File Ref.No.Ac.A3/Faculty of Technology/2023

COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

(Abstract)

Faculty of Technology - Programmes offered at the Department of Electronics - Resolution of the Academic Council - Communicated - Orders issued.

ACADEMIC A SECTION

No.CUSAT/AC(A).A3/4083/2024 Dated,KOCHI-22,26.09.2024

Read:-Item No. I (f) (6) of the minutes of the meeting of the Academic Council held on 30.04.2024

ORDER

The Academic Council considered along with the recommendations of it's standing committee, the Minutes of the Faculty of Technology held on 08.04.2024 and resolved to approve the following :

i. Syllabus and course structure for new M.Tech course in VLSI and Embedded systems with effect from 2024 admissions (Appendix I).

ii. Syllabus and course structure for new M.Tech course in Microwave and Communication Engineering with effect from 2024 admissions (Appendix II).

iii. Revised syllabus for the existing M.Sc in Electronics Science with effect from 2024 admissions (Appendix III).

Orders are issued accordingly.

Dr. Arun A U *
Registrar

To:

1. The Dean, Faculty of Technology
2. Chairperson, BoS under Faculty of Technology
3. TheHead, Department of Electronics
4. All AR/DR Examination wing - with a request to forward to concerned sections
5. The Director, IQAC/ DoA
6. CIRM/Conference Sections
7. PS To VC/PVC;PA To Registrar/CE.

* This is a computer generated document. Hence no signature is required.

Master of Technology

(M.Tech.) Degree Program

VLSI and Embedded Systems

Outcome Based Syllabus

DEPARTMENT OF ELECTRONICS
COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

MASTER OF TECHNOLOGY

in

VLSI AND EMBEDDED SYSTEMS

Syllabus

(2024 Admission Onwards)

DEPARTMENT OF ELECTRONICS

COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

Kochi - 682 022, India

Contents

1 Vision, Mission, PEO and PO . . . 1

2 Course Structure . . . 3

3 **Semester 1** . . . 7

3.1 24-509-0101 : Digital System Design Using HDLs . . . 9

3.2 24-509-0102 : Digital Integrated Circuits . . . 11

3.3 24-509-0103 : Advanced Embedded System Design . . . 13

3.4 24-509-0104 : Digital System Design Using HDLs Lab . . . 15

3.5 24-509-0105 : Digital Integrated Circuits Lab . . . 17

3.6 24-509-0106 : Intelligent Embedded Systems Lab . . . 19

4 **Semester 2** . . . 21

4.1 24-509-0201 : Design Verification and Testing . . . 23

4.2 24-509-0202 : FPGA Based Embedded SoC Design . . . 25

4.3 24-509-0203 : Design Verification and Testing Lab . . . 27

5 **Semester 3** . . . 29

5.1 24-509-0301 : Project Part 1 . . . 31

5.2 24-509-0302 : NPTEL/MOOC Course . . . 33

6 **Semester 4** . . . 35

6.1 24-509-0401 : Project Part 2 . . . 37

7 **Electives** . . . 39

7.1 24-509-0X11 : VLSI Technology . . . 41

7.2 24-509-0X12 : VLSI Design Automation . . . 43

7.3 24-509-0X13 : Low Power VLSI . . . 45

7.4 24-509-0X14 : Neural Networks 47

7.5 24-509-0X15 : Analog & RF IC Design 49

7.6 24-509-0X16 : Robotics Technology 51

7.7 24-509-0X17 : Device Physics and Modeling for Integrated Circuits 53

7.8 24-509-0X18 : Advanced Computer Architectures 55

7.9 24-509-0X19 : Deep Neural Network Signal Processing 57

7.10 24-509-0X20 : Image & Video Processing 59

7.11 24-509-0X21 : Advanced Digital Signal Processing 61

7.12 24-509-0X22 : Real Time Operating Systems 63

7.13 24-509-0X23 : Image & Video Processing Lab 65

7.14 24-509-0X24 : Robotics Lab 67

7.15 24-509-0X25 : Semiconductor Device Modeling Lab 69

7.16 24-509-0X26 : Processor Architecture Lab 71

7.17 24-509-0X27 : Deep Neural Network Signal Processing Lab 73

7.18 24-509-0X28 : FPGA System Design Lab 75

7.19 24-509-0X29 : Analog IC Design Lab 77

7.20 24-509-0X30 : Neural Networks Lab 79

7.21 24-509-0X31 : Real Time Operating Systems Lab 81

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	Graduates apply their technical competence in theory, hardware, software and EDA tools to solve engineering problems in their chosen specialization
PEO2	Graduates apply their communication skill, leadership quality, research aptitude and ethics to build a strong career in their chosen areas of specialization through continuous learning
PEO3	Graduates develop capabilities for occupying prominent professional positions in academia, industry, research, and entrepreneurship

PEO-Mission Matrix:

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

Programme Outcomes: At the end of the programme, the student will be able to

PO1	Apply engineering knowledge to carry out research, and analysis of technical problems
PO2	Develop solutions and design system components or processes that meet the specified needs considering all constraints
PO3	Create, select, and apply appropriate techniques, resources, and modern engineering tools
PO4	Ability to communicate effectively by preparing and presenting technical reports
PO5	Apply professional ethics and responsibilities in engineering practice
PO6	Engage in lifelong learning independently to enhance knowledge and skills that can contribute to the continuous improvement of individuals and society

Programme Specific Outcomes: At the end of the programme, the student will be able to

PSO1	Acquire competency in design, testing, verification and prototype development focusing on applications in areas of VLSI and Embedded Systems
PSO2	Integrate subsytems to develop embedded/intelligent/integrated circuit systems to solve real life problems
PSO3	Proficiency in using off the self electronic design and automation tools to develop systems for a given application

PEO-PO/PSO Mapping:

	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
PEO1	✓	✓	✓				✓	✓	✓
PEO2				✓	✓	✓			
PEO3	✓	✓	✓	✓	✓	✓	✓	✓	✓

COURSE STRUCTURE

Semester 1

No.	Course Code	Course Title	L	T	P	Credits	C/E	CA	ES	Total
1	24-509-0101	Digital System Design using HDLs	3	2	0	3	C	50	50	100
2	24-509-0102	Digital Integrated Circuits	3	2	0	3	C	50	50	100
3	24-509-0103	Advanced Embedded System Design	3	2	0	3	C	50	50	100
4	24-509-0104	Digital System Design using HDLs Lab	0	0	4	2	C	100	0	100
5	24-509-0105	Digital Integrated Circuits Lab	0	0	4	2	C	100	0	100
6	24-509-0106	Intelligent Embedded Systems Lab	0	0	4	2	C	100	0	100
7	24-509-01XX	Program Elective	3	1	0	3	E	50	50	100
8	24-509-01XX	Program Elective	3	1	0	3	E	50	50	100
		Interdepartmental Elective*				3	E	50	50	100
		Total				21				

Semester 2

No.	Course Code	Course Title	L	T	P	Credits	C/E	CA	ES	Total
1	24-509-0201	Design Verification and Testing	3	2	0	3	C	50	50	100
2	24-509-0202	FPGA Based Embedded SoC Design	3	2	0	3	C	50	50	100
3	24-509-0203	Design Verification and Testing Lab	0	0	4	2	C	50	50	100
4	24-509-02XX	Program Elective	3	1	0	3	E	50	50	100
5	24-509-02XX	Program Elective	3	1	0	3	E	50	50	100
6	24-509-02XX	Program Elective	3	1	0	3	E	50	50	100
		Interdepartmental Elective*				3	E	50	50	100
7	24-509-02XX	Program Elective Lab	0	0	4	2	E	100	0	100
		Total				19				

* At least one interdepartmental elective is mandatory. Need to compulsorily register for the same before third semester. This can be opted instead of a program elective in either first or second semester.

Semester 3

No.	Course Code	Course Title	L	T	P	Credits	C/E	CA	ES	Total
1	24-509-0301	Project : Part 1	0	0	28	14	C	100	100	200
2	24-509-0302	Elective-MOOC/NPTEL Course#				2	E	0	100	100
		Total				16				

At least one MOOC/NPTEL course is mandatory. Need to compulsorily register for the same before registering for fourth semester exam.

