

DRAM basics - Access and sense operations, Write operation, Opening a row, Open/Folded DRAM Array Architectures. The DRAM Array: The Mbit cell, The DRAM Capacitor - stacked and trench capacitors, The Sense Amplifier – Equilibration and bias circuits, Isolation Devices, Input/Output transistors, Nsense and Psense Amplifiers, Configurations, Operation; High Speed DRAMs: SDRAM, DDR

12 Hours

Unit 3: Non-volatile memories: ROM:

Cell structure – NAND and NOR Arrays; EPROM: Floating gate EPROM Cell, EEPROM Cell-FLOTOX Technology, EEPROM Architecture; Flash Memory: Cell operation, NOR and NAND Flash; New Memory Cells: FeRAM, STT RAM, MRAM

10 Hours

Unit 4: Memory Testing: Memory Faults:

General Fault Modeling, 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

10 Hours

Unit 5: 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

11 Hours

Note: Demo using memory compiler design for practical implementation will be given

Text Book:

1. “Digital Integrated Circuits–A Design Perspective”, Jan, M. Rabaey, ChandrakasanAnantha and Nikolic Borivoje, 2nd Edition.,Pearson, 2016

Reference Books:

1. "High Performance Memory Testing: Design Principles, Fault Modeling and Self Test", R.Dean Adams, Kluwer Academic Publishers, 2003.
2. "DRAM Circuit Design: Fundamental and High-Speed Topics",BrentKeeth, R. Jacob Baker, Brian Johnson, Feng Lin 2E, Wiley - IEEE Press, 2007.
3. "Semiconductor Memories- Technology, Testing and Reliability", Ashok K. Sharma, PHI, 2004.

UE20EC334: 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: Introduction to Quantum basics:

Quantum mathematics refresher: Bra-ket algebra, Matrix form of state vectors, Bloch sphere, superposition quantum state decomposition, working with IBM quantum computer and Qiskit.

10 Hours

Unit 2: Quantum transport:

Quantum transport: methods, MOSFET; Green's function, Interaction of representation, role of temperature, Quantum devices, Introduction to Density Functional Theory free software tools and usage.

13 Hours

Unit 3: Computational Quantum theory:

Solving Schrodinger equation using Python in 1D, 2D: Basic statistical python, FDTD and utilization in quantum programming.

11 Hours

Unit 4: Quantum Gates and Circuits:

Qubits, single Qubit Gates, many single-Qubit gates, Basic quantum circuit diagrams, Quantum transport and spin qubits.

11 Hours

Unit 5: Application:

Quantum entanglement and teleportation, quantum cryptography, solving problems using Quantum computers.

10 Hours

Textbook:

1. "An Introduction to Quantum Transport in Semiconductors", David K. Ferry, Taylor and Francis, 2018.
2. "A First Introduction to Quantum Computing and Information",BernardZygelman, Springer, 2018.

Reference Books:

1. Quantum Computing Explained, David McMahon, Wiley, 2007.
2. Mathematics of Quantum Computation and Quantum Technology, Goong Chen Louis Kauffman Samuel J. Lomonaco, Chapman and Hall, 2007.

UE20EC335: Synthesis Physical Design and Timing Analysis of Digital Circuits (4-0-0-4-4)

Course Description:

This course covers the basic concepts of synthesis and static timing analysis and apply them to constrain a digital design. Students apply these concepts to set constraints, calculate slack values for different path types, identify timing problems, and analyse reports generated by static timing analysis tools.

Course Objectives:

- To learn the need and applications of timing analysis in various stages of a VLSI design.
- To learn methods for timing analysis of combinational and sequential digital circuits.
- To learn timing models in cell and interconnects and differentiating the two and their applicability in timing analysis.
- Analysis of the timing parameters and constraints.
- To learn cross talk and noise analysis.

Course Outcomes:

Students completing the course should be able to:

- Analyse and understand the Digital Synthesis and Gate level simulation
- Analyse given digital circuit for timing in pre-silicon and post-silicon design levels
- Analysis of effects of cross talk and glitches and their significance in timing analysis.
- Able to write and apply the timing constraints and analyze the design simulations using SDC on CAD tools.
- On-chip variations.

