M.TECH IN ELECTRONICS AND COMMUNICATION ENGINEERING

I SEMESTER (2022-24 BATCH)

CC= Core Course, EC= Elective Course

Sl. No.	Course Code	Course Title	Hours / week				Credits	Course Type	S/W / Tools
			L	T	P	S			
1.	UE22EC641A	Advanced Wireless Communication	4	0	0	4	4	CC	MATLAB/Python, Wireshark
2.	UE22EC642A	Advanced Embedded Systems	3	0	2	4	4	CC	Keil Compiler ,Arduino Uno and Raspberry PI
3.	UE22EC643A	Modern Digital Signal Processing	4	0	0	4	4	CC	Matlab R2020a +/Python
Elective-I									
4.	UE22EC644AA1	Wireless Communication and Networks	4	0	0	4	4	EC	MATLAB
5.	UE22EC644AB1	Analog VLSI	4	0	0	4	4	EC	Cadence Virtuoso 2020.1 Version
6.	UE22EC644AB2	Low Power VLSI Design	4	0	0	4	4	EC	Cadence NcSim/Genus/Conformal 2020.1 Version
7.	UE22EC644AC1	Image and Video Processing	4	0	0	4	4	EC	Matlab R2020a +/Python/OpenCv/ NVIDIA Cuda
Elective-II									
8.	UE22EC645AA1	Cryptography and Watermarking	4	0	0	4	4	EC	MATLAB
9.	UE22EC645AB1	CMOS Memory Design and Testing	4	0	0	4	4	EC	Cadence Virtuoso 2020.1 Version
10.	UE22EC645AB2	Real Time Embedded Systems	4	0	0	4	4	EC	SDK flow in Vivado 2018.1 Version
11.	UE22EC645AC1	Speech and Audio Processing	4	0	0	4	4	EC	Matlab R2020a +/Python/HTK Tool

12.	UE22EC621A	Soft Skills	2	0	0	2	2	CC	NA
		TOTAL	21	0	2	22	22		

Sl. No.	SPECIALIZATION	ELECTIVE- I	ELECTIVE –II
A	Communication Systems	UE22EC644AA1	UE22EC645AA1
B	VLSI Design	UE22EC644AB1 UE22EC644AB2	UE22EC645AB1 UE22EC645AB2
C	Signals and Systems	UE22EC644AC1	UE22EC642AC1

II SEMESTER (2022-24 BATCH)

CC= Core Course, EC= Elective Course

Sl. No.	Course Code	Course Title	Hours / week				Credits	Course Type	S/W / Tools
			L	T	P	S			
1	UE22EC641B	Advanced Digital Design using Verilog and Verification	4	0	0	4	4	CC	Cadence NcSim, Genus, Tempus, 2020.1 Version
2	UE22EC642B	Machine Learning Techniques	4	0	0	4	4	CC	Python
Elective-III									
3	UE22EC643BA1	Optical Fiber Communication and Networking	4	0	0	4	4	EC	MATLAB
4	UE22EC643BB1	Design For Testability	4	0	0	4	4	EC	Cadence Modus Tools. Version 2020.1
5	UE22EC643BB2	Test and Debug of Analog and Digital Circuits	4	0	0	4	4	EC	Cadence
6	UE22EC643BC1	Reinforcement Learning Applications	4	0	0	4	4	EC	Matlab R2020a +
Elective IV									

7	UE22EC644BA1	Error Control Coding	4	0	0	4	4	EC	MATLAB
8	UE22EC644BB1	Advanced SoC Architecture	4	0	0	4	4	EC	Cadence Spectre RF 2020.1
9	UE22EC644BB2	Heterogeneous Computing	4	0	0	4	4	EC	Cadence NcSim/Genus /Conformal 2020.1 Version
10	UE22EC644BC1	Adaptive Signal Processing	4	0	0	4	4	EC	Matlab R2020a +
Elective V									
11	UE22EC645BA1	Advanced Digital Communication	4	0	0	4	4	EC	MATLAB
12	UE22EC645BB1	Radio Frequency Integrated Circuit Design	4	0	0	4	4	EC	Cadence [Spectre RF] 2020.1 Version
13	UE22EC645BB2	RF and Optical Amplifier Design	4	0	0	4	4	EC	Cadence Spectre RF 2020.1
14	UE22EC645BC1	Robotics	4	0	0	4	4	EC	Matlab R2020a +/Python
15	UE22EC621B	Research Methodology	2	0	0	2	2	CC	Latex/Plagiarism Check tools/Turnitin
		TOTAL	**22**	**0**	**0**	**22**	**22**		
ELECTIVES TO BE OPTED FOR SPECIALIZATION									

Sl. No.	SPECIALIZATION	ELECTIVE- III	ELECTIVE- IV	ELECTIVE- V
A	Communication Systems	UE22EC643BA1	UE22EC644BA1	UE22EC645BA1
B	VLSI Design	UE22EC643BB1 UE22EC643BB2	UE22EC644BB1 UE22EC644BB2	UE22EC645BB1 UE22EC645BB2
C	Signals and Systems	UE22EC643BC1	UE22EC644BC1	UE22EC645BC1
Note: Pre-requisite courses: Nil				

III and IV SEMESTER (2021-23 BATCH)

III Semester (2021-23 BATCH)

EC= Elective Course, PW=Project Work

Sl. No.	Course Code	Course Title	Hours / week				Credits	Course Type	S/W / Tools
			L	T	P	S			
1	UE21EC751A	Project Phase I	0	0	20	0	10	PW	
Elective VI									
2	UE21EC722AA1	Optimization I	2	0	0	2	2	EC	Python, CPLEX, CVXPY
3	UE21EC722AA2	Antenna theory	2	0	0	2	2	EC	Feko, CST (desired)
4	UE21EC722AB1	Selected Topics in Reconfigurable Computing	2	0	0	2	2	EC	Xilinx EDA tools 2018 Version
5	UE21EC722AB2	Formal Verification of Hardware Designs	2	0	0	2	2	EC	Cadence Jasper Tools 2020.1 Version
6	UE21EC722AB3	Micro-electromechanical techniques and optics	2	0	0	2	2	EC	

7	UE21EC722AC1	Deep learning	2	0	0	2	2	EC	Matlab R2020a +/ Tensorflow/Tensor board
		Total	**2**	**0**	**20**	**2**	**12**		

ELECTIVES TO BE OPTED FOR SPECIALIZATION		
Sl. No.	**SPECIALIZATION**	**ELECTIVE- VII**
A	Communication Systems	UE21EC722AA1, UE21EC722AA2
B	VLSI Design	UE21EC722AB1, UE21EC722AB2, UE21EC722AB3
C	Signals and Systems	UE21EC722AC1
Note: Pre-requisite courses: Nil		

IV SEMESTER (2021-23 BATCH)
EC= Elective Course, PW=Project Work

Sl. No.	**Course Code**	**Course Title**	**Hours / week**				**Credits**	**Course Type**	**S/W / Tools**
			L	**T**	**P**	**S**			
1	UE21EC751B	Project Phase II	0	0	20	0	10	PW	
Elective VII									
2	UE21EC722BA1	Optimization II	2	0	0	2	2	EC	Python, CPLEX, CVXPY
3	UE21EC722BA2	Antenna Design using simulation tools	2	0	0	2	2	EC	CST, Feko, Matlab
4	UE21EC722BB1	VLSI for DSP	2	0	0	2	2	EC	MATLAB , Cadence NcSim 2020.1 Version
5	UE21EC722BB2	Post Silicon Validation	2	0	0	2	2	EC	LtSPICE 2021 Version
6	UE21EC722BB3	High Speed Serial Interface Design	2	0	0	2	2	EC	Cadence NC Sim 2020 Version, Genus 2021
7	UE21EC722BB4	Design and Implementation of RISC-V Microprocessor	2	0	0	2	2	EC	Cadence NC Sim 2020 Version,

									Genus 2021
8	UE21EC722BC1	Digital Processing of Random Signals	2	0	0	2	2	EC	Matlab R2020a +
Total			**2**	**0**	**20**	**2**	**12**		

ELECTIVES TO BE OPTED FOR SPECIALIZATION		
Sl. No.	**SPECIALIZATION**	**ELECTIVE- VII**
1	Communication Systems	UE21EC722BA1, UE21EC722BA2
2	VLSI Design	UE21EC722BB1, UE21EC722BB2, UE21EC722BB3, UE21EC722BB4,
3	Signals and Systems	UE21EC722BC1

M.TECH. in Electronics and Communication Engineering

Program Educational Objectives

1. 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.
2. Facilitate students to be conversant in design, development and implementation skills through application of technologies related to Electronics and Communication engineering, in a sustained manner.
3. 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.
4. To inculcate and engage in research in the field of Electronics and Communication engineering that facilitate publications, promote consulting and industry partnerships.
5. To prepare students secure befitting placements in industries, be competent globally both as employees and entrepreneurs in their chosen areas of specialization.

Program Outcomes

1. **Scholarship of Knowledge:** To acquire in depth knowledge in the field of Electronics and Communication Engineering with specialization in VLSI and Embedded Systems, Signal Processing and Communication and apply the same in the design and development of Software and Hardware Systems
2. **Critical Thinking:** Analyze complex problems in Electronics Communication & Engineering and its associated domains; analyze alternative designs for trade-offs between various design factors such as power, performance and accuracy.
3. **Problem Solving:** Identify, formulate and critically study the problem, understand the interplay between theory and practice, design and develop efficient algorithms, conduct experiments, analyzing the results and applying the knowledge to different domains by considering social, environmental, economic, and security constraints.
4. **Research Skill:** Critically analyze existing literature in an area of specialization, conduct investigative research to develop innovative methodologies to tackle issues identified and contribute to the development of technological knowledge and intellectual property.
5. **Modern Tool Usage:** Apply current techniques, skills and modern computing tools to build and analyze robust, reliable, maintainable, scalable and efficient computing systems
6. **Collaborative and Multidisciplinary work:** Enhance skills and continuously acquire advanced knowledge in Electronics and Communication Engineering, multi and inter disciplinary domains for professional excellence.
7. **Project Management and Finance:** Manage and execute complex software/Hardware engineering projects under economic, time and performance constraints both working in teams and in an individual capacity.
8. **Communication**: Contribute and communicate effectively with the society confidently, be able to write effective reports and design documents by adhering to the appropriate standards, make effective presentations, give and receive clear instructions

9. **Life-long Learning**: Engage in lifelong learning with persistent scientific temper for professional advancement and effective communication of the technical information.
10. **Ethical Practices and Social Responsibility:** Become a complete professional with high integrity and ethics, with excellent professional conduct and with empathy towards the environmental and contribute to the community for sustainable development of society
11. **Independent and Reflective Learning:** Critically evaluate the outcomes of one's actions and apply self corrective measures to improve the performance.

UE22EC641A: Advanced Wireless Communication (4-0-0-4-4)

Course Description:

Given the extensive growth and application of wireless technology, this course brings advanced concepts of wireless communication relating to PHY layer and networking. This course starts by examining the wireless channel characteristics followed by exploring the theory and design aspects of some emerging modulation and access techniques, MIMO and next generation cellular networks.

Course Objectives:

- The chief objective is to introduce the advanced concepts in modern wireless communication.
- To understand the concepts of OFDM
- To understand MIMO techniques, 3G and 4G systems and standards.
- To impart knowledge of Ultra – Wide Band
- To impart knowledge on wide area networks.
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Course Outcomes:

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

- Appreciate the concepts of wireless communications.
- Analyze different factors relating to performance of wireless links.
- Analyze the 3G and 4G networks.
- Analyze Ultra-Wide band Features.
- Analyze Wide Area Networks

Course Content:

Unit 1: Wireless Communication Models

Ray-tracing models and shadowing, Fast Fading Wireless Channel Modelling, Rayleigh/ Ricean Fading Channels, Power Delay profile, RMS Delay Spread, Coherence Bandwidth, Flat and Frequency fading, Capacity in Frequency selective channels, Concept of Diversity – Frequency, Time, Space (Brief discussion only)

10 Hours

Unit 2: Concept of OFDM:
Introduction to OFDM, Multicarrier Modulation and Cyclic Prefix, Channel model and SNR performance, OFDM Issues – PAPR, Frequency and Timing Offset Issues.

12 Hours

Unit 3: Concept of Multi-Input Multi-Output (MIMO) Systems
Introduction to MIMO, MIMO Channel Capacity, SVD and Eigenmodes of the MIMO Channel, MIMO Spatial Multiplexing, Alamouti Scheme

12 Hours

Unit 4: Ultra-Wide Band
UWB Definition and Features, UWB Wireless Channels, UWB Data Modulation, Uniform Pulse Train, Bit-Error Rate Performance of UWB.

11 Hours

Unit 5: Wide Area Networks
3G networks **-** Physical layer and link layer profile and Standards, 4G networks - LTE-Advanced – Physical layer and link layer profile and standards, Brief overview on 5G.

10 Hours

Text Books:

1. "Wireless Communications," Goldsmith, Cambridge University Press, 2005.

Reference Books:

1. "Fundamentals of Wireless Communication," D. Tse and P. Viswanath, CUP, 2005.
2. "MIMO-OFDM Wireless Communication with MATLAB," Y. S. Cho, J. Kim, W. Y. Yang, and C.-G. Kang, Wiley, 2010.