Semester 4

No.	Course Code	Course Title	L	T	P	Credits	C/E	CA	ES	Total
1	24-509-0401	Project : Part 2	0	0	32	16	C	100	100	200
		Total				16				

Electives

No.	Course Code	Course Title	L	T	P	Credits	C/E	CA	ES	Total
1	24-509-0X11	VLSI Technology	3	1	0	3	E	50	50	100
2	24-509-0X12	VLSI Design Automation	3	1	0	3	E	50	50	100
3	24-509-0X13	Low Power VLSI	3	1	0	3	E	50	50	100
4	24-509-0X14	Neural Networks	3	1	0	3	E	50	50	100
5	24-509-0X15	Analog & RF IC Design	3	1	0	3	E	50	50	100
6	24-509-0X16	Robotics Technology	3	1	0	3	E	50	50	100
7	24-509-0X17	Device Physics and Modeling for Integrated Circuits	3	1	0	3	E	50	50	100
8	24-509-0X18	Advanced Computer Architectures	3	1	0	3	E	50	50	100
9	24-509-0X19	Deep Neural Network Signal Processing	3	1	0	3	E	50	50	100
10	24-509-0X20	Image & Video Processing	3	1	0	3	E	50	50	100
11	24-509-0X21	Advanced Digital Signal Processing	3	1	0	3	E	50	50	100
12	24-509-0X22	Real Time Operating Systems	0	0	4	2	E	50	50	100
13	24-509-0X23	Image & Video Processing Lab	0	0	4	2	E	100	0	100
14	24-509-0X24	Robotics Lab	0	0	4	2	E	100	0	100
15	24-509-0X25	Semiconductor Device Modeling Lab	0	0	4	2	E	100	0	100
16	24-509-0X26	Processor Architecture Lab	0	0	4	2	E	100	0	100
17	24-509-0X27	Deep Neural Network Signal Processing Lab	0	0	4	2	E	100	0	100
18	24-509-0X28	FPGA System Design Lab	0	0	4	2	E	100	0	100

19	24-509-0X29	Analog IC Design Lab	0	0	4	2	E	100	0	100
20	24-509-0X30	Neural Networks Lab	0	0	4	2	E	100	0	100
21	24-509-0X31	Real Time Operating Systems Lab	0	0	4	2	E	100	0	100

MASTER OF TECHNOLOGY

in

VLSI & EMBEDDED SYSTEMS

Semester 1

DEPARTMENT OF ELECTRONICS

COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

Kochi - 682 022, India

24-509-0101 **Digital System Design Using HDLs**

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

Prerequisites : Digital design

Course Description : This course trains the students to design digital system using HDLs and provides an overview of building a processor using basic components.

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

CO1	Design combinational and sequential circuits	Apply
CO2	Design basic combinational/sequential building blocks of a digital system using Verilog/Bluespec HDLs	Apply
CO3	Compare different implementations in terms of timing and hardware resources	Analyze
CO4	Understand RISC processor pipeline and design a simple processor that support a subset of instruction	Apply

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	2	2					3	2	
CO2	3	3	3	2			3	3	3
CO3	3	3	3				3	3	3
CO4	3	3					3	3	3

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Review of Digital Design:** Combinational Logic - Karnaugh Maps, Sequential Circuits- Flip Flops and Latches, Mealy and Moore Circuits, State Reduction, Sequential Circuit Timing
Module 2	**Verilog HDL:** 4-Valued Logic System, Compilation, Simulations and Synthesis, Basic Constructs- Modules, Variables, Data types and Operators, Delays, Constants, Assignments, Initial and Always block, Blocking and Nonblocking Assignments, Statements – if, case, and casez, Constants arrays and loops, Structural model and Behavioral models, Testbench
Module 3	**Digital Building Blocks:** decoder, multiplexers, code converters, counters, shift registers, FSMs, Arithmetic Circuits -adders, multipliers, dividers, Number Systems (fixed and floating point), Sequential Building Blocks, Memory Arrays, Logic Arrays

Module 4	**Bluespec Verilog (BSV) HDL:** BSV's advantages over Verilog, Basic Syntax, Combinational Structures: Types and Type-checking, Parameterized Description, Sequential Design: Registers, Methods and method types, Rules and atomicity, Guarded interfaces, Iterative circuits: spatial and temporal unfolding, BSV to RTL: Interface, Registers, Ready-Enable interface protocol; Linearizability and Serializability, Concurrent execution of rules, rule scheduler
Module 5	**Processor Design:** MIPS ISA, Microarchitecture - Performance Analysis, Pipelined Processor- Data path, Control Path, HDL Representation-Instruction Encoding, Implementation of MIPS Subset

References:

[1] Charles H. Roth Jr., Lizy Kurian John, and Beyeong Kil Lee, *Digital Systems Design Using Verilog*. CL Engineering, 2015.

[2] David Money Harris and Sarah L Harris, *Digital Design and Computer Architecture*. Elsevier, 2019.

[3] Charles H. Roth Jr, *Fundamentals of Logic Design*. CL Engineering, 2013.

[4] Arvind, Rishiyur S. Nikhil, James C. Hoe, and Silvina Hanono Wachman, "Introduction to digital design as cooperating sequential machines."

[5] Bluespec Reference Guide, "https://web.ece.ucsb.edu/its/bluespec/doc/BSV/reference-guide.pdf."

[6] Rishiyur S. Nikhil and Kathy R. Czeck, *BSV by Example: The next-generation language for Electronic System Design,*. Bluespec, 2010.

[7] Stuart Sutherland, Simon Davidmann, and Peter Flake, *SystemVerilog for Design: A Guide to Using SystemVerilog for Hardware Design and Modeling*. Springer, 2006.

[8] John F. Wakerley, *Digital Design Principles and Practice*. Pearson Education, 2018.

[9] Samir Palnitkar, *Verilog HDL*. Pearson Education, 2004.

[10] J. Bhasker, *A Verilog HDL Primer*. Star Galaxy Publishing, 2005.

24-509-0102 **Digital Integrated Circuits**

L	T	P	C
3	2	0	3

Prerequisites : MOSFET basics, digital design

Course Description : This course introduces students to the analysis and design of digital integrated circuits along with the trade-offs involved in the design of combinational and sequential circuits.

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

CO1	Apply MOSFET characteristic equations to understand the design trade-offs in static CMOS inverters	Apply
CO2	Implement a combinational logic circuit for a given functionality with specific speed, area and power requirements	Apply
CO3	Analyze functionality, area, performance and power dissipation of combinational and sequential circuits	Analyze
CO4	Illustrate the use of combinational and sequential circuit design principles for building efficient arithmetic circuits	Apply
CO5	Summarize the different implementation strategies for digital circuits and the impact of interconnects on these circuits	Understand

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	2					3		
CO2	3	3					3		
CO3	3	3					3	2	
CO4	3	3					3	2	
CO5	3						3		

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Introduction:** Issues in digital integrated circuit design, quality metrics, manufacturing process, static & dynamic behavior of MOSFETs, interconnects **Static CMOS Inverter:** CMOS inverter, static & dynamic behavior, robustness, performance, sizing, power dissipation
Module 2	**Combinational Logic:** Complementary CMOS, delay estimation, logical effort, sizing, delay optimization, ratioed logic, pass-transistor logic, dynamic logic

Module 3	**Sequential Logic:** Timing metrics, static latches & registers, dynamic latches & registers, delay constraints & violations, time borrowing, synchronous design, pipelining **Memory:** Classification, architecture, static and dynamic RAMs, non-volatile read-write RAMs, peripheral circuitry, power dissipation
Module 4	**Adders:** Definition, full adder circuit, inverting adder, carry save adder, carry select adder, carry look ahead adder **Multipliers:** Definition, Booth and modified Booth encoding, array multiplier, carry save multiplier, signed multiplication, carry save implementation, final addition
Module 5	**Design flow:** Custom design, semicustom design, array based design. **Interconnects**: Capacitive parasitics, resistive parasitics, inductive parasitics

References:

[1] Jan M. Rabaey, Anantha P. Chandrakasan, and Borivoje Nikolić, *Digital Integrated Circuits: A Design Perspective*, 2nd ed. Pearson Education, 2003.