Course content:

Unit 1: Introduction to Synthesis and Static Timing Analysis: Introduction to ASIC design flow, Introduction to Synthesis, Timing constraints in Synthesis, Testbench verification, code coverage, Gate-level simulation, Basics of STA, STA at different design phases, Limitation of STA, Power and reliability considerations of STA, STA concepts: CMOS logic design, modelling of CMOS cells, Switching waveform, propagation delay, slew of a waveform, skew between signals, timing arcs and unateness, Min and max timing paths, clock domains, operating conditions, relationship between synthesis and static timing analysis. (Introduction to SDC through tcl). **09 Hours**

Mandatory Demo sessions for Unit-1

1. Testbench Simulation (Cadence NCSim)
2. Code Coverage Demo (including FSM coverage)
3. Synthesis Demo with constraints
4. Gate level Simulation

Unit 2: - Physical Design: Standard Cells, Transistor Sizing, I/O pads, Library characterization, Floorplanning: Design planning, Pad placement, Power planning, Macro placement and Clock planning. Placement: Global Placement, Detail placement, Clock Tree Synthesis, Routing, Global and Detail routing.

Mandatory Demo Sessions for Unit-2: -

1. Semi-custom layout using Cadence Innovus
2. Detailed Clock Tree Synthesis experiment in Cadence Innovus **08 Hours**

Unit 3: Timing models and interconnect parasitics

Pin capacitance, Timing modelling, timing models: - combinational cells, timing models-sequential cells, state dependent models, interface timing model for a black box, advanced timing modelling. RLC for interconnect, Wire load models, representation of extracted parasitics, representing coupling capacitances, hierarchical methodology, reducing parasitics for critical nets, delay calculation: delay calculation basics, delay calculation with interconnect, cell delay using effective capacitance, interconnect delay, slew merging, different slew thresholds, different voltage domains, path delay calculation, slack calculation. **12 Hours**

Unit 4: Crosstalk, Noise and Timing Verification:
Crosstalk glitch analysis, crosstalk delay analysis, timing verification using crosstalk delay, configuring the STA environment: Introduction to STA environment, specifying clocks and important commands, Setup timing check, Hold timing check, multi-cycle paths, false paths, half-cycle paths, removal timing check, recovery timing check, timing across clock domains, examples and case studies. **14 Hours**

Mandatory Demo Sessions for Unit-2: -

1. Tempus Demo with combinational circuit
2. Tempus Demo with Sequential circuit -1
3. Tempus Demo with Sequential circuit -2 (preferably large circuit like processor etc)

Unit 5: Robust Timing Verification: On-Chip Variations, Time Borrowing, Data to Data Checks, Non-Sequential Checks Clock Gating Checks, Power Management, Back-annotation. Sign-off Methodology Statistical Static Timing Analysis, Paths Failing Timing, Validating Timing Constraints **12 Hours**

Mandatory Demo Session for Unit -5: -

1. On-chip Variation demo using tempus

Textbook:
1. "Static Timing Analysis for Nanometer Designs, A Practical Approach", J. Bhasker, Rakesh Chadha, 1st Edition, Springer-2009.

Reference Book:

1. "Constraining Designs for Synthesis and Timing Analysis- A practical guide to synopsys design constraints", Sridhar Gangadharan and Sanjay Churiwala, 1st edition, Springer-2013.
2. "Physical Design Essentials, An ASIC Design Implementation Perspective". Khosrow Golshan, Springer, 2007.

UE20EC336: 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 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 and Bias Sources
- 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 an Dynamic Range, Passive impedance transformation. **12 Hours**

Unit2: Transceiver Architectures: Receiver architectures and Transmitter architectures, transceiver performance tests **10 Hours**

Unit3: Low Noise Amplifiers: General considerations, LNA topologies, Gain switching, Band switching, High IP2 -LNAs **10 Hours**

Unit 4: Mixers: General Considerations, Passive down conversion mixers, Active down conversion mixers, Improved mixer topologies, Up conversion mixers

11 Hour

Unit 5: Oscillators and Power Amplifiers: Basic principles, cross coupled Voltage controlled oscillators, Low noise VCOs, Phase noise, Classification of power amplifiers, high frequency power amplifiers **12 Hours**

Text Books:

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

Reference Books:

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

UE20EC337: Speech Processing (4-0-0-4-4)

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.

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 show how signal processing algorithms are driven by both time domain.
- To understand frequency-domain representations of speech production and aspects of speech perception.
- To introduce applications such as speech recognition, speaker recognition, enhancement etc.

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)

Course Content:

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: Time Domain Models for Speech Processing:

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

12 Hours

Unit 3: Frequency Domain Methods for Speech Processing:

Short Time Fourier Analysis: Fourier transform and Linear Filtering interpretation, Filter bank summation method, Overlap addition method, Design of digital filter banks, Implementation using FFT, Spectrographic displays, Pitch detection.