UE22EC642A: ADVANCED EMBEDDED SYSTEMS (3-0-2-4-4)

Course Description:

Develop knowledge and understanding of fundamental embedded systems (ES) design paradigms, architectures, possibilities, and challenges, both with respect to software and hardware and wide competence from different areas of technology. Theoretical knowledge in the areas of real time operating systems (RTOS), sensor and measuring systems, and their interdisciplinary nature needed for integrated hardware/software development of embedded systems. Ability to analyze a system both as whole and in the included parts, to understand how these parts interact in the functionality and properties of the system. To educate students to meet current and future industrial challenges and emerging embedded systems engineering trends with a suitable lab training. For this course, knowledge of embedded systems and fundamental electronics is required.

Course Objectives:

- To educate students to meet current and future industrial challenges and emerging embedded systems engineering trends.
- To provide confidence to design and develop a few popular state-of-the-art micro-controllers based embedded systems.
- To enable them understand the role of hardware and firmware in the embedded systems and their efficient partitioning.
- To gain hands-on experience with the embedded system by conducting laboratory experiments.

- To introduce the open-source hardware and embedded system components

Course Outcomes:

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

- Understand the building blocks of Embedded systems and interfacing of various peripherals like I2C, SPI, UART and USB.
- Study the embedded system hardware components and software tool chain, design an embedded system, debug and test it.
- Design and implement applications on Arduino / ARM based controllers.
- Write applications in assembly and embedded C languages and run them on target systems.
- Understand the role of RTOS features like inter process communication, process synchronization techniques, process scheduling algorithms.

Course Contents:

Unit 1: Introduction to Embedded Systems:
A) Typical Embedded systems: Core of the embedded system, Memory, Sensors and Actuators, Embedded Firmware, other system components;
B) Communication Interfaces: I2C bus, SPI bus, USB bus, UART and CAN bus protocols.

9 Hours

Unit 2 : The Embedded system development Environment: The Integrated development environment (IDE), Types of files generated on cross compilation, disassembler/Decompilers, Emulators and debugging, target hardware debugging, Introduction to `Arduino' IDE environment with interfacing to IOT hardware. Typical programming examples.

8 Hours

Unit 3: Introduction to ARM Instruction Set Architecture (ISA): Data Processing Instructions, Branch Instructions, Load-Store Instructions, Software Interrupt Instruction, Program status register Instructions, Loading constants, ARM Extensions, conditional execution. Introduction to Thumb Instruction set. Programming examples.

9 Hours

Unit 4: Real Time Operating systems (RTOS): Embedded system design, operating system basics, Types of OS, Tasks, processes, threads, Multi-processing and Multi-tasking, Task scheduling, threads, processing and scheduling.

8 Hours

Unit 5: Characteristics and Quality Attributes of Embedded Systems: Hardware-software co-design and program modelling. Fundamental Issues in hardware-software Co-design, Computational Models in embedded design, Hardware software trade-off. Quality Attributes of Embedded Systems.

8 Hours

Lab Experiments:

Embedded System Kit Experiments Using Arduino Uno and Raspberry PI- 3/4:

CYCLE I

1. Write an Embedded C program to design a system to demonstrate a street traffic light management system using Arduino Uno Board.
2. Write an Embedded C program to interface gas sensor/IR sensor/Relay shield using Arduino Uno Board.
3. Write a PYTHON program to demonstrate I/O operation of Raspberry Pi kit for ARM processor using GPIO LEDinterface.
4. Write a PYTHON program to interface Ultrasonic sensor to display various control parameters using Raspberry Pi kit for ARMprocessor.
5. Write a PYTHON program to interface Moisture sensor to display control parameter using Raspberry Pi kit for ARMprocessor.

CYCLE II

6. Write an Assembly Language Program (ALP) to find the GCD (Greatest Common Divisor) of two numbers using ARM instructions.
7. WriteanALPtocopyandexchangethegivenstringfromsourcetodestinationusingARM instructions.
8. Write an ALP to find the product of two matrices using with and without MLA ARM instruction.
9. Write an ALP to link Multiple object files and link them together.
10. Write an ALP to find the convolution of two sequences using with and without MLA ARM instruction.

Text Books:

1. “**Introduction to Embedded Systems**”, K.V. Shibu, TMH Education Pvt. Ltd. 2009.

Reference Books:

1. “**Embedded Systems- A Contemporary Design Tool**”, James K. Peckol, John Wiley, 2008.
2. “**ARM System Developer’s Guide – Designing and optimizing system software**”, Andrew N SLOSS, Dominic SYMES and Chris Wright, Morgan Kaufmann Publications, 2004.
3. “**Arduino Cookbook - Third Edition**”, Michael Margolis, Brian Jepson and Nicholas Robert Weldin, O'Reilly Media, Inc, April 2020.
4. “**Programming the Raspberry Pi & Getting Started with Python, 3rd Edition**”, Simon Monk, McGraw-Hill Education TAB, June 2021.

UE22EC643A: Modern Digital Signal Processing (4-0-0-4-4)

Course Description:

This course will provide an overview of signals, systems and important digital signal processing techniques. It also provides an understanding of multirate systems and filter banks.

Course Objectives:

- To introduced basics of signals and systems.
- To familiarize with the design of digital filters
- To learn multirate signal processing and their applications.
- This course also covers the relevant background theory for understanding and designing multirate systems.
- To understand DFT filter banks and Transmultiplexers

Course Outcomes:

Students completing the course should be able to

- Analyse and process signals in the discrete domain.
- Design FIR and IIR filters to suit specific requirements for specific applications.
- Understand the applications of multirate systems and filter banks
- Designing M-channel quadrature mirror filters
- A good understanding of Wavelet Transform and its relation to multirate filter banks

Course Content:

Unit 1 : Review of Signals and Systems

Signals, Systems and Processing, Classification of Signals, The Concept of Frequency in Continuous-Time and Discrete-Time Signals, Analog-to-Digital and Digital-to-Analog Conversion; Discrete Fourier transform, its properties and applications; Frequency-Domain Sampling: The Discrete Fourier Transform, Properties of the DFT, Linear Filtering Methods Based on the DFT;

12 Hours

Unit 2 : Design of digital filters

General Considerations, Design of FIR Filters, Design of IIR Filters from Analog Filters, Frequency Transformations

12 Hours

Unit 3 :Multirate Digital Signal Processing : Introduction, EL Decimation by a factor 'D', Interpolation by a factor 'I', Sampling rate Conversion by a factor 'I/D', implementation of Sampling rate conversion, Multistage implementation of Sampling rate conversion, Sampling rate conversion of Band Pass Signals, Sampling rate conversion by an arbitrary factor, Applications of Multirate Signal Processing;

11 Hours

Unit 4 :DFT Filter Banks and Transmultiplexers

Digital Filter Banks, Two-channel quadrature Mirror filter bank, M-channel QMF bank, transmultiplexers and Application of transmultiplexers in communications Modulation

10 Hours

Unit 5 : Introduction to Time Frequency Expansion

Introduction, The STFT, The Gabor Transform, The Wavelet Transform and its relation to Multirate Filter Banks. Applications of Filter banks to Communication

10 Hours

Text Books:

1. "Digital Signal Processing", Proakis and Manolakis, 4th Edition, Prentice Hall, 2007.
2. "Modern Digital Signal Processing", Roberto Cristi, Cengage Publishers (Erstwhile Thompson Publications), India, 2007.

Reference Books:

2. "Multirate Systems and Filter Banks", P. P. Vaidyanathan, Pearson Education, Inc., 1993.
3. "Digital Signal Processing: A Computer Based Approach", S.K. Mitra, 3rd Edition, Tata McGraw Hill, India, 2007.

UE22EC644AA1: Wireless Communication and Networks (4-0-0-4-4)

Course Description:

This course provides an overview of the wireless networks both from a physical layer and upper layer (link and network) standpoint. Different types of wireless network models and applications are analyzed in terms of frame structure and performance. Different types of routing algorithms are analyzed for ad hoc networks.

Course Objectives:

- Understand wireless channel impairments and network design concepts
- Learn different wireless network protocols
- Understand the parameters on which a mobile network performance depends
- Understand different techniques to increase data rate in a wireless system and network
- Learn latest transmitter and receiver techniques used in wireless systems and standards

Course Outcomes:

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

- Appreciate the challenges in designing a wireless communication system and network
- Appreciate the need and difference between different wireless protocols
- Decide on a wireless network protocol for a given application
- Apply principles learnt to develop next generation wireless standards
- Apply wireless networking concepts for future research projects

Course Content:

Unit 1: Introduction to Wireless System:
Wireless transmission – Antennas, Propagation Modes, Line-of-Sight Transmission, Fading in the Mobile Environment (multipath fading, Doppler effect, shadowing), Purpose of encoding techniques; Wireless network architecture; Case study: Satellite networks

10 Hours

Unit 2: Wireless LANs
Overview of wireless data network, Switching, OSI and TC/IP model, WLAN technology, IEEE 802 Protocol Architecture, IEEE 802.11 Architecture and Services, IEEE 802.11 Medium Access Control, Other IEEE 802.11 Standards

12Hours

Unit 3: Wide Area Networks
Principles of cellular networks, Cellular network architecture**,**3G cellular network, LTE, Brief overview of 5G; LoRa and IoT

12 Hours

Unit 4: Wireless Personal Area Networks
Overview, Radio Specification, Baseband Specification, Link Manager Specification, Logical Link Control and Adaptation Protocol, IEEE 802.15.

11Hours

Unit 5: Routing in wireless networks
Mobility management principles, Mobile IP, Ad hoc network overview, Routing in wireless mobile networks

10Hours

Text Books:

1. "Wireless Communications & Networks", W. Stallings, Prentice-Hall, 2nd Edition, 2004.

Reference Books:

1. "Computer Networking: A Top-down Approach", J. F. Kurose and K. Ross, Pearson, 7th Edition, 2017.
2. "The LTE Network Architecture: A Comprehensive Tutorial", Alcatel-Lucent White paper, https://ia801905.us.archive.org/25/items/LTEAlcatelWhitePaper/LTE_Alcatel_White_Paper.pdf
3. "A Survey on LoRa Networking: Research Problems, Current Solutions, and Open Issues", J. P. ShanmugaSundaram, W. Du and Z. Zhao, *IEEE Communications Surveys & Tutorials*, vol. 22, no. 1, pp. 371-388, First quarter 2020
4. "5G: A Tutorial Overview of Standards, Trials, Challenges, Deployment, and Practice", M. Shafi *et al*., *IEEE Journal on Selected Areas in Communications*, vol. 35, no. 6, pp. 1201-1221, June 2017
5. "A review of current routing protocols for ad hoc mobile wireless networks", E. M. Royer and Chai-KeongToh, *IEEE Personal Communications*, vol. 6, no. 2, pp. 46-55, April 1999
6. "From GSM to LTE-Advanced Pro and 5G: An Introduction to Mobile Networks and Mobile Broadband",Martin Sauter,Wiley,4th Edition,2021

UE22EC644AB1: ANALOG VLSI (4-0-0-4-4)

Course Description:

This course deals with Integrated circuit design in MOS (Metal-Oxide-Semiconductor) technologies for communications, sensor, instrumentation, data conversion, and power management applications. Models for active devices in MOS technologies; transistor-level amplifiers, transistor-level current mirrors and voltage reference generators, transistor-level operational amplifiers; transistor-level feedback circuits; noise and linearity; layout and simulation of Analog integrated circuits with modern VLSI CAD (Very Large-Scale Integration-Computer Aided Design) software.

Course Objectives:

- Provide basic understanding of the theoretical models of MOSFET.
- Impart understanding of single-stage CMOS amplifiers with emphasis on practical design considerations.
- Operational Amplifier Design concepts
- Bandgap reference design
- Introduce multistage amplifiers and PLL concepts

Course Outcomes:

On successful completion of this course, the students 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
- Operational Amplifier Design
- Design CMOS analog circuits against given specifications and implement the same using CAD tools.

Unit 1: Overview of the physics of MOS and Single Stage Amplifiers

Formation of inversion layer, drain-current equation, pinch-off, MOS I/V characteristics and channel length modulation, MOSFET small-signal model of single stage amplifiers such as CS, CG, source follower and cascode with resistive, current-source and MOSFET load, CS stage with source degeneration. Frequency response of CS and CG amplifiers.

10 Hours

Unit 2: Differential Amplifier

Short overview of basic differential pair, Common mode response, Differential pair with MOSFET loads, Gilbert cell with explanation and application

12 Hours

Unit 3 : Passive and Active Current Mirrors

Overview of basic current mirror, Cascode mirrors with advantages and limitations, Active Current Mirrors, Current mirrors for low-voltage application

12 Hours

Unit 4 : Amplifiers

One and two-stage op-amp, Gain boosting - application of cascode, folded cascode and and active-cascode stages, Common mode feedback, Slew Rate and ICMR, PSRR – definition and analysis, Frequency compensation – Need and techniques, Design technique with a hands-on example

11 Hours

Unit 5 : Bandgap Reference

General considerations, supply-independent biasing, temperature-independent references, PTAP current generation, constant GM biasing.

