Master of Technology

(M.Tech.) Degree Program

ELECTRONICS AND COMMUNICATION ENGINEERING

Specialization in
VLSI and Embedded Systems
Microwave and Radar Engineering
Robotics and Intelligent Systems

Outcome Based Syllabus

DEPARTMENT OF ELECTRONICS
COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

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COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

July 2020

COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

VISION

The University's basic philosophy and goals find eloquent expression in its Coat of Arms emblazoning the motto "Tejaswinavadhitamastu" which in essence means "may the wisdom accrued deify us both the teacher and the taught and percolate to the Universe in its totality", which in essence means "may learning illumine us both" (the teacher and the taught).

MISSION

The University shall have the following objectives as its mission:

(i) to prosecute and promote research in applied science, technology, industry, commerce, management and social science for the advancement of knowledge and for the betterment of society;

(ii) to provide facilities and offer opportunities for graduate and post-graduate education in applied science, technology, industry, commerce, management and social science by instruction, training, research, development and extension and by such other means as the University may deem fit;

(iii) to devise and implement programmes of education in applied science, technology, industry, commerce, management and social science that are relevant to the changing needs of society, in terms of breadth of diversity and depth of specialization;

(iv) to serve as a centre for fostering co-operation and exchange of ideas between the academic and research community on the one hand and industry on the other;

(v) to organise exchange programmes with other institutions of repute in India and abroad with a view to keeping abreast of the latest developments in relevant areas of teaching and research.

DEPARTMENT OF ELECTRONICS

VISION

To nourish and tone the legendary status in the field of Electronics by inspiring knowledge seekers to meet the challenges of evolving technology through innovative practices.

MISSION

M1 : *To strengthen technical education in Electronics for graduates by utilising the state of the art facilities and adopting latest trends in technology.*

M2 : *To impart knowledge and skills so as to kindle innovation & creativity among students leading to a progressive global career in industry & academy.*

M3 : *To facilitate best opportunities for challenging young minds fostered through interaction with leading research organizations as well as industry.*

M4 *To develop and sustain a culture of focused work based on societal needs.*

M5 *To provide with avenues for recognition by participation in challenging platforms, while upholding values, ethics and professionalism.*

PROGRAM EDUCATIONAL OBJECTIVES

Graduates will have

PEO1 : *Technical competence in design, development and implementation of electronics and communication technology and capability to extend its applications to different thrust areas like Embedded Systems, Machine Learning, Microwave, Radar Engineering, Robotics and VLSI.*

PEO2 : *Advanced and skilful knowledge for analysing, modelling, and evaluating all research problems in major thrust areas of electronics.*

PEO3 : *Technical expertise to carry out independent research while handling all themes which constantly evolve in multidisciplinary technological challenges through continuous learning, constant engagement and appraisal.*

PEO4 : *Effective communication skills and leadership qualities embedded with ethical attitudes in the broad societal context while setting best standards in multi/interdisciplinary areas.*

PEO5 : *Capabilities for higher professional positions on acquiring proficiency while imparting excellence in academics/industry/research and entrepreneurial skills.*

PEO-Mission matrix

Mission	PEO1	PEO2	PEO3	PEO4	PEO5
M1	✓	✓	✓		
M2		✓	✓		
M3				✓	✓
M4				✓	✓
M5			✓	✓	✓

PROGRAM OUTCOMES

After the completion of M.Tech. programme, the students would have :

PO1 : Acquired in-depth knowledge of Electronics with emphasis on thrust areas like Embedded Systems, Machine Learning, Microwave, Radar Engineering, Robotics and VLSI, including wider and global perspective, with an ability to discriminate, evaluate, analyse and synthesise existing and new knowledge, and integration of the same for enhancement of knowledge.

PO2 : Capability to think laterally and originally, conceptualize and solve engineering problems, evaluate a wide range of potential solutions for those problems and arrive at feasible, optimal solutions

PO3 : Communication skills to interact with the engineering community, and with society at large, regarding complex engineering activities confidently and effectively. They would be able to comprehend and write effective reports and design documentation by adhering to appropriate standards.

PO4 : Acquired professional and intellectual integrity, professional code of conduct, ethics of research and scholarship, consideration of the impact of research outcomes on professional practices and an understanding of responsibility to contribute to the community for sustainable development of society.

PEO – PO Mapping

	PO1	PO2	PO3	PO4
PEO1	✓			
PEO2		✓		
PEO3	✓			
PEO4			✓	
PEO5				✓

Course structure

Semester I

Course Code	Name of the Course	C/E	Credits
20-437-0101	Embedded Architecture and Interfacing	C	3
20-437-0102	Advanced Digital Communication	C	3
20-437-0103	Advanced Digital Signal Processing	C	3
20-437-0104	Embedded Systems Laboratory	C	1
	Elective-I (Specialization)	E	3
	Elective-Lab (Specialization)	E	1
	Elective-II (General)	E	3
	Elective-Lab (General)	E	1
Total credits			**18**
Specialization Electives			
VLSI and Embedded Systems			
20-437-0105	VLSI Technology and Design	E	3
20-437-0106	VLSI Laboratory	E	1
Microwave and Radar Engineering			
20-437-0107	Microwave Devices & Circuits Design	E	3
20-437-0108	Microwave Lab	E	1
Robotics and Intelligent Systems			
20-437-0109	Robotics and Automation	E	3
20-437-0110	Robotics Lab	E	1
General Electives			
20-437-0111	FPGA Based System Design	E	3
20-437-0112	FPGA Based System Design Laboratory	E	1
20-437-0113	Antenna Theory	E	3
20-437-0114	Antenna Design Lab	E	1
20-437-0115	Neural Networks	E	3
20-437-0116	Neural Networks Lab	E	1

Semester II

Course Code	Name of the Course	C/E	Credits
20-437-0201	Seminar	C	1
20-437-0202	Image and Video Processing	C	3
20-437-0203	Wireless Communication Techniques	C	1
20-437-0204	Communications Laboratory	C	1
	Elective-III (Specialization)	E	3

	Elective-IV (Specialization)	E	3
	Elective-Lab (Specialization)	E	1
	Elective-V (General)	E	3
Total credits			**18**

Specialization Electives

VLSI and Embedded Systems

20-437-0205	Design Verification and Testing	E	3
20-437-0206	Design Verification Lab	E	1
20-437-0207	Real Time Operating Systems	E	3
20-437-0208	Real Time Operating Systems Lab	E	1

Microwave and Radar Engineering

20-437-0209	Electromagnetic interference and compatibility	E	3
20-437-0210	EMI/EMC Lab	E	1
20-437-0211	Radar Systems	E	3

Robotics and Intelligent Systems

20-437-0212	Mobile Robotics	E	3
20-437-0213	Mobile Robotics Lab	E	1
20-437-0214	Deep Neural Network Signal Processing	E	3
20-437-0215	Deep Neural Network Signal Processing Lab	E	1

General Electives

20-437-0216	Machine Learning	E	3
20-437-0217	Analog Integrated Circuits	E	3
20-437-0218	Adaptive Signal Processing	E	3
20-437-0219	RFIC Design	E	3
20-437-0220	Signal Integrity in High-Speed Digital Systems	E	3
20-437-0221	Advanced Electromagnetic Engineering	E	3
20-437-0222	Computational Electromagnetics	E	3
20-437-0223	Software Defined Radios	E	3

Semester III

Course Code	Name of the Course	C/E	Credits
20-437-0301	Project Part 1	C	15
20-437-0302	NPTEL(minimum 8 weeks duration) /MOOC course (with pre approval of Department)	C	3
Total credits			**18**

Semester IV

Course Code	Name of the Course	C/E	Credits
20-437-0401	Project Part 2	C	18

Total credits for the course =18+18+18+18 = 72

20-437-0101

EMBEDDED ARCHITECTURE AND INTERFACING

L	T	P	C
3	2	0	3

Prerequisites : None

Course Description : This course will teach the architectural optimizations of processors and embedded systems. Covers architectural optimizations and introduces new concepts such as cyber physical systems and internet of things. Low power embedded devices are reviewed and its interfacing with peripherals are discussed.

Course Outcome : After the completion of the course the student will be able to

CO1	Learn about the operation of Embedded Systems	Understand
CO2	Evaluate the performance and power parameters of embedded architectures	Evaluate
CO3	Understand the optimizations in processor and memory for various architectures	Understand
CO4	Discuss latest developments in Cyber Physical Systems and Internet of Things	Understand
CO5	Solve programming questions in microcontrollers for interfacing peripherals	Analyze
CO6	Interface an ADC and other peripherals with embedded systems	Apply

Course content :

Module 1 : **Embedded Architecture**: Evolution of microprocessors and embedded systems. General purpose computers vs Embedded system. Performance and power consumption, CPI, Moore’s law, Amdahl’s law. **Embedded System Architecture**: Intel x86, IBM PowerPC, ARM. Classifications: RISC, CISC, Fylnn’s Classification, Big and little endian. Computer Architecture: Pipelining stages, Superscalar processing, Throughput and latency.

Module 2 : **Optimizations in Architecture:** Pentium processor architecture, Out of order execution, micro ops and caching, branch prediction, register renaming. Pipeline conflicts and Hazards. Pipeline stalling, Delay Slot, Result forwarding, Speculative Execution. **Memory Organization:** Caches, multi-levels, placement and replacement policies, Cache hit and miss Cache performance and prediction. Address translation, base and bound registers, paging, virtual address, Translation Lookaside Buffer.

Module 3 : **ARM Architecture:** Evolution of ARM architecture, programming model, Cortex M3 Processor architecture, registers and flags, operation modes, memory map, Nested Vector Interrupt Controller, power management. **Graphics**

Processing: Abstraction, multi-threaded programming, Thread building blocks, Hybrid processors, General Purpose-GPU, NVIDIA CUDA architecture.

Module 4 : **Low power Embedded Systems:** 16F87X series PIC processor organization, Instruction Set, Memory organization, Timing modes, Input-Output ports, Compare and Capture modes, Pulse Width Modulation, Interrupt Structure and handling.
Cyber Physical Systems: Client server model, Cloud computing, Edge computing, Internet of Things. Development and interfacing with evaluation boards: Arduino, Galileo, Raspberry Pi, etc.

Module 5 : **Interfacing of Embedded Systems:** Sensors and Transducers for interfacing. Wireless, Bluetooth, Zigbee. Interfacing standards: 1^2C, SPI, USB. Analog to Digital Convertors: Properties, Parallel Comparator, Dual Slope and Successive Approximation methods. Interfacing of Real Time Clock, Pulse Width Modulation, Stepper motors, LCD.

References :

1. David Patterson and John L. Hennessy, "Computer Architecture: A quantitative approach", 5th Edition, Elsevier, 2012.
2. Microarchitecture of the Pentium 4 processor, Intel Technology Journal, 2001.
3. Joseph Yiu, "The definitive guide to ARM Cortex M3", Elsevier, 2nd Edition, 2010.
4. "NVIDIA® CUDA™ Architecture: Introduction and Overview", NVIDIA, 2009.
5. Microchip PIC - Microcontroller application notes / data sheets.
6. Mazidi et. al., "The PIC microcontroller and embedded systems", Pearson, 2008.
7. Wayne Wolf, Computers as Components: Principles of Embedded Computing System Design, Elsevier Publication 2000.
8. Barry B. Brey., "The Intel Microprocessors – Architecture, programming & Interfacing", Prentice Hall.

20-437-0102 **ADVANCED DIGITAL COMMUNICATION**

L	T	P	C
3	2	0	3

Prerequisites : Communication, Basics of Probability theory

Course Description : This course introduces students to the advanced concepts of digital communication. In particular, the course will review the concepts of probability and statistics
and prepare a mathematical background for communication signal analysis.

Course Outcome : After the completion of the course the student will be able to

CO1	Integrate the basics of random processes in digital communication concepts	Apply
CO2	Compare the working of correlation receivers and matched filter receivers	Understand
CO3	Calculate the bit error rate of digital modulation schemes	Analyze
CO4	Identify various equalization techniques used in digital communication systems	Understand
CO5	Discuss the effects of signaling over fading channels	Understand

Course content :

Module 1 : **Signal Analysis & Stochastic Processes –** Transmission of signals through LTI system, Complex envelopes of band-pass signals, Complex low-pass representation of band-pass systems, Review of probability theory, Random variables, Concept of Expectation, Characteristic functions, Gaussian distribution, Markov and Chebyshev Inequalities, Central limit theorem, Stochastic process, Mean, correlation and covariance functions of Weakly stationary processes, Transmission of Weakly Stationary process through a LTI filter

Module 2 : **Characterization of Communication Signals and Systems –** Geometric representation of signals, Gram-Schmidt Orthogonalization Procedure, Conversion of Continuous AWGN Channel in to a vector channel, Likelihood function, Maximum Likelihood Decoding, Correlation Receivers, Matched Filter Receiver, Probability of Error

Module 3 : **Optimum Receiver –** Digital modulation using coherent detection – BPSK, BFSK, MSK, Signals with random phase in AWGN Channels, Quadrature receivers, non-coherent orthogonal modulation techniques, BFSK and DPSK using non-coherent detection, BER comparison of signaling schemes over AWGN channels, Synchronization – Recursive Maximum Likelihood Estimation

Module 4 : **Signaling over Band-Limited Channels –** Inter Symbol Interference (ISI), Signal design for zero ISI, Ideal Nyquist pulse for distortionless baseband transmission, raised cosine spectrum, square root raised cosine spectrum, Eye pattern, Equalization Techniques- Zero forcing linear Equalization- Decision feedback equalization- Adaptive Equalization.

Module 5 : **Signaling over Fading Channels –** Propagation effects, Statistical characterization of wideband wireless channels, Power-Delay profile, Doppler power spectrum, Classification of multipath Channels, FIR modeling of doubly spread channels, Comparison of BER of modulation schemes, Diversity techniques, Multiple-Input Multiple-Output Systems, Orthogonal Frequency Division Multiplexing

References :

1. Simon Haykin, "Digital Communication Systems", Wiley India Pvt. Ltd., 2015
2. John G. Proakis and Masoud Salehi, "Digital Communication", McGraw Hill Education (India) Private Limited, 2015
3. John G. Proakis and Masoud Salehi, "Communication Systems Engineering", Pearson India Education Services Pvt. Ltd., 2017
4. Edward A. Lee and David G. Messerschmitt, "Digital Communication", 2nd Edition, Springer, 1993
5. Marvin K. Simon, Sami M. Hinedi and William C. Lindsey, "Digital Communication Techniques – Signal Design and Detection", Prentice Hall, 1994
6. Ian A. Glover and Peter M. Grant "Digital Communication", 2nd Edition, Pearson Education, 2008.
7. William Feller, "An Introduction to Probability Theory and its Applications", 3rd Edition, Wiley, 2008.
8. Sheldon M. Ross, "Introduction to Probability Models", 10th edition, Academic Press, 2010.