[2] Neil H.E. Weste and David Harris, *CMOS VLSI Design: A Circuits and Systems Perspective*, 4th ed. Addison Wesley, 2015.

[3] David A. Hodges, Horace G. Jackson, and Resve A. Saleh, *Analysis and Design of Digital Integrated Circuits: In Deep Submicron Technology*, Sp. Indian 3 ed. McGraw Hill, 2005.

[4] Ivan Sutherland, Robert F. Sproull, and David Harris, *Logical Effort: Designing Fast CMOS Circuits.* Elsevier Science, 1999.

[5] Sung-Mo Kang and Yusuf Leblebici, *CMOS Digital Integrated Circuits: Analysis and Design*, 4th ed. McGraw-Hill, 2003.

24-509-0103 **Advanced Embedded System Design**

L	T	P	C
3	1	0	3

Prerequisites : Digital design

Course Description : This course introduces the architecture of embedded system using commercially available microcontrollers and platforms.

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

CO1	Summarize the general architecture of an embedded system	Understand
CO2	Illustrate the architecture of ARM processors	Understand
CO3	Design an embedded system for a given application by interfacing suitable peripherals	Apply
CO4	Describe the architecture of GPU that can be used for building smart systems	Apply

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	2							2
CO2	3			2					2
CO3	3	3						3	2
CO4	3	2		2				2	2

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Introduction:** Overview of general embedded systems - General architecture, Sensors and Actuators, characteristics, Real Life examples : Robotics, Automotive Electronics, Biomedical Applications, Embedded Programming - IDE, Compiler/Assembler, Simulator/Emulator
Module 2	**Processing Element:** Microprocessor, Micro-controller, System on chip (SoC), Digital Signal Processors (DSP), Application Specific IC (ASIC), Field Programmable Gate Arrays (FPGA). Basic concepts of Embedded system design using these elements - Typical architecture of a microcontroller unit by taking ARM Cortex
Module 3	**Overview of Cortex:** Register architecture, Instruction set, GPIO, timer/counter, watch dog timer, Stack, Interrupts, DMA and other peripherals, Debug support, Programming and Design examples of embedded system using ARM Cortex based processors
Module 4	**Smart Embedded Systems :** IoT, Edge Computing, Cyber Physical systems, Example controller - Graphics Processing Unit (GPU)- Programming GPU, Scheduling SIMD threads, NVIDIA GPU architecture, Memory structure

Module 5	**Interfacing Buses and Protocols:** Advanced Microcontroller Bus Architecture (AMBA), Inter-Integrated Circuit (I2C), Serial Peripheral Interphase (SPI), UART, Universal Synchronous Bus (USB), Control Area Network (CAN). Ethernet/WLAN/ Bluetooth/Zigbee. Development Boards - Arduino, LPC1768 ARM Cortex M3, Gelileo, Raspberry, NVDIA Jetson board

References:

[1] Lyla. B. Das, *Embedded Systems, An Integrated Approach.* Pearson Ed, 2013.

[2] John L. Hennessy and David A. Patterson, *Computer Architecture - A Quantitative Approach.* Morgan Kaufmann, 2017.

[3] Jonathan W. Valvano, *RTOS for ARM Cortex-M Microcontrollers.* Createspace Independent Pub, 2017.

[4] Documentation on ARM Cortex processors and develoment boards by ARM.

24-509-0104 Digital System Design Using HDLs Lab

L	T	P	C
0	0	4	2

Prerequisites : Digital design

Lab Description : The lab focuses on design of digital system using HDLs like Verilog and Bluespec. Use front end tools for RTL design and simulations.

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

CO1	Develop basic testbench, simulate and debug Verilog/Bluespec designs using RTL simulation tools	Analyze
CO2	Design combinational and sequential using Verilog/Bluespec HDL	Apply
CO3	Design basic bulding blocks of a processor to realize a simple RISC processor using HDLs	Analyze

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3	3	3	3	3	3	2	3
CO2	3	2	3	3	3	3	3	2	3
CO3	3	3	3	3	3	3	3	3	3

3-High; 2-Medium; 1-Low

Course Content:

Sample List of Experiments*	
1	Design and simulate : full adder, multiplexer, priority encoder, code convertors, flipflops etc.
2	Design 4-bit adder/code converter using structural, data flow and behavioural models
3	Design of sequential circuits like: counter, shift registers, FIFO, pattern detection etc.
4	Implement 8 bit array multiplier and serial multiplier and compare area, power and delay
5	Design and simulate basic building blocks of processor like register file, ALU, decode unit etc.
6	Design of a simple RISC processor pipeline using the basic building blocks and debug the design using simulations

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

References:

[1] Charles H. Roth Jr., Lizy Kurian John, and Beyeong Kil Lee, *Digital Systems Design Using Verilog.* CL Engineering, 2015.

[2] David Money Harris and Sarah L Harris, *Digital Design and Computer Architecture.* Elsevier, 2019.

[3] Documentation for Cadence, Synopsis and Siemens Front end and Back end tools.

[4] Arvind, Rishiyur S. Nikhil, James C. Hoe, and Silvina Hanono Wachman, "Introduction to digital design as cooperating sequential machines."

[5] Bluespec Reference Guide, "https://web.ece.ucsb.edu/its/bluespec/doc/BSV/reference-guide.pdf."

[6] Stuart Sutherland, Simon Davidmann, and Peter Flake, *SystemVerilog for Design: A Guide to Using SystemVerilog for Hardware Design and Modeling.* Springer, 2006.

[7] J. Bhasker, *A Verilog HDL Primer.* Star Galaxy Publishing, 2005.

24-509-0105 **Digital Integrated Circuits Lab**

L	T	P	C
0	0	4	2

Prerequisites : Taken with Digital Integrated Circuit Design

Lab Description : This lab introduces the use of front-end and back-end tools for standard cell based designs.

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

CO1	Characterize speed, energy consumption, and robustness of combinational, sequential, and memory circuits using circuit simulation tools	Analyze
CO2	Draw optimized layouts for standard cells	Apply
CO3	Demonstrate the use of front-end and back-end design tools to obtain optimized layout from RTL models	Apply
CO4	Evaluate different implementation strategies for arithmetic circuits	Evaluate

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3		3	2	2	2	3		3
CO2	3	3	3	2	2	2	3		3
CO3	3		3	2	2	2	3		3
CO4	3	3	3	2	2	2	3	2	3

3-High; 2-Medium; 1-Low

Course Content:

Sample List of Experiments*	
1	MOSFET circuit simualtion and parameter extraction
2	Characterization of static CMOS inverter
3	Characterization of NAND/NOR logic gates
4	Design and analysis of chain of gates
5	Characterization of D flip flops
6	Layout of NAND/NOR standard cell
7	Front end and back end design and analysis of an 8 bit adder
8	Implement 8 bit ripple carry adder and carry look ahead adder and compare area, power and delay

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

References:

[1] Jan M. Rabaey, Anantha P. Chandrakasan, and Borivoje Nikolić, *Digital Integrated Circuits: A Design Perspective*, 2nd ed. Pearson Education, 2003.

[2] Documentation for Cadence, Synopsis and Siemens Front-end and Back-end tools.

24-509-0106 **Intelligent Embedded Systems Lab**

L	T	P	C
0	0	4	2

Prerequisites	:	None
Lab Description	:	This lab provides experiments to implement embedded systems using development boards, implement intelligent algorithms using neural network and port in edge devices for real work applications.
Course Outcome	:	After the completion of the lab, the student will be able to

CO1	Familiarise embedded development board and utilise the micro-controller peripherals	Apply
CO2	Integrate sensors and actuators with microcontrollers and implement solutions for problems	Apply
CO3	Solving regression and classification problems using neural network	Apply
CO4	Use neural network for solving real world problems	Apply
CO5	Port intelligent algorithms to embedded edge device for real world problems and analyse the performance	Analyse

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1			3	3	2	2	3	2	3
CO2			3	3	2	2	3	2	3
CO3			3	3	2	2	3	2	3
CO4			3	3	2	2	3	2	3
CO5			3	3	2	2	3	2	3

3-High; 2-Medium; 1-Low

Course Content:

Sample List of Experiments*	
1	Familiarise embedded development board. Utilise the micro-controller peripherals such as Timer, Counter, Interrupts, ADC, GPIO, RTC, UART, I2C. SPI, etc.
2	Integrate sensors and actuators with microcontrollers and implement solutions for problems like temperature monitoring, LCD display, motor control, alarms, communication, etc.
3	Familiarisation of Python, Jupyter notebook and libraries like TensorFlow, Keras, PyTorch, etc for implementing neural network algorithms
4	Model neural networks for Regression tasks and Classification tasks for linear and non-linear data
5	Neural Network models for object detection, image classification, etc.