10 Hours

Text Books:

1. Behzad Razavi, "Design of Analog CMOS Integrated Circuits", India Edition, TMH, 2017

Reference Books:

1. Paul R. Gray, P.J. Hurst, S.H. Lewis and R.G. Meyer, "Analysis and Design of Analog Integrated Circuits", 4th Edition, John Wiley & Sons 2001,
2. Phillip E. Allen and Douglas R. Holberg, "CMOS Analog Circuit Design", 3nd Edition, Oxford University Press 2002.

UE22EC644AB2: LOW POWER VLSI DESIGN (4-0-0-4-4)

Course Description:

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

Course Objective:

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

Course Outcome:

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

- Perform static and dynamic power analysis
- Factors driving power consumption and techniques to reduce the power consumption from gate level to RTL level.
- Evaluate performance of different standard structured low power techniques with respect to various parameters.

- Designing IP cores with low power.
- Hands on learning and skill for developing end to end low power solutions in chip design.

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.

12 Hours

Unit 3: 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

12 Hours

Unit 4: Power Gating

Power Gating Overview, Designing Power Gating, Architectural Issues for Power Gating, A Power Gating Example, IP Design for Low Power.

11 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.

10 Hours

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. J. Bhasker and Rakesh Chadha, "An ASIC Low Power Primer: Analysis, Techniques and Specification", Springer, 2012 edition, ASIN: B01A0CKNTU

UE22EC644AC1: IMAGE AND VIDEO PROCESSING (4-0-0-4-4)

Course Description:

As the image processing happens to be emerging technology, this course provides very useful concepts in the analysis of image in frequency domain using different transformation technique. In addition to this, this course also gives an idea of image enhancement, image filtering, image segmentation. It also deals with the video compression techniques such as MJPEG. The basic decoding techniques of video compression also gives a step for further analysis. It also gives an insight into feature extraction which can be used for automation of the system.

Course Objectives:

- This course provides analyse of image using different image transforms
- This course also provides pre-processing of image using different color conversion techniques
- This course also gives an insight into image enhancement
- This course also gives the knowledge of image segmentation.
- This course also provides an idea about video compression

Course Outcomes:

Students completing the course should be able to

- Analyze general terminology of digital image processing.
- Examine various types of images, intensity transformations and special filtering.
- Evaluate the methodologies for image filtering and restoration.
- Implement image enhancement algorithms
- Analyse different algorithms for video compression.

Course Content:

Unit 1: Introduction

2D systems, Mathematical preliminaries – Fourier Transform, Z Transform, Optical & Modulation transfer function, Matrix theory, spectral density function

10 Hours

Unit 2: Image Perception

Light, Luminance, Brightness, Contrast, MTF of the visual system, Visibility function, Color representation, Chromaticity diagram, Color coordinate systems, Color vision model, Temporal properties of vision. Image Transforms, Introduction,2D-orthogonal and unitary transforms, Properties of unitary transforms, DFT, DCT, DST, Hadamard, Haar, Slant, KLT, SVD transform.

12 Hours

Unit 3: Image Enhancement

Point operations, Histogram modelling, spatial operations, Transform operations, Image filtering & restoration, Image observation models, Inverse &Wiener filtering, Fourier Domain filters, Least squares filters.

11 Hours

Unit 4: Image analysis & Computer Vision

Spatial feature extraction, Transform features, Edge detection, Boundary Extraction, Boundary representation, Image segmentation, Classification Techniques, Image data compression, Introduction, Pixel-coding, Predictive techniques, Transform coding.

12 Hours

Unit 5: Video processing

Fundamental Concepts in Video – Types of video signals, Analog video, Digital video, Color models in video, Video Compression Techniques – Motion compensation, Search for motion vectors, H.264, H.265, MJPEG.

10 Hours

Text Books:

1. "Fundamentals of Digital Image Processing", Anil K Jain, Pearson Education Pvt. Ltd. Prentice Hall of India, 2004

Reference Books:

1. "Fundamentals of Multimedia", Z. Li and M.S. Drew, Pearson Education Pvt. Ltd, 2004.
2. "Digital Video Processing", R.C.Gonzalez and R.E.Woods, 2nd Edition, Prentice Hall, 2005.
3. "Digital Image Processing", M.Tekalp, Prentice Hall, USA, 1995.

UE22EC645AA1: CRYPTOGRAPHY AND WATERMARKING (4-0-0-4-4)

Course Description:

The course aims to provide an in-depth understanding of the various algorithms used for network security and data security. Upon completion of this course, the student will have sound knowledge in the mathematical background of communication by secure means. In this course, the students will learn various types of secure communications relating to cryptography and water marking.

Course Objectives:

- Understand the different kinds of attacks on information systems, and techniques to prevent them or mitigate their effects.
- The course aims to provide an in-depth understanding of the various algorithms used for network security and data security.
- Upon completion of this course, the student will have sound knowledge in the mathematical background of communication by secure means.
- The student is exposed to the design of network security protocols based on standard cryptographic primitives such as symmetric key cryptography, asymmetric key cryptography and one-way hash functions.
- In this course, the students will learn various types of secure communications relating to cryptography and water marking.

Course Outcomes:

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

- Understand the basic concepts of data security and network security.
- Obtain a basic foundation of aspects of number theory applied to cryptography and information security.
- Design algorithms for encryption and decryption.
- Understand 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.
- Implement digital watermarking in the spatial domain and frequency domain.

Course Content:

Unit 1: Introduction

Data security and network security. Cryptography and watermarking Rings and fields, Homomorphism, Euclidean domains, Principal Ideal Domains, Unique Factorization Domains, Field extensions, Splitting fields, Divisibility, Euler theorem, Chinese Remainder Theorem, Primality;

10 Hours

Unit 2: Cryptography Algorithms

Basic encryption techniques, Concept of cryptanalysis, Shannon′s theory, Perfect secrecy, Block ciphers, Cryptographic algorithms - Features of DES, Stream ciphers, Pseudo random sequence generators, linear complexity, Non-linear combination of LFSRs, Boolean functions;

12 Hours

Unit 3:Cryptography Systems

Private key and Public key cryptosystems, One way functions , Discrete log problem, Factorization problem, RSA encryption, Diffie Hellmann key exchange, Message authentication and hash functions, Digital signatures, Secret sharing, features of visual cryptography, other applications of cryptography;

12 Hours

Unit 4: Elliptic Curves, Basic Theory

Weirstrass equation, Group law, Point at Infinity, Elliptic curves over finite fields, Discrete logarithm problem on EC, Elliptic curve cryptography, Diffie Hellmann key exchange over EC, Elgamal encryption over EC – ECDSA;

11 Hours

Unit 5: Watermarking

Watermarking in spatial domain, Additive methods, spread spectrum based methods, Information theoretic approach for watermarking, Watermarking in frequency domain, Based on Discrete cosine transform, Discrete Wavelet transform and Contourlet transform, different methods - Comparison between frequency domain and spatial domain methods

10 Hours

Text Books:

1. "Cryptography -Theory and Practice", Douglas A. Stinson, 3rd Edition, CRC Press Company, 2005.

Reference Books:

1. "Elliptic Curves: Number Theory and Cryptography", Lawrence C. Washington, 2nd Edition, CRC Press, 2008.
2. "Primality and Cryptography", EvangelosKranakis, John Wiley & Sons, 1986.
3. "Analysis and Design of Stream Ciphers", Rainer A. Ruppel, SpringerVerlag, 1986.
4. "Digital Watermarking and Steganography", Ingemar Cox, Matthew Miller, Jeffrey Bloom, Jessica Fridrich, Ton Kalker, Second Edition, Morgan Kaufman, 2007.
5. "Fundamentals of Digital Image Watermarking", Fernando Perez Gonzalez, SviatoslavVoloshynovskiy, John Wiley & Sons, 2009.

UE22EC645AB1: 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.

UE22EC645AB2: REAL TIME EMBEDDED SYSTEMS (4-0-0-4-4)

Course Description:

This course provides real time system concepts. Course also introduces analysis of real time systems sufficient and necessary conditions. Introduces different real time scheduling algorithms, synchronization techniques. Introduces embedded components, their design trade-offs, reliability and availability.

Course Objectives:

- The primary goal of this course is to meet the basics of real-time systems and enable the students with the knowledge and skills necessary to design and develop embedded applications by means of real-time operating systems.
- Necessity of Real time systems and their applications
- Various processing and scheduling techniques are explained.
- Difference between General operating system and Real time systems
- Imparts training different components in embedded hardware like memory, etc.

Course outcomes

Students completing the course should be able to

- Use the multitasking techniques in real-time systems.
- Use real time scheduling policies in applications
- Design embedded applications using RTOS.
- Use RTOS software mechanisms
- Identify real time service and estimate the WCET and schedule it

Course content:

Unit 1: Introduction to Real-Time Embedded Systems

Brief history of Real Time Systems, A brief history of Embedded Systems; System Resources: Resource Analysis, Real-Time Service Utility, Scheduling Classes, The Cyclic Executive, Scheduler Concepts, Pre-emptive Fixed Priority Scheduling Policies, Real-Time OS, Thread Safe Re-entrant Functions

10 Hours

Unit 2: Processing

Pre-emptive Fixed-Priority Policy, Feasibility, 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.

12 Hours

Unit 3: Distributed Operating Systems

Topology – Network types – Communication – RPC – Client server model – Distributed file system – Design strategies; (i) Real Time Models And Languages: Event Based – Process Based and Graph based Models – Petrinet Models – Real Time Languages – RTOS Tasks – RT scheduling - Interrupt processing – Synchronization – Control Blocks – Memory Requirements

12 Hours

Unit 4: Memory

Physical hierarchy, Capacity and allocation, Shared Memory, ECC Memory, Flash file systems; (i) Multi-resource Services: Blocking, Deadlock and livestock, Critical sections to protect shared resources, priority inversion; (ii) Soft Real-Time Services: Missed Deadlines, QoS, Alternatives to rate monotonic policy, Mixed hard and soft real-time services.

11 Hours

Unit 5: Embedded System Components

Firmware components, RTOS system software mechanisms, Software application components; High availability and Reliability Design: Reliability and Availability, Similarities and differences, Reliability, Reliable Software, Available Software, Design trade-offs, Hierarchical applications for Fail-safe design; Modularizing An Application For Concurrency: Introduction, An Outside-In approach to decomposing applications, Guidelines and recommendations for identifying concurrency, schedulability analysis.

10 Hours

Text Books:

1. “Real-Time Embedded Systems and Components”, SamSiewert, Cengage Learning India Edition, 2007.

Reference Books:

1. “Programming for Embedded Systems”, Dreamtech Software Team, Jhon Wiley, India Pvt. Ltd., 2008.
2. “Real Time Concepts for Embedded Systems”, Qing Li and Croline Yao CMP Books, India Edition, 2011.

UE22EC645AC1: SPEECH AND AUDIO PROCESSING (4-0-0-4-4)

Course Description:

This course deals with modeling and analysis of speech signals, wherein concepts of digital signal processing techniques are applied to understand various applications involving speech and audio processing. In addition to a detailed description of human speech production and perception, students will learn about techniques to analyze, code, recognize, and synthesize speech. From a discussion of how humans produce and perceive speech to details of computer-based speech processing for diverse applications like design a simple systems for speech and audio processing (speech activity detector, recognizer of limited number of isolated words, music analysis and synthesis).

Course Objectives:

- To teach basics of speech and audio signal processing, analysis and modeling 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 and frequency-domain representations of speech production, as well as by aspects of speech perception
- To provide knowledge on homomorphic signal processing.
- To introduce applications such as speech modification, speech enhancement, speech coding, speech recognition, speech synthesis, pattern recognition, music signal processing 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 and synthesis
- Construct/develop speech recognition, synthesis and coding, music analysis and synthesis
- Illustrate practical aspects of speech algorithms and its implementation
- Design a simple system for speech and audio processing (speech activity detector, recognizer of limited number of isolated words, music analysis and synthesis).

Course content:

Unit 1: Speech Production and Acoustics of speech production

Anatomy and Physiology of Speech production; speech sounds, Articulatory phonetics; Acoustic phonetics, Acoustic theory of speech production, Lossless tube models, and Digital models for speech signals; Coarticulation and Prosody; Hearing and Speech perception: Sound Perception; Response of the ear to complex Stimuli; Perceptually important features of Speech signals; Models of Speech Perception; Vowel Perception and consonant perception; Duration and phonemic cue; Intonation and other aspects of speech perception

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, Pitch period estimation, Short time autocorrelation function, Short time average magnitude difference function, Median smoothing; Short time Fourier analysis and synthesis:Linear Filtering interpretation, Filter bank summation method, Overlap addition method, Design of digital filter banks, Implementation using FFT, Spectrographic displays, Pitch detection, Frequency-Domain Pitch period estimation, Analysis by synthesis, Analysis synthesis systems

12 Hours

Unit 3: Analysis and synthesis of Pole-Zero Speech Models

All-pole modelingof Deterministic Signals; Linear prediction analysis of Stochastic speech sounds; Basic principles of linear predictive analysis, Solution of LPC equations, Prediction error signal, Frequency domain interpretation, Relation between the various speech parameters, Synthesis based on all-pole modeling, Pole-zero estimation; decomposition of Glottal Flow Derivatives;

12 Hours

Unit 4: Homomorphic Signal processing

Homomorphic systems for convolution, Complex cepstrum of speech like sequences, spectral-root Homomorphic filtering; Short-time Homomorphic analysis of periodic sequences, Short-time speech analysis/synthesis using Homomorphic processing, Contrasting Linear prediction and Homomorphic filtering, Pitch detection, Formant estimation, and Homomorphic vocoder

11Hours

Unit 5: Applications of speech and audio processing

Speech recognition vs. Speaker recognition, Hidden Markov Models, Automatic Speech Recognition, Signal processing and analysis methods, Pattern comparison techniques, Principles of speech synthesis, Synthesizer methods, Synthesis of intonation.:Introduction, music processing and synthesis

10 Hours

Text Books:

1. Thomas F. Quatieri (2002), *Discrete-time Speech Signal Processing: Principles and Practice*, Pearson Education (Singapore) Pvt. Ltd.