20-437-0103 **ADVANCED DIGITAL SIGNAL PROCESSING**

L	T	P	C
3	2	0	3

Prerequisites : Signals & Systems, Digital Signal processing, Mathematics

Course Description : This course deals with the analysis & design of analog and digital DSP filters. It also gives an overview regarding multidimensional and multi rate signal processing. A basic understanding of DSP hardware chips.

Course Outcome : After the completion of the course the student will be able to

CO1	Discuss various transforms related with signal processing	Understand
CO2	Explain classical filter design methods	Analyse
CO3	Calculate 2D DFT of signals	Apply
CO4	Summarize decimation and interpolation	Understand
CO5	Experiment with DSP hardware	Apply

Course content :

Module 1 : **Overview of Transforms :** Z – Transform, DFT, FFT, DCT, Hillbert Transform, Short-time Fourier Transom, Wavelet Transform.

Module 2 : **Filter Design** – LTI System as Frequency Selective Filters - FIR Filters - Characteristics of FIR Filters with Linear Phase - Fourier Series Method of FIR Filter Design – Windows - Design of FIR Filters by Frequency Sampling Technique - IIR Filters - Impulse Invariant Transformation, Bilinear Transformation - Design of Lowpass Digital Butterworth Filter, Design of Lowpass Digital Chebyshev Filter , Frequency Transformations.

Module 3 : **Multidimensional Signal Processing:** 2-D Signals and Systems, Multi-dimensional Sampling, Difference Equations, Convolution, Fourier representation, 2-D DFT, Multidimensional FFT, z – Transforms.

Module 4 : **Multi-rate Signal Processing:** Sampling and Sampling rate Conversion, Decimation and Interpolation, FIR & IIR Decimators and Interpolators.

Module 5 : **Hardware:** Finite word length effect in Signal Processing, Signal Processing Hardware – TMS 320 Series Chips. Real-time Implementation Considerations.

References :

1. Proakis, J.G., Manolakis, D.G. “Digital Signal Processing Principle Algorithms and Applications”. PHI 1996.
2. Dudgeon, D.E., Merseraus, R.M., “Multi-Dimensional Digital Signal Processing”. Prentice-Hall, N.J., 1984.
3. Oppenheim, A.V., Schafer, R.W. , “Discrete – Times Signal Processing”. PHI, 1992
4. Crochiere, R.E., Rabiner, L.R., “Multi rate Digital Signal Processing, Prentice-Hall, N.J. 1983

5. Haddad, Richard A., Parsons, Thomas W., "Digital Signal Processing: Theory Applications & Hardware", Computer Science Press, 1991.
6. Ahmed, N., Natarajan, T.R., "Theory and Applications of Digital Signal Processing." Reston Publishing Co., 1983.

20-437-0104 **EMBEDDED SYSTEMS LABORATORY**

L	T	P	C
0	**0**	**4**	**1**

Prerequisites : None

Lab Description : This lab will involve working on programming embedded devices, communicating with peripherals.

Course Outcome : After the completion of the lab the student will be able to

CO1	Familiarize with different embedded boards and their capabilities	Understand
CO2	Learn and use software tools for multiple development boards for testing functionalities.	Apply
CO3	Solve specific problems which come under interface categories such as display, counter, motor drive, etc.	Apply
CO4	Learn about profiling of processor execution by using Software tools in an in-circuit debugging method	Analyse
CO5	Propose and design solutions for real world problems using embedded systems	Apply

Sample List of Experiment* **:**

1. Interface a 16x2 LCD to PIC16F887 microcontroller and display a Malayalam word
2. Interface a keypad to PIC16F887 microcontroller and display a key switch being pressed in the board.
3. Interface built-in DS1307 real time clock chip and display the time, day and date.
4. Use PIC16F887 to perform Compare, Capture and PWM operations.
5. Familiarization of deployment flow ARM Development Kit, Keil Mvision IDE, Flash Programming. Flash a sample blinky program into ARM Cortex M3.
6. Write a program to display hello world on terminal. Interface 4X4 Matrix Keypad and display in LCD.
7. Interface Zigbee modules to two ARM Cortex M3 devices and communicate a string containing names of team members.
8. Use stepper motor interface module to rotate the motor in both directions.

9 Familiarization with ulink pro. Flash a sample program with loop containing arithmetic operations. View registers and memory, use watch window to view variables. Familiarization of basic debugging. Identify code optimizations done by compiler or processor from your input program.

10. Write a program to find the first 20 prime numbers and save it in an array and also to find its sum. Use ULINK pro to flash the program. Run the program in debug mode, do step by step execution and observe the registers and watch window. View the memory of the array as it gets updated. Run the program till N=20, get sum of all prime numbers.

11 Design project: Define a problem statement that can be solved by an embedded system. Design and implement an embedded system for solving this problem statement. It is mandatory to have a computation unit, interfacing with a peripheral and a wireless communication protocol.

* The list is not exhaustive. Additional experiments or project based on the experiments can be included in the laboratory activity.

20-437-0105 **VLSI TECHNOLOGY & DESIGN**

L	T	P	C
3	2	0	3

Prerequisites : A basic course on Digital Circuits

Course Description : This course deals with the analysis and design of digital MOS circuits and the various stages of the CMOS design process. It also discusses the scaling trends of CMOS technology and the latest trends in semiconductor device technology

Course Outcome : After the completion of the course the student will be able to

CO1	Use the fundamental concepts of MOS device physics to derive device characteristics	Apply
CO2	Analyse the delay and power dissipation of static and dynamic combinational CMOS circuits.	Analyze
CO3	Understand the concept of sequential circuit timing.	Understand
CO4	Design circuits with combinational and sequential elements based on delay specification.	Analyze
CO5	Compare circuits with combinational and sequential elements in terms of area, power and timing.	Analyze
CO6	Differentiate between Custom, Semicustom and Array based VLSI Design approaches.	Understand
CO7	Explain the latest scaling trends and technology innovations in semiconductor devices.	Understand

Course content :

Module 1 : **Introduction to CMOS VLSI:** PN Junctions, Static and Dynamic Behaviour, Secondary Effects, MOS Transistor, Ideal I-V Characteristics, C-V Characteristics, Non-Ideal I-V Effects, Latch-up in CMOS, CMOS Fabrication Process -FEOL and BEOL processes.

Module 2 : **Combinational Circuit Design:** Static CMOS Circuits - CMOS Inverter, Static and Dynamic Behavior, Complementary CMOS, Delay models, Logical Effort, Electrical Effort and Stage Effort, Intrinsic delay, Ratioed Logic, Pass-Transistor Logic, Transmission gates, Dynamic CMOS Circuits

Module 3 : **Sequential Circuit Design:** Timing Metrics- Setup Time, Hold Time, Propagation Delay, Contamination delay, skew and jitter, Setup and Hold violations, Classification of Memory Elements, Static Latches and Registers, Dynamic Latches and Registers, Pipelining, Memory Cells.

Module 4 : **VLSI Design Flow:** Custom, Semicustom and Structured-Array Design

Approaches,, Cell Based Design Methodology, Semicustom Design Flow - Design Capture, Register Transfer Logic, Functional Simulation, High Level Synthesis, Logic Synthesis, Timing Simulation, Static Timing Analysis, Power Analysis, Planning, Partitioning, Placement and Routing, Extraction, Packaging, IC testing.

Module 5 : **CMOS Scaling and Sub-Micron Trends:** Propagation Delays, Logic and Interconnect delays, Scaling Factors for Device Parameters, Constant field scaling and constant voltage scaling, Challenges going to sub-100 nm MOSFETs , Multiple gate MOSFETs, FinFETs, Carbon nanotube FET, SpinFET, Nanowire FETs.

References :

1. Jan M. Rabaey, Anantha Chandrakasan, Borivoje Nikolic, "Digital Integrated Circuits – A Design Perspective", Pearson Education India, 2nd edition, 2016.
2. Neil H. E. Weste & David M. Harris, "CMOS VLSI Design, - A Circuits and Systems Perspective", Pearson Education India, 4th edition, 2015.
3. Donald A. Neamen & Dhrubes Biswas, "Semiconductor Physics and Devices", McGraw Hill Education, 4th edition, 2017.
4. D. S. Pucknell & K. Eshraghian, "Basic VLSI Design", Prentice Hall, 3rd edition, 2000.
5. S. M. Sze, "VLSI Technology", McGraw Hill Education, 2nd edition, 2017.
6. J. P. Colinge (ed), FinFETs and Other Multi-Gate Transistors, Springer, 1st edition, 2008.
7. Jerry G. Fossum & Vishal P. Trivedi, "Fundamentals of Ultra-Thin-Body MOSFETs and FinFETs", Cambridge University Press, 1st edition, 2013.
8. Recent papers from IEEE Transactions on Electron Devices, IEEE Transactions on VLSI.

20-437-0106 **VLSI LABORATORY**

L	T	P	C
0	0	4	1

Prerequisites	:	A basic course on CMOS VLSI Design, Digital Logic Design
Lab Description	:	This lab has two components. The first part provides training on CAD tools for designing and simulating CMOS digital circuits draw layouts and analyze the designs in terms of area and delay. The second part deals with Register Transfer Level (RTL) implementation of a digital design with Verilog HDL, perform basic functional verification, synthesize the RTL and compare the implementations in terms of delay, area and power.
Course Outcome	:	After the completion of the lab the student will be able to

CO1	Design and simulate CMOS combinational and sequential logic circuits	Apply
CO2	Draw layout of CMOS circuits using Layout editor tools and compare implementations in terms of area and delay	Evaluate
CO3	Design a digital logic circuit for a given functionality, develop RTL implementation of the logic using Verilog and develop a testbench to verify the design.	Apply
CO4	Synthesize a RTL design and select appropriate implementations subjected to trade-offs between delay, area and power.	Evaluate

Sample List of Experiment* :

1 NMOS and PMOS characteristics using SPICE based simulator

2 DC and transient analysis of static CMOS inverter

3 DC and transient analysis of static CMOS logic gates.

4 DC and transient analysis of static CMOS logic gates

5 Draw layout for CMOS gate using a Layout Editor

6 Combinational circuits in Verilog using gate-level, dataflow and behavioural Modeling.

7 Model sequential circuits like Latch, Register, Flip flop and counters using Verilog

8 Develop Verilog models using the concepts of tasks and functions

9 Develop a testbench in Verilog to verify a given design

* The list is not exhaustive. Additional experiments or project based on the experiments can be included in the laboratory activity.

20-437-0107 **MICROWAVE DEVICES & CIRCUIT DESIGN**

L	T	P	C
3	2	0	3

Prerequisites : A basic course in Electromagnetic Theory

Course Description : The course introduces the basic microwave design principles and discusses their application in microwave circuits. Through problem-solving and design activities, the course facilitates the students to have an in depth understanding of the transmission line theory and impedance matching techniques, microwave circuit network analysis and gives an overview of active and passive microwave components and discusses the design of practical microwave circuits such as low-noise, broadband and power amplifiers.

Course Outcome : After the completion of the course the student will be able to

CO1	Understand the behaviour of components and circuits at microwave frequencies using transmission line theory and Smith chart.	Understand
CO2	Apply Immittance and S parameters in describing microwave circuit characteristics.	Apply
CO3	Employ various networks for impedance matching.	Apply
CO4	Design the various microwave components.	Analyse
CO5	Describe the various microwave passive devices and components based on them.	Understand
CO6	Describe the various active microwave semiconductor devices, MMIC components, their applications in amplifier design and an understanding of high power sources.	Apply

Course content **:**

Module 1 : **Introduction:** Revision of Prerequisite Background Material- Behavior of Materials and Real Components at Microwave Frequencies, Transmission Line Theory, Practical Transmission Lines, Smith Charts-Uses and its Variants.

Module 2 : **S Parameters and Matching Networks:** S Parameters - Classification, Signal Flow Graphs, Input and Output Impedance, Measurement**.** Immittance Parameters. Lumped Element Matching Networks, Distributed Element Matching Network-Impedance Transformation with Line Sections, Stub Matching, Quarter-Wave Transformer, Bandwidth.

Module 3 : **Microwave Components:** Resonator circuits – Transmission line, Cavity and Dielectric resonators; Power dividers and Directional couplers – Basic Properties, T Junction, Wilkinson, Waveguide Directional Couplers, 90^0 & 180^0 Hybrid; Filters - Design, Transformation & Implementation.

Module 4 : **Microwave Passive Devices**: Schottky Diodes and Detectors, Varactor Diodes, PIN Diode Parameters, Switches, Attenuators, Diode Phase Shifters, Ferrite Phase

Shifters; Distributed Ferrite Circulators and Isolators, Lumped-Element Ferrite Circulators and Isolators, Power Combining.

Module 5 : **Microwave Active Devices:** Microwave BJT, HBT & FET; MMIC- Technology, Elements & Applications; Microwave Amplifier Design: Single stage, Multistage and Broadband; Microwave High Power Sources – SSPA vs Tubes.

References :

1. Clive Poole, Izzat Darwazeh "Microwave Active Circuit Analysis and Design", Academic Press, Amsterdam, ISBN 9780124078239, 2016.
2. David M. Pozar, "Microwave Engineering", Wiley, 4th ed, Hoboken, NJ, ISBN 9780470631553, 2011.
3. Leo G. Maloratsky, "RF and Microwave Integrated Circuits - Passive Components and Control Devices", Elsevier, 2004.
4. Kai Chang, "Microwave Solid State Circuits and Applications", John Wiley, ISBN: 9780471540441, 1994.
5. Matthew M. Radmanesh, "Radio Frequency and Microwave Electronics Illustrated", Prentice Hall, ISBN: 9780130279583, 2001.
6. Samuel Liao, "Microwave Circuit Analysis and Amplifier Design", Prentice Hall, ISBN: 9780135817865, 1986.
7. R Ludwig & Bretchko, "RF Circuit Design, Theory and Applications", Pearson Education Inc, ISBN: 9788131762189, 2011.

20-437-0108 **MICROWAVE CIRCUITS LAB**

L	T	P	C
0	0	4	1

Prerequisites : None

Lab Description : This lab familiarizes the student with the experimental set up for carrying out microwave measurements followed by characterising the various Microwave/RF components. In addition, this lab includes design/characterisation of various planar, passive and active microwave circuits using computer aided design tools.