12Hours

Unit 4: 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

11 Hours

Unit 5: 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

10 Hours

Text Book:

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

Reference Books:

1. "Discrete-time Speech Signal Processing: Principles and Practice", Thomas F. Quatieri, Pearson Education (Singapore) Pvt. Ltd., 2002.
2. "Speech Communications: Human and Machine", D. O'Shaughnessy, Universities Press, 2001.
3. "Fundamentals of Speech Recognition", L. R. Rabiner and B. Juang, Pearson Education (Asia) Pvt. Ltd., 2004.
4. "Discrete-Time Processing of Speech Signals", J. R. Deller, Jr., J. H. L. Hansen and J. G. Proakis, IEEE Press, 2000.

UE20EC338: Detection and Estimation (4-0-0-4-4)

Course Description:

This course will introduce students to random process representation, detection and estimation of signals and noise.This course requires the knowledge of Principles of Digital Signal Processing, Mathematics for Electronics Engineers.

Course Objectives:

- To understand the basics of binary hypothesis testing leading to signal detection theory with Neyman-Pearson and Bayesian approaches.
- To understand the representation of random process.
- To understand the fundamentals of single- and multi-parameter estimation theory with deterministic and Bayesian philosophies.
- To impart knowledge on estimation of continuous waveforms.

- To understand linear estimation.

Course Outcomes:

Students completing the course should be able to

- Representation of Random signals.
- Apply hypotheses test.
- Detection and estimation of Signal with Gaussian noise.
- Detection and estimation of Signal with nonwhite Gaussian noise.
- Design of Kalman-Bucy liner filter and optimum linear filters.

Course Content:

Unit 1: Classical Detection and Estimation Theory:

Introduction, simple binary hypothesis tests, M Hypotheses, estimation theory, composite hypotheses, general Gaussian problem, performance bounds and approximations.

10 hours

Unit 2: Representations of Random Processes:

Introduction, orthogonal representations, random process characterization, homogenous integral equations and eigen functions, periodic processes, spectral decomposition, vector random processes.

12 hours

Unit 3: Detection of Signals: (Estimation of Signal Parameters):

Introduction, detection and estimation in white Gaussian noise, detection and estimation in nonwhite Gaussian noise, signals with unwanted parameters, multiple channels, multiple parameter estimation.

12 hours

Unit 4: Estimation of Continuous Waveforms:

Introduction, derivation of estimator equations, a lower bound on the mean-square estimation error, multidimensional waveform estimation, non-random waveform estimation.

11 hours

Unit 5: Linear Estimation:

Properties of optimum processors, realizable linear filters, Kalman-Bucy filters, fundamental role of optimum linear filters.

10 hours

Text Book:

1. "Fundamentals of Statistical Signal Processing", Volume I: Estimation Theory, S. M. Kay, Prentice Hall, USA, 1993.

Reference Books:

1. "Fundamentals of Statistical Signal Processing", S. M. Kay, Volume II: Detection Theory, Prentice Hall, US edition, 1998.

2. "Detection, Estimation, and Modulation Theory: Part I", H. L. Van Trees, John Wiley & Sons, USA, 2001.
3. "Introduction to Statistical Signal Processing with Applications", M.D.Srinath, P.K.

Rajasekaran and R. Viswanathan, 2nd edition, Prentice Hall of India, 2003.

UE20EC339: Robotic Systems (4-0-0-4-4)

Course Description: This course covers the kinematics and dynamics 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 path and trajectory planning of manipulators. It also includes the study of sensors, actuators and various applications of robotic systems.
The Robot Operation Systems (ROS) will be the platform used for practical understanding.

This course requires the Knowledge of Linear Algebra and Control Systems.

Course Objectives:

- Develop skills in performing spatial transformations associated with rigid body motions.
- Understand kinematic and dynamic analysis of manipulators
- Understand path planning and trajectories.
- Ability to understand use of sensors and actuators in robotic systems
- Provide knowledge on various applications of robotic systems

.

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
- Apply the principles of path and trajectory tracking in a practical system
- Understand the use of ROS, Sensors and actuators in the design of Robotic motion.
- Use of the concepts in various applications like Mobile Robots, Flying robots, underwater robotics etc.