Reference Books:

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

2. D. O'Shaughnessy (2001), *Speech Communications: Human and Machine*, Universities Press.
3. L. R. Rabiner and B. Juang (2004), *Fundamentals of Speech Recognition*, Pearson Education (Asia) Pvt. Ltd.
4. J. R. Deller, Jr., J. H. L. Hansen and J. G. Proakis (2000), *Discrete-Time Processing of Speech signals*, IEEE Press.

UE22EC641B: ADVANCED DIGITAL DESIGN USING VERILOG AND VERIFICATION (4-0-0-4-4)

Course Description:

This course includes advanced digital design concepts like FSM design, Global reset and clock design, Clock domain crossing, clock gating, verification concepts using the system Verilog and ASIC design flow comprehensively. This course requires the knowledge of Digital Design and Verilog HDL.

Course Objectives:

- This course intended to enhance the skill set of the students in RTL coding, FSM design using Verilog and System Verilog for Verification.

- This course also equips the students to understand hardware verification language lexical elements of System Verilog and its application in Digital design verification.
- Impart training in Layered testbench architecture using system Verilog testbench
- Impart training in writing system Verilog assertions for functional and formal verification.
- Design and development of solutions for Clock domain crossing and Reset Domain crossing.

Course Outcomes:

Students completing the course should be able to

- Good RTL design and FSM design using Verilog
- Good understanding of System Verilog and writing effective system Verilog testbenches.
- Writing System Verilog Assertions.
- Understand and design solutions for clock domain crossing
- Understand and design solutions for metastability, reset domain crossing.

Course Content:

Unit 1: RTL coding using Verilog HDL
RT level Combination Circuit, Regular Sequential circuit, FSM, FSMD and Selected topics in Verilog. (Reference -I).

10 Hours

Unit 2: Advanced Digital Design Concepts
Metastability, Clocks and Resets, Clock dividers, Clock Domain crossing, Low power design. (Reference -II, Reference III, Reference VII).

12 Hours

Unit 3: System on Chip
System on Chip (SOC) Design, SOC Constituents, SOC Synthesis, Static Timing Analysis (STA). (Reference -III).

11 Hours

Unit 4: **System Verilog for Verification**
SOC Design Verification, Basic OOP of System Verilog, Threads and IPC, Randomization, Code coverage, Functional coverage, Advanced OOPs and testbench guidelines, Complete System verilogtestbench. Design Verification examples for complete system verilog layered testbench (Reference -IV).

12 Hours

Unit 5: System Verilog Assertions
System Verilog Assertions, Immediate Assertions, Concurrent Assertions, System Verilog Semantics, Operators, Sampled Value Functions, System functions and tasks, Multiple clocks, "assume", "expect", Local variables and recursive property, Asynchronous assertions. (Reference -V and VI).

10 Hours

Text Books:

1. Pong P Chu, "FPGA Prototyping by Verilog Examples: Xilinx Sparta-3 Version", Wiley Blackwell, ISBN-13: 978-0470185322, 2008.

Reference Books: -

1. Mohit Arora, "The Art of Hardwre Architecture: Design Methods and Techniques for Digital Circuits", Springer-2012, ISBN-13: 978-1461403968.
2. Chris Spear and Greg Tumbush, "System Verilog for Verification", Springer, 3rd edition, ISBN: -978-1461407140, 2012.

3. Veena S Chakravarthi, "A Practical Approach to VLSI System on Chip (SoC) Design: A Comphrehensive Guide", Springer, 1st edition, 2020, ISBN 978-3-030-23049-4.

4. Ashok Mehta "System Verilog Assertions and Functional Coverage: Guide to language, methodoloby and applications" , Springer, ISBN-13: 978-1461473237, 2013.
5. Clifford E Cummings, Arturo Salz, "System Verilog Event Regions, Race Avoidance and Guidelines", Sunburst Design Inc White paper. http://www.sunburst-design.com/papers/CummingsSNUG2006Boston_SystemVerilog_Events.pdf.

Clifford E Cummings, ":Clock Domain Crossing (CDC) Design &VerificationTechniques", http://www.sunburst-design.com/papers/CummingsSNUG2008Boston_CDC.pdf.

UE22EC642B: Machine Learning Techniques (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.
- Understand a range of machine learning algorithms along with their strengths and weakness.
- Understand how to apply machine learning algorithms to solve problems of moderate complexity.
- Ability to formulate machine learning problems for different applications.

Course Outcomes:

Students completing the course should be able to

- Use effective machine learning techniques for various applications.
- Identify the characteristics of datasets and choose appropriate learning models and algorithms.
- Implement practical machine learning algorithms.
- Evaluate learning methods and relate to particular problems.
- Design practical machine learning systems and apply machine learning for their projects.

Course Content:

Unit 1: Foundation of Machine Learning: Introduction to machine learning**,** 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

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. Bayesian Decision Theory, Introduction, Classification, Losses and Risks, Discriminant functions, Association Rules ,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

10 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", Ethem Alpaydin , 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.

UE22EC643BA1: OPTICAL FIBER COMMUNICATION AND NETWORKING (4-0-0-4-4)

Course Description:

Optical fiber communication (OFC) is enabling new designs for 5G communication as the backhaul and core get connected by fiber. The next generation 5G networks will have most signal processing done at remote clouds which communicate with the antenna frontend in the cell sites using optic fiber technology. Given this influx of OFC, it becomes pertinent to know the principles of OFC and the network operations. Hence, this course intends to develop a strong background in light wave transmission, reception, modulation, multiple access and networking.

Course Objectives:

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

Course Outcomes:

Students completing the course should be able to

- Identify the basic elements of optical communication.
- Able to choose an optical source and detector for a given application
- Capable of deciding on an optical receiver architecture for a given application
- Design an optical communication link and/or network
- Analyze the implication of nonlinearities on optical system and network design

Course Content:

Unit 1: Overview of Optical Fiber Communication

(i) Motivations for Lightwave Communications, Optical Spectral Bands, Fundamental Data Communication Concepts Network Information Rates, WDM Concepts, Key elements of optical Fiber Systems; (ii) Optical Fibers.

10 Hours

Unit 2: Optical Sources

Review of Semiconductor Physics, Light Emitting diodes, Laser Diodes; Power Launching and Coupling Source to Fiber Power Launching, Lensing schemes for Coupling Improvement, Fiber- to-Fiber joints, LED coupling to Single Mode Fibers, Fiber Splicing, Optical fiber connectors (Qualitative); Photodetectors Physical principles of photodiodes, Photodetector Noise, Detector Response Time, Avalanche Multiplication Noise, Structure for InGaAsAPDs, Temperature effect on Avalanche gain, Comparison of Photodetectors.

12 Hours

Unit 3: Optical Receiver Operation

Fundamental Receiver Operation, Digital Receiver Performance, Eye Diagrams, Coherent Detection, Burst Mode Receivers, Analog Receivers; Digital Links Point to point links, Link Power Budget, Rise -Time Budget; Analog links – Overview of Analog links, Carrier to Noise Ratio, Multichannel Transmission Techniques, RF over Fiber, Radio over Fiber links, Microwave Photonics.

12 Hours

Unit 4: WDM Concepts and Components

Overview of WDM, Passive Optical couplers, Isolators and circulators, Fiber Grating filters, Dielectric thin film filters, Phased array based devices, Diffraction Gratings Active optical components, and Tunable Light sources.

11 Hours

Unit 5: Optical Amplifiers

Basic applications and types of Optical amplifiers, Semiconductor Optical Amplifiers. Erbium doped fiber amplifiers, Raman Amplifiers, Wideband Optical Amplifiers; Nonlinear Effects General overview of Nonlinearities, Effective Length and Area, Stimulated Raman scattering, Stimulated Brillouin scattering, Self Phase modulation, Cross Phase modulation. Four wave mixing FWM mitigation, Wavelength Converters, Solitons; Optical Networks: Network concepts, Network topologies, SONET / SDH, High speed light wave links, Optical Add/Drop multiplexing, optical switching, WDM Network examples

10 Hours

Text Books:

1. "Optical Fiber Communications", Gerd Keiser, 4th Edition, TMH, 2008.

Reference Books:

1. "Fiber – Optic Communication Systems", Govind P. Agarwal, 3rd Edition, John Wiley & Sons, 2002.

2. "Optical Fiber Communication: Principles and Practices", John M. Senior, 2nd Edition, PHI, 1993.

UE22EC643BB1: DESIGN FOR TESTABILITY (4-0-0-4-4)

Course Description:

This course deals with Modern Integrated Circuit test methods to find as much faults as possible before shipping the product to the customer. In this course we discuss basic fault models, automatic test pattern generation algorithms for different faults and how to make design more testable. This course also includes test economics.

Course Objectives:

- This course aims at demonstrating the concepts of testing and applying the various test strategies to VLSI circuits. The course targets those engineers who upon graduation engage in electronic hardware design, testing or manufacturing projects.
- The course also gives a good foundation for students intending to continue their research in the area of testing.
- This course imparts training in basic ATPG algorithms and enable students to conduct research in algorithms for testing
- Imparts training in scan insertion and comparison of different scan insertion techniques
- Imparts training in memory testing and logic BIST.

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.
- Analyse and develop test for delay faults in the digital circuits
- Develop fault models and testing strategies for analog circuits
- Effectively use the concepts for testing VLSI systems using existing test methodologies, tools and equipment.

Course content:

Unit 1: Introduction to Testing

Role of Testing, Digital and Analog VLSI Testing, VLSI Technology Trends Affecting Testing, Types of Testing; Fault Modeling: Defects, Errors, Faults, Functional Versus Structural Testing, Levels 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, ATPG Algebras, Redundancy Identification (RID), Testing as a Global Problem, Definitions, D-Calculus and D-Algorithm. PODEM and FAN algorithms

12 Hours

Unit 3: Sequential Circuit Test Generation

ATPG for Single-Clock Synchronous Circuits ,Time-Frame Expansion Method, Use of Nine-Valued Logic, 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: Digital DFT and Scan Design

Ad-Hoc DFT Methods, Scan Design, Scan Design Rules, Tests for Scan Circuits, Overheads of Scan Design, Physical Design and Timing Verification of Scan, Variations of Scan; **Delay Test:** Delay Test Problem, Path-Delay Test, 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

12 Hours

Unit 5: Model-based Analog and Mixed -Signal Testability:

Analog Testing difficulties, Analog Fault Models, Levels of Abstaraction, Types of Analog Testing, Analog Fault Simulation, Motivation, DC Fault simulation of Nonlinear Circuits,Linear Analog Circuit AC Fault Simulation, Analog Automatic Test-Pattern Generation, ATPG Using Sensitivites, ATPG using Signal Flow Graphs

10 Hours

Note: Verification of pre-synthesis and post-synthesis design by applying scan-chain and ATPG using TESSENT tool

Text Books :

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. "Digital Systems Testing and Testable Design" M. Abramovici, M. A. Breuer and A. D. Friedman, IEEE Press, 1990.
2. "Digital Circuit Testing and Testability", P. K. Lala, Academic Press, 1997.

UE22EC643BB2: Test and Debug of Analog & Digital 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.

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.

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. **08 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. **11 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.

UE22EC643BC1: Reinforcement Learning Applications (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: The reinforcement learning problem. Examples. Elements of reinforcement learning. Limitations and scope. Multi Arm bandits: An n-Armed Bandit Problem, Action value methods.

Incremental implementations. Tracking a Nonstationary Problem, optimistic initial values, upper confidence bound action selection. Gradient Bandits. Associative search.

10 Hours

Unit 2: 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 3: Dynamic Programming: Policy evaluation, improvement and iteration, value iteration, asynchronous dynamic programming, generalised policy iteration, efficiency of dynamic programming.

12 Hours

Unit 4: 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 5: Model-Free Approximate Solution Methods: 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

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.

UE22EC644BA1: ERROR CONTROL CODING (4-0-0-4-4)

Course Description

This course provides an introduction to coding theory that governs Shannon's second theorem in information theory, and provides an in-depth introduction and mathematical treatment of various channel codes such as linear block codes, cyclic codes, convolution codes and turbo codes. The concept of error detection and correction is studied, whose knowledge helps in understanding modern day communication systems, including the present day fourth generation and the awaited fifth generation systems.