6	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. Port the neural network model into an edge embedded system for deployment and analyse the performance

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

References:

[1] Syed R. Rizvi, *Microcontroller Programming.* CRC Press, 2016.

[2] Jon Krohn, *Deep Learning with TensorFlow, Keras, and PyTorch.* Pearson, 2020.

[3] Datasheets of microcontrollers and Documentations of python libraries.

MASTER OF TECHNOLOGY

in

VLSI & EMBEDDED SYSTEMS

Semester 2

DEPARTMENT OF ELECTRONICS

COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

Kochi - 682 022, India

24-509-0201 **Design Verification and Testing**

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

Prerequisites	:	Digital design, Verilog
Course Description	:	This course deals with the design verification and testing stages of ASIC design flow. It provides an overview of the various components involved in the verification of a digital circuits. It also includes the basic testing and design for testability concepts.
Course Outcome	:	After the completion of the course, student will be able to

CO1	Summarize the components of design verification environment including coverage and assertion	Understand
CO2	Develop a self checking testbench to verify the given RTL design	Analyze
CO3	Generate test patterns for a circuit considering single-stuck-at fault model	Apply
CO4	Illustrate different design for testability techniques used for digital ICs	Understand

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3					3	3	2
CO2	3	3					3	3	2
CO3	3	3					3		2
CO4	3	3		3			3	3	2

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Introduction to Verification:** Functional verification versus Formal verification; Testbench; Verification versus Testing; Design and Verification Reuse, The Cost of Verification, Simulation, Waveform Viewers, Code Coverage, Functional Coverage, Assertions, Metrics
Module 2	**Verification Envirnment:** Verification Plan- Levels of Verification, Directed Testbenches Approach, Coverage-Driven Random-Based Approach; High-Level Modeling- Structure of High-Level Code, Race Conditions; Stimulus and Response- Reference Signals, Simple and Complex Stimulus, Bus-Functional Models, Response Monitor
Module 3	**Testbench Architecture:** Design Configuration, Self-Checking Testbenches, Directed Stimulus, Random Stimulus; Transaction-Level Model, Regression, Universal Verification Methodology (UVM)

Module 4	**Fundamentals of VLSI testing:** Fault modeling: Logical fault models, Single Stuck at Faults (SSF), Fault detection, Fault equivalence and fault dominance; Automatic test pattern generation - ATPG for SSF in combinational circuit, D-Algorithm, Sequential ATPG – Time Frame Expansion
Module 5	**Design for testability:** Controllability and Observability, Ad Hoc Design for testability, Generic scan based design, Test interface and boundary scan, Built-in-self- test (BIST)- BIST Architecture, Memory Test-MBIST

References:

[1] Janick Bergeron, *Writing Testbenches using System Verilog.* Springer, 2006.

[2] Charles H. Roth Jr., Lizy Kurian John, and Beyeong Kil Lee, *Digital Systems Design Using Verilog.* C L Engineering, 2015.

[3] Michael L. Bushnell and Vishwani D. Agrawal, *Essentials of Electronic Testing for Digital Memory and Mixed Signal VLSI Circuits.* Springer, 2005.

[4] Miron Abramovici, Melvin A. Breuer, and Arthur D. Friedman, *Digital System Testing and Testable Design.* IEEE Press, 1994.

[5] Chris Spear and Greg Tumbush, *System Verilog for Verification.* Springer, 2012.

[6] Stuart Sutherland, Simon Davidmann, and Peter Flake, *SystemVerilog for Design: A Guide to Using SystemVerilog for Hardware Design and Modeling.* Springer, 2006.

24-509-0202	**FPGA Based Embedded SoC Design**	

L	T	P	C
3	2	0	3

Prerequisites	:	Digital design basics
Course Description	:	This course presents basic FPGA architectures and FPGA SoC architectures. Implementation of embedded systems on FPGA SoCs is also covered.
Course Outcome	:	After the completion of the course, student will be able to

CO1	Summarize architectural features of various types of FPGAs	Understand
CO2	Model hardware blocks for optimized implementation on FPGAs	Apply
CO3	Explain different blocks in FPGA SoCs	Understand
CO4	Illustrate the concepts involved in system design on FPGAs	Apply
CO5	Discuss the different steps in SoC Design	Understand

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3						3		
CO2	3	3					3		
CO3	3						3		
CO4	3	3					3	2	
CO5	3		2				3		2

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**FPGA Overview:** Introduction, requirements & specification, hierarchical design, design abstraction **FPGA Architecture:** SRAM based FPGAs, permanently programmable FPGAs, I/O, circuit design & architecture of FPGA fabrics, carry chains and cascade chains, design flow, Case study: Xilinx 7-series architecture
Module 2	**Hardware Design & Optimization:** Modeling combinational logic using HDLs, combinational network delay, power and energy optimization, logic implementation, physical design, sequential design styles, clocking rules, architecting for speed, area and power, Case study - AES
Module 3	**FPGA SoCs:** Buses - AMBA & AXI, platform FPGA architectures, high speed transceivers, clocks, embedded memories & arithmetic blocks, creating IP blocks, soft core & hard core processors, Case Study: Xilinx Zync 7000 SOC **Clocks & Resets:** Crossing clock domains, gated clocks, asynchronous vs synchronous resets, Case study - I2S

Module 4	**System Design:** Principles, control flow graphs, hardware design, software design, debugging, Partitioning - analytical solution, communication, practical issues, Parallelism - principles, identifying parallelism, spatial parallelism, Bandwidth - techniques, scalable designs, on-chip and off-chip memory access
Module 5	**SoC Design:** SoC Overview, taxonomy of ICs, design abstraction, design flow, behavioral synthesis, scheduling, binding, resource sharing, on-chip communication architecture, modeling & co-simulation, hw/sw partitioning & co-synthesis, Case study - example using Xilinx Vivado HLS

References:

[1] Wayne Wolf, *FPGA Based System Design.* Prentice Hall PTR, 2004.

[2] Steve Kilts, *Advanced FPGA Design Architecture, Implementation, and Optimization.* Wiley-IEEE Press, 2007.

[3] Ron Sass and Andrew G. Schmidt, *Embedded Systems Design with Platform FPGAs, Principles and Practices.* Elsevier, 2007.

[4] Charles H. Roth Jr., Lizy Kurian John, and Beyeong Kil Lee, *Digital Systems Design Using Verilog.* Elsevier, 2007.

[5] Xilinx FPGA user guides and documentation.

24-509-0203	**Design Verification and Testing Lab**

L	T	P	C
0	0	4	2

Prerequisites	:	Digital design, Verilog
Lab Description	:	The lab will provide hands-on experience on implementing a test-bench to verifying a given digital design. This will also include exposure to testing tool for scan insertion and ATPG.
Course Outcome	:	After the completion of the lab, the student will be able to

CO1	Develop a test plan for a given specification	Analyze
CO2	Design functional verification environment for a Verilog RTL that can achieve the target coverage	Evaluate
CO3	Perform gate level timing simulation of netlist post and pre-layout	Apply
CO4	Stitch scan and generated test pattern for desired coverage using tools	Apply

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3	3	3	3	3	3	3	
CO2	3	3	3	3	3	3	3	3	3
CO3	3	3	3	3	3	3	3	3	3
CO4	3	3	3	3	3	3	3	3	3

3-High; 2-Medium; 1-Low

Course Content:

Sample List of Experiments*	
1	Familiarise the components of functional verification environment using simple components like full adder, multiplexer etc.
2	Functional verification of 4-bit adder with code/functional coverage
3	Functional verification of 8-bit counter with code/functional coverage
4	Functional verification of a simple RISC processor with code/functional coverage
5	Generate a gate level netlist of the given RTL and complete the physical design flow to extract timing parameters
6	Insert scan in the given netlist and generate test pattern to get 100% coverage
7	Gate level simulation post and pre-scan insertion

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

References:

[1] Janick Bergeron, *Writing Testbenches using System Verilog.* Springer, 2006.