Course Outcome : After the completion of the lab the student will be able to

CO1	Setup a X band microwave bench and carry out measurements using a slotted line.	Apply
CO2	Using an X band microwave bench characterize the various waveguide components and sources.	Apply
CO3	Familiarization of measurement with Network Analyzer.	Apply
CO4	Computer aided design and characterization of transmission lines, microwave transistors and matching networks.	Apply
CO5	Computer aided design of microwave filters, couplers & dividers and amplifier design.	Analyse
CO6	Prepare the reports and present the results correctly.	Apply

Sample List of Experiment* **:**

1. The Slotted Line (waveguide hardware, measurement of SWR, λg, impedance).
2. The Vector Network Analyzer (one-and two-port network analysis, frequency response).
3. The Gunn Diode and Klystron source (the spectrum analyzer, power meter, V/I curve).
4. Impedance Matching and Tuning (stub tuner, $\lambda/4$ transformer, network analyzer).
5. Cavity Resonators (resonant frequency, Q, frequency counter).
6 Directional Couplers, Circulators, Waveguide Tees, Isolators, Attenuators (insertion loss, coupling, directivity).
7 Computer Aided Design and Testing of
   - Planar Transmission Lines
   - Planar Filters
   - Microwave Transistors (Biasing and Layout) and Amplifiers
   - Matching Network (Design and Layout)
   - Branch Line Couplers & Power Dividers

* The list is not exhaustive. Additional experiments or project based on the experiments can be included in the laboratory activity.

20-437-0109	ROBOTICS AND AUTOMATION	L	T	P	C
		3	2	0	3

Prerequisites : None

Course Description : This course introduces the concept of robot classifications, sensors and actuators. It also provides an overview into control and dynamics of robots, and its used in automation.

Course Outcome : After the completion of the course the student will be able to

CO1	Discuss the basic classification and structure of a robot.	Understand
CO2	Explain the working and applications of various sensors and actuators used in robotics.	Understand
CO3	Use spatial transformation to obtain forward kinematic equation of a robot manipulator.	Apply
CO4	Obtain Jacobian matrix of a manipulator and use it to identify singularities.	Apply
CO5	Derive kinetic and potential energy in a robot manipulator using Euler – LaGrange Equation.	Understand
CO6	Compare various programming and controlling techniques used in robotics.	Understand
CO7	Design a closed loop control for a joint using DC motor.	Apply

Course content :

Module 1 : **Introduction:** Definition, Robot Classifications – Cartesian, Cylindrical, Spherical Work Envelope, Types of joints, Prismatic, Revolute, Ball and socket, Number of Axes, Degree of freedom, Joint variables, Grippers - Mechanical Grippers, Pneumatic and Hydraulic Grippers, Magnetic Grippers, Vacuum Grippers .

Module 2 : **Sensors:** Measurement devices, Range, response time, Accuracy, Precision, Sensitivity, resolution, linearity, error, Dead band, Dead time, costs and uncertainty. Position and Odometry Sensors. Beacons and Range Sensors**:** Doppler Sensors, Haptic sensors. Touch Screen/ Touch Panel. **Actuators:** solenoids, DC motor, AC motor, Servomotors, Stepper motor, BLDC Motors, speed control, Pulse width modulation (PWM) frequency drive, vector drive, H-bridge. Pneumatics & Hydraulic Systems, directional & pressure control valves, Drive mechanisms: Lead screw, Ball screw, Chain linkage, belt drive and gear drives.

Module 3 : **Kinematics:** World frame, joint frame, end-effectors frame, Rotation Matrix, composite rotation matrix, Homogeneous Matrix, Link Coordinate, Denavit-Hartenberg representation, Arm equation, Tool Configuration. **Robot Dynamics:** Velocity Kinematics, Jacobian, Singularities, Differential motion, Euler – LaGrange Equation, Expression of Kinetic and Potential Energy, Equations of Motion.

Module 4 : **Robot Programming & Robot Controllers:** Teach-in, Teach-Through, High-Level languages –robot talk, Comparison of teaching and programming methods, Software speedup, Robot Controllers – essential components, joint actuation and Sensing, Overload, Over current and stall detection methods, Position, Speed, Direction Sensing.

Module 5 : **Control of Manipulators:** Open- and Close-loop Control, Linear Control Schemes – Second order Linear Systems, Linear Second order SISO Model of a Manipulator Joint, Joint Actuator – Model of a DC Motor, PID Control Scheme.

References :

1. Fu,K.S. ,et al "Robotics- Control, Sensing, Vision and Intelligence ", McGraw – Hill. Inc., Singapore,1987.
2. H.R.Everett, "Sensors for Mobile Robots – Theory and Applications", A.K.PeteresLtd. ISBN 1-56881- 048-2, 1995.
3. Kurfess, Thomas R., ed. "Robotics and automation handbook". CRC press, 2004
4. Selig J.M, "Introductory Robotics",PHY(UK), 1992.
5. Yorem Koren, "Robotics for Engineers", McGraw-Hill Book Co., 1992.
6. Groover M.P et al., "Industrial Robotics – Technology, Programming & Applications", McGraw-Hill. 1986.
7. Derby, Stephen J. "Design of Automatic Machinery". CRC Press, 2004.
8. Groover, Mikell P. "Automation, production systems, and computer-integrated manufacturing". Pearson Education India, 2016.
9. Siciliano, Bruno, and OussamaKhatib, eds. "Springer handbook of robotics". Springer, 2016
10. R K Mittal, I J Nargrath," Robotics and Control", Tata McGraw Hill, 2005.

20-437-0110 **ROBOTICS LAB**

L	T	P	C
0	0	4	1

Prerequisites : None

Lab Description : The lab includes experiments using SCARA robot and Robotics toolbox from MATLAB. This lab also provides students with the skill to design microcontroller based joint actuators for robotics applications.

Course Outcome : After the completion of the lab the student will be able to

CO1	Program SCARA robot to perform tasks.	Apply
CO2	Design a robot joint using DC motor controlled by a closed loop system.	Analyse
CO3	Use Robotics Toolbox from MATLAB to solve forward and inverse kinematics for a given manipulator.	Apply

Sample List of Experiment* :

1. Design, construct a DC motor driver using L298 with speed, overload and direction control.
2. Find the accuracy, repeatability and work envelop of SCARA robot.
3. Design, construct and study a quadrature encoder for a given DC motor.
4 Program the SCARA robot for transfer of a stack of objects from one position to another.
5 Implement a closed loop control system for dc motor that maintains a constant speed of rotation (with 1%) different loads.
6 Using Robotics Toolbox from MATLAB perform forward kinematics for the given manipulator.
7 Using Robotics Toolbox for MATLAB perform 2-D Path Tracing with inverse kinematics.

* The list is not exhaustive. Additional experiments or project based on the experiments can be included in the laboratory activity.

20-437-0111 **FPGA BASED SOC DESIGN**

L	T	P	C
3	2	0	3

Prerequisites : Digital Logic Design

Course Description : This course will provide an understanding of the fundamental building blocks of a digital system and the concepts, issues, and process of designing highly integrated System on Chip using Field Programmable Gate Arrays following systematic hardware/software co-design principles.

Course Outcome : After the completion of the course the student will be able to

CO1	Use sequential and combinational design techniques to implement digital systems	Apply
CO2	Implement a digital design in Verilog HDL using structural, behavioural and dataflow modelling.	Apply
CO3	Compare different implementations in terms of timing and hardware resources.	Apply
CO4	Discuss the FPGA architecture and process flow.	Understand
CO5	Design and implement System-on-Chips on FPGA using system design methodologies.	Analyze

Course content :

Module 1 : **Introduction to Digital Design:** Boolean Algebra and Algebraic Simplification, Combinational Logic, Karnaugh Maps, Designing Using NAND and NOR gates, Sequential Circuits, Flip Flops and Latches, Mealy and Moore Circuits, State Reduction. Sequential Circuit Timing.

Module 2 : **System Design using Verilog HDL:** HDLs, Verilog description of combinational circuits, Modules, Assignments, Procedural Assignments, Always block, Delays, Compilation, simulations and synthesis, Variables, datatypes, operators and language constructs, Behavioral and structural verilog, Constants arrays and loops, Verification and testbenches, Functions and tasks, File I/O, Multivalued Logic and signal resolution

Module 3 : **Digital System Design:** Top down Approach to Design, Data Path, Control Path, Controller behaviour and Design, Design Examples - BCD Adder, Traffic Light Controller, Binary Multiplier & Divider.

Module 4 : **Programmable Devices:** Overview of Programmable Devices, CPLDs, FPGAs – Implementing functions using FPGAs, Architectures of Commercial FPGAs Xilinx, Intel - Altera and Atmel, Carry Chains and Cascade chains, Logic Blocks, Dedicated memories and ALUs, Cost of programmability, Maximum gates vs usable gates, Synthesis, mapping, placement and routing, Timing analysis and timing constraints. I/O constraints.

Module 5 : **Embedded System Design Using FPGAs:** Embedded cores in FPGAs, hard vs soft core processors, C-to-RTL High Level Synthesis, Hardware Software co-design, Case Study I: System Design using Microblaze softcore processor and Xilinx Embedded Design Kit (EDK), peripherals, developing software applications on microblaze. Case Study I: Xilinx Zynq SOCs, Programmable Logic and Processor Systems, High Level Synthesis using Xilinx Vivado HLS, Creating a complete system using built-in ARM Cortex processor and an IP block in PL.

References :

1. Charles H. Roth Jr. Lizy Kurian John, Beyeong Kil Lee, "Digital Systems Design Using Verilog", CL Engineering, 1st edition, 2015.
2. Samir Palnitkar, "Verilog HDL", Pearson Education, 2nd edition, 2004
3. Charles H. Roth Jr, "Fundamentals of Logic Design", CL Engineering, 7th edition, 2013.
4. John F. Wakerly, "Digital Design - Principles and Practices", Pearson, 4th edition, 2008.
5. W. Wolf, "FPGA- based System Design", Pearson, 1st edition, 2004.
6. D. Gajski, S. Abdi, A. Gerstlauer, G. Schirner, Embedded System Design: Modeling, Synthesis, Verification, Springer, 2009.
7. Steve Kilts, "Advanced FPGA Design: Architecture, Implementation, and Optimization", Wiley-IEEE Press, 1st edition, 2007 .
8. J. Bhasker, "A Verilog HDL Primer", Star Galaxy Publishing, 3rd edition, 2005.
9. Xilinx FPGA user guides and University Program Course materials

20-437-0112 **FPGA BASED SYSTEM DESIGN LAB**

L	T	P	C
0	0	4	1

Prerequisites : Digital Electronics

Lab Description : This lab focuses on design and implementation of digital systems in platforms with tightly coupled processing system and FPGA based programmable logic. The first part of the lab involves familiarization of system design flow using available IP/cores/peripherals. This will be followed by embedded system design flow to create unique prototype.

Course Outcome : After the completion of the lab the student will be able to

CO1	Implement a digital system on FPGA and compare the design implementation based on area, delay and power trade-offs.	Evaluate
CO2	Develop system using Microblaze soft core processor and IP blocks.	Apply
CO3	Realize a practical digital system on platform having FPGA based Programmable logic and processing system.	Evaluate

Sample List of Experiment* :

1. Design and implement a 4/8-bit counter on a Xilinx FPGA using Vivado .
2. Creating a system (hardware and software) that can output a simple message via the UART and blink LEDs on the board.
3. Write a C program and run it on a single processor system, based on a MicroBlaze soft core, using the available Xilinx FPGA platform.
4. Create a simple ARM Cortex based processor system through Vivado and IP integrator on available Xilinx FPGA platform.
5. Create an ARM Cortex based processor system through Vivado and IP integrator with two GPIO IPs in Programmable logic (PL).
6. Create a custom IP and adding it in the PL of the previously created processor system.
7. Write a basic software application using SDK and verify its functionality on the developed processor system in the Xilinx FPGA platform.

* The list is not exhaustive. Additional experiments or project based on the experiments can be included in the laboratory activity.

20-437-0113 **ANTENNA THEORY**

L	T	P	C
3	2	0	3

Prerequisites : A basic course in Electromagnetic Theory

Course Description : This course on the theory and analysis of antennas is intended to provide a comprehensive coverage on the working of a wide variety of antennas and its arrays relevant to numerous communication systems. This course presents the basic antenna theory together with practical design techniques, their measurements and applications ranging from the radio frequency to milli-meter wave frequency ranges.

Course Outcome : After the completion of the course the student will be able to

CO1	Understand the principle of radiation, describe its parameters and measure them.	Understand
CO2	Employ wire antennas for various applications and incorporate ground effects.	Apply
CO3	Analyse and synthesize antenna arrays.	Analyse
CO4	Describe the two basic classes of antennas, namely broadband and aperture.	Understand
CO5	Employ small antennas for mobile applications and smart antennas for base stations.	Apply
CO6	Understand the fundamentals of CEM for antennas.	Understand

Course content **:**

Module 1 : **Introduction:** *Fundamentals of Radiation*- Solution of Maxwell's Equations for Radiation Problems, The Ideal Dipole, Radiation Patterns, Directivity and Gain, Antenna Impedance, Radiation Efficiency, Antenna Polarization, Receiving Properties of Antennas, Antenna measurement- Principle, Ranges, Antenna Parameters, Mobile Radio Antenna Measurement.

Module 2 : **Wire Antennas***: Simple Radiating Systems*- Electrically Small Dipoles, Half-Wave Dipoles, Monopoles and Image Theory, Small Loop Antennas and Duality; Types of Dipole Antennas, Yagi-Uda Antennas, Feeding & Loading Wire Antennas, Ground Effects on Wire Antennas.

Module 3 : **Array Antennas**: *Linear Arrays*- Array Factor, Pattern Multiplication, Uniform and Non-uniform Excitation, Mutual Coupling, Phased Arrays and Array Feeding Techniques; *Array Synthesis*- Line Source and Linear Array Shaped Beam Synthesis Methods, Low Side Lobe and Narrow Main Beam Synthesis Methods.