Course objectives

- The course aims to provide an in-depth understanding of the various channel coding and decoding techniques and also provides insight into data security.
- Understand the concepts of error detecting codes
- Understand the concept of correcting the errors during data transmission.
- Understand the concept of convolutional codes.
- It gives an insight into concatenated codes and turbo codes.

Course Outcomes:

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

- Completely analyse the data to be fed for modulation after channel encoding.
- Design of cyclic error codes for efficient Transmission.
- Analysis of BCH Codes for transmission
- Design of convolutional codes.
- Analysis of turbo codes.

Course content

Unit 1: Linear Block Codes

Generator and Parity check Matrices, Encoding circuits, Syndrome and Error Detection, Minimum Distance Considerations, Error detecting and Error correcting capabilities, Standard array and Syndrome decoding, Decoding circuits, Hamming Codes, Reed – Muller codes, The (24, 12) Golay code, Product codes and Interleaved codes

10 Hours

Unit 2: Cyclic codes

(i) Introduction, Generator and Parity check Polynomials, Encoding using Multiplication circuits, Systematic Cyclic codes – Encoding using Feedback shift register circuits, Generator matrix for Cyclic codes, Syndrome computation and Error detection, Meggitt decoder, Error trapping decoding, Cyclic Hamming codes, The (23, 12) Golay code, Shortened cyclic codes;

12 Hours

Unit 3: BCH codes

Binary primitive BCH codes, Decoding procedures, Implementation of Galois field Arithmetic, Implementation of Error correction. Non – binary BCH codes: q – ary Linear Block Codes, Primitive BCH codes over GF (q), Reed – Solomon Codes, Decoding of Non – Binary BCH and RS codes: The Berlekamp - Massey Algorithm, Majority Logic Decodable Codes, One – Step Majority logic decoding.

12 Hours

Unit 4: Convolutional codes

Encoding of Convolutional codes, Structural properties, Distance properties, Viterbi Decoding Algorithm for decoding, Soft – output Viterbi Algorithm.

11 Hours

Unit 5: Concatenated codes & turbo codes

(i) Single level Concatenated codes, Multilevel Concatenated codes, Soft decision Multistage decoding, Concatenated coding schemes with Convolutional Inner codes, Introduction to Turbo coding and their distance properties, Design of Turbo codes; (ii) Burst – error – correcting codes:Burst and Random error correcting codes, Concept of Inter – leaving, cyclic codes for Burst Error correction – Fire codes, Convolutional codes for Burst Error correction.

10 Hours

Text Books:

1. "Error Control Coding", Shu Lin & Daniel J. Costello, Second Edition, Pearson / Prentice Hall, 2004.

Reference Book:

1. "Theory and Practice of Error Control Codes", Blahut, Addison Wesley, 1984.

UE22EC644BB1: ADVANCED SOC ARCHITECTURE (4-0-0-4-4)

Course Description:

A System - on - chip (SOC) architecture is an ensemble of processors, memories, and interconnects tailored to an application domain. This course gives overview of IP integration to build system on Chip. Emphasizes on design and reuse of IP in a systemintegration. The computer system designers will be concerned more about the elements of a system tailored to particular applications than with the details of processors and memories.Such designers would have rudimentary knowledge of processors and other elements in the system, level trade - offs that optimize the cost, performance, and other attributes to meet application requirements.

Course Objectives:

- To study a System - on - chip (SOC) architecture which is an ensemble of processors, memories, and interconnects tailored to an application domain.
- To Customize Instruction Processor and learn Reconfiguration Technologies
- Memory design and its integration for SoC
- System Bus in SoC
- Processor design for different applications and choosing a right processor for application specific SoC design

Course outcomes:

Students completing the course should be able to

- Perform computer system design
- Fundamental ideas and analytical techniques that are applicable to a range of applications and architectures.
- Understanding of different types of processors and selecting suitable processor for given application.
- Aware of complementary treatments on embedded software development and electronic system – level design
- Understanding of different system buses for SoC design.

Course Content:

Unit 1: Introduction to the System Approach

System Architecture, Components of the system, Hardware & Software, Processor Architectures, Memory and Addressing, System level interconnection, An approach for SOC Design, System Architecture and Complexity.

10 Hours

Unit 2: Chip Basics

Time, Area, Power, Reliability, and Configurability, Introduction : Design Trade-Offs , Requirements and Specifications, Cycle Time Defining a Cycle Optimum Pipeline Performance, Die Area and Cost , Ideal and Practical Scaling , Power Area–Time–Power Trade-Offs in Processor Design , Reliability, Configurability, Area Estimate of Reconfigurable Device

12 Hours

Unit 3: Processors

Introduction , Processor Selection for SOC, Basic concepts in Processor Architecture, Basic concepts in Processor Micro Architecture, Basic elements in Instruction handling; Buffers: minimizing Pipeline Delays, Branches, More Robust Processors, Vector Processors and Vector Instructions extensions, VLIW Processors, Superscalar Processors;

12 Hours

Unit 4: Memory Design for SOC

Overview of SOC external memory, Internal Memory, Size, Scratchpads and Cache memory, Cache Organization, Cache data, Write Policies, Strategies for line replacement at miss time, Types of Cache, Split – I, and D – Caches, Multilevel Caches, Virtual to real translation ,SOC Memory System, Models of Simple Processor – memory interaction.;

11 Hours

Unit 5: Interconnect Customization and Configuration

Inter Connect Architectures, Bus: Basic Architectures, SOC Standard Buses , Analytic Bus Models, Using the Bus model, Effects of Bus transactions and contention time. (i) SOC Customization: An overview, Customizing Instruction Processor, Reconfiguration Technologies, Mapping designontoReconfigurable devices, Instance- Specific design, Customizable Soft Processor, Reconfiguration - overhead analysis and trade-off analysis on reconfigurable Parallelism; (ii) Application Studies / Case Studies: SOC Design approach, AES algorithms, Design and evaluation, Image compression – JPEG compression; Introduction to Network on Chip

10 Hours

Text Books:

1. "Computer System Design System-on-Chip", Michael J. Flynn and Wayne Luk, Wiely India Pvt. Ltd., 2011.

Reference Books:

1. "ARM System on Chip Architecture", Steve Furber, 2nd Edition, Addison Wesley Professional. 2000.
2. "Design of System on a Chip: Devices and Components", Ricardo Reis, 1st Edition, Springer, 2004.
3. "Advanced Computer Architecture: Parallelism,Scalability,Programmability", Kai Hwang, 1st Edition, McGraw-Hill Higher Education, 1992

UE22EC644BB2: HETEROGENEOUS COMPUTING (4-0-0-4-4)

Course Description:

Heterogeneous computing using central processing units (CPUs) and graphical processing units (GPUs)/DSPs is a new paradigm in the high performance computing (HPC) due to present day computer architectures. It is important to familiarize with such processing units for upcoming computational research. The course is planned to be offered in collaborative manner by a group of faculty from different disciplines

Course Objectives:

- To understand the necessity of Heterogenous computing
- Introduce concepts, languages, techniques, and patterns for programming heterogeneous, parallel processors.
- To introduce the concept of data parallel execution models, memory models for managing locality
- To compare multicore with multithreading
- Simulation of memory model and super scalar execution-SIMD and Vector Processing-Multi-core CPU-GPU Architecture on OPENCL

Course Outcomes:

Students completing the course should be able to

- Utilize GPU computing terminology accurately
- Understanding the difference between multiprocessor and multicomputers.
- Learn MPI programming.
- Learn Heterogeneous Environment.
- Learn OpenCL programming and OpenCL Environment.

Course Content:

Unit1: Introduction to Heterogeneous Computing platform

Introduction, Thinking Parallel,Concurrency and Parallel Programming Models Threads and Shared Memory Message-Passing Communication Different Grains of Parallelism, Data Sharing and Synchronization Shared Virtual Memory**,** Heterogeneous Computing with OpenCL Device Architectures : introduction,Hardware Trade-offs The Architectural Design Space.

10 Hours

Unit2: Introduction to multiprocessor concepts:

Multiprocessors and Multicomputer concepts, Shared memory multiprocessors, Distributed memory multicomputer, Cache coherence, Snoopy protocol, Directory protocol, Conditions for parallelism-Data and resource dependencies, Hardware and software parallelism, Speedup performance laws-Amdhal's law for a fixed workload. **12 Hours**

Unit3:Distributed-Memory Programming with MPI

Introduction , Compilation and execution, MPI programs, SPMD programs, Communication, Semantics of MPI Send and MPI Recv. Some potential pitfalls,The Trapezoidal Rule in MPI, Dealing with I/O, Collective Communication, Collective Communication ,MPI Derived Datatypes, Performance Evaluation of MPI Programs, A Parallel Sorting Algorithm.

12 Hours

Unit4: Introduction to OpenCL

Introduction to OpenCL,The OpenCL Platform Model, The OpenCL Execution Model, Kernels and the OpenCL Programming Model, OpenCL Memory Model, The OpenCL Runtime with an Example, Vector Addition Using an OpenCL C++ Wrapper,OpenCL Examples. **11 Hours**

Unit5: C programming with LINUX

History,ModularStructure,Kernel Components, Linux Process And Thread Management, Linux Kernel Concurrency Mechanisms, Linux Memory Management, Linux Networking, Programming Examples. **10 Hours**

Textbooks:

1. Benedict R.Gaster ,Lee Howes ,David Kaeli, Heterogeneous computing with OpenCL

Reference Book:

1. “The Linux Operating System” by William Stallings
2. Computer Organization and Design”, David A, Patterson and John L Hennessy, 4th(ARM) Edition, Morgan Kaufmann, 2010.
3. “Advanced Computer Architecture”, Kai Hwang, TATA Mc-Graw Hill Publications,2008
4. “An introduction to Parallel Programming” Peter S. Pacheco

UE22EC644BC1: ADAPTIVE SIGNAL PROCESSING (4-0-0-4-4)

Course Description:

This course provides the mathematical theory behind various linear adaptive filters, thereby providing insights into the algorithms used in various fields and help in developing concepts in a unified and accessible manner.

Course Objectives:

- To understand stochastic process and models
- To understand the concepts of Steepest Descent
- To impart the knowledge on LMS algorithm
- To impart the knowledge on RLS algorithm
- To understand Kalman filters.

Course outcomes

Students completing the course should be able to

- Describe the properties of optimal filters.
- Explain the conditions for stable adaptive algorithms.
- Use the Wiener and Kalman filters in given applications.
- Apply adaptive algorithms in given applications.
- Characterize and examine the properties of adaptive algorithms.

Course content:

Unit 1: Stochastic Processes and Models
Definition and characteristics, discrete-time stochastic processes, mean ergodic theorem, correlation,, Yule-Walker equations, complex Gaussian processes, power spectral density, power spectrum estimation, Wiener filters, Principle of orthogonality, Wiener-Hopf equation.

12 Hours

Unit 2: Method of Steepest Descent
Basic idea, application to Wiener filter, stability, example, virtues and limitations, principleo stochastic gradient descent, applications.

10 Hours

Unit 3: Least-Mean-Square (LMS) Algorithm
Principles, optimality, learning theory, transient behaviour and convergence, efficiency, applications and experiments, normalized LMS algorithm and applications.

12 Hours

Unit 4: The Recursive Least-Squares (RLS) Algorithm
Cost function, normal equations, linear least squares and properties, NLMS viewed as and underdetermined LS estimation problem, RLS algorithm, updates, recursion, learning theory, efficiency, applications and examples.

11 Hours

Unit 5: Kalman Filters
Minimum mean-squared error estimates, theory of innovations, Kalman filters and state estimation, initial conditions, optimality criteria, Kalman filter as unifying basis for RLS algorithms, covariance filtering, information filtering, applications.

10 Hours

Text Book:

1. S. Haykin, "Adaptive Filter Theory," 5^{th} (international) edition, Pearson Education Asia. 2013.

Reference Books:

1. B. Widrow and S. D. Stearns, "Adaptive Signal Processing," Pearson Education Asia, 1985.
2. M. H. Hayes, "Statistical Digital Signal Processing and Modeling," John Wiley, 2002.

UE22EC645BA1: ADVANCED DIGITAL COMMUNICATION (4-0-0-4-4)

Course Description:

This course provides a second-level treatment on the well-known digital communication concepts such as source coding, modulation and demodulation, and spectral characteristics for high-dimensional constellations. Additionally, introduction and characterization of fading models are studied, which helps in the first-level understanding of wireless communication systems.

Course Objectives:

- This course will expose the students to the digital communication coding,
- It includes the understanding of signal space design,

- It gives broader view on modulation methods, demodulation methods,
- It gives an insight into M-ary modulation techniques.
- Students will learn concepts of Digital Communications through fading Multipath channels

Course Outcomes:

Students completing the course should be able to

- Understand the concepts of advanced digital communication systems.
- Visualization of signal in Signal Space.
- Apply different modulation schemes to baseband signals.
- Analyze the characteristics of M-ary Bandpass Modulated signals.
- Analyze the digital modulated wave in various fading Channels

Course Contents:

Unit 1: Source Coding

Coding Techniques for Analog sources: Temporal Waveform Coding, Spectral Waveform coding, Model based Source Coding.CodingforDiscrete sources: Coding for discrete memory less sources, discrete stationary sources, Lempel-Ziv Algorithm.