[2] Charles H. Roth Jr. , Lizy Kurian John, and Beyeong Kil Lee, *Digital Systems Design Using Verilog.* C L Engineering, 2015.

[3] David Money Harris and Sarah L. Harris, *Digital Design and Computer Architecture.* Elsevier, 2019.

[4] Michael L. Bushnell and Vishwani D. Agrawal, *Essentials of Electronic Testing for Digital Memory and Mixed Signal VLSI Circuits.* Springer, 2005.

[5] Chris Spear and Greg Tumbush, *System Verilog for Verification.* Springer, 2012.

[6] Ray Salemi, *Python for RTL Verification: A complete course in Python, cocotb, and pyuvm.* Amazon Digital Services LLC, 2022.

[7] Documentation for Cadence, Synopsis and Siemens Front end and Back end tools.

MASTER OF TECHNOLOGY

in

VLSI & EMBEDDED SYSTEMS

Semester 3

DEPARTMENT OF ELECTRONICS

COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

Kochi - 682 022, India

24-509-0301	PROJECT : PART 1

L	T	P	C
0	0	28	14

Prerequisites : None
Course Description : This is the first part of the final project.
Course Outcome : After the completion of the course, the student will be able to

CO1	Identify unresolved problems and challenges in the selected domain through literature survey	Analyze
CO2	Determine appropriate tools and procedures for design, development & verification	Evaluate
CO3	Develop practical solutions for the chosen problem for a given specification	Create
CO4	Develop the ability to write good technical report, to make oral presentation of the work, and to publish the work in reputed conferences/journals	Create

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3			3	3	3	3		
CO2	3	3	3	2	2	3	3		3
CO3	3	3	3	2	2	3	3	3	3
CO4				3	3	3			

3-High; 2-Medium; 1-Low

Course Content:

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 VLSI & Embedded Systems under the supervision of a faculty from the Dept. of Electronics or in R and D institutes/ Industry. The specific project topic undertaken will reflect the common interests and expertise of the student(s) and supervisor. Students doing their project outside the department will be assigned an internal supervisor.

Students will be required to

- perform a literature search to review current knowledge and developments in the chosen technical area
- 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 project supervisor/internal supervisor shall do monthly evaluation of the progress. M. Tech project evaluation committee for the course shall evaluate the project work during the third semester in two stages. 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.

24-509-0302 **NPTEL/MOOC Course**

L	T	P	C
2	0	0	2

Prerequisites	:	None
Course Description	:	This course has to be completed through MOOC mode using NPTEL/SWAYAM or other university approved MOOC platforms.
Course Outcome	:	After the completion of the course, the student will be able to

CO1	Demonstrate the ability for independent learning	Apply
CO2	Follow ethical practices for timely submissions	Apply

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3			3	3	3	3		
CO2				3	3	3			

3-High; 2-Medium; 1-Low

Course Content:

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 2. The selection of the course will be dependent on their specialisation and should be approved by the committee constituted for the same. The modality of the course will be as per the university guidelines on MOOC courses.

MASTER OF TECHNOLOGY

in

VLSI & EMBEDDED SYSTEMS

Semester 4

DEPARTMENT OF ELECTRONICS

COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

Kochi - 682 022, India

24-509-0401 **PROJECT : PART 2**

L	T	P	C
0	0	32	16

Prerequisites : Successful completion of 20-509-0301 Project: Part 1
Course Description : This is the second and final part of the final project.
Course Outcome : After the completion of the course, the student will be able to

CO1	Identify unresolved problems and challenges in the selected domain through literature survey	Analyze
CO2	Determine appropriate tools and procedures for design, development & verification	Evaluate
CO3	Develop practical solutions for the chosen problem for a given specification	Create
CO4	Develop the ability to write good technical report, to make oral presentation of the work, and to publish the work in reputed conferences/journals	Create

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3			3	3	3	3		
CO2	3	3	3	2	2	3	3		3
CO3	3	3	3	2	2	3	3	3	3
CO4				3	3	3			

3-High; 2-Medium; 1-Low

Course Content:

Project: Part 2 is a continuation of Project: Part 1 in 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 project supervisor/internal supervisor shall do monthly evaluation of the progress. 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 middle of the semester. This shall be followed by the end semester evaluation by the committee.

MASTER OF TECHNOLOGY

in

VLSI & EMBEDDED SYSTEMS

Electives

DEPARTMENT OF ELECTRONICS

COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

Kochi - 682 022, India

24-509-0X11 **VLSI Technology**

L	T	P	C
3	1	0	3

Prerequisites	:	None
Course Description	:	This course impart an in-depth knowledge of the wafer preparation methods, details of VLSI processing steps and isolation techniques used in VLSI fabrication.
Course Outcome	:	After the completion of the course, student will be able to

CO1	Understand the wafer preparation methods and the concept of clean room	Understand
CO2	Analyse the deposition, epitaxy, and oxidation methods	Analyze
CO3	Understand etching and diffusion mechanisms in semiconductors	Understand
CO4	Understand ion implantation and isolation techniques used in VLSI fabrication	Understand
CO5	Analyse integration processes and packaging technologies	Analyze

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3					2		
CO2	3	3	3	3			3		
CO3	3	3		3			3	3	
CO4	3	3		3			2	2	
CO5	3	3					3		

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Semiconductor Crystal Growth and Wafer Engineering:** Historical perspective, semiconductor manufacturing, processing overview, Crystal growth- Electronic grade silicon, Czochralski growth, Bridgman growth, Float zone growth, Si wafer characterization and properties of Silicon wafers, clean rooms, gettering and wafer cleaning
Module 2	**Deposition:** Deposition- Thin films deposition, evaporation, E-beam and resistive heating evaporation, Sputtering, PLD and chemical vapor deposition **Epitaxy and Oxidation:** Molecular beam epitaxy, vapor phase epitaxy, liquid phase epitaxy, ALD, evaluation of epitaxial layers. silicon oxidation- Thermal oxidation process, kinetics of growth, Deal-Grove model, properties of Silicon dioxide, oxide quality, high K and low K dielectrics

Module 3	**Lithography and Diffusion:** Lithography - photo-reactive materials, pattern generation and mask making, pattern transfer, photolithography, electron beam, Ion beam and X-ray lithography- Etching- Wet and dry etching, reactive ion etching, plasma and ion beam techniques.Diffusion-Diffusion process, modeling of diffusion, diffusion in a concentration gradient, impurity behaviour, diffusion systems, problems in diffusion, evaluation of diffused layers
Module 4	**Ion Implantation:** Types Ion Implantation, modeling of Ion implantation, penetration range, Ion implantation systems, process considerations, implantation damage and rapid thermal annealing Device Isolation - Junction and oxide isolation, LOCOS, shallow trench isolation, contacts and Metallization-Schottky contacts, ohmic contacts, planarization techniques
Module 5	**Integration of processes for bipolar :** N well, P-well and Twin tub CMOS, BiCMOS fabrication processes -Defining system rules for IC layout - Packaging - Diebonding, wire-bonding, flip-chip technology - Future trends and challenges- Challenges for integration, system on chip

References:

[1] Sorab K. Ghandhi, *VLSI Fabrication principles.* John Wiley Inc, 2008.

[2] S. M. Sze, *VLSI Technology*, 4th ed. McGraw Hill Co. Inc, 2017.

[3] James D. Plummer, Michael D. Deal, and Peter B. Griffin, *Silicon VLSI Technology.* Prentice Hall Electronics, 2010.

[4] Richard C. Jaeger, *Introduction to microelectronic fabrication*, 2nd ed. Prentice Hal, 2013.

[5] C. Y. Chang and S. M. Sze, *VLSI Technology.* McGraw Hill Co. Inc., New York, 1996.

[6] Stephen A. Campbell, *The Science and Engineering of Microelectronic Fabrication*, 4th ed. Oxford University Press, 1996.