Course Content:

Unit 1: Robot Mechanics: Transformations, Introduction – Robot Configuration Space, Grasp Statistics – Planar frictionless, with friction, spatial grasps, Rigid Body Motion - rotational and rigid motions, Euler Angles.

12 Hours

Unit 2: Manipulator Kinematics: Homogeneous transformations, Forward and inverse kinematics, Assigning coordinate frames, kinematic decoupling, manipulator Jacobian,

10 Hours

Unit 3: Path Planning and Trajectories: – Path and trajectory planning, Joint Space Trajectory Planning, Cartesian Space Trajectory Planning, Point to point planning, Continuous path generation and curve fitting

12 Hours

Unit 4: Interfaces: Introduction to Robotic Operating Systems (ROS), Actuators - Hydraulic & Electric Actuators, Sensors - Encoders, Tactile Sensors, Visual Sensors, Sonic Sensors, Gyros, GPS, Localization – SLAM, Kalman filter for SLAM

11 Hours

Unit 5: Applications: Mobile Robots – Locomotion, perception, navigation and path planning Flying Robots, Underwater robotic applications

10 Hours

Text Book:

1. M. W. Spong, S. Hutchinson and M. Vidyasagar (2020), *Robot Modeling and Control*, 2nd edition, John Wiley.

Reference Books:

1. Saeed B Niku (2020), *Introduction to Robotics: Analysis, Control and Applications,* 3rd 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
3. Gerald Cook, Feitian Zhang (2020), Mobile Robots: Navigation, Control and Sensing, Surface Robots and AUVs, Second Ed., Wiley-IEEE Press.
4. Jason M O'Kane (2013), A Gentle Introduction to ROS, CreateSpace Independent Publishing Platform

UE20EC341 : 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: Introduction:

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;

10 Hours

Unit 2: Number Theory:

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, Euler's theorem, and Fermat's theorem;

12 Hours

Unit 3: Symmetric Key Cryptography (SKC):

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;

12 Hours

Unit 4: One-Way Hash (OWH) Functions:

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. Internal structure of OWH functions:

Compression functions, SHA-512, Applications of OWH functions: Message integrity, Password maintenance, Message authentication; 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;

11 Hours

Unit 5: Network Security Protocols:

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.

10 Hours

Text Books:

1. "Cryptography and Network Security", Behrouz A. Forouzan and DebdeepMukhopadhyay, 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.

UE20EC342: Mobile Multimedia and Security (4-0-0-4-4)

Course Description:

This course builds on the core course Computer Communication Networks. This course provides an overview of some of the topics in next generation computer networks. This course deals with the challenges for link layer and higher layers due to a variety of issues such as wireless medium, mobility, security, multimedia requirements and other application requirements. This course also introduces various types of network architectures based on the application needs.This course requires the knowledge of Computer Communication Networks

Course Objectives:

- To provide a broad overview on emerging trends in data communication and applications.

- To provide an understanding of wireless and mobility related challenges and solution.
- To provide basic knowledge of cryptography and analyze network security challenges.
- To provide a basic understanding of multimedia representation
- To provide a basic understanding of multimedia networks and protocols for dealing with multimedia traffic.

Course Outcomes:

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

- Analyze the WiFi networks using Wireshark
- Understand advanced network problems in 4G and 5G cellular networks
- Analyze compression techniques and network architectures for multimedia transmission
- Understand principles of cryptography
- Analyze data security and network security solutions

Course Content:

Unit 1: Wireless and mobile networks:

Review of IEEE 802.11 network architecture, Mobility in the same IP subnet, Advance features in 802.11, Personal Area Networks: Bluetooth and Zigbee, Cellular Internet Access, Mobility Management Principles, Mobile IP, Managing mobility in Cellular Networks, Impact on Higher-layer protocols, Wireshark Lab IEEE 802.11(WiFi)

11 Hours

Unit 2: Emerging network architectures:

(i) LTE-Advanced – Background, Network Architecture, Spectrum and Bandwidth Management, MIMO, Relays, (ii) 5G networks – Requirements, Wireless SDN, Network Function Virtualization, Millimeter wave, Internet of things

11 Hours

Unit 3: Multimedia Data Representation

Multimedia networking applications, Introduction, compression principles, text compression, image compression, Introduction, audio compression, DPCM, ADPCM, APC, LPC, video compression, video compression principles, H.264, H.265 and MJPEG.