Module 4 : **Types of Antennas**: *Broadband Antennas*- Helical, Bi-conical, Sleeve, Frequency Independent Antennas; *Aperture Antennas*- Rectangular & Circular Apertures, Rectangular Horn Antennas, Reflector Antennas, Feed Antennas for Reflectors

Module 5 : **Communication Antennas***: Low-Profile Antennas and Personal Communication Antennas & Terminal and Base Station Antennas for Wireless Applications:* Microstrip Antenna Elements, Microstrip Leaky Wave Antennas, Fundamental Limits on Antenna Size, Antennas for Compact Devices, Human Body Effects on Antenna Performance, Radiation Hazards, Satellite Terminal Antennas, Base Station Antennas, Mobile Terminal Antennas, Smart Antennas, Adaptive and Spatial Filtering Antennas, *CEM for Antennas:* General Introduction to CEM & Comparison of the Different Methods.

References :

1. W. L. Stutzman and G. A. Thiele, "Antenna Theory and Design", John Wiley & sons, 3rd edition, ISBN: 978-0-470-57664-9, 2012.
2. C. A. Balanis, "Antenna Theory Analysis and Design", John Wiley & sons, 4th edition, ISBN: 978-1-118-64206-1, 2016.
3. J. D. Kraus, R. J. Marhefka and A. S. Khan, "Antennas and Wave Propagation", Tata Macgraw Hill, 4th edition, ISBN: 9780070671553, 2017.
4. John L Volakis, "Antenna Engineering Hand Book", Tata McGraw Hill Companies, 4th edition, ISBN: 978-0071475747, 2007.

20-437-0114 **ANTENNA DESIGN LAB**

L	T	P	C
0	**0**	**4**	**1**

Prerequisites : None

Lab Description : This lab familiarizes the student with the experimental set up for carrying out antenna measurements followed by characterising the various standard antennas. In addition, this lab also includes design/characterisation of different types of antennas using computer aided design tools.

Course Outcome : After the completion of the lab the student will be able to

CO1	Understand the principle of radiation, describe its parameters and measure them.	Understand
CO2	Design and Simulation of different antennas using CAD tools	Apply
CO3	Analyze the simulated results and infer.	Analyse
CO4	Measure the radiation properties different antennas and deduce the antenna paramters.	Apply
CO5	Design, simulate, fabricate and measure a simple patch antenna.	Apply
CO6	Prepare the reports and present the results correctly.	Apply

Sample List of Experiment* :

1. Familiarization with antenna measurement setup.
2. Computer aided design, simulation and analysis of basic antenna types: Dipole, Horn (different types), Patch (various types of feed and different polarizations).
3. Measurement of antenna characteristics from the radiation patterns of standard antennas: Horn, Dipole, Vivaldi, Spiral etc.
4. Design, simulation, fabrication and measurement of a Patch Antenna for a given operating frequency and for a given substrate eg. 1.88GHz with ε_r =4.4, h=31mils.

* The list is not exhaustive. Additional experiments or project based on the experiments can be included in the laboratory activity.

20-437-0115 **NEURAL NETWORKS**

L	T	P	C
3	2	0	3

Prerequisites : None

Course Description : This course provides a broad overview to neural networks and its design approaches.

Course Outcome : After the completion of the course the student will be able to

CO1	Mathematically model a neuron	Understand
CO2	Model a linear regressor/classifier using a perceptron model	Apply
CO3	Solve non-linear problems using multi-layer neural network	Apply
CO4	Implement better training algorithms for neural network	Analyse
CO5	Model RBFN networks to solve non-linear problems with kernel functions	Understand

Course content :

Module 1 : **Introduction:** Motivation from Human Brain, mathematical model of a neuron, basic computational unit, Activation Functions, Neural networks viewed as Directed Graphs, Feedback, Network Architectures, Knowledge Representation. Learning Process–Supervised, Unsupervised and Reinforcement learning, Learning Tasks-Pattern Association, recognition, function approximation, control, beamforming.

Module 2 : **Perceptron**: Perceptron convergence theorem, Relation between perceptron and Bayes classifier for a Gaussian Environment, computer, batch perceptron algorithm. Model building through regression- linear regression model, Cost Function, gradient descent algorithm, chain rule, optimization, Local minima, Global Minima, computer experiment: pattern classification. Least-Mean-Square Algorithm

Module 3 : **Multilayer Perceptron**: Batch learning and Online learning, Back propagation algorithm, XOR problem, heuristics for making the back-propagation algorithm perform better, activation functions, differentiability, symmetric, feature scaling, initialization, stopping criteria, computer experiment: pattern classification.

Module 4 : **Learning**: back propagation and differentiation, Hessian matrix, optimal annealing and adaptive control of the learning rate, Approximations of function, Generalization, Cross validation, Network pruning Techniques, Virtues and limitations of back propagation learning.

Module 5 : **Kernel Methods and Radial-Basis Function networks:** Cover's theorem on the separability of patterns, the interpolation problem, radial-basis-function networks, k-means clustering, recursive least-squares estimation of the weight vector, hybrid learning procedure for RBF networks, computer experiment: pattern classification, interpretations of the Gaussian hidden units.

References :

1. Simon Haykin, “Neural Networks and Learning Machines”, Pearson Education India; Third edition 2016
2. Martin T Hagan, Howard B Demuth, Mark H Beale, Orlando De Jesús, "Neural Network Design", Cengage Learning,2nd Edition, 2014
3. S. Haykin, “Neural Networks: A Comprehensive Foundation”, 2nd edition, (Prentice Hall, 1999)
4. Philip D. Wasserman, “Neural Computing: Theory and Practice”, Coriolis Group, 1989
5. B.Vegnanarayana, “Artificial neural networks”, Prentice Hall of India, 2005
6. James. A. Freeman and David M. Skapura, "Neural Networks Algorithms, Applications and. Programming Techniques ", Pearson Education, 2002

20-437-0116 **NEURAL NETWORKS LAB**

L	T	P	C
0	**0**	**4**	**1**

Prerequisites : None

Lab Description : This lab provides experiments to implement neural network algorithms using Python with the help of open source libraries such as TensorFlow, Keras, etc.

Course Outcome : After the completion of the lab the student will be able to

CO1	Implement regression models using neural network	Apply
CO2	Implement classifier models using a neural network	Apply
CO3	Solving non-linear problems using multi-layer neural network	Apply
CO4	Solution proposal for a real world problem	Apply
CO5	Improving the learning algorithms through parameter tuning	Analyse

Sample List of Experiment* :

1. Python and Jupyter notebook familiarisation
2. Implement the Perceptron model with gradient descent optimisation
3. Model a multilayer feed forward neural network and implement back propagation algorithm
4. Model neural networks for Regression tasks and Classification tasks for linear and non-linear data
5. Solution proposal for a real world problem, model a neural network, pre-process the data, train the model and evaluate the performance and improve the learning through parameter tuning.

* The list is not exhaustive. Additional experiments or project based on the experiments can be included in the laboratory activity.

20-437-0201 **SEMINAR**

L	T	P	C
0	0	2	1

Prerequisites : NIL

Course Outcome : After the completion of the course the student will be able to

CO1	Survey the literature on new research areas and compile findings on a particular topic	Understand
CO2	Organize and illustrate technical documentation with scientific rigor and adequate literal standards on the chosen topic strictly abiding by professional ethics while reporting results and stating claims.	Evaluate
CO3	Demonstrate communication skills in conveying the technical documentation via oral presentations using modern presentation tools.	Apply

The objective of the seminar is to impart training to the students in collecting materials on a specific topic in the broad domain of Engineering/Science from books, journals and other sources, compressing and organizing them in a logical sequence, and presenting the matter effectively both orally and as a technical report. The topic should not be a replica of what is contained in the syllabi of various courses of the M.Tech program. The topic chosen by the student shall be approved by the Faculty-in-Charge of the seminar. The seminar evaluation committee shall evaluate the presentation of students. A seminar report duly certified by the Faculty-in-Charge of the seminar in the prescribed form shall be submitted to the department after the approval from the committee.

20-437-0202 **IMAGE AND VIDEO PROCESSING**

L	T	P	C
3	2	0	3

Prerequisites : Calculus and Matrices

Course Description : This course deals with digital images and processing of digital images for various applications like Image Enhancement, Image Restoration, Image Compression, Image Segmentation, Morphological Image Processing, Image Representation & Description.

Course Outcome : After the completion of the course the student will be able to

CO1	Apply basic image enhancement algorithms in practical applications	Apply
CO2	Evaluate basic 2D transforms needed for image processing	Evaluate
CO3	Identify basic problems of image degradation	Understand
CO4	Discuss basic image segmentation and representation strategies	Understand
CO5	Discuss various video processing techniques	Understand

Course content :

Module 1 : **Fundamentals of Digital Image Processing:** 2D systems & mathematical preliminaries – Linear Shift Invariant Systems, 2D convolution, Matrix notation – Toeplitz and Circulant matrices, Orthogonal and unitary matrices, Types of images – black & white, gray scale and color images, Basic relationship between pixels, Intensity transformations, Histogram processing, Spatial filtering, frequency domain filtering

Module 2 : **Image Transforms:** Two dimensional orthogonal and unitary transforms - Separable unitary transforms, Basis images, Dimensionality of Image Transforms, Discrete linear orthogonal transforms – Haar transform, DFT, WHT, KLT and DCT.

Module 3 : **Image Restoration:** Degradation Models, Noise models, Restoration in the presence of noise only, Periodic noise reduction by frequency domain filtering, Estimating the degradation functions, Inverse Filtering, Wiener Filtering, Image reconstructions from Projections – Radon Transform, Fourier-slice theorem.

Module 4 : **Image Segmentation & Representation:** Image Segmentation – Discontinuity based and region-based approaches, Morphological image processing techniques – Dilation, Erosion, Opening, and Closing, Applications in enhancing object structures, Image representation – boundary and region based, Descriptors – region and boundary-based approaches.

Module 5 : **Video Processing:** Video Formation, Perception and Representation - Principles of Color Video, Video Cameras, Video Display, Composite versus Component Models, Gamma Correction, Video modeling – Camera model, Object model, Scene model, Two-Dimensional motion models, Two-Dimensional Motion Estimation – General methodologies, Optical flow, pixel-based motion estimation.

References :

1. Rafael C. Gonzalez and Richard E. Woods, "Digital Image Processing" - Pearson India Education Services Pvt. Ltd, 2018
2. Anil K. Jain, "Fundamentals of Digital Image Processing", Prentice Hall India Learning Private Limited, 1995
3. B. Chanda and D. Dutta Majumder, "Digital Image Processing & Analysis", Prentice Hall of India, 2001
4. S. Jayaraman, S. Esakkirajan & T. Veerakumar," Digital Image Processing", Mcgraw Hill, 2015
5. Alan C. Bovik, "Handbook of Image and Video Processing", Academic Press, 2010.
6. Kenneth R. Castleman, "Digital Image Processing", Pearson, 1995
7. Bernd Jahne, "Digital Image Processing", 6th Edition, Springer, 2005
8. William K. Pratt, "Digital Image Processing", 4th Edition, Wiley Interscience, 2007.

20-437-0203 **WIRELESS COMMUNICATION TECHNIQUES**

L	T	P	C
3	2	0	3

Prerequisites : Communication Theory

Course Description : This course reviews the various communication standards in wireless domain. This course will provide students an understanding about the wireless standards, modes of communication and efficiency criteria.

Course Outcome : After the completion of the course the student will be able to

CO1	Classify the wireless channel of a given wireless communication system into the available analytical or empirical models	Evaluate
CO2	Apply appropriate techniques to mitigate the impact of channel impairments	Apply
CO3	Analyze the capacity and reliability of wireless communication systems	Analyze
CO4	Design and Develop resource efficient and eco-friendly wireless technologies	Understand

Course content :

Module 1 : Wireless Channel Models, Path loss and Shadowing models, Empirical path loss models, Statistical fading models, Time varying channel impulse response, Narrow band and wideband fading models, Performance of digital modulation schemes over wireless channels

Module 2 : Time diversity, Frequency and Space diversity, Receive diversity, Concept of diversity branches and signal paths, Performance gains, Selective combining, Maximal ratio combining, Equal gain combining, performance analysis for Rayleigh fading channels, Transmit Diversity, Cellular Networks.

Module 3 : Multiple Access- TDMA, FDMA, CDMA, OFDMA, Spatial reuse, Co-channel interference analysis, Spectral efficiency and Grade of Service, Improving capacity -Cell splitting and sectorization.

Module 4 : AWGN channel capacity, Capacity of flat and frequency selective fading channels, multiuser capacity, opportunistic communication

Module 5 : Uplink (multiple access) channel capacity, Downlink (broadcast) channel capacity, Cellular wireless communication standards – LTE and LTE-Advanced, vision of 5G.

References :

1. Andrea Goldsmith, *Wireless Communications*, Cambridge University press, 2006.
2. David Tse and PramodV
3. iswanath, Fundamentals of Wireless Communication, Cambridge University Press, South Asian Edition, 2006
4. T.S. Rappaport, Wireless Communication, Principles and Practice, PHI, 2002.
5. Simon Haykinand Michael Moher, Modern Wireless Communications, Person Education, 2007
6. Andrea Goldsmith, "Wireless Communications" ,Cambridge University press.
7. A.J.Viterbi, "CDMA- Principles of Spread Spectrum", Addison Wesley, 1995.

20-437-0204 **COMMUNICATIONS LABORATORY**

L	T	P	C
0	**0**	**4**	**1**

Prerequisites : Communication Theory

Lab Description : Implementation of basic analog and digital communication systems in Octave/Python & GNURadio

Course Outcome : After the completion of the lab the student will be able to

CO1	To understand the communication toolbox in OCTAVE	Understand
CO2	To implement basic analog and digital communication systems in OCTAVE/PYTHON	Apply
CO3	To familiarize communication toolbox in GNU Radio	Understand
CO4	To implement analog and digital modulation and demodulation schemes in GNU Radio	Apply
CO5	To implement communication system prototype in SDR	Apply

Sample List of Experiment* **:** SDR Implementation of

1. PCM Modulation & Demodulation
2. Delta Modulation
3. QPSK Modulator & Demodulator
4. DPSK Modulator & Demodulator
5. OFDM

* The list is not exhaustive. Additional experiments or project based on the experiments can be included in the laboratory activity.

20-437-0205 **DESIGN VERIFICATION AND TESTING**

L	T	P	C
3	2	0	3

Prerequisites : Digital Circuits

Course Description : This course deals with the design verification and testing in the VLSI design process. It provides an overview of the various components involved in the process of verification of digital circuits. It also includes the different concepts and techniques in digital system testing for digital circuits.