10 Hours

Unit 2: Characterization of Communication Signals and Systems

Representation of Band pass signals and systems, Signal space representation, Representation of digitally modulated signals, spectral characteristics of digitally Modulated signals.

12 Hours

Unit 3: Baseband Modulation and demodulation

Spectral Attributes of PCM Waveform Bits per PCM Word and Bits per Symbol, M-ary Pulse Modulation Waveforms Correlative Coding, Detection of Binary Signals in Gaussian Noise, Intersymbol Interference, Linear Equalization.

12 Hours

Unit 4: Bandpass modulation and Demodulation

Digital Band Pass Modulation Techniques, Detection of Signals in Gaussian Noise, Coherent and non Coherent Detection, Error Performance for Binary Systems, M-arySignalingand Performance, Symbol Error Performance for M-ary Systems (M> 2)

11 Hours

Unit 5: Digital Communications through Fading Multipath Channels

Characterization of fading multipath channels, effect of signal characteristics, Diversity techniques, Digital Signalling over a frequency selective slowly fading channel.

10 Hours

Text Books:

1. "Digital Communications: Fundamentals & Applications", Bernard Sklar and Dorling Kindersley, Prentice Hall, 2009.

Reference Books:

1. "Digital Communications" , John G Proakis , , 4th Edition ,McGraw Hill, 2001
2. "Digital Communication Systems Using Matlab& Simulink", David Silage, Bookstand Publishing, 2009.
3. "Digital Communication Systems", Simon Haykin, Wiley Student Edition, 2013.

UE22EC645BB1: Radio Frequency Integrated Circuit design (4-0-0-4-4)

Course Description:

The objective of this course is to present the concepts of design and analysis of modern RF and wireless communication integrated circuits. Topics covered are: basic concepts in RF design, scattering parameters, modern integrated circuit technologies, fundamental limitations of speed of operation of transistors, physics of noise, impedance matching, low-noise amplifiers, mixers, oscillators, phase noise, and phase locked loops. This course requires the knowledge of Analog VLSI. For this course knowledge of Analog VLSI is required.

Course Objectives:

- Impart understanding of high frequency circuit design
- Introduce RF circuit design parameters
- To put forward RF circuit design blocks for system integration
- Layout design and isolation techniques for RF circuits
- Understanding of RF Power amplifiers.

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
- Know RFIC Design Topologies, Techniques
- Design and development of Oscillators and Power amplifiers.
- Design Amplifiers, Mixers and Bias Sources

Course Content:

Unit 1: **Basic Concepts in RF Design**

Introduction to RF design and Wireless technology, General Considerations, Effects of Nonlinearity, Noise, Sensitivity and Dynamic Range, Passive impedance transformation

10 Hours

Unit 2: **Transceiver Architectures**

Receiver architectures and Transmitter architectures

12 Hours

Unit 3: **Low Noise Amplifiers**

General considerations, LNA topologies, Gain switching, Band switching, High IP_2–LNAs

12Hours

Unit 4:Mixers

General Considerations, Passive down conversion mixers, Active down conversion mixers, Improved mixer topologies, Up conversion mixers

11 Hours

Unit 5: Oscillators and Power Amplifiers

Basic principles, cross coupled oscillators, Voltage controlled oscillators, Low noise VCOs, Phase noise, Classification of power amplifiers, high frequency power amplifiers

10 Hours

Text Books:

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

Reference Books:

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

UE22EC645BB2: RF AND OPTICAL AMPLIFIER DESIGN AND IMPLEMENTATION (4-0-0-4-4)

Course Description:

This course deals with circuit level design and analysis of RF and Optical circuits. This course includes study of device level RF characterization, Wide band RF amplifiers and Optical amplifiers.

Course Objectives:

- The course will enable the students with basic circuit level and design level knowledge of RF and optical amplifiers.
- It will equip the students with analytical designing capabilities and basic computing capabilities.
- To introduce the design principles of narrow band and wideband RF amplifiers
- To introduce the design principles of modern optical amplifiers
- The gained knowledge will give basics of the current RF and Optical amplifier technology for further studies or employment.

Course Outcomes:

Students who successfully complete the course will be able to:

- Be familiar with the basic electronic and optical principles and components for high frequency application;
- Understand the designing and material principles for various bandwidth amplifier designs.
- Apply designing techniques to build RF power amplifiers with stabilization adjustments etc.
- Understand the silicon optical amplifier basics
- Design parametric optical amplifiers.

Course Contents:

Unit 1: Introduction to RF devices:

RF diodes, Bipolar junction transistors (BJT), RF-field effect transistors (FETs), High electron mobility transistors; Transistor Large signal and small signal models, review of Smith chart.

10 Hours

Unit 2:RF amplifiers
Amplifier classes, BJT and FET biasing networks, amplifier characteristics: amplifier power relationships; stability; constant gain; noise figure circles; constant VSWR circles; broadband, high power and multistage amplifiers, switching amplifiers.

12 Hours

Unit 3: Wideband amplifiers
Distributed amplifiers, differential amplifiers, RFICs.

12 Hours

Unit 4: Optical amplifiers
Introduction to non-linear optics, Erbium doped fiber amplifier, design and characterization issues in amplifiers, Semiconductor optical amplifiers, Quantum well and Quantum dot amplifiers, modelling of selective structures using Python.

11 Hours

Unit 5: Parametric amplifiers
Noise factor; microwave parametric amplifier basics and application; small signal analysis; Optical parametric amplifiers.

10 Hours

Text Books:

1. Reinhold Ludwig, Pavel Bretchko, RF Circuit Design: Theory and Applications, Prentice Hall, 2000.

Reference Books:

1. Michel J. F. Digonnet (ed.), Rare-Earth-Doped Fiber Lasers and Amplifiers, CRC Press, 2001.
2. Dutta N.K., Qiang W., *Semiconductor Optical Amplifiers*, World Scientific, 2013.
3. Michael Steer, *Microwave and RF Design Amplifiers and Oscillators*, vol.5, 3rd Ed., N.C. State university press, 2019.
4. J. c. Decroly, L. Laurent, J. c. Lienard, G. Marechal, J. Vorobeitchik, *Parametric Amplifiers*, McMillan Education, 1973.
5. Michel E. Marhic, *Fiber Optical Parametric Amplifiers, Oscillators and Related Devices*, Cambridge, 2007.

UE22EC645BC1: Robotics (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

UE22EC621B: RESEARCH METHODOLOGY (2-0-0-2-2)

Course Description:

The course describes a broad understanding of research methodology, including theory of scientific and research methods. It is designed to impart education in the foundational methods and techniques of academic research.

Course Objectives:

- Familiarize the foundations of research.
- Familiarize research methodologies, problem identification and formulation.
- Developing skills to understand research design.
- Improve paper writing skill and understanding research ethics.
- Familiarizing the tools and techniques for research.

Course Outcomes:

Students completing the course should be able to

- Understand the foundations of research.
- Understand how to do research, including the research topics to be selected.
- Comprehend variety of research methods, including survey research, case studies, comparative analysis, and the use of documentary/primary sources.
- Understand the ethical issues in research.
- Prepare for and present a conference paper/poster at a national/international conference.

Course Content:

Unit 1 : Foundations of Research

Meaning, Objectives, Motivation, Utility. Concept of theory, empiricism, deductive and inductive theory. Characteristics of scientific method – Understanding the language of research – Concept, Construct, Definition, Variable. Research Process.

6 Hours

Unit 2 : Problem Identification & Formulation

Research Question – Investigation Question – Measurement Issues – Hypothesis – Qualities of a good Hypothesis – Null Hypothesis & Alternative Hypothesis. Hypothesis Testing – Logic & Importance,Literature Survey.

6 Hours

Unit 3 : Research Design

Concept and Importance in Research – Features of a good research design – Exploratory Research Design, Descriptive Research Designs, Experimental Design, Qualitative and Quantitative Research, Measurement: Concept of measurement –what is measured? Problems in measurement in research – Validity and Reliability.

6 Hours

Unit 4 : Technical Paper Writing

Layout of a Research Paper, Journals in electronics and communication, Impact factor of Journals, when and where to publish Ethical issues related to publishing, Plagiarism and Self – Plagiarism.

5 Hours

Unit 5 :Use of Tools / Techniques for Research

Methods to search required information effectively, Reference Management Software like Zotero/Mendeley, LaTeX/MS Office, Software for detection of Plagiarism.

5 Hours

Text Books:

1. "Research Methodology: Methods and Techniques", C. R. Kothari ,New Age International Publications, 1985.

Reference Books:

1. "Research Methodology", R. Panneerselvam, PHI Learning , 2004.

UE21EC722AA1 : Optimization I (2-0-0-2-2)

Course Description:

Network design problems are generally formulated as optimization problems. The principles of optimization can be applied to other important disciplines such as portfolio management, process scheduling, IoT and automation, Industry 4.0, etc. Many real world problems can be cast as linear programs or integer programs. In fact, assignment problems are commonly referred to as assignment problems or resource allocation problems. This hands-on course intends to develop a strong background in formulating optimization problems.

Course Objectives:

- To provide an understanding of unconstrained optimization problems and their applications
- To introduce solution methods for unconstrained optimization problems
- To provide an understanding of linear programming problems and their applications
- To introduce solution methods for LP problems
- To provide an understanding of IP problems, their applications and solution methods

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 using geometry, Optimization problem structure, types and complexity, System design.

05 Hours

Unit 2: Unconstrained optimization problems:

Single variable and multivariable solution methods, Introduction to solvers: CVX and CPLEX.

05 Hours

Unit 3:Linear Programming:

Standard form of LP, structural properties, Simplex method, Duality and Economic interpretation, Formulating and coding LP problems.

06 Hours

Unit 4:Integer programming:

Structure and Types, Formulating and coding IP problems, Branch and bound methods, Cutting plane method, MINLP to MILP conversion, Benders Decomposition for MIP

06 Hours

Unit 5:Case studies:

Coding using CVX

06 Hours

Text Book:

1. "Introduction to Applied Optimization", Urmila Diwekar, 2nd edition, Springer, 2008

Reference Books:

1. "Linear Algebra", Paul Dawkins, Lamar University, 2007.
2. "Convex Optimization", Stephen Boyd and L. Vandenberghe, 7th Edition, Cambridge University Press, 2004.
3. "Partitioning Procedures for Solving Mixed-Variables Programming Problems, Computational Management Science", J. F. Benders, Springer-Verlag, 2005.

UE21EC722AA2: Antenna Theory (2-0-0-2-2)

Course Description:

This course aims to give an in-depth understanding the principles of antenna theory and design. The course will enable the students to understand the operation of common antennas and provide them an opportunity to design and test antennas. Students are able to design and analyse wire, aperture and broadband antennas in theory and using computational electromagnetic software. Students are able to extend the analysis and design from a single antenna to an antenna array. Thus, the course will combine both the theoretical and practical aspects of antenna design.

Course Objectives:

- This course aims to give an in-depth understanding of antenna arrays, travelling wave antennas, and aperture antennas.
- This course will enable the students to choose proper antenna to the desired specifications and design the antennas.

Course Outcomes:

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

- Solve problems in uniformly and non-uniformly excited arrays incorporating the mutual coupling.
- Analyze and design aperture antennas like offset feed parabolic reflectors and dual reflectors.
- Analyze and design broadband antennas.

Course Content:

Unit 1: Arrays:

Nonuniformly excited equally spaced linear arrays, Mutual coupling, Multidimensional arrays, Phased arrays, Feeding techniques, Perspectives on Arrays.

06 Hours

Unit 2: Travelling wave antennas:

Helical antennas, Biconical antennas Sleeve antennas, and Principles of frequency independent antennas, Spiral antennas, and Log – periodic antennas;

06 Hours

Unit 3: Aperture antennas:

Techniques for evaluating gain, Reflector antennas – Parabolic reflector antenna principles, Axi-symmetric parabolic reflector antenna, Offset parabolic reflectors,

06 Hours

Unit 4: Dual reflector antennas:

Gain calculations for reflector antennas, Feed antennas for reflectors, FiECS representations,

05 Hours

Unit 5: Matching the feed to the reflector:

General feed model, Feed antennas used in practice.

05 Hours

Text Book:

1. "Antenna Theory and Design", Warren.L.Stuzman and Gary.A.Thiele, 3^{rd} Edition, John Wiley and Sons, 2012.

Reference Books:

1. "Antenna Theory Analysis and Design", C. A. Balanis , 2^{nd} Edition, John Wiley, 1997.

UE21EC722AB1: Selected Topics in Reconfigurable Computing (2-0-0-2-2)

Course Description:

This course deals with one of the modern computing paradigm: Reconfigurable Computing. This course discusses FPGA devices, tools, reliability and security aspects of reconfigurable computing.

Course Objectives:

- To introduce to the basic concepts of computing and the issues in system design.
- To understand the modern FPGA devices.
- To bring in the significance of reconfigurable computing which helps in addressing some of the issues of system design like resource and timing constraint.
- To illustrate architectures and computing models and to identify the trends and latest development of the technologies in the area.
- To study various technological algorithms

Course Outcomes:

Students completing the course should be able to

- Know the strengths of reconfiguration.
- Understand the factors to be considered in building reconfiguration systems
- Build reconfigurable system.
- Apply reconfiguration concepts while building systems to address resource constraints, area constraint etc.
- Understand architecture development.