11 Hours

Unit 4: Multimedia Networking

Streaming Stored Video, VoIP, Protocols for Real-time Conversational Applications, Network Support for Multimedia, Video Streaming and Content distribution Networks

11 Hours

Unit 5: Security in computer networks:

Introduction to network security, Principles of Cryptography, Message Integrity and Digital Signatures, End-point authentication, Securing E-mail, Securing TCP Connections: SSL, Network Layer Security: IPSec and VPNs, Securing Wireless LANs, Operational Security: Firewalls and IDS

11 Hours

Text Book:

1. "Computer Networking: A Top Down Approach", James F Kurose and Keith W Ross, 7th Edition, Pearson Education, 2017.

Reference Books:

1. "Multimedia Communications: Applications, Networks, Protocols, and Standards", Fred Halsall, 1 st Edition, Addison Wesley, 2000.
2. I. Akyildiz, D. Gutierrex-Estevez, E. Reyes, "The Evolution to 4G Cellular Systems, LTE Advanced," Physical Communication, Elsevier, 3 (2010), 217–244.
3. Ian F. Akyildiz, ShuaiNie, Shih-Chun Lin, and Manoj Chandrasekaran, "5G roadmap: 10 Key Enabling Technologies", Computer Networks, Vol 106, pp. 17–48, Sept. 2016

UE20EC343: MIMO Wireless 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– Introduction to MIMO

Evolution of Wireless systems from 1G to 5G, building blocks of a digital communication transceiver, what is 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, why we need MIMO, Numerical **10 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, Numerical **12 Hours**

Unit 3 - Single User MIMO - II
Capacity of SISO system, Capacity of MIMO system, Ergodic Capacity, Outage Capacity, 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, Numerical **12 Hours**

Unit 4 – Multi User 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 **11 Hours**

Unit 5 – Special Topics in MIMO
What is Massive MIMO, Pilot contamination, Mitigation of pilot contamination, Channel hardening, Machine Learning aided MIMO Communication **10Hours**

Text Books

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

Reference Books:

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

UE20EC344: Testing of VLSI Circuits (4-0-0-4-4)

Course Description:

This course deals with digital systems testing, which is an integral part of IC design and manufacturing. The topics discussed are: Importance of VLSI Testing, Test process and Automatic Test Equipment, Defects versus Fault Models, Fault Simulation, Logic Simulation, Combinational

Circuit Testing, Sequential Circuit Testing, Memory Testing, 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 test strategies 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, design for testability (DFT).
- VLSI scan testing and built-in self-test (BIST) will also be covered. Students will learn various 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.
- Develop fault models, testing strategies for combinational/sequential circuits and memory circuits.
- Various ATPG Algorithms for Stuck at fault and Delay fault.
- Insertion of Design for testability (DFT) circuits and taxonomy of DFT circuits.
- Built-in self-test (BIST) and boundary scan, effectively use the concepts for testing VLSI systems using existing test methodologies, tools and equipment.

Course Content:

Unit 1: Introduction to Testing and Verification:(i)Introduction to testing, need for testing, Testing Philosophy, Role of Testing, Digital andAnalog VLSI Testing, VLSI Technology Trends Affecting Testing Verification and ValidationDefinitions; (ii) Fault Modelling: Defects, Errors, Faults Functional Versus Structural Testing,Levels of Fault Models, A Glossary of Fault Models, Single Stuck-at Fault, Fault Equivalence,Equivalence of Single Stuck-at Faults Fault Collapsing, Fault Dominance and Checkpoint Theorem **10 Hours**

Unit 2: Combinational Circuit Test Generation: Algorithms and Representations, Structural vs. Functional Test, Definition of Automatic Test-Pattern Generator, Search Space Abstractions, Algorithm Completeness, ATPG Algebras, Algorithm Types, and Redundancy Identification (RID), Testing as a Global Problem, Definitions. Boolean Difference Method. Significant Combinational ATPG Algorithms D-Calculus and D-Algorithm, PODEM.

12 Hours

Unit 3: Sequential Circuit Test Generation: ATPG for Single-Clock Synchronous Circuits, A Simplified Problem Time-Frame Expansion Method, Use of Nine-Valued Logic, Development of Time-Frame Expansion Methods, Approximate Methods, Implementation of Time-Frame Expansion Methods Complexity of Sequential ATPG, Cycle-Free Circuits, Cyclic Circuits Clock Faults and Multiple-Clock Circuits, Asynchronous Circuits Simulation-Based Sequential, Circuit ATPG, CONTEST Algorithm. **11 Hours**

Unit 4: Delay Test and Boundary Scan:(i) Delay Test Problem, Path-Delay Test, Test Generation for Combinational Circuits, Number of Paths in a Circuit, Transition Faults, Delay Test Methodologies, Slow-Clock Combinational Test Enhanced-Scan Test, Normal-Scan Sequential Test, Variable-Clock Non-Scan Sequential Test, Rated-Clock Non-Scan Sequential Test, Practical Considerations in Delay Testing. (ii) Boundary Scan Standards: Motivation, Purpose of Standard, System Configuration with Boundary Scan TAP Controller and Port.