Course Outcome : After the completion of the course the student will be able to

CO1	Differentiate between design verification and testing of digital circuits.	Understand
CO2	Describe the basic principles of different verification methodologies and explain the operation of event driven and cycle based simulators.	Understand
CO3	Design a systematic test plan with required coverage and implement a simulation based verification for a design.	Analyze
CO4	Determine collapsed fault lists for a combinational circuits by apply the concept of fault equivalence and fault dominance	Apply
CO5	Generate test pattern for any combinational circuit based on single-stuck-at fault model	Apply
CO6	Illustrate different design for testability techniques used in IC design process.	Understand

Course content :

Module 1 : **Introduction** – VLSI Design flow, Scope of verification and testing in VLSI design processes, Basic Principle of design verification, Verification methodology, Simulation based verification versus Formal verification.

Module 2 : **Simulator Architecture and Operations** – Compilers, Simulators – cycle based, event driven, hybrid, Hardware simulator and emulator, Simulator structures and operations, Incremental compilation.

Module 3 : **Test Bench organization and design** – test environment, initialization, clock generation, Stimulus generation, Response assessment, Test plan, Assertions, Verification coverage. Case study of verification of a digital design (e.g. counter).

Module 4 : **Fundamentals of VLSI testing** – Fault modeling: Logical fault models, Fault detection, fault equivalence and fault dominance; Automatic test pattern generation - ATPG for SSF in combinational circuit, D-Algorithm, Sequential circuit test generation.

Module 5 : **Design for testability (DFT)** – Introduction – controllability and observability, Ad Hoc Design for testability, Generic scan based design, Test interface and boundary scan, Built-in-self- test (BIST)- BIST Architecture .

References :

1. William K. Lam, Hardware Design Verification: Simulation and Formal Method-Based Approaches, Prentice Hall Modern Semiconductor Design Series, 2005.
2. M. Abramovici, M. Breuer, and A. Friedman, Digital System Testing and Testable Design, IEEE Press, 1994.
3. Chris Spear, Greg Tumbush, System Verilog for Verification: A Guide to Learning the Test bench Language Features, Springer 2012.
4. Charles H. Roth Jr "Digital System Design using verilog" Cengage India, 2015.
5. M. L. Bushnell and V.D. Agrawal, Essentials of Electronic Testing for Digital Memory and Mixed Signal VLSI Circuits, Springer, 2005.

20-437-0206 **DESIGN VERIFICATION LAB**

L	T	P	C
0	**0**	**4**	**1**

Prerequisites : Digital Electronics, 20-437-0106

Lab Description : The lab will provide hands-on experience on implementing a testbench to verifying a given digital design. The various components of testbench like stimulus, reference model and response checker will be designed and used to create the verification environment.

Course Outcome : After the completion of the lab the student will be able to

CO1	Design sequential circuits using Verilog HDL.	Apply
CO2	Develop a test plan for a given specification	Analyse
CO3	Implement a Verilog based verification environment a given design.	Evaluate
CO4	Realize verification testbench using high level language like System Verilog or C++ to verify a given design.	Apply

Sample List of Experiment* **:**

1. Design a digital system using Verilog based on given specification - e.g. FIFO, ALU, updown counter, Pingpong buffer etc.

2. Verify an unknown digital system based on the specification using Verilog :
    a. Develop a Test Plan for the verification of a digital system.
    b. Implement a verification testbench based on the test plan.
        a. Design the input stimulus for the design under test (DUT)
        b. Implement the reference model for the golden response generation
        c. Realize a response checker for the testbench

3. Verify an unknown digital system using C++ or System Verilog verification environment.

* The list is not exhaustive. Additional experiments or project based on the experiments can be included in the laboratory activity.

20-437-0207 **REAL TIME OPERATING SYSTEMS**

L	T	P	C
3	2	0	3

Prerequisites : None

Course Description : This course provides an understanding on the various aspects of real time operating systems. It covers methodologies in task scheduling and resource management.

Course Outcome : After the completion of the course the student will be able to

CO1	Solving shared data problems using multi-threaded programming	Apply
CO2	Understand OS architecture basics and RTOS approaches	Understand
CO3	Make feasible schedules using various scheduling algorithms	Analyze
CO4	Understand resource management and deadlock avoidance techniques	Understand
CO5	Discuss various commercial RTOS flavors and study FreeRTOS in detail	Understand

Course content :

Module 1 : **Embedded system review**: CPU and memory types, Direct memory access, Interrupt basics, interrupt latency, disabling and masking interrupts. **Shared data problems**: atomicity, critical section and its properties. Peterson's Solution, test and set, lock and swap. **Multi-threaded programming**: SMT vs Co-operative threads, IEEE POSIX standard for programming, POSIX Threads, producer consumer example. POSIX primitives: Mutex, Condition variables, Semaphores.

Module 2 : **Operating Systems:** UNIX System architecture, user mode and kernel mode, Application program Interface, system calls, Process Control Block, Process Scheduling, Context Switch, Shared Memory, Message passing, Dining Philosopher's example. **Software Architectures & RTOS:** Embedded Architecture Types: Round Robin approach, Round-Robin with interrupts, Real Time Operating Systems. Soft and hard real time OS, tasks and task states, RTOS process life cycle, Reentrancy.

Module 3 : **Tasks Scheduling:** Modeling of real time systems, Event triggered and Time triggered approach, Worst case execution time, pre-emptive priority systems, hybrid systems. **Scheduling algorithms:** schedulability test and criteria, Fixed and dynamic priority scheduling – Rate Monotonic approach, First Come First Serve, Shortest Job First, Shortest Remaining Time, Earliest Deadline First, Gantt Charts. Time quantum, Multi-level queue, Little's formula.

Module 4 : **Communication and resource management:** Message queue, mailbox, pipes. Inter-task communication, Blocking and non-blocking task synchronization. Linear buffer, ring buffer, double buffering. **Deadlock avoidance:** starvation, aging, resource allocation graph. Priority inversion, Nested critical sections, priority inheritance, disadvantages, priority ceiling protocol.

Module 5 : **RTOS software development:** Host and target machines, cross compilers, Linker, locator, emulators. Review of free and commercial Real Time Operating Systems- VxWorks, RTlinux, uCOS, etc. **FreeRTOS**: architecture and simulation on embedded platforms. RTOS Programming practise in FreeRTOS.

References :

1. David E. Simon, An Embedded Software Primer - Pearson Education, 2000.
2. Abraham Silberschatz, Operating Systems Concepts, John Wiley & Sons, 2004.
3. Herman Kopetz, Real-Time systems, Design principles for distributed embedded applications, Springer 2011.
4. Philip A. Laplante, Real- Time Systems Design and Analysis, John Wiley & Sons, 2004.
5. Frank Vahid and Tony Givargis, Embedded System Design: A Unified Hardware/ Software Introduction, John Wiley & Sons, 1999.
6. Wayne Wolf, Computers as Components: Principles of Embedded Computing System Design, Elsevier 2000.
7. VxWorks, https://www.windriver.com/products/vxworks/
8. Micrium uCOS, https://www.micrium.com/rtos/kernels/.
9. Real Time Linux https://rt.wiki.kernel.org/index.php/Main_Page
10. Nicolas Melot: Study of an operating system: FreeRTOS.

20-437-0208 **REAL TIME OPERATING SYSTEMS LAB**

L	T	P	C
0	0	4	1

Prerequisites : 20-437-0104 Embedded Systems Laboratory

Lab Description : The lab will provide hands-on experience on implementing a testbench to verifying a given digital design. The various components of testbench like stimulus, reference model and response checker will be designed and used to create the verification environment.

Course Outcome : After the completion of the lab the student will be able to

CO1	Familiarize with parallel programming primitives and deadlock situations	Analyze
CO2	Implement thread safe programs for parallel threaded environments	Apply
CO3	Porting an open source RTOS into development boards for demonstrating real world scenarios	Apply
CO4	Modify and customize operation of an RTOS to desired specifications	Apply
CO5	Propose and design solutions for real world problems using Real Time Operating Systems	Apply

Sample List of Experiment* :

1. Write a POSIX thread program with 25 threads generating a random number in them. The main thread should find the sum of all random numbers and the sum of all thread ids. Display these sums and end the child threads safely.
2. Write a POSIX program to design a producer consumer example with buffer of size 10 between them. There should be checks in place using semaphores to avoid writing to full buffer and to prevent reading from empty buffer.
3. Port FreeRTOS into Arudino board and write a program to blink LED for a fixed duration.
4. Port FreeRTOS into XILINX Zybo board containing ARM processor using VIVADO. Flash sample program to blink LEF for a fixed duration.
5. Demonstrate multi-level queue scheduling with pre-emption in FreeRTOS using a custom program.
6. Implement Earliest Deadline First scheduling in FreeRTOS and display the schedule taken based on varying execution times and deadlines for tasks from user.
7. Design project: Define a real time system, which requires an RTOS schedule as a solution. Implement it using FreeRTOS and demonstrate in a board of your choice.

* The list is not exhaustive. Additional experiments or project based on the experiments can be included in the laboratory activity.

20-437-0209	**ELECTROMAGNETIC INTERFERENCE AND COMPATIBILITY**

L	T	P	C
3	2	0	3

Prerequisites : A basic course in Electromagnetic Theory

Course Description : This courses intends to introduce the students to the basics of EMI/EMC, EMI coupling mechanisms and its mitigation techniques, EM compatible design of PCBs, an insight in to the current EMC standards and about various measurement techniques

Course Outcome : After the completion of the course the student will be able to

CO1	Describe the concept of EMI/EMC related to product design & development.	Understand
CO2	Analyse the different EM coupling principles and its impact on performance of electronic system.	Apply
CO3	Analyse the electromagnetic interference, highlighting the concepts of both susceptibility and immunity.	Apply
CO4	Analyse various EM compatibility issues with regard to the design of PCBs and ways to improve the overall system performance.	Analyse
CO5	Describe various EM radiation measurement techniques and the present leading edge industry standards in different countries.	Apply

Course content **:**

Module 1: EMI/EMC Concepts: EMI-EMC definitions and Units of parameters; Sources and victim of EMI; Conducted and Radiated EMI Emission and Susceptibility; Transient EMI, ESD; Radiation Hazards.

Module 2: EMI Coupling Principles*:* Coupling paths, Coupling via the supply network, Common mode coupling, Differential mode coupling, Impedance coupling, Radiative coupling, Ground loop coupling, Cable related emissions and coupling, Transient sources, Automotive transients. Categorization of the electromagnetic interference: emission, susceptibility, transients, crosstalk, shielding and compatibility, signal integrity.

Module 3: EMI Control Techniques: Shielding- Shielding Material-Shielding integrity at discontinuities, Filtering- Characteristics of Filters- Impedance and Lumped element filters-Telephone line filter, Power line filter design, Filter installation and Evaluation, Grounding- Measurement of Ground resistance-system grounding for EMI/EMC-Cable shielded grounding, Bonding, Isolation transformer, Transient suppressors, Cable routing, Signal control. EMI gaskets.

Module 4 : EMC Design of PCBs: EMI Suppression Cables-Absorptive, ribbon cables-Devices-Transient protection hybrid circuits, Component selection and mounting; PCB trace impedance; Routing; Cross talk control- Electromagnetic Pulse-Noise from relays and switches, Power distribution decoupling; Zoning; Grounding; VIAs connection; Terminations.

Module 5 : EMI Measurements and Standards*:* Open area test site; TEM cell; EMI test shielded chamber and shielded ferrite lined anechoic chamber; Tx /Rx Antennas, Sensors, Injectors / Couplers, and coupling factors; EMI Rx and spectrum analyzer; Civilian standards-CISPR, FCC, IEC, EN; Military standards-MIL461E/462. Frequency assignment - spectrum conversation. British VDE standards, Euro norms standards in japan - comparisons. EN Emission and Susceptibility standards and Specifications.

References :

1. Clayton R. Paul, "Introduction to Electromagnetic Compatibility", John Wiley Publications, 2nd edition, ISBN: 9788126528752, 2010.
2. Henry W. Ott.," Electromagnetic Compatibility Engineering", John Wiley Publications, 2nd edition, ISBN: 9780470189306, 2009.
3. Daryl Gerke and William Kimmel, "Electromagnetic Compatibility in Medical Equipment", IEEE & Interpharm press, ISBN: 0935184805, 1995.
4. V. P. Kodali, "Engineering EMC Principles, Measurements and Technologies", Wiley-Blackwell; 2nd edition, ISBN: 0780347439, 2001.

20-437-0210 **ELECTROMAGNETIC INTERFERENCE AND COMPATIBILITY LAB**

L	T	P	C
0	0	4	1

Prerequisites : None

Lab Description : This lab familiarises the student with the significance of EMI EMC and their impact in RF circuit design using appropriate experiments and simulation studies.

Course Outcome : After the completion of the lab the student will be able to

CO1	Understand and illustrate the importance of EMI & EMC.	Understand
CO2	Measure and analyse the conducted emission, radiated emission and crosstalk and determine the compatibility of a device.	Apply
CO3	Understand the impact of crosstalk, placement of components etc. on EMI.	Understand
CO4	Analyse and evaluate the impact of EMI mitigation techniques such as shielding.	Analyse
CO5	Prepare the reports and present the results correctly.	Apply

Sample List of Experiment* :

1. To study electrostatic discharge, different crosstalk in the cable and its reduction technique.
2. To measure crosstalk in a three conductor transmission line using VNA.
3. To study the characteristics and measure the conducted emission of a Current Probe.
4. To measure radiated emission from mobile tower and mobile phone.
5. To measure the performance parameter of an EMI sensor.
6. To measure of Shielding Effectiveness of conducting materials.
7. To measure board level emission using Magnetic Field loop Probes.
8. To design and simulate an EMI Sensor and EMI Filter.

* The list is not exhaustive. Additional experiments or project based on the experiments can be included in the laboratory activity.

20-437-0211 **RADAR SYSTEMS**

L	T	P	C
3	**2**	**0**	**3**

Prerequisites : A course in communication and signal processing.

Course Description : Study of different radars and signal processing associated. Study of different antennas used in radar applications.

Course Outcome : After the completion of the course the student will be able to

CO1	Understand the different types of radars and analyze different radar functions.	Analyze
CO2	Understand the different radar systems, tracking of radar and types of antennas used in radar systems.	Understand
CO3	Understand detection of radar signals and analysis of information extraction.	Analyze
CO4	Understand the radar signal processing.	Understand
CO5	Understand the different radar applications.	Understand

Course content :

Module 1 : **Radar fundamentals and operation:** Introduction, principles, types of radar, transmitter functions, wave form spectra, receiver functions, signal processing, Radar equation, Radar cross section.