24-509-0X12	VLSI Design Automation

L	T	P	C
3	1	0	3

Prerequisites	:	None
Course Description	:	To explore the principles and techniques for automating the design and optimization of integrated circuits to enhance efficiency and productivity in the semiconductor field.
Course Outcome	:	After the completion of the course, student will be able to

CO1	Understand the basic graph algorithms, optimizations and design styles used in digital IC designs	Understand
CO2	Understand placement and partitioning algorithms	Understand
CO3	Apply the floor planning concepts to compute the optimal shape of the circuit	Apply
CO4	Interconnect the cells to the positions assigned by placement	Apply
CO5	Map the behavioral description at the algorithmic level to a structural description	Apply
CO6	Review the recents trends and developments in VLSI design automation	Understand

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3		2				2		2
CO2	3		2				3		2
CO3	3	3	2				3		2
CO4	3	3	2				3		2
CO5	3	3	2				3		2
CO6	3		2	2			3		2

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Introduction to digital IC design:** VLSI Design Cycle, Physical Design Cycle, Design Styles-Full custom, standard cell, gate array, FPGA. Design problem, design domains, Introduction to VLSI design automation tools. Graph algorithms – Depth-first search, Breadth-first search, Dijikstra's shortest path algorithm, Prim's algorithm. Combinatorial optimization problems, decision problems, NP-completeness, NP-hardness, backtracking, branch and bound, dynamic programming, inter linear programming

Module 2	**Partitioning:** Simulated annealing and evolution.Algorithms for constraint-graph compaction, standard cell placement and building block placement. Partitioning - Constructive and iterative algorithms - Kernighan-Lin algorithm - Fiduccia-Mattheyses algorithm – Goldberg-Burstein Algorithm - Multilevel partitioning, clustering
Module 3	**Floor planning and Placement:** Slicing and non-slicing floor plan - Polish expression - Constraint-based, analytical, rectangular dual graph, hierarchical tree methods - Pin assignment – General and channel pin assignment – Placement – Cost function – Simulation, partitioning and performance based placement algorithms
Module 4	**Routing:** Global routing - Maze routing, line search, Steiner tree based algorithms – Detailed routing–Constraint graphs – Channel routing - Left edge algorithm – Dog leg routing – Switch box routing – Over the cell routing – Clock network design considerations - Clock tree synthesis - Power and ground routing - Static timing analysis and timing closure
Module 5	**High Level Synthesis:** Allocation assignment and scheduling, Simple scheduling, algorithm level transformations **Current trends:** CAD for 2.5D/3D integration, CAD for Novel Semiconductor Devices based designs, Machine Learning/AI driven EDA etc.

References:

[1] Sabih H. Gerez, *Algorithms for VLSI Design Automation.* John Wiley & Sons, 2006.

[2] Naveed A. Sherwani, *Algorithms for VLSI Physical Design Automation*, 3rd ed. Springer, 2013.

[3] Andrew B. Kahng, Jens Lienig, Igor L. Markov, and Jin Hu, *VLSI Physical Design: From Graph Partitioning to Timing Closure.* Springer Netherlands, 2011.

[4] Laung-Terng Wang, Yao-Wen Chang, and Kwang-Ting (Tim) Cheng, *Electronic Design Automation: synthesis, verification, and test.* Morgan Kaufmann, 2009.

[5] Sadiq M. Sait and Habib Youssef, *VLSI Physical Design Automation: Theory and Practice.* World Scientific, 1999.

[6] Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest, and Clifford Stein, *Introduction to Algorithms*, 4th ed. The MIT Press, 2022.

[7] Recent articles from IEEE Transactions on Very Large Scale Integration (VLSI) Systems and IEEE Transactions on Computer-Aided Design of Integrated Circuits and Systems.

24-509-0X13 **Low Power VLSI**

L	T	P	C
3	1	0	3

Prerequisites	:	MOSFET basics, digital circuits
Course Description	:	This course introduces students to power reduction techniques at different levels of abstraction of digital design flow.
Course Outcome	:	After the completion of the course, student will be able to

CO1	Discuss circuit level optimizations and leakage reduction techniques	Understand
CO2	Perform gate level and RTL level optimizations for dynamic power reduction	Apply
CO3	Design the different components and IPs for power gated designs	Apply
CO4	Explain the techniques applied for frequency and voltage scaling designs	Understand
CO5	Summarize the different stages in the design flow for multi-voltage, power gated designs	Understand

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3						3		
CO2	3	2					3		
CO3	3	2					3		
CO4	3						3		
CO5	3		2				3		2

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Introduction:** Static, dynamic and leakage power dissipation, power vs. energy, limits of low power VLSI designs **Circuit level optimizations:** Transistor and gate sizing, optimal supply voltage, pin reordering, network restructuring, special latches and flip flops **Leakage Reduction Techniques:** Transistor stacks, power gating, multi-threshold CMOS, variable threshold CMOS, dynamic threshold CMOS

Module 2	**Gate Level Optimizations:** Minimizing switched capacitance, switching activity reduction, gate reorganising, signal gating, logic encoding, state machine encoding, precomputation logic, clock gating, reducing glitching through path balancing, input reordering **RTL & Block Level Optimizations:** RTL coding for low power, glitch reduction, clock gating, gated clock FSM, bus encoding, clock control, clock skew, input control
Module 3	**Designing Power Gating:** Power switching – fine grain vs. coarse grain, switching fabric design, signal isolation, state retention and restoration methods, power gating control, power networks and their control, power state tables and always on regions, case study **IP Design for Low Power:** Architecture and partitioning for power gating, power controller design example- issues, clocks and resets, verification. packaging IP for reuse with power intent, unified power format(UPF) examples
Module 4	**Frequency & Voltage Scaling:** Voltage scaling interfaces- level shifters, timing issues in multi-voltage designs, voltage scaling approaches, dynamic voltage and frequency scaling (DVFS), CPU subsystem design issues, adaptive voltage scaling (AVS), level shifters and isolation, voltage scaling interfaces - effect on synchronous timing, control of voltage scaling, examples of voltage and frequency scaling design
Module 5	**Design Flow for Multi-Voltage, Power Gated Designs:** Overview, partitioning, synthesis, multi corner multi mode optimization, design planning, power planning, clock tree synthesis, power analysis, timing analysis, low power validation, manufacturing test **Physical Libraries:** Standard cell libraries, isolation cells, level shifters, memories, power gating strategies and structures, power gating cells, power gated standard cell libraries, retention registers, memory retention methods

References:

[1] Michael Keating, David Flynn, Robert Aitken, Alan Gibbons, and Kaijian Shi, *Low Power Methodology Manual For System-on-Chip Design*, 1st ed. Springer New York, NY, 2007.

[2] Roy Kaushik and Sharat C. Prasad, *Low-power CMOS VLSI circuit design*, Wiley Student ed. John Wiley & Sons, 2009.

[3] Gary K. Yeap, *Practical low power digital VLSI design.* Springer Science & Business Media, 2012.

[4] Abdellatif Bellaouar and Mohamed Elmasry, *Low-power digital VLSI design: circuits and systems.* Springer Science & Business Media, 2012.

[5] Christian Piguet, *Low-power CMOS circuits: technology, logic design and CAD tools.* CRC Press, 2005.

[6] Jan M. Rabaey, Anantha P. Chandrakasan, and Borivoje Nikolić, *Digital Integrated Circuits: A Design Perspective*, 2nd ed. Pearson Education, 2003.

24-509-0X14 **Neural Networks**

L	T	P	C
3	1	0	3

Prerequisites : None

Course Description : This course provides a broad overview to neural networks and its optimisation algorithm, heuristics and model analysis.