10 Hours

Unit 5: Design for Testability: Digital DFT and Scan Design: Ad-Hoc DFT Methods, Scan Design, Scan Design Rules, Tests for Scan Circuits, Multiple Scan Registers, Overheads of Scan Design, Physical Design and Timing Verification of Scan, Partial-Scan Design, Variations of Scan; Built-In Self-Test: Random Logic BIST, Definitions BIST Process, BIST Pattern Generation BIST Response Compaction, Built-in Logic Block Observers, Device Level BIST, Test Point Insertion.

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

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.

UE20EC345: LOW POWER VLSI (4-0-0-4-4)

Course Description:

This course deals with low power VLSI circuit and system design. Designing low power circuits has become very important in last three decades of Chip design and engineering, as the world moved towards more and more battery-operated electronic gazettes. The course includes circuit level, cell level and system level low power techniques along with description of power intent languages (UPF). This course requires the knowledge of Digital VLSI.

Course Objective:

- To understand importance of low power design.
- To understand measurement and analysis of static and dynamic power.

- Learn about the various techniques used in modern chip design industry to achieve low power.
- To understand structured low power techniques like clock gating, power gating and dynamic voltage and frequency scaling.
- 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.
- Measure the dynamic power across the ASIC design flow.
- Designing structured low power techniques like Clock gating, power gating, etc.
- Designing IP cores with low power.
- Hands on learning and skill for developing end to end low power solutions in chip design.

Course content:

Unit 1: Introduction
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. **10 Hours**

Unit 2: Power Analysis in ASICs
Switching Activity, Power consumption for basic cells and macros, Specifying activity at the block or chip level, power analysis of chip level. **08 Hours**

Unit 3: Device and Circuit level Techniques for Low Power: Modelling for Designing in Deep Submicron Technologies, Logic Circuits and Standard Cells, Low-Power Very Fast Dynamic Logic Circuits, Circuits Techniques for Dynamic Power Reduction. **12 Hours**

Unit 4: 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, Power Gating Overview**,** Designing Power Gating**,** Architectural Issues for Power Gating**,** A Power Gating Example, IP Design for Low Power.
16 Hours

Unit 5: 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. **9 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.

Reference Books:

1. "Low-Power CMOS Circuits: Technology, Logic Design and CAD Tools" by Christian Piguet, CRC Press, ISBN-10: 02849395372
2. J. Bhasker and Rakesh Chadha, "An ASIC Low Power Primer: Analysis, Techniques and Specification", Springer, 2012 edition, ASIN: B01A0CKNTU

UE20EC346: 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
- Custom architectures for signal processing and sorting architectures.
- 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 in System C/Verilog HDL.
- Design architectures for signal processing and sorting architectures.
- 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. **07 hours**

Unit 2: Basic Building Blocks of Accelerator Logic: Floating Point Arithmetic, IEEE floating point formats, Floating point adders and multipliers, Systolic Arrays, Matrix multiplication using Systolic arrays, Convolution architecture, FIR and Parallel FIR architecture, CORDIC architecture, Sorting Architectures. **10 Hours**

Unit 3: Cache Memory and Network on Chip design: Memory Hierarchy, Virtual Memory, Modelling and Designing a Cache, Advanced Cache Design, Trace caches, Instruction and data prefetching, Overview of Network on Chip (NoC), Message transmission, Routing and Router design, non-uniform cache architectures, performance aspects. **11 hours**

Unit 4: Multicore Systems: Basics of Parallel programming, Shared and Distributed Caches, Overview of Issues in Parallel hardware, Cache Coherence, Memory Consistency, Data races and Transactional memory **12 Hours**

Unit 5: Platforms and Case Studies:
GPU: Traditional GPUs, Programming GPUs, General purpose graphics processor architecture.
Secure Processor Architecture: Data Encryption basics, Hashing and Data integrity, Secure Architectures and Side Channel attacks
Architectures for Machine Learning: Basics of Deep learning, Design of CNN, Intra PE Parallelism, Optimizations in computing and memory access, Memory Systems for ML architecture. **15 Hours**

Text Book:

1. "Advanced Computer Architecture", by Smruti R Sarangi, Mc Graw Hill, 1st Edition, -2021.