Course Content:

Unit 1: Device Architecture:
Logic—The Computational Fabric, The Array and Interconnect, Extending Logic Configuration; (i) Reconfigurable Computing Architectures: Reconfigurable Processing Fabric Architectures, RPF Integration into Traditional Computing Systems

06 Hours

Unit 2: Reconfigurable Computing Systems:
PAM, VCC, and Splash, Small-scale Reconfigurable Systems, Reconfigurable Supercomputing; (i) Reconfiguration Management: Configuration Architectures, Managing the Reconfiguration Process, Reducing Configuration Transfer Time

06 Hours

Unit 3: Compute Models and System Architectures:
Compute Models, System Architectures;

06 Hours

Unit 4: Programming FPGA Applications in HDL: HDL Programming

05 Hours

Unit 5: Technology Mapping: Structural Mapping Algorithms, Integrated Mapping Algorithms, Mapping Algorithms for Heterogeneous Resources

05 Hours

Text Book:

1. "Reconfigurable Computing", Scout Hauck and Andre Dehon, Elsevier, 2008.

Reference Books:

1. "Partial Reconfiguration on FPGAs Architectures, Tools and Applications", Dirk Koch, Springer, 2013.
2. "Multicore Technology: Architecture, Reconfiguration, and Modeling", Muhammad YasirQadri, Stephen J. Sangwine, CRC Press, 2014.

UE21EC722AB2 : Formal Verification of Hardware Designs (2-0-0-2-2)

Course Description:

This course deals with formal 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 formal verification of Digital VLSI design.
- To learn and understand System Verilog Assertions.
- To learn methods for formal analysis of combinational and sequential digital circuits.
- Analysis of the constraining 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 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

Course contents:

Unit 1: Formal verification:

The Emergence of Practical FV, Challenges in Implementing FV, Amplifying the Power of Formal, Basic formal verification algorithms, Formal Verification (FV) in the Validation Process, Comparing Specifications, Formalizing Operation, Definitions, Boolean Algebra Notation, BDDs, Boolean Satisfiability.

06 Hours

Unit 2: Assertions:

Introduction to systemverilog assertions, Basic Assertion Concepts, Immediate Assertions, Sequences, Properties, and Concurrent Assertions, Formal property verification: What is FPV, Combination Lock, Bringing up a Basic FPV Environment, How is FPV Different from Simulation, Effective FPV for design exercise: - Traffic Light Controller, Creating a Design Exercise Plan, Setting Up the

Design Exercise FPV Environment, Wiggling the Design, Exploring More Interesting Behaviors, Removing Simplifications and Exploring More Behaviors.

06 Hours

Unit 3: Effective FPV for verification:

Deciding on Your FPV Goals, Staging Your FPV Efforts, Simple ALU, Understanding the Design, Creating the FPV Verification Plan, Removing Simplifications and Exploring More Behaviors. FPV "Apps" for specific SOC problems: - Reusable Protocol Verification, Unreachable Coverage Elimination, Connectivity Verification, Control Register Verification, Post-Silicon Debug.

06 Hours

Unit 4: Formal equivalence verification:

Types of Equivalence to Check, FEV Use Cases, Running FEV, Additional FEV Challenges, Formal verification's greatest bloopers: The danger of false positives , Misuse of the SVA Language, Vacuity Issues, Implicit or Unstated Assumptions.

05 Hours

Unit 5: Dealing with complexity:

Design State and Associated Complexity, Memory Controller, Observing Complexity Issues, Simple Techniques for Convergence, Helper Assumptions and Not-So-Helpful Assumptions, Generalizing Analysis Using Free Variables, Abstraction Models for Complexity Reduction

05 Hours

Text Book:

1. "Formal Verification, An essential toolkit for modern VLSI design", Erik Seligman, Tom Schubert, M. V Achutha Kiran Kumar, 1st Edition, Morgan Kaufmann, August-2015.

UE21EC722AB3: Micro-electro mechanical techniques and optics

Course Description:

Research and development of MEMS (Micro Electro Mechanical Systems) builds on the dramatic advances in silicon processing infrastructure to create micron-scale machines. Unlike conventional integrated circuits, MEMS devices can have many functions, including sensing, communication, and actuation. Just like microelectronics, MEMS technology has started to permeate our everyday lives.

Course Objectives:

This subject is expected to introduce to the attendees:

- Basics of electro-mechanical systems in actuation;
- Basics of optoelectronic and optical systems in actuation;
- Modern sensors and building blocks of System-on-Chip (SoC);
- MEMS and MOEMS overview with essential material parameters;
- Fabrication and integration processes;

Course Outcomes:

Students who successfully complete the course will be able to:

- Understand the analytical basics of applied electro-mechanics;
- Understand the analytical basics of applied electronics.
- Understand the basics of applied optics.
- Understand basic material properties in action;
- Get an overview of fabrication principles.

Pre-requisite: Basic circuit theory and electromagnetics.

Course Content:

Unit1:**Introduction to MEMS devices:** The basics and application of MEMS; Mechanical, Electrical and Optical effects in MEMS and MOEMS; Differences between MEMS and MOEMS; Recapitulation: Stress/Strain Hooke's law; Natural/damped and forced vibrations; diaphragm basics; Fluid drag, viscosity; Electrostatic and Capacitive effects; Piezoelectric effect.

06 Hours

Unit2: Optical essentials for MOEMS: Fourier Optics, Holography, Optical thin films and periodical structures Bragg gratings, Gaussian beam propagation, ultra fast lasers, Fundamentals of Nonlinear Optics. **06 Hours**

Unit3: **Electro-mechanical actuation:** Flow models for damped and non-damped oscillation, electrostatic actuation, Capacitive sensing and effects of electrical excitation, piezoelectric sensing element, cantilevers, essential material properties. **06 Hours**

Unit4: Opto-electronic effects: various waveguides and essential analyses, Quantum optics introduction, grating based sensors, photonic crystals, ring resonators, passive and active devices, actuation principles. **05 Hours**

Unit5: micromachining principles: introduction to bulk micromachining, surface micromachining, heterogenous integration, MEMS using CMOS wafer; packaging, sealing, interconnection; Optical integration techniques basics. **05 Hours**

Text Book :

Masayoshi Esashi (ed.), *3D and Circuit Integration of MEMS*, Wiley-VCH, 2021; Print ISBN: 978-3-527-34647-9

References

1. Minhang Bao, *Analysis and Design Principles of MEMS Devices*, Elsevier, 2005, ISBN: 0 444 51616 6
2. Paolo Di Barba, Slawomir Wiak, MEMS: Field Models and Optimal Design, Springer Nature, 2020, ISBN 978-3-030-21495-1

UE21EC722AC1: Deep Learning (2-0-0-2-2)

Course Description: This course gives the deep learning concepts like convolutional neural networks, recurrent neural networks. It also gives an insight into concepts such as optimization for training models, extraction of features from the image. It provides good knowledge about optimization, dataset augmentation and noise robustness.

Course Objectives:

- To give good knowledge about regularization.
- To understand semi supervised learning.
- To impart knowledge on optimization of deep neural networks
- To provide in depth knowledge of convolutional neural networks
- To understand recurrent neural networks

Course Outcomes:

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

- Analyze regularization in deep neural networks
- Design models based on semi supervised learning
- Analyze the concepts of optimization
- Design convolutional neural networks
- Design recurrent neural networks

Course Content:

Unit 1: Regularization for Deep learning: Parameter Norm penalties. Norm penalties as constrained optimization, Regularization and under constrained problems, Dataset augmentation, noise robustness

5 Hours

Unit 2: Semi supervised learning, Multi task learning, early stopping, parameter tying and parameter sharing. Sparse Representations, Bagging and other ensemble methods. Drop out, Adversarial Training, Tangent Distance, Tangent prop and Manifold Tangent Classifier.

6 Hours

Unit 3: Optimization for Training Deep Models: How learning differs from Pure optimization. Challenges in Neural Network Optimization, Basic Algorithms, Parameter for Initial strategies. Algorithms with adaptive learning rates

6 Hours

Unit4: Convolutional Networks: The convolution operation, Motivation, Pooling, Convolution and Pooling as an infinitely strong Prior. Variants of the basic convolution function. Data types. Efficient convolution algorithms.

6 Hours

Unit 5: Sequence Modelling: Recurrent and Recursive Nets: Unfolding Computational graphs, Recurrent Neural Networks, Bidirectional RNN

5 Hours

Text books:

4. "Deep Learning ",Ian Goodfellow, Yoshua Bengio, Aaron Courville, MIT Press Ltd,2016.

UE21EC722BA1: OPTIMIZATION II (2-0-0-2-2)

Course Description:

Optimization has been a game changer in the field of network design. The principles of optimization can be applied to other important disciplines such as portfolio management, process scheduling, IoT and automation, Industry 4.0, etc. However, decisions in these real world problems are often taken under uncertainty. Further, these problems tend to be NP hard making them difficult to solve. To address the trade-offs in computation complexity and accuracy/scalability, this course brings in convex optimization, convex relaxation techniques and stochastic programming. This hands-on course intends to develop a strong background in formulating optimization problems. This course requires the knowledge of Optimization I.

Course Objectives:

- To provide an understanding of convex optimization problems and their applications
- To introduce solution methods for convex optimization problems
- To provide an understanding of non-convex optimization problems and relaxation techniques
- To introduce stochastic programming problems

- To introduce solution methods for SP and introduce other SP types

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: Convex Optimization – Part 1:
Convexity, convex geometry, Convex functions, Lagrangian relaxation and Duality, KKT conditions

06 Hours

Unit 2: Convex Optimization – Part 2:
Interior point method, Formulating convex problems - examples; Multi-objective problems;

05 hours

Unit 3: Convex Relaxations using Examples:
Semidefinite programming, SOCP, Geometric programming;

06 Hours

Unit 4: Stochastic Programming (SP):
Deterministic versus stochastic optimization, Basic structure of SP and types of decisions, Two-stage stochastic programming, Solution method: L-shaped method, ADMM

06 Hours

Unit 5: Monte Carlo Methods and Other SP Types:
Sampling and sample average approximation; Brief overview of other SP formulations

05 Hours

Text Book:

1. “Convex Optimization”, Stephen Boyd and L. Vandenberghe, 7th Edition, Cambridge University Press, 2004.

Reference Books:

1. “Introduction to Stochastic Programming”, J. R. Birge and F. Louveaux, 2nd edition, Springer Series in Operations Research and Financial Planning, 2011.

2. “Stochastic Programming,” Peter Kall and Stein W. Wallace, 2nd Edition, John Wiley & Sons, 2003.

UE21EC722BA2: Antenna Design using Simulation tools (2-0-0-2-2)

Course Description:

Antenna design/simulation Course covers all the aspects of Engineering, theory, analysis, and design. Learn about antenna array theory, electromagnetic radiation, and antenna characteristics such as impedance, VSWR, radiation pattern, polarization, gain, and efficiency this also include design considerations for wire, aperture, reflector, and printed circuit antennas. In this course, the students will learn how to apply the learned topics in practice. This course will help students to design antennas in FEKO software and MATLAB. After learning this course students will be able to design an antenna at any frequency range and will learn about the important design tips in FEKO by use of which anyone can easily design antennas. This course will also help the students who are zero level and want to learn the antennas designing.

Course Objectives:

- The course objective is to understand the theory and fundamentals of antenna design.
- The course helps the students to learn key aspects of practical antenna design. A broad range of antennas such as dipole, loop, micro strip patch, horn, etc. are studied during the course.
- After studying the single antenna element design, the course focuses on antenna array theory and design. Students will learn industry standard software CST and FEKO to complete their design projects.

Course Outcomes:

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

- Good understanding of antenna fundamentals and the know-how of designing various kinds
- of antennas such as dipole, loop, microstrip patch antennas and arrays.
- Students will also learn industry standard simulation software CST, FEKO and MATLAB which they will use for their design projects.
- Design an antenna from scratch, will simulate it in software

Course Content:

Unit 1: Introduction, Fundamental antenna system parameters, Antenna types **2 Hours**

Unit 2 :CST Studio Experiments **10 Hours**

1. Familiarization of CST Simulator using Monopole/Dipole antenna.
2. Analysis of Horn antenna using CST simulator.
3. Analysis of Yagi antenna using CST simulator.
4. Analysis of Helical antenna using CST simulator.
5. Construct a reflector antenna and calculate the far field of the full system (horn + reflector) using the Hybrid Solver Task.
6. Construct a dual patch antenna and a corresponding matching network.
7. Analysis of Microstrip antenna.
8. Construct a Patch Antenna Array and study gain, return loss.

Unit 3: Antenna Hardware Experiments **5 Hours**

1. Measurement of Radiation pattern, beam width, polarization of Horn antenna, Parabolic antenna.
2. Measurement of Radiation pattern, beam width & of micro strip Antenna.
3. Determination of Axial ratio of a Helical antenna.

Unit 4:FEKO antenna simulation Experiments. **5 Hours**

9. Familiarization of FEKO using Monopole and Dipole antenna.
10. Measurement of Radiation pattern, beam width of helical antenna
11. Measurement of Radiation pattern, beam width of Parabolic antenna.
12. Measurement of Radiation pattern, beam width of micro strip Antenna.