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

CO1	Concept of learning, architectures and mathematical modelling of neuron	Understand
CO2	Model a linear regressor and classifier using a perceptron	Apply
CO3	Solve non-linear problems using multi-layer neural network	Apply
CO4	Analyse model performance and implement better training algorithms for neural network	Analyse
CO5	Understand RBFN networks and how to solve non-linear problems with kernel functions	Understand

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3						3		
CO2	3	2	2				3	2	2
CO3	3	2	2				3	2	2
CO4	3	2	2				3	2	2
CO5	3						3		

3-High; 2-Medium; 1-Low

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, batch perceptron algorithm. Model building through regression- linear regression model, Cost Function, learning rate, gradient descent algorithm, chain rule, optimization, Local minima, Global Minima, computer experiment: regression and pattern classification. Least-Mean-Square Algorithm

Module 3	**Multilayer Perceptron:** XOR problem, hidden layer, non-linearity, Back propagation algorithm, local error gradients, Back propagation and differentiation, Hessian matrix, optimal annealing and adaptive control of the learning rate, Approximations of function, Generalization, Cross validation, Network pruning Techniques, Optimal Brain Surgeon, Virtues and limitations of back propagation learning. computer experiment: pattern classification
Module 4	**Heuristics:** Heuristics for making the back-propagation algorithm perform better, batch learning and stochastic learning, activation functions, differentiability, symmetric, feature scaling, initialization, learning rate, momentum term, stopping criteria, Learning Curves, Early Stopping, Evaluation Measures: Training, Validation, Testing. Two class evaluation measures, Confusion Matrix
Module 5	**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*, 3rd ed. Pearson Education India, 2016.

[2] Martin T. Hagan, Howard B. Demuth, Mark H. Beale, and Orlando De Jesús, *Neural Network Design*, 2nd ed. Cengage Learning, 2014.

[3] Simon Haykin, *Neural Networks: A Comprehensive Foundation*, 2nd ed. Prentice Hall, 1999.

[4] Philip D. Wasserman, *Neural Computing: Theory and Practice.* Coriolis Group, 1989.

[5] B. Yegnanarayana, *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.

24-509-0X15 **Analog & RF IC Design**

L	T	P	C
3	1	0	3

Prerequisites	:	Circuit analysis
Course Description	:	This course introduces students to the analysis and design of basic analog integrated circuit components like amplifiers, current mirrors and biasing circuits. Specifications and trade-offs involved in analog design are covered. The course also covers various factors involved in the design of RF integrated circuit components.
Course Outcome	:	After the completion of the course, student will be able to

CO1	Perform small signal analysis using MOSFET models	Apply
CO2	Design single stage and differential amplifiers for given specification	Apply
CO3	Discuss about appropriate current sources and voltage references for biasing	Undersatnd
CO4	Understand the basic building blocks of RF ICs and the trade-offs involved in RF designs	Understand
CO5	Explain the methodologies for designing RF IC components with given specifications	Undersatnd

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3					3		
CO2	3	3					3		
CO3	3						3		
CO4	3						3		
CO5	3						3		

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Introduction:** Review of 4 terminal MOSFET, small signal model and analysis, high frequency model **RF Basic Concepts:** Non linearity and its effects, noise, sensitivity & dynamic range, passive impedance transformation, scattering parameters, bandwidth estimation techniques
Module 2	**Single Stage Amplifiers:** Single stage amplifiers - common source, source follower, common gate, cascode amplifiers, frequency response, noise

Module 3	**Differential Amplifiers:** Basic differential pair, common mode response, frequency response, noise, MOS transistor mismatch, effect of transistor mismatch **Current Mirrors & Biasing:** Basic and cascode current mirrors, effect of transistor mismatch, biasing techniques, self biasing circuits, supply independent bias circuits, bandgap reference
Module 4	**Low Noise Amplifiers:** Input matching, LNA topologies, gain and band switching, non linearity calculations, power constrained design optimizations, design examples **Mixers:** Mixer fundamentals, mixing using non linear systems, multiplier based mixers
Module 5	**Oscillators:** Ring oscillators, LC oscillators, inductors and capacitors, voltage controlled oscillators **Phase Locked Loops**: Simple PLL, Type II PLL, Non-idealities, phase noise

References:

[1] Behzad Razavi, *Design of Analog CMOS Integrated Circuit*, 2nd ed. McGraw Hill India, 2017.

[2] Thomas H. Lee, *The Design of CMOS Radio-Frequency Integrated Circuits*, 2nd ed. Cambridge University Press, 2014.

[3] Behzad Razavi, *RF Microelectronics*, 2nd ed. Prentice Hall, 2012.

[4] Phillip E. Allen and Douglas R. Holberg, *CMOS Analog Circuit Design*, 3rd ed. Oxford University Press, 2013.

[5] Jacob Baker R., *CMOS Circuit Design, Layout and Simulation*, 3rd ed. Wiley-Blackwell, 2010.

24-509-0X16	**Robotics Technology**

L	T	P	C
3	**1**	**0**	**3**

Prerequisites	:	None
Course Description	:	This course provides an overview of Robot mechanisms for the design and control of robotic systems.
Course Outcome	:	After the completion of the course, student will be able to

CO1	Apply the mathematics of spatial descriptions and transformations and determine the kinematic equation of the manipulator	Apply
CO2	Illustrate the concept of singularity by calculating the Jacobian of a manipulator and Derive kinetic and potential energy in a robot manipulator	Apply
CO3	Discuss about the basics of locomotion, kinematics, dynamics and motion control of mobile robots	Understand
CO4	Determine appropriate localization strategies for mobile robots based on the perception capabilities	Apply
CO5	Learn different motion planning, navigation schemes and the latest developments in mobile robotics	Understand

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3					2		
CO2	3	3	3	3			3		
CO3	3	3		3			3	3	
CO4	3	3		3			2	2	
CO5	3	3					3		

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Introduction to robotics, transformations, and Kinematics:** Brief history, types and applications of robots, robot configurations and concept of workspace, types of actuators and sensors in robotics, types of grippers. Basics of kinematics, coordinate frames and transformations, homogenous transformations, kinematics parameters, D-H representation, Arm equation, Inverse Kinematics
Module 2	**Serial robotic manipulator dynamics:** Velocity propagation from link to link, Jacobian, singularities; static forces in manipulators; Jacobians in force domain, Newton-Euler dynamic formulation; Lagrange-Euler formulation, dynamic equations for multiple degrees of freedom robot

Module 3	**Introduction to Mobile robots:** Key issues for locomotion, Legged Mobile Robots, Wheeled Mobile Robots **Kinematics, Dynamics and Motion Control of mobile robots:** Kinematic Models and Constraints of wheeled mobile robot, Forward kinematic models, Wheel kinematic constraints, Robot kinematic constraints, Mobile Robot Maneuverability, Mobile Robot Workspace, Mobile Robot Workspace, Dynamics and motion controlling methods
Module 4	**Perception:**Proprioceptive/Exteroceptive and passive/active sensors, Performance measures of sensors, Wheel/motor sensors, Representing uncertainty, Error propagation: combining uncertain measurements, Feature extraction **Localization:** Introduction - Challenges, Odometric position estimation, Belief representation, Map representation, map based localization, Probabilistic rap-based Localization, Markov localization, Autonomous map building, SLAM
Module 5	**Motion Planning and Navigation:** Path planning, graph search methods, potential field planning, path planning algorithms based on Breadth-first, Depth-first, Dijkstra, A-star, rapidly exploring random trees, Obstacle avoidance **Introduction to modern mobile robots:** Swarm robots, cooperative and collaborative robots, mobile manipulators, autonomous mobile robots

References:

[1] King-Sun Fu, C.S.George Lee, and Ralph Gonzalez, *Robotics: Control, Sensing, Vision and Intelligence.* McGraw-Hill, 1987.

[2] Mark W. Spong and M. Vidyasagar, *Robot Dynamics and Control.* Wiley, 2008.

[3] Roland Siegwart, Illah Reza Nourbakhsh, and Davide Scaramuzza, *Introduction to Autonomous Mobile Robots.* MIT Press, USA, 2011.

[4] H. R. Everett, *Sensors for Mobile Robots – Theory and Applications.* A. K. Peters Ltd., 1995.

[5] Thomas R. Kurfees, *Robotics and Automation Handbook.* CRC Press, 2004.

[6] Johann Borenstein, *Where am I? Sensors and Methods for Mobile Robot Positioning.* The University of Michigan, 1996.