Reference Books:

1. Parallel Programming for FPGAs by Ryan Kastner, Janarbek Matai, and Stephen Neuendorffer, Creative Commons, 2018

2. High Level Synthesis: from Algorithm to Digital Circuit, Editors: Coussy Philppe, Morawiec Adam. Springer, 2008

3. Relevant academic papers and manuals prescribed by instructor.

UE20EC347: 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 and manufacturing. The topics discussed are: Importance of VLSI Testing, Test process and Automatic Test Equipment, Defects versus Fault Models, Fault Simulation, Logic Simulation, Combinational Circuit 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 test strategies 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 learn various VLSI testing strategies and how to design a testable VLSI circuit.
- Debug, Diagnosis, and JTAG, IEEE 1500 and IEEE IJTAG (1687) protocol

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 memory circuits.
- 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, tools and equipment.
- To thoroughly understand JTAG, IEEE 1500 and IEEE IJTAG (1687) protocols.

Pre - Requisite: Knowledge of Digital Design using HDL

Course Content:

Unit 1: Introduction to VLSI Testing: 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. **09 Hours**

Unit 2: Test Pattern Generation: Test pattern generation for combinational logic circuits, Pseudorandom test pattern generation, Test pattern generation for sequential circuits, Exhaustive, non-exhaustive and pseudorandom test pattern generation, IDDQ and CMOS testing, Delay fault testing. **12 Hours**

Unit 3: Design for Testability and BIST: Basics of DFT, Scan cell designs, Scan architectures, Scan Design rules, Scan Design flows. Logic BIST: BIST Design rules, Test pattern generation, Output response analysis, Logic BIST architectures. **12 Hours**

Unit 4: Analog Test: Analog and Mixed Signal Circuit trends, Functional DSP based testing, Static ADC and DAC testing methods, realizing emulated instruments using Fourier transforms, CODEC testing, Dynamic flash ADC testing FFT technique. **10 Hours**

Unit 5: 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). **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. 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. "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.

Reference Books:

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

UE20EC347A: 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: Introduction to Non-linear Optics: Non-linear refractive-index, Dispersion, optical susceptibility, second and third order harmonic generation, non-linear optical combination effects, problem solving and computations.

11 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.

12 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.

12 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.

10 Hours

Unit-5: Quantum-Computing and optical non-linearity – Linear optical computing, Non-linear optics quantum computing with circuit QED.

10 Hours

Text Book:

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

References

- Published SCI journal papers

UE20EC348: Digital Image Processing-2 (4-0-0-4-4)

Course Description:

This course introduces image and texture segmentation, symbolic representation, image compression, advanced segmentation, morphological image processing and object recognition. This course requires the knowledge of Principles of Digital Signal Processing and Digital Image Processing.

Course Objectives:

- To expose students to advanced concepts of image processing.
- To investigate 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).
- Apply the notions learned in the course to practical image processing problems.
- Apply techniques for image enhancement, filtering and compression.
- Process and analyze image data.
- Show how higher-level image concepts such as edge detection, segmentation, representation can be implemented and used.

Course Content:

Unit 1: Image Compression:
Fundamentals, Need for image compression, Image Compression models, Elements of Information Theory, Error free compression, Lossy compression, Image Compression Standards.

10 Hours

Unit 2: Morphological Image Processing:
Preliminaries, Dilation and Erosion, Opening and Closing, The Hit-or-Miss Transformation, Some Morphological Algorithms, Extensions to Grayscale Images.

12 Hours

Unit 3: Image Segmentation:
Introduction, Classification of image Segmentation techniques, Region approach-segmentation, Clustering techniques, Segmentation based on thresholding, Water -shed transformation, Edge based segmentation, Classification of edges, Edge detection, Edge Linking, Hough Transform, Shape representation.

10 Hours

Unit 4: Wavelet based image processing:
Introduction, Evolution of wavelet transform, wavelet transform, 2D continuous wavelet

transform, Multi resolution analysis, Examples of wavelets, Wavelet based image compression.

11Hours

Unit 5: Object Recognition:

Introduction, Need for an object-recognition System, Automated Object-recognition Systems, Patterns and Pattern Class, Selection of Measurement Parameters, Relation between Image Processing and Object Recognition, Approaches to object recognition, Baye's Parametric Classification, Neural Network approach to object recognition, Template-Matching based Object Recognition, Applications of Object Recognition.