Module 2 : **Radar Systems:** Pulse, CW, FM-CW, MTI, Doppler and multimode techniques, Tracking Radar: Tracking system parameters, Conical Scan, amplitude comparison DTOA and phase interferometry. Range and velocity tracking, Tracking accuracy, types of antennas using in radar systems.

Module 3 : **Detection of Radar Signals and information extraction and estimation:** Detection introduction, threshold detection, Signal integration, Binary integrators, CFAR, Theoretical accuracy of radar measurements, ambiguity function and radar waveform design, correlation detection and matched filter receiver.

Module 4 : **Radar signal processing:** Signal integration, spectrum analysis, windows and resolution, MTI principles and methods, De staggering and processing, Moving Radars and moving clutter, Doppler processing.

Module 5 : **Radar Applications:** Direction finders, instrument landing systems, Radar beacons, Electronic Warfare, ECM and ECCM, high resolution radar, range and Doppler resolution, Pulse compression (analog and digital), Synthetic aperture radar, millimeter wave radars for radio fuse applications.

References :

1. Skolnik M.M., "Introduction to Radar systems & quot;, McGraw Hill, (Second Edition) 1981.

2. Byron Edde. 'Radar: principles, technology and applications Pearson Education Inc., 1995.
3. D.Curtis Scheleher, "Introduction to Electronic Warfare Artech House Inc., 1986.
4. Wheeler G.J., "Radar Fundamentals & quot;, Prentice Hall Inc. NJ 1967.
5. LavanonNadav, "Radar Principles & quot; john Wiley & Sons, 1988.

20-437-0212 **MOBILE ROBOTICS**

L	T	P	C
3	2	0	3

Prerequisites : Fundamentals of Robotic systems

Course Description : This course discusses robots which are mobile and sense real time data. It also introduces various locomotion techniques and navigational systems. This course provides an information about the latest trends in localization systems.

Course Outcome : After the completion of the course the student will be able to

CO1	Introduces various Locomotion techniques	Understand
CO2	Detailed discussion about the Kinematics of wheeled Robots	Understand
CO3	Steering and control schemes are discussed	Understand
CO4	Various Localization techniques are explained	Apply
CO5	Discuss Navigation schemes and case study	Apply

Course content :

Module 1 : **Locomotion of Robots:** Locomotion in biological systems, Legged Mobile Robots, Aerial Robots, Wheeled Robots, Classification of wheels, Fixed wheel, Centered Oriented Wheel, Off-centered oriented wheel, Swedish wheel, Mobile robot locomotion, Differential Wheel, Tricycle, Synchronous drive, Omni-directional, Ackerman Steering, Kinematics models of WMR.

Module 2 : **Mobile Robot Kinematics:** Kinematic Models and Constraints: Representing robot position, Forward kinematic models, Wheel kinematic constraints, Robot kinematic constraints. Mobile Robot Maneuverability: Degree of mobility, Degree of steerability, Robot maneuverability. Mobile Robot Workspace: Degrees of freedom, Holonomic robots, Path and trajectory considerations, Beyond Basic Kinematics, Motion Control (Kinematic Control): Open loop control (trajectory-following), Feedback control

Module 3 : **Perception:** Sensors for Mobile Robots: Sensor classification, Characterizing sensor performance, Wheel/motor sensors, Heading sensors, Ground-based beacons, Active ranging, Motion/speed sensors, Vision-based sensors. Representing Uncertainty: Statistical representation, Error propagation: combining uncertain measurements, Feature Extraction: Feature extraction based on range data (laser, ultrasonic, vision-based ranging), Visual appearance based feature extraction.

Module 4 : **Mobile Robot Localization:** Introduction, Localization: Noise, Aliasing, Localization Based Navigation, Programmed Solutions, Belief

Representation, Map Representation: Continuous representations, Decomposition strategies, Challenges in map representation. Probabilistic Map-Based Localization: Markov localization, Kalman filter localization, Landmark-based navigation, Positioning beacon systems, Route-based localization, Autonomous Map Building, The stochastic map technique.

Module 5 : **Planning and Navigation:** Introduction, Competences for Navigation: Planning and Reacting: Path planning, Obstacle avoidance, Navigation Architectures: Modularity for code reuse and sharing, Control localization, Techniques for decomposition, Introduction to IoT. Case studies: ESP32 based Mobile Robot.

References :

1. Siegwart, Roland, Illah Reza Nourbakhsh, and DavideScaramuzza. "Introduction to autonomous mobile robots ", 2nd Edition, MIT press, 2011. ISBN 0-262-01535-8
2. H.R.Everett, "Sensors for Mobile Robots – Theory and Applications", A.K.Peteres Ltd. ISBN 1-56881- 048-2. 1995.
3. Kurfess, Thomas R., ed."Robotics and automation handbook". CRC press, 2004.
4. David Poole, Alan Mackworth "Artificial Intelligence: Foundations of Computational Agents", Cambridge University Press, 2010.
5. "Where am I? Sensors and Methods for Mobile Robot Positioning", J. Borenstein, et al., The University of Michigan, 1996.
6. Janakiraman P.A, "Robotics and Image Processing", Tata McGraw-Hill, 1995.
7. Siciliano, Bruno, and OussamaKhatib, eds. "Springer handbook of robotics". Springer, 2016.

20-437-0213 **MOBILE ROBOTICS LAB**

L	T	P	C
0	0	4	1

Prerequisites : Basic Knowledge of Embedded systems and interfacing

Lab Description : The lab includes the realization and study of encoders. It also provides strong experience with the state of art modern sensors and systems.

Course Outcome : After the completion of the lab the student will be able to

CO1 Realize and interface encoders <level>

CO2 Integrate various sub systems for the implementation of Robot vehicle

CO3 Expertise the state of the art sensor modules and sub systems

Sample List of Experiment* **:**

1. Design, construct and study a Quadrature encoder for a given DC motor.
2. Design & construct a DC motor driver (using L298 or similar) with speed, overload and direction control
3. Interface the encoder and driver developed (I & II) to a microcontroller and program it for different speeds (user Selectable) at various load conditions.
4. Interface a standard ***Ultrasonic module*** to a microcontroller and find the rage and display the same to an LCD.
5. Interface the given ***Lidar range finder*** to a microcontroller and find the rage and display the same to an LCD.
6. Interface the given ***Doppler radar module*** to a microcontroller and find the obstacle and plot the wave form in a PC display.
7. Interface the given ***Inertial Measurement Unit*** to a microcontroller and find the 3- axis acceleration and orientation.

* The list is not exhaustive. Additional experiments or project based on the experiments can be included in the laboratory activity.

20-437-0214 **DEEP NEURAL NETWORKS FOR SIGNAL PROCESSING**

L	T	P	C
3	2	0	3

Prerequisites : 20-437-0114 Neural Networks

Course Description : This course provides an overview to various deep neural network architectures and algorithms for spatial and temporal signal processing.

Course Outcome : After the completion of the course the student will be able to

CO1	Model convolution based feature extraction and prediction	Apply
CO2	Model recurrent networks for temporal and sequential signals	Apply
CO3	Model encoder-decoder networks for spatial/temporal signals	Understand
CO4	Generate signals through adversarial learning methods	Understand
CO5	Regularize deep neural network and apply strategies for better learning	Analyse

Course content :

Module 1 : **Convolution:** Convolution Operation, Variants of the basic convolution function, Feature Extraction, Pooling, Convolution and Pooling as an Infinitely Strong Prior, Structured Outputs, Random or Unsupervised Features. Convolutional Neural Networks, Relation between input size, output size and filter size, Visualizing filters of a CNN, Occlusion experiments, Finding influence of input pixels using backpropagation, Guided Backpropagation

Module 2 : **Sequential Processing:** Sequence Learning, Recurrent Neural Networks, Backpropagation through time (BPTT), Vanishing and Exploding Gradients, Truncated BPTT, Selective Read, Selective Write, Selective Forget - The Whiteboard Analogy, Long Short Term Memory, Gated Recurrent Units

Module 3 : **Encoding Decoding:** Encoder Decoder Models, Applications of Encoder Decoder models, Attention Mechanism, Attention over images, Hierarchical Attention. Introduction to Autoencoders, Link between PCA and Autoencoders, Regularization in autoencoders, Denoising Autoencoders, Sparse Autoencoders, Contractive Autoencoders

Module 4 : **Generation:** Generative Modeling, Principle of Generative Modeling, PixelRNN and PixelCNN, Variational Autoencoder, Generative Adversarial Network, Conditional Probability, Generator, Discriminator, Minimax objective function, gradient ascent, gradient descent

Module 5 : **Strategies for Training and Regularisation:** Momentum Based GD, Nesterov Accelerated GD, Stochastic GD, AdaGrad, RMSProp, Adam, Normalisation, Batch Normalization, Instance Normalization, Group Normalization. Regularization: Bias Variance Tradeoff, L2 regularization, Early stopping, Dataset augmentation, Parameter sharing and tying, Injecting noise at input, Adding Noise to the outputs, Early stopping, Ensemble Methods, Dropout

References :

1. Huttunen H., “Deep Neural Networks: A Signal Processing Perspective”. In: Bhattacharyya S., Deprettere E., Leupers R., Takala J. (eds) Handbook of Signal Processing Systems. Springer, Cham, 2019
2. Yu Hen Hu, Jenq-neng Hwang, “Handbook Of Neural Network Signal Processing”, The Electrical Engineering And Applied Signal Processing Series, Crc Press, 2002.
3. Ian Goodfelllow, Yoshua Benjio, Aaron Courville, “Deep Learning”, The MIT Press, 2016
4. Christopher M. Bishop, “Pattern Recognition and Machine Learning”, Springer - Information Science and Statistics, 2011
5. Christopher M. Bishop, “Neural Networks for Pattern Recognition”, Oxford University Press, 1996

20-437-0215 **DEEP NEURAL NETWORK SIGNAL PROCESSING LAB**

L	T	P	C
0	**0**	**4**	**1**

Prerequisites : 20-437-0116 NEURAL NETWORKS LAB

Lab Description : This lab provides experiments to implement deep neural network architectures and algorithms for spatial and temporal signal processing using Python with the help of open source libraries such as TensorFlow, Keras, etc.

Course Outcome : After the completion of the lab the student will be able to

CO1	Implement CNN based feature extraction and prediction models	Apply
CO2	Model RNN for temporal and sequential signals	Apply
CO3	Model encoder-decoder based neural networks for spatial/temporal signals	Apply
CO4	Implement Generative model to generate signals/images	Apply
CO5	DNN solution proposal for a real world problem and analysing various models/algorithms for a better solution.	Analyse

Sample List of Experiment* **:**

1. Implement CNN, analyse the feature extraction, visualise the feature vectors using Images
2. Implement RNN using LSTM/GRU to predict sequence/temporal signal
3. Implement encoder-decoder model for sequence/spatial signal
4. Implement generative adversarial network for sequence/spatial signal generation
5. Solution proposal for a real world problem, model a deep neural network utilising CNN/RNN/encoder-decoder/GAN networks or ensemble models and analyse and evaluate the performance of model. Analyse better optimisation methods, regularisation aspects, data augmentation, etc and improve the performance of model.

* The list is not exhaustive. Additional experiments or project based on the experiments can be included in the laboratory activity.

20-437-0216 **MACHINE LEARNING**

L	T	P	C
3	**2**	**0**	**3**

Prerequisites : None

Course Description : This course provides a broad introduction to machine learning and how to apply learning algorithms.

Course Outcome : After the completion of the course the student will be able to

CO1	Design linear, nonlinear regression and logistic regression models	Apply
CO2	Use ANN and SVM for solving ML problems	Apply
CO3	Utilize DT based non-parametric supervised method for classification and regression	Understand
CO4	Model unsupervised clustering algorithms and dimensionality reduction	Apply
CO5	Design ML system suitable to the type of data and evaluate the model performance	Analyse

Course content :

Module 1 : **Introduction**: Concept of learning models, Supervised Learning, Unsupervised Learning, Reinforcement Learning. Linear Regression with One Variable - idea of cost function, and gradient descent method for learning, Linear Regression with Multiple Variables- Multiple Features, Gradient Descent for Multiple Variables, Feature Scaling, Learning Rate, Normal Equation, Non-invertibility, Polynomial Regression, Logistic Regression-classification, hypothesis representation, decision boundary, cost function, optimization, multiclass classification.

Module 2 : **ANN:** Linear hypothesis, Non-linear hypotheses, model representation, Learning-cost function, gradient descent back propagation algorithm, unrolling parameters, gradient checking, random initialization. **SVM:** introduction, optimization objective, large margin classification, support vectors, Separating hyperplane approaches, support vector machine formulation, interpretation and analysis, SVMs for Linearly Non Separable Data, SVM Kernels, Hinge Loss formulation

Module 3 : **Decision Tree:** Introduction, Non-linearity, Selecting Regions, Defining Loss Function, Regression Trees, Stopping Criteria and Pruning, Loss Functions, Categorical Attributes, Multiway Splits, Missing Values, Imputation, Surrogate Splits, Instability, Smoothness, Repeated Subtrees. Ensembling Methods-Bagging, Boosting

Module 4 : **Unsupervised Learning:** Clustering: Introduction, k-means algorithm, optimization, random initialization, clustering. Dimensionality Reduction: Data compression, visualization, principal component analysis algorithm, reconstruction from compressed representation, Independent Components Analysis.

Module 5 : **ML System Design and Evaluation Measures:** Learning with large datasets, stochastic gradient descent, mini-batch gradient descent, stochastic gradient descent convergence, online learning, map reduce and data parallelism. Two Class Evaluation Measures, Confusion Matrix, Accuracy, Precision, Recall, Sensitivity, Specificity, F1-score, Precision Recall curve, Break Even Point, ROC Curve, Area Under Curve(AUC), Evaluating a Hypothesis, Model Selection, Regularisation, Training Validation Testing, Diagnosing Bias vs. Variance, Learning Curves.