24-509-0X17 Device Physics and Modeling for Integrated Circuits

L	T	P	C
3	1	0	3

Prerequisites	:	None
Course Description	:	This course reviews and strengthens the understanding of device physics studied at undergraduate level and provides indepth discussions on short channel MOSFETs and advanced MOS devices. The course also covers circuit level modeling of MOS devices.
Course Outcome	:	After the completion of the course, student will be able to

CO1	Apply fundamental physics to model PN junctions and metal semiconductor junctions	Apply
CO2	Model the characteristics of MOS devices	Apply
CO3	Employ appropriate models to analyze and characterize MOSFET circuits	Apply
CO4	Explain the physics behind advanced FETs	Understand

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3	2				3		2
CO2	3	3	2				3		2
CO3	3	3	2				3		2
CO4	3						3		

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Semiconductor fundamentals:** Band model for solids, carrier concentrations, transport, generation-recombination, excess carriers **P-N junctions:** potential barrier, quasi-neutrality, reverse biased junction, breakdown, static and dynamic behavior, small signal and large signal models, SPICE model, simulation exercises using TCAD
Module 2	**Metal-semiconductor junction:** Band diagram, depletion region, capacitance, Schottky barrier, I-V characteristics, Ohmic contacts, TCAD exercises **MOS Capacitor:** Basic physics and analysis, equilibrium and non-equilibrium, C-V characteristics, oxide and surface charges, TCAD exercises
Module 3	**MOS Transistors:** Long-channel MOSFET - basic physics and models, channel-length modulation, body effect, sub threshold regime, small signal model, short and narrow channel effects, radiation and hot-carrier effects, parameter extraction, Spice Models, BSIM model, TCAD exercises

Module 4	**Complementary MOS:** Design considerations, latchup, digital design quality metrics, transient response, switch model, interconnect models, Elmore delay model, sequential circuit timing parameters, MOSFET Scaling
Module 5	**Modern MOSFETs:** High-k dielectrics, metal gates, strain, silicon-on-insulator, FINFETs **Nanoscale MOSFETs**: Basic theory, ballistic transport, scattering, nanowire and carbon nanotube transistors

References:

[1] Theodore I. Kamins and Richard S. Muller, *Device Electronics for Integrated Circuits*, 3rd ed. Wiley, 2002.

[2] Yannis Tsividis and Colin McAndrew, *Operation and Modeling of the MOS Transistor*, 3rd International ed. OUP USA, 2012.

[3] Jan M. Rabaey, Anantha P. Chandrakasan, and Borivoje Nikolić, *Digital Integrated Circuits: A Design Perspective*, 2nd ed. Pearson Education, 2003.

[4] Chenming Hu, *Modern Semiconductor Devices for Integrated Circuits*, 1st ed. Prentice Hall, 2010.

[5] Mark S. Lundstrom and Jing Guo, *Nanoscale Transistors: Device Physics, Modeling and Simulation*, 1st ed. Springer US, 2006.

[6] Sung-Mo (Steve) Kang and Yusuf Leblebici, *CMOS Digital Integrated Circuits: Analysis and Design*, 2nd ed. McGraw-Hill, 2003.

[7] J. P. Colinge, *FinFETs and Other Multi-Gate Transistors.* Springer, 2008.

[8] Mark Lundstrom. (2008) Physics of Nanoscale MOSFETs. 2/3/2024. [Online]. Available: https://nanohub.org/resources/5306#series

[9] Sentaurus TCAD Documentation Synopsys Inc. 2/3/2024. [Online]. Available: https://www.synopsys.com/manufacturing/tcad/device-simulation/sentaurus-device.html

24-509-0X18 **Advanced Computer Architectures**

L	T	P	C
3	1	0	3

Prerequisites : Digital design

Course Description : This course provides an insight in the design of high-end microprocessors that support modern applications.

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

CO1	Design RISC-V processors with performance optimization and hazard avoidance techniques	Apply
CO2	Understand the various optimizations in memory and build a memory hierarchy	Apply
CO3	Compare the performance of various techniques that make use of instruction level parallelism	Analyze
CO4	Illustrate vector and graphics processor architectures that exploit data level parallelism to achieve high performance	Understand

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3					3	3	
CO2	3	3					3	3	
CO3	3	3					3	3	
CO4	3	3		2			3	3	

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Review of basics:** Von-Neumann architecture, Concept of memory and addressing. Performance measurement- IPC, CPI, benchmarks. Speed-up Law. RISC vs CISC architectures, RISC-V instruction set architecture (ISA) - classification, addressing modes, instruction set encoding, assembly language syntax and convention, RISC-V pipeline architecture - Performance, Pipeline hazards and analysis, Branch Prediction
Module 2	**Memory Hierarchy:** Locality of reference, Cache - Performance, Mapping, Identification, Cache Replacement, Write Strategy, Types of misses, Cache optimizations, Virtual memory concepts - Address Translations, Page tables, TLB, DRAM system- Organization, Memory controllers, DRAM refresh circuitry and power managements schemes, DRAM scheduling

Module 3	**RISC-V Architecture:** Interrupts and exceptions handling, Privilege levels and protection mechanisms, System calls and operating system interface, interrupt controllers and device drivers. Pipelined processor design using RISC-V ISA, performance analysis and evaluation. RISC-V Tools Ecosystem - assemblers, compilers, and linkers, simulation and debugging tools, development boards and platforms, software development and debugging. RISC-V extensions, Case study of RISC-V based processor design
Module 4	**Instruction Level Parallelism:** Compiler techniques to exploit ILP, pipeline scheduling, loop unrolling, advanced branch prediction schemes, dynamic scheduling, Tomasulo's approach, hardware base speculation, VLIW approach for multi-issue, advanced pipelining, superscalar processors and super pipelining
Module 5	**High Performance Computing:** Fine-grained multithreading, Coarse-grained multithreading, Shared-Memory Architectures- Centralized, Distributed, Coherence protocols, Models of Memory Consistency, Tiled chip Multicore processor, Data Level Parallelism - Vector architectures and GPU architecture

References:

[1] John L. Hennessy and David A. Patterson, *Computer Architecture - A Quantitative Approach*. Morgan Kaufmann, 2017.

[2] Bruce Jacob, Spencer W. Ng, and David T. Wang, *Memory System-Cache, DRAM and Disk*. Morgan Kaufman, 2007.

[3] David A. Patterson and John L. Hennessy, *Computer Organization and Design,The Hardware/Software interface: RISC-V Edition* . Morgan Kaufman, 2017.

[4] William Stallings, *Computer Organization and Architecture*. Pearson Ed, 2022.

[5] Dezso Sima, Terence Fountain, and Peter Kacsuk, *Advanced Computer Architectures-A Design Space Approach*. Pearson, 2002.

[6] “RISC-V International,” https://riscv.org/.

[7] “Shakthi Processors,” https://shakti.org.in/.

[8] “Vega Processors,” https://vegaprocessors.in/.

24-509-0X19 **Deep Neural Network Signal Processing**

L	T	P	C
3	**1**	**0**	**3**

Prerequisites	:	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, student will be able to

CO1	Model convolution network 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	Apply
CO4	Understand generative networks and adversarial learning methods	Understand
CO5	Understand the regularization of deep neural networks and strategies for better learning	Understand

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	2	2				3	2	2
CO2	3	2	2				3	2	2
CO3	3	2	2				3	2	2
CO4	3						3		
CO5	3						3		

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Convolution:** Convolution Operation, Variants of the basic convolution function, Correlation, Filters, 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:** Sequential Processing: Sequence Learning, Recurrent Neural Networks, loss function, recurrent connections, teacher forcing training, 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, Principal Component Analysis and Autoencoders, Regularization in autoencoders, Denoising and Sparse Signal processing, Denoising Autoencoders, Sparse Autoencoders, Contractive Autoencoders
Module 4	**Generation:** Generative Modeling, Principle of Generative Modeling, PixelRNN and PixelCNN, Variational Autoencoder, latent vector, reparameterisation trick, reconstruction and KL divergence loss, Generative Adversarial Network, Conditional Probability, Generator, Discriminator, Minimax objective function, gradient ascent, gradient descent
Module 5	**Strategies for Training and Regularisation:** Universal function approxination, Stochastic Gradient Descent, Momentum Based GD, Nesterov Accelerated 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] Heikki Huttunen, *Deep Neural Networks: A Signal Processing Perspective*, 3rd ed. Springer, 2019, pp. 133–163.

[2] Yu Hen Hu and Jenq-Neng Hwang