12 Hours

Textbook:

1. "Digital Image Processing", R. C. Gonzalez and R. E. Woods, 4th Edition, Pearson Education Limited ,2018

Reference Books:

1. "Digital Image Processing", S Jayaraman, S Esakkirajan and T Veerakumar, Mc Graw Hill, 2009.
2. "Digital Image Compression Techniques", M. Rabbani and P W Jones, SPIE Press, 1991.
3. "A Wavelet Tour of Signal Processing", S Mallat, Second Edition, Academic Press,

UE20EC349: 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 Linear Algebra, Mathematics for Electronics Engineers.

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: Markov Decision Process: Agent-environment interface, goals and rewards, returns and episodes, policies and value functions, optimal policies and value functions; optimality and approximation.

10 Hours

Unit 2: Dynamic Programming: Policy evaluation, improvement and iteration, value iteration, asynchronous dynamic programming, generalised policy iteration, efficiency of dynamic programming.

12 Hours

Unit 3: Model-Free Tabular Solution Methods: Monte Carlo prediction, estimation and control, temporal-difference prediction and optimality, Sarsa, Q-learning, n-step TD prediction, n-step Sarsa, n-step off-policy learning.

12 Hours

Unit 4: Model-Free Approximate Solution Methods – Part I: Value-function approximation, prediction objective, stochastic-gradient and semi-gradient methods, linear methods and feature construction, nonlinear function approximation, least-squares TD, memory- and kernel-based function approximation; episodic semi-gradient control, semi-gradient n-step Sarsa, average reward;

11 Hours

Unit 5: Model-Free Approximate Solution Methods – Part II: Eligibility traces: TD(lambda), Sarsa (lambda); policy approximation, policy gradient theorem, actor-critic methods.

10 Hours

Text books:

1. R.S. Sutton and A. G. Barto (2018), Reinforcement Learning: An Introduction, MIT Press, 2nd edition.

Reference books:

1. W. B. Powell (2011), Approximate Dynamic Programming, John Wiley.
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.

UE20EC349A: Adaptive Systems (4-0-0-4-4)

Course Description:

This course provides a comprehensive foundation for model reference adaptive control of linear systems. It enables the student to design adaptive systems for unknown and/or slowly varying dynamical systems. This course requires the knowledge of Linear Algebra, Knowledge of Control Systems

Course Objectives:

- Understand the basic concepts of adaptive systems.
- Provide knowledge of stability of dynamical systems.
- Understand algebraic systems and dynamical systems.
- Ability to design stable adaptive laws for unknown dynamical systems.
- Understand the control problems involved in the adaptive systems.

Course Outcomes:

Students completing the course should be able to

- Predict the stability of simple adaptive systems.
- Use Lyapunov stability analysis for stable adaptive systems.
- Derive adaptive laws for stable adaptive systems.
- Design adaptive observers.
- Develop adaptive controllers.

Course Content:

Unit 1: Systems Theory:

State-space representations; adaptive systems; direct and indirect control; model reference adaptive systems and self-tuning regulators; stable adaptive systems; applications.

10 Hours

Unit 2: Stability Theory:

Linear systems; Lyapunov stability; positive-real functions; Kalman-Yakubovich lemma; input-output stability; stability of adaptive systems; other stability concepts.

12 Hours

Unit 3: Simple Adaptive Systems:

Algebraic systems; dynamical systems; state variables accessible.

12 Hours

Unit 4: Adaptive Observers:

Luenberger observer; adaptive observers; design of adaptive observers.

11 Hours

Unit 5: Control Problem:

Adaptive control of plants with relative degree unity; adaptive control of plants with relative degree greater than or equal to 2. Comments on the proof of global stability, the control problem and the controller structure. Combined direct and indirect approach. Relaxation of assumptions; Notion of persistent excitation

10 Hours

Text Book:

1. "Stable Adaptive Systems", K.S. Narendra and A.M. Annaswamy (1989), Prentice Hall (Dover), 2005

Reference Books:

1. “Adaptive Control: Stability, Convergence and Robustness”, S. Sastry and M. Bodson, Prentice-Hall., 1989.
2. “Adaptive Control Tutorial”, P. Ioannaou and B. Fidan SIAM., 2006.“
3. “Adaptive Control”, K. Astron, 2nd Edition, Pearson Education, 1995.