References :

1. Tom Mitchell, “Machine Learning”, McGraw-Hill 1997
2. Trevor Hastie, Robert Tibshirani, Jerome H. Friedman, “The Elements of Statistical Learning: Data Mining, Inference, and Prediction”, Second Edition, Springer Series in Statistics, 2016
3. Christopher M. Bishop, “Pattern Recognition and Machine Learning”, Springer - Information Science and Statistics, 2011
4. Shai Shalev Shwartz, Shai Ben David, "Understanding Machine Learning: From Theory to Algorithms", Cambridge University Press, 2014
5. Ethem Alpaydin, “Introduction to Machine Learning”, Second Edition, MIT Press, 2010
6. Mehryar Mohri, Afshin Rostamizadeh and Ameet Talwalkar, "Foundations of Machine Learning", MIT Press, 2012
7. Simon Haykin, “Neural Networks and Learning Machines”, Pearson Education India; Third edition 2016

20-437-0217 **ANALOG INTEGRATED CIRCUITS**

L	T	P	C
3	2	0	3

Prerequisites : A basic course in CMOS VLSI Design

Course Description : This course explores the fundamentals of the analog IC design, starting from single stage amplifiers to Operational Amplifiers

Course Outcome : After the completion of the course the student will be able to

CO1	Understand small signal modelling of MOS transistor circuits	Understand
CO2	Use small Signal Models and Analyse Single stage and Differential MOSFET Amplifiers.	Apply
CO3	Design MOSFET amplifiers for a given specification and simulate using SPICE.	Analyze
CO4	Understand the trade-offs involved in CMOS analog circuit design.	Understand
CO5	Describe the processes followed in CMOS Fabrication.	Understand
CO6	Compare the various biasing techniques for MOSFET amplifiers.	Understand
CO7	Discuss the working of non linear circuits like Oscillators and PLLs.	Understand

Course content :

Module 1 : **MOSFET Models:** Large-Signal Behaviour of Metal-Oxide-Semiconductor Field-Effect Transistors, Small-Signal Models of MOS Transistors, Advanced MOS modeling, SPICE modeling and simulations. Basics of single stage CMOS amplifiers -common Source, gate and source follower stages.

Module 2 : **MOS Fabrication & Layout:** Basic Processes in Integrated-Circuit Fabrication – Silicon wafer preparation, FEOL processing-Diffusion of impurities, ion implantation, annealing, oxidation, lithography, Chemical Vapour Deposition, epitaxial growth, BEOL process- metalization, patterning, wire bonding, packaging, MOS Layers, Layout Design Rules, Yield & Cost Considerations in Integrated-Circuit Fabrication.

Module 3 : **Single Stage & Differential Amplifiers:** Common Source Stage with resistive load, diode connected load, current source load and active load. Source Follower, Common Gate stage, Cascode and Folded Cascode Amplifiers. Frequency Response – Miller Effect, Poles, Gain Bandwidth trade-offs. Design and Simulate Single stage amplifiers using SPICE.

Module 4 : **Differential Amplifiers, Current Mirrors and References:** Basic Differential Pair - Analysis, Common Mode Response, Frequency Response. Differential Pair with

MOS Loads, Current Mirrors – Cascode and Active current Mirrors, Opamps- single stage and Two stage opamps, Biasing Techniques, Voltage and Current References, Bandgap References, Supply Independent Biasing, Temperature Independent References, Constant-Gm Biasing

Module 5 : **Noise:** Types of Noise, Representation of Noise in circuits, Noise in single stage amplifier, Noise in differential amplifiers. **Nonlinear Analog Circuits:** , Gilbert Cell, Gilbert Cell as an Analog Multiplier, A Complete Analog Multiplier, Oscillators – Ring Oscillator, LC Oscillator, Phase-Locked Loops (PLL), PLL Concepts, Simple PLL, Charge Pump PLL, Nanometer Design studies

References :

1. Behzad Razavi, "Design of Analog CMOS Integrated Circuits", Tata McGraw Hill, McGraw Hill Education (India) Edition, 2018.
2. Behzad Razavi, "Fundamentals of Microelectronics", Wiley, 2nd Edition, 2013.
3. R. Jacob Baker, "CMOS Circuit Design, Layout, and Simulation", Wiley, 4th Edition, 2019.
4. Paul. R. Gray, Paul J. Hurst, Stephen H. Lewis, Robert G. Meyer, "Analysis and Design of Analog Integrated Circuits" , Wiley, 5th Edition, 2009.
5. Phillip E. Allen and Douglas R. Holberg, , "CMOS Analog Circuit Design", Oxford University Press, 3rd Edition 2012.
6. Stephen A. Campbell , "The Science and Engineering of Microelectronic Fabrication", Oxford University Press, 2nd Edition, 2012.
7. S. M. Sze, "VLSI Technology", McGraw Hill Education, 2nd edition, 2017.

20-437-0218 **ADVANCED DIGITAL SIGNAL PROCESSING**

L	T	P	C
3	2	0	3

Prerequisites : Signals & Systems, Digital Signal processing, Mathematics

Course Description : A beginner course in adaptive signal processing intended to be taught to intermediate degree qualified students. The course is aimed at providing a basic idea of adaptation that is employed in numerous adaptive systems across various domains.

Course Outcome : After the completion of the course the student will be able to

CO1	Discuss various adaptation techniques related with signal processing	Understand
CO2	Theory of adaptation and eigen vectors	Understand
CO3	Basic gradient search methods and Performance penalties	Analyse
CO4	Adaptive algorithm and derivations	Understand
CO5	Different applications of adaptive modelling	Apply

Course content :

Module 1 : **Introduction** : Adaptive Systems - Definition and Characteristics - Open-and Closed-Loop Adaptation - Adaptive Linear Combiner - Input Signal and Weight Vectors - Desired Response and Error - Performance Function

Module 2 : **Theory of Adaptation** - Properties of the Quadratic Performance Surface - Normal Form of the Input Correlation Matrix - Eigenvalues and Eigenvectors of the Input - Correlation Matrix - Geometrical Significance of Eigenvectors and Eigenvalues

Module 3 : **Performance Surface** - Methods of Searching the Performance Surface - Basic Ideas of Gradient Search Methods - simple Gradient Search Algorithm - Gradient Estimation and its Effects on Adaptation - Gradient Component Estimation by Derivative Measurement - Derivative Measurement and Performance Penalties with Multiple Weights

Module 4 : **Adaptive Algorithms** - The LMS Algorithm - Derivation of the LMS Algorithm - Convergence of the Weight Vector - An Example of Convergence - Learning Curve Noise in the weight-Vector Solution.

Module 5 : **Applications**: Adaptive Modelling and System Identification - Adaptive Modelling of a Multipath Communication Channel. Inverse Adaptive Modelling Deconvolution and Equalization - General Description of Inverse Modelling- Adaptive Equalization of Telephone Channels - The Concept of Adaptive Noise Cancelling - Stationary Noise-Cancelling Solutions, Filtered-X LMS Algorithm - Adaptive Arrays - Sidelobe Cancellation - Beam forming with a Pilot Signal- Spatial Configurations, Adaptive Algorithms

References :

1. Proakis, J.G., Manolakis, D.G. “Digital Signal Processing Principle Algorithms and Applications”. PHI 1996.
2. Dudgeon, D.E., Merseraus, R.M., “Multi-Dimensional Digital Signal Processing”. Prentice-Hall, N.J., 1984.
3. Oppenheim, A.V., Schafer, R.W. , “Discrete – Times Signal Processing”. PHI, 1992
4. Crochiere, R.E., Rabiner, L.R., “Multi rate Digital Signal Processing, Prentice-Hall, N.J. 1983
5. Haddad, Richard A., Parsons, Thomas W., “Digital Signal Processing: Theory Applications & Hardware”, Computer Science Press, 1991.
6. Ahmed, N., Natarajan, T.R., “Theory and Applications of Digital Signal Processing.” Reston Publishing Co., 1983.

20-437-0219 **RFIC DESIGN**

L	T	P	C
3	2	0	3

Prerequisites : Microwave Devices and Analog Circuit design

Course Description : This course elaborates the integrated circuit (IC) implementation of RF circuits for wireless communications applications, namely - Transceiver architectures for current wireless communications standards; active/passive device technologies for RFIC implementations; low noise amplifiers; mixers; frequency sources; power amplifiers; single-chip radios; and RFIC packaging and testing. Case studies of modern RFIC chip sets for current wireless communications standards are also examined.

Course Outcome : After the completion of the course the student will be able to

CO1	Understand fundamentals of RF Integrated circuits and Transceiver design.	Understand
CO2	Understand the implementation of active and passive components in RFIC systems	Understand
CO3	Apply the Noise concepts in RF circuit design.	Apply
CO4	Design Low Noise and Power Amplifiers and compare the performance of its various types.	Analyse
CO5	Design oscillators and mixers and compare the performance of its various types.	Analyse

Course content :

Module 1 : **Fundamentals of RF circuits and Systems**: Overview of RFIC and circuit design review. Time Variance and Nonlinearity, Effects of nonlinearity, Noise, Sensitivity & SFDR. Transceiver link analysis and relationship to RF circuit specifications. General considerations, Receiver Architectures. Transmitter Architectures.

Module 2 : **Passive and Active Components for RFIC:** On-chip implementation of R, L and C; On-chip implementation transformers and transmission lines, RFMEMS devices; Characterization of silicon MOSFETs and SiGe-HBTs, and CMOS/BiCMOS technologies for RF and high-speed applications. Feedback and wideband preamplifiers.

Module 3 : **Noise Calculations, LNA & Mixers:** Noise in resistors and MOSFET; NF of a CS stage; two port noise theory. LNA: General considerations, Problem of input matching, Low Noise Amplifiers design in various topologies. Mixers: General considerations, Passive down conversion mixers, Active down conversion mixers, Up conversion mixers.

Module 4 : **Power Amplifiers:** Large signal amplifiers: Issues & performance measures, Classification of PAs, Class D, E, F, Power combining, Linearity improvement techniques.

Module 5 : **Oscillators, PLLs and Synthesizers:** Oscillators - requirements & performance measures Cross coupled oscillator, Three point oscillators, Voltage Controlled Oscillators, LC VCOs with wide tuning range, phase noise, Mathematical model of VCOS, Quadrature Oscillators; Phase noise; Type I PLLs, Type II PLLs, Integer N Synthesizers

References :

1. Behzad Razavi, "RF Microelectronics", 2nd Ed., Prentice Hall, 2011.
2. Thomas H. Lee, "The design of CMOS radio-frequency integrated circuits", 2nd Ed., Cambridge University Press, ISN 0521835399, 2004.
3. S. Voinigescu, “High-Frequency Integrated Circuits”, The Cambridge RF and Microwave Engineering Series, 1st edition, ISBN 978-0-521-87302-4, 2013.
4. David M. Pozar, “Microwave Engineering”, Wiley, 4th ed, Hoboken, NJ, ISBN 9780470631553, 2011.
5. John Rogers & Calvin Plett, “Radio Frequency Integrated Circuit Design”, Artech House, ISBN 1-58053-502-x, 2003.

20-437-0220 **SIGNAL INTEGRITY FOR HIGH SPEED DIGITAL DESIGN**

L	T	P	C
3	2	0	3

Prerequisites : Basic knowledge of electromagnetics and circuit design

Course Description : This course will discuss the principles of signal integrity and its applications in the proper design of high-speed digital circuits. As interconnect data rates increase, phenomena that have historically been negligible begin to dominate performance, requiring techniques that were not previously necessary. This course is designed to give the students the theoretical and simulation tools needed to determine where signal integrity issues may arise, how to prevent such problems and how to resolve problems when they arise in practice.

Course Outcome : After the completion of the course the student will be able to

CO1	Understand fundamental signal integrity concepts	Understand
CO2	Understand how high-frequency signals propagate on cables and circuit board traces.	Understand
CO3	Understand design parameters that affect signal integrity including reflections, attenuation, and crosstalk	Understand
CO4	Develop the skills for analysing high-speed circuits with signal behaviour modelling.	Apply
CO5	Design PCB's with consideration of signal integrity and impedance matching.	Apply

Course content :

Module 1 : **Introduction to Signal Integrity**: Definitions, Signal quality on a single net; Cross talk. Creating circuit models; the role of measurements. **The Physical Basis of Resistance, Capacitance & Inductance**: Bulk resistivity, resistance per length, sheet resistance, current flows in capacitors, power and ground planes and decoupling capacitance, capacitance per length. 2D solvers; Partial inductance, effective inductance, total or net inductance, and ground bounce, loop inductances, current distribution and skin depth, Eddy currents. 2D model examples of inductance circuits.

Module 2 : **Transmission Lines & Reflections:** Driving a transmission line, return paths. Characteristic and controlled impedance. Frequency variation of the characteristic impedance. Reflection at impedance changes. Source impedance. Bounce diagrams. Simulating reflected waveforms. Measuring reflections with TDR. Effects of corners and vias. Loaded lines.

Module 3 : **Lossy lines, Rise Time Degradation and Material Properties:** Losses in transmission lines, modeling lossy transmission line. Signal velocity. The bandwidth of an inter connect. Time domain behavior of lossy lines. Eye diagram of transmission line. Pre-emphasis and equalization. Modeling, simulation, verification, and testing of lossy line examples.

Module 4 : **Cross Talk in Transmission Lines**: Origin of coupling, cross talk in transmission lines: NEXT and FEXT, describing cross talk. The Maxwell capacitance matrix and 2D field solvers, the inductance matrix. Near-end cross talk. Far-end cross talk. Decreasing Far-End cross talk. **De-embedding:** Basic Concepts of De-embedding. Different de-embedding methods. Phase uncertainty and error analysis.

Module 5 : **Differential Signaling**: Removal of common-mode noise, Differential crosstalk, Differential crosstalk, Differential crosstalk; **I/O design considerations:** Push–pull transmitters, CMOS receivers, ESD Protection circuits, On-chip termination.

References :

1. Eric Bogatin, Signal and Power Integrity -Simplified (2nd Edition), Prentice Hall, 2009.
2. Stephen H. Hall, Howard L. Heck, “Advanced signal integrity for high-speed digital designs, John Wiley, 2009.
3. H. Johnson and M. Graham, High-Speed Digital Design: A Handbook of Black Magic, Prentice Hall 1993.
4. D. Brooks, Signal Integrity Issues and Printed Circuit Board Design, Prentice Hall, 2003.
5. S. Hall, G. Hall and J. McCall High Speed Digital Design: A Handbook for Interconnect Theory and Design Practices, Wiley IEEE Press 2000.

20-437-0221	ADVANCED ELECTROMAGNETIC ENGINEERING

L	T	P	C
3	2	0	3

Prerequisites : Basic EM Theory, Coordinate system and Transmission lines

Course Description :

Course Outcome : After the completion of the course the student will be able to

CO1	Develop understanding about energy, power & current.	Understand
CO2	Develop understanding about waves & propagation.	Understand
CO3	Develop understanding about the theorems & concepts concerned with**.**	Apply
CO4	Demonstrate understanding on the plane waves functions and calculation of various performance parameter.	Analyse
CO5	Demonstrate insight to use the perturbational and variational techniques.	Analyse

Course content :

Module 1 : **Fundamental Concepts:** Introduction, Basic equations, Constitutive relationships, Generalized current concepts, Energy and power, Circuit concepts, Complex quantities, Complex equations, Complex constitutive parameters, Complex power, A-C Characteristics of matter, A discussion of current, A-C behavior circuit elements, Singularities of field.