Unit 5:MATLAB antenna simulation experiments & coding **6 hours**

13. To write a program to plot radiation pattern of linear array of isotropic antennas.
14. To perform the numerical evaluation of directivity for a half wave dipole.
15. To write a program to determine the directivity [D(θ,Φ)], the beam solid angle ΩA and the maximum directivity [Do] of an antenna defined by F(θ,Φ) = sin2θcos2θ.
16. To write a program to plot 3D radiation pattern for Binomial antenna array.
17. To write a program to plot 3D radiation pattern for Broadside, and Endfire antenna array.

Text Book:

1. “Antenna theory analysis and design”, C.A.Balanis, Third Edition, John Wiley & sons.

Reference Book:

2. “Antennas and Propagation”, A.R.Harish and M.Sachidananda, Oxford University Press

UE21EC722BB1: VLSI FOR DSP (2-0-0-2-2)

Course Description:

This course aims to providing a comprehensive coverage of techniques for designing VLSI architectures for signal processing.

Course Objectives:

- To understand how algorithms can be mapped to architectures.
- To expose to the basic concepts in digital processing system design with emphasis on the digital filter design and related algorithmic and implementation issues.
- Specifically, focus will be on FIR, IIR Filters classical and optimized design techniques, issues related to finite word length and advantage of specific structures for implementation.
- To understand the concepts of time borrowing, parallel filter design and optimal design
- To understand implementation challenges

Course Outcomes:

Students completing the course should be able to

- Acquired knowledge about DSP algorithms, its DFG representation, pipelining and parallel processing approaches.
- Ability to acquire knowledge about retiming techniques, unfolding, folding and register minimization path problems.
- Ability to understand the concepts of systolic architecture and its methodology.
- Ability to have knowledge about different methods of convolutions.
- Acquired knowledge on concepts of algorithmic strength reduction.

Course Content:

Unit 1: Introduction to DSP systems:

Representations of DSP Algorithms, Iteration Bounds: Data flow graph Representations, Loop bound and Iteration bound, Algorithms for Computing Iteration Bound, Iteration Bound of multi rate data flow graphs, Pipelining and parallel processing ,Pipelining of FIR Digital Filters, Parallel processing, Case study: Implementation of filters in MATLAB and FPGA

06 Hours

Unit 2: Retiming:

Definition and Properties, Solving Systems of Inequalities, Retiming Techniques different methods, Case study: Implementation of retiming in MATLAB and FPGA

06 Hours

Unit 3: Unfolding and folding: Unfolding An Algorithm for Unfolding, Properties Of Unfolding, applications of unfolding, Case study: Implementation of COMB filter inMATLAB and FPGA

06 Hours

Unit 4: Application of Unfolding Systolic Architecture Design:

Systolic array design Methodology, FIR systolic array, Selection of Scheduling Vector.

05 Hours

Unit 5: Fast Convolution Algorithms:
Cook-Toom Algorithm, Winograd Algorithm, Iterated convolution, Cyclic Convolution, Design of fast convolution Algorithm by Inspection, Case study: Implementation of convolution algorithm inMATLAB and FPGA

05 Hours

Text Books:

1. "VLSI Digital Signal Processing Systems, Design and Implementation", Keshab K. Parthi, Wiley, Inter Science, 1999.

Reference Books:

1. "Analog VLSI Signal and Information Processing", Mohammed Ismail and Terri Fiez, McGraw-Hill, 1994.
2. "VLSI and Modern Signal Processing", S.Y. Kung, H.J. White House, T. Kailath, Prentice Hall, 1985.
3. "Design of Analog - Digital VLSI Circuits for Telecommunication and Signal Processing", Jose E. France, YannisTsividis, , Prentice Hall, 1994.

UE21EC722BB2: Post Silicon Validation (2-0-0-2-2)

Course Description:

Post fabrication testing of semiconductor chips is an important engineering process in electronics industry. This course discusses basics of ATE (Automatic Test Equipment) based testing, production flow testing, parametric analysis and characterization of properties of modern-day System on chips. This course requires the basic understanding of analog and digital circuits.

Course Objective:

- To introduce the importance and concepts of post silicon validation
- To impart training in design and development of post silicon test process.
- To introduce the product engineering concepts of semiconductor industry
- To introduce the challenges and research prospects in chip testing
- To introduce the challenges in advanced test tools.

Course Outcomes

- Understanding economics connected with chip design and post silicon validation.
- Understanding of wafer sorting, final testing and characterization practices.
- Student will understand post fabrication testing of VLSI devices
- Sound understanding of different equipments used in post silicon validation
- Test program development for production flow and characterization.

Course Contents

Unit-1: Introduction: Post silicon production flow, test and packaging, characterization versus production testing, Components of Test program, DC and parametric measurements: continuity, leakage currents, power supply currents, impedance measurements, DC offset measurements, DC tests for digital circuits. **5 Hours**

Unit-2: ATE Instrumentation: High speed digital basics, Digital pin electronics ATE card, Sampler/Digitizer ATE card, parametric measurements with sampled data **6 Hours**

Unit-3: Tests and Measurements: Bit and Pattern alignment, Functional test, Shmoo tests, Driver tests, Driver Jitter tests, receiver tests, PLL Characterization. **6 Hours**

Unit-4: Production testing: - Golden device, System level test, At-speed ATE tests, Active test fixture and multi-site testing. **6 Hours**

Unit-5: Support Instrumentation: Oscilloscopes, Bit error rate tester, time interval analyzer, spectrum analyzer, vector network analyzer, arbitrary waveform and function generator, text fixtures, Sockets, Relays, Wafer probing. **5 Hours**

Textbooks:

1. Mark Burns and Gordon Roberts, "An Introduction to Mixed –Signal IC Test and Measurement", Oxford University Press-2001.

Reference Books:

1. Jose Moreira and Hubert Werkmann, "An Engineer's Guide to Automated Testing of High Speed Interfaces", Artech House-2010.

UE21EC722BB3: High Speed Serial Interface Design (2-0-0-2-2)

Course Description: This course covers circuit and system design techniques for high-speed serial links or wireline communications. Topics include high-speed electrical channel modelling, digital communication techniques, design specifications and implementation details of high-speed serial link circuits. For this course knowledge of Digital circuit design is required.

Course Objectives:

- To give an understanding of High-Speed Serial Interfaces based on SERDES
- To understand the applications of SERDES in standard high-speed protocols like PCI, etc.
- To understand the analysis of high-speed serial interfaces using eye diagrams and other tools
- To understand the Low power implementations of SERDES based protocols
- To understand basics of differential signalling and signal integrity.

Course Outcomes:

Students completing the course should be able to

- Understanding of high-speed digital serial interface basics.
- Understanding of important high speed digital interfaces like PCI, DDR and LPDDR.
- Designing low power implementation of high-speed protocols.
- Protocol Specifications and control design
- System design concepts of High-speed serial protocols.

Course Content:

Unit 1: SERDES Concepts:

The Parallel Data Bus, Source Synchronous Interfaces, High Speed SERDES, Signal Integrity and Signalling methods. **4 Hours**

Unit 2: HSS (High Speed Serial) Architecture and Design:
Phase Locked Loop (PLL), SERDES Transmitter and Receiver. **6 Hours**

Unit 3: Protocol Logic and Specifications:
Protocol Specifications: Protocol Layers, Protocol Logic Functions: Bit/Byte Order and Striping/Interleaving, Data Encoding and Scrambling, Error Detection and Correction, Parallel Data Interface, Bit Alignment, De-skewing Multiple Serial Data links. **7 Hours**

Unit 4: PCI Express: PCI Express Architecture, Physical layer logic, Electrical Physical layer, Power states and PCI Express Implementation example.

6 Hours

Unit 5: DDR/LPDDR:
DDR Architecture, Different versions of DDR, DDR implementation

5 Hours

Pre - Requisite: Knowledge of Digital circuit design

Text Book:

1. Stauffer, Mechler et al, "High Speed SERDES Devices and Applications", Springer 2008.

Reference Books:

1. Mike Jackson and Ravi Budruk, "PCI Express Technology: Comprehensive Guide to Generations", Mindshare Press-2015.
2. Data sheets prescribed by Instructor.

UE21EC722BB4: Design and Implementation of RISC-V Microprocessor (2-0-0-2-2)

Course Description:

This course concisely delivers the RISC-V ecosystem, ISA architecture of RISC -V Processor and Verilog implementation and verification. The course also includes the industry and academic case studies of RISC-V microprocessor-based products and services. For this course Knowledge of Digital Design and Verilog HDL is required.

Course Objectives:

- The course intended to introduce the world of RISC-V microprocessors
- This course also equips the students to understand the intricacies of modern-day microprocessor.
- To understand the ISA design and its extensions in RISC-V.
- To understand the importance of RISC -V based SoC and challenges.
- To understand the design and development of single cycle processor, multi-cycle processor and pipelined processor.

Course Outcomes:

Students completing the course should be able to: -

- Good RTL design and FSM design using Verilog

- Understanding of microarchitecture of advanced microprocessors
- ISA of advanced microprocessors
- Design of single cycle, multi-cycle and pipelined processor.
- Design and Verification Methodologies of modern-day microprocessors.

Course Content:

Unit 1: RISC-V Ecosystem

History of RISC-V, RISC-V Community and Ecosystem, Necessity of designing open-source ISA, Difference between ARM and RISC-V ISA. **5 Hours**

Unit 2: RISC-V ISA

ISA of RISC-V, Memory operands, Arithmetic operands, RISC-V fields, logical operations, addressing modes. **5 hours**

Unit 3: RISC-V Architecture Design

Building datapath, clocking methodology, ALU control, Pipelining, Implementation of RISC-V architecture, Agile approach to build RISC-V microprocessors **10 Hours**

Unit 4: RISC-V Verification:

Complete architecture of RISC-V, Specification and testing of RISC-V ISA Compliance, RISC-V tool chain, Assembly program development, Code and functional coverage.

4 Hours

Unit 5: **RISC-V Case studies**

Customizing RISC-V for IoT edge nodes and functional safety, Security extensions to RISC-V, POSIT extensions to RISC-V and Data centre applications. **4 Hours**

Text Books:

1. Patterson and Hennessy, "Computer Organization, RISC-V Edition", Elsevier, 2017.
2. Research Papers and Whitepapers prescribed by the instructor.

Demonstration

1. Simulation of Building blocks of RISC-V processor and microarchitecture in Cadence EDA Tools
2. Verification of RISC-V processor using standard benchmarks in Cadence EDA tools.
3. Andes RISC-V compilers and Toolchain for RISC-V program development and Simulation.

UE21EC722BC1: DIGITAL PROCESSING OF RANDOM SIGNALS (2-0-0-2-2)

Course Description:

This course introduces a discussion of signal processing and filtering, and presents several new methods that can be used for a more dynamic analysis of random digital signals with both linear and non-linear filtering. This course also emphasizes problem solving and result analysis, enabling students to take a hands-on approach to advance their own understanding of algorithms used within signal processing and filtering.

Course Objectives:

- To introduce the fundamentals of random signal processing.
- To understand the AR, MA and ARMA models.
- To understand Wiener filters.
- To understand advanced filtering techniques which are adaptive in nature.
- To understand non linear filtering.

Course Outcomes:

Students completing the course should be able to

- Analyse the signal modelling techniques.
- Implement non-parametric and parametric spectral estimation techniques
- Implement Weiner filter and adaptive filters to suit specific requirements for specific applications.
- Implement Adaptive algorithms
- Analyse different Non-linear filtering.

Course Content:

Unit 1: Classical Spectra Estimators

Periodogram and correlogram, Daniell, Bartlett, Blackman-Tukey, Welch and modified Welch periodogram methods.

06 Hours

Unit 2: Parametric Spectra Estimators

AR, MA and ARMA models, Yule-Walker equations, LS method and prediction, Levinson-Durbin method, spectra, eigenvalues, and eigenvectors.

06 Hours

Unit 3: Optimal Wiener Filters

Mean squared error, FIR Wiener filters, orthogonality principle, examples and applications.

05 Hours

Unit 4: Adaptive Algorithms

LMS, examples, sign algorithms – NLMS, error sign and their variants, variable step variant, leaky LMS, convergence studies.

05 Hours

Unit 5: Nonlinear Filtering

Preliminaries, CRLB and other performance metrics, mean and median filters, variants, L-filters, R-filters, edge enhancement filters, ranked-order statistic filters, applications.

06 Hours

Text Book:

1. “Discrete Random Signal Processing and Filtering Primer with MATLAB”, Alexander D. Poularikas,Electrical Engineering and Applied Signal Processing Series, CRC Press, 2008.

Reference Books:

1. “Statistical Digital Signal Processing and Modeling," Monson H. Hayes, John Wiley & Sons (Asia) Pvt. Ltd., 2002.
2. "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.
3. "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.
4. "Adaptive Signal Processing,"BernardWidrow and Samuel D. Stearns, Pearson Education (Asia) Pvt. Ltd., 2001.
5. "Adaptive Filters," Simon Haykin, 4th Edition , Pearson Education (Asia) Pvt. Ltd, 2002.