Module 2 : **Introduction of Waves:** Wave Equation, Waves in perfect dielectrics, Intrinsic wave constants, Waves in lossy matter, Reflection of waves, Transmission line concepts, Waveguide concepts, Resonator concepts, Radiation, and Antenna concepts.

Module 3 : **Some Theorems & Concepts:** Source concepts, Duality, Uniqueness, Image theory, Equivalence principle, Fields in half space, Induction theorem, Reciprocity, Green's functions, Integral equations, Construction of solutions, The radiation field.

Module 4 : **Plane Wave Functions:** Wave functions, Plane waves, Rectangular waveguides, Alternative mode sets, Rectangular cavity, Partially filled wave guide, Dielectric-slab guide, Surface guided waves, Modal Expansions of fields, Currents in waveguides, Apertures in ground planes.

Module 5 : **Perturbational and Variational Techniques**: Perturbation of Cavity Walls, Cavity Material Perturbations, Waveguide Perturbations, Stationary Formulas for Cavities.

References :

1. R. F. Harrington., "Time Harmonic Electromagnetics", McGraw Hill, 1961.
2. RF Harrington, "Field Computation by Moment Methods", New York: MacMillan, 1968.

3. E.C Jordan & K.G. Balmain, "Electromagnetic Waves and Radiating Systems", 2nd Edition, Prentice Hall India, Pvt. Ltd., New Delhi.
4. William H. Hayt and John A. Buck, Engineering Electromagnetics", 8th Edition, McGraw Hill, 2010.
5. C.A. Balmain, "Advanced Engineering Electromagnetics", Wiley India, Pvt. Ltd., 2005.

20-437-0222 **COMPUTATIONAL ELECTROMAGNETICS**

L	T	P	C
3	2	0	3

Prerequisites : Basic EM Theory, Coordinate system and Transmission lines

Course Description :

Course Outcome : After the completion of the course the student will be able to

CO1	Classify the EM problems	Understand
CO2	Acquire theoretical knowledge and explain various numerical methods of electromagnetics.	Understand
CO3	Formulate real life problem to mathematical model and develop computational skills in applied electromagnetics.	Apply
CO4	Apply various numerical methods to different static, scattering and radiation problems.	Apply

Course content :

Module 1 : **Introduction**: Need for Numerical Solution of Electromagnetic problems, Selection of a numerical method, Classification of Electromagnetic problems, Classification of Solution Region, Classification of Boundary Conditions.

Module 2 : **Finite Difference (FD) Methods**: Introduction, FD schemes for parabolic, hyperbolic& Elliptical partial differential equations, solving the Laplace, diffusion and wave equations by FD method. Application to Guided structures: microstrip line and rectangular waveguide. FDTD: Yee's FD algorithms, Accuracy & stability, Lattice truncation condition, Initial fields, Absorbing Boundary conditions for FDTD, Scattering problems.

Module 3 : **Integral Equations:** Classification of Integral Equations, Relation between Differential and Integral Equations, Green's function: definition, Green's function for free space.

Module 4 : **Method of Moments (MoM)**: Solution of integral equations using MoM, Quasi-static problems (thin conducting wire, parallel plate capacitor), Dipole antenna current distribution & input impedance, mutual impedance of two short dipoles, Scattering from a dipole antenna.

Module 5 : **Finite Element Method**: Finite Element Discretization, Element Governing Equations, Assembling of all Elements, Solving the resulting equations, Typical Applications.

References :

1. Numerical Techniques in Electromagnetics Mathew N. O. Sadiku (CRC Press)

2. Analytical and Computational Methods in Electromagnetics, Ramesh Garg, Artech House, 2008.

20-437-0223 **SOFTWARE DEFINED RADIOS**

L	T	P	C
3	2	0	3

Prerequisites : A basic course in communication system & DSP

Course Description : This course provides an overview of software-defined radio systems and the technologies necessary for their successful implementation. The student will also appreciate the current and future trends in the SDR space and implemented SDR.

Course Outcome : After the completion of the course the student will be able to

CO1	Demonstrate understanding of the need, characteristics and benefits of SDR.	Understand
CO2	Analyze the RF Chain of SDR and components for overall performance.	Apply
CO3	Compare direct digital synthesis with analog signal synthesis in SDR.	Apply
CO4	Demonstrate understanding of polyphase filters, digital filter banks, timing recovery in digital receivers using multi-rate digital filters.	Understand
CO5	Demonstrate insight to evaluate the parameters of Ideal Data Converters and Practical data Converters.	Apply

Course content :

Module 1 : **Introduction to Software radio concepts**: Introduction, need, characteristics, benefits and design principles of Software Radios. Traditional radio implemented in hardware (first generations of 2G cell phones), Software controlled radio (SCR), Software defined radio (SDR), Ideal software radio (ISR), Ultimate software radio (USR)

Module 2 : **Radio frequency implementation issues** : The purpose of RF Front-End, Dynamic range, RF Receiver Front-End Topologies, Enhanced Flexibility of the RF Chain with Software Radios, Importance of Components to Overall performance, Transmitter Architecture and their issues, Noise and Distortion in RF Chain.

Module 3 : **Digital generation of signals**: Introduction, Comparison of Direct Digital Synthesis with Analog Signal Synthesis, Approaches to Direct Digital Synthesis, Analysis of Spurious Signals, Spurious components due to Periodic Jitter.

Module 4 : **Multirate Signal Processing**: Introduction, Sample Rate Conversion Principles, Polyphase Filters, Digital Filter Banks, Timing Recovery in Digital receivers Using Multirate Digital Filters.

Module 5 : **A/D & D/A Conversion** : Introduction, Parameters of Ideal Data Converters, Parameters of Practical data Converters, Techniques to improve Data Converter performance, Complex SPEAKeasy, JTRS.

References :

1. Jeffery H. Reed, “Software Radio, (A modern approach to radio engineering)”, PHI PTR, 2002.
2. John J. Rouphael, “RF and Digital Signal Processing for Software Defined Radio” Elsevier, Newness Publications.
3. C. Richard Johnson, Jr., and William A. Sethares, Telecommunication Breakdown, Prentice Hall, ISBN 0-13-143047-5, 2004.

20-437-0217 **ANALOG INTEGRATED CIRCUITS**

L	T	P	C
3	2	0	3

Prerequisites : A basic course in CMOS VLSI Design

Course Description : This course explores the fundamentals of the analog IC design, starting from single stage amplifiers to Operational Amplifiers

Course Outcome : After the completion of the course the student will be able to

CO1	Understand small signal modelling of MOS transistor circuits	Understand
CO2	Use small Signal Models and Analyse Single stage and Differential MOSFET Amplifiers.	Apply
CO3	Design MOSFET amplifiers for a given specification and simulate using SPICE.	Analyze
CO4	Understand the trade-offs involved in CMOS analog circuit design.	Understand
CO5	Describe the processes followed in CMOS Fabrication.	Understand
CO6	Compare the various biasing techniques for MOSFET amplifiers.	Understand
CO7	Discuss the working of non linear circuits like Oscillators and PLLs.	Understand

Course content :

Module 1 : **MOSFET Models:** Large-Signal Behaviour of Metal-Oxide-Semiconductor Field-Effect Transistors, Small-Signal Models of MOS Transistors, Advanced MOS modeling, SPICE modeling and simulations. Basics of single stage CMOS amplifiers -common Source, gate and source follower stages.

Module 2 : **MOS Fabrication & Layout:** Basic Processes in Integrated-Circuit Fabrication – Silicon wafer preparation, FEOL processing-Diffusion of impurities, ion implantation, annealing, oxidation, lithography, Chemical Vapour Deposition, epitaxial growth, BEOL process- metalization, patterning, wire bonding, packaging, MOS Layers, Layout Design Rules, Yield & Cost Considerations in Integrated-Circuit Fabrication.

Module 3 : **Single Stage & Differential Amplifiers:** Common Source Stage with resistive load, diode connected load, current source load and active load. Source Follower, Common Gate stage, Cascode and Folded Cascode Amplifiers. Frequency Response – Miller Effect, Poles, Gain Bandwidth trade-offs. Design and Simulate Single stage amplifiers using SPICE.

Module 4 : **Differential Amplifiers, Current Mirrors and References:** Basic Differential Pair - Analysis, Common Mode Response, Frequency Response. Differential Pair with MOS Loads, Current Mirrors – Cascode and Active current Mirrors, Opamps- single stage and Two stage opamps, Biasing Techniques, Voltage and Current References, Bandgap References, Supply Independent Biasing, Temperature Independent References, Constant-Gm Biasing

Module 5 : **Noise:** Types of Noise, Representation of Noise in circuits, Noise in single stage amplifier, Noise in differential amplifiers. **Nonlinear Analog Circuits:** , Gilbert Cell, Gilbert Cell as an Analog Multiplier, A Complete Analog Multiplier, Oscillators – Ring Oscillator, LC Oscillator, Phase-Locked Loops (PLL), PLL Concepts, Simple PLL, Charge Pump PLL, Nanometer Design studies

References :

1. Behzad Razavi, "Design of Analog CMOS Integrated Circuits", Tata McGraw Hill, McGraw Hill Education (India) Edition, 2018.
2. Behzad Razavi, "Fundamentals of Microelectronics", Wiley, 2nd Edition, 2013.
3. R. Jacob Baker, "CMOS Circuit Design, Layout, and Simulation", Wiley, 4th Edition, 2019.
4. Paul. R. Gray, Paul J. Hurst, Stephen H. Lewis, Robert G. Meyer, "Analysis and Design of Analog Integrated Circuits" , Wiley, 5th Edition, 2009.
5. Phillip E. Allen and Douglas R. Holberg, , "CMOS Analog Circuit Design", Oxford University Press, 3rd Edition 2012.
6. Stephen A. Campbell , "The Science and Engineering of Microelectronic Fabrication", Oxford University Press, 2nd Edition, 2012.
7. S. M. Sze, "VLSI Technology", McGraw Hill Education, 2nd edition, 2017.

20-437-0301 **PROJECT: PART 1**

L	T	P	C
0	**0**	**24**	**15**

Prerequisites : NIL

Course Outcome : After the completion of the course the student will be able to

CO1 Develop aptitude for research and independent learning.

CO2 Demonstrate the ability to carry out literature survey and select unresolved problems in the domain of the selected project topic.

CO3 Gain the expertise to use new tools and techniques for the design and development.

CO4 Acquire the knowledge and awareness to carry out cost-effective and environment friendly designs

CO5 Develop the ability to write good technical report, to make oral presentation of the work, and to publish the work in reputed conferences/journals.

The major project in the third and fourth semesters offer the opportunity to apply and extend knowledge acquired in the first year of the M. Tech. program. The major project can be analytical work, simulation, hardware design or a combination of these in the emerging areas of Communication Engineering under the supervision of a faculty from the ECE Department or in R & D institutes/ Industry. The specific project topic undertaken will reflect the common interests and expertise of the student(s) and supervisor. Students will be required to1) perform a literature search to review current knowledge and developments in the chosen technical area; 2) undertake detailed technical work in the chosen area using one or more of the following:

- Analytical models
- Computer simulations
- Hardware implementation

The emphasis of major project shall be on facilitating student learning in technical, project management and presentation spheres. Project work will be carried out individually. The M. Tech. project evaluation committee of the department shall evaluate the project work during the third semester in two phases. The first evaluation shall be conducted in the middle of the semester. This should be followed by the end semester evaluation. By the time of the first evaluation, students are expected to complete the literature review, have a clear idea of the work to be done, and have learnt the analytical / software / hardware tools. By the time of the second evaluation, they are expected to present the results of their advancements in the chosen topic, write an interim technical report of the study and results and clearly state the work plan for the next semester.

20-437-0302 **NPTEL COURSE/MOOC**

L	T	P	C
3	0	0	3

Prerequisites : NIL

Course Outcome : After the completion of the course the student will be able to

CO1 Develop aptitude for independent learning.

CO2 Flexible way to learn new skills, advance career and deliver quality educational experiences at scale

National Programme on Technology Enhanced Learning (NPTEL) is a project of MHRD initiated by seven Indian Institutes of Technology (Bombay, Delhi, Kanpur, Kharagpur, Madras, Guwahati and Roorkee) along with the Indian Institute of Science, Bangalore in 2003, to provide quality education to anyone interested in learning from the IITs. The main goal was to create web and video courses in all major branches of engineering and physical sciences at the undergraduate and postgraduate levels and management courses at the postgraduate level. It is the largest online repository in the world of courses in engineering, basic sciences, and selected humanities and social sciences subjects, Online web portal http://nptel.ac.in.

Since 2013, through an online portal, 4-, 8-, or 12-week online courses, typically on topics relevant to students in all years of higher education along with basic core courses in sciences and humanities with exposure to relevant tools and technologies, are being offered. An in-person, proctored certification exam and a certificate is provided through the participating institutions and industry, when applicable.

Massive Open Online Courses (MOOCs) are free online courses available for anyone to enroll. MOOCs provide an affordable and flexible way to learn new skills, advance your career and deliver quality educational experiences at scale.

The students have to complete a minimum 8 week duration course which will yield them a credit of 3. The selection of the course will be dependent on their specialisation and should be approved by the committee constituted for the same.

20-437-0401 **PROJECT: PART 2**

L	T	P	C
0	**0**	**24**	**18**

Prerequisites : Successful completion of 20-437-0301 Project: Part 1

Course Outcome : After the completion of the course the student will be able to

CO1 Develop aptitude for research and independent learning.

CO2 Demonstrate the ability to carry out literature survey and select unresolved problems in the domain of the selected project topic.

CO3 Gain the expertise to use new tools and techniques for the design and development.

CO4 Acquire the knowledge and awareness to carry out cost-effective and environment friendly designs

CO5 Develop the ability to write good technical report, to make oral presentation of the work, and to publish the work in reputed conferences/journals.

20-437-0401 Project: Part 2 is a continuation of 20-437-0301 Project: Part 1in the third semester. Students should complete the work planned in the third semester, attaining all the objectives, and should prepare the project report of the complete work done in the two semesters. They are expected to communicate their innovative ideas and results in reputed conferences and/or journals. The M. Tech. project evaluation committee of the department shall evaluate the project work during the fourth semester in two phases. The first evaluation shall be conducted towards the end of the semester. This should be followed by a second evaluation by the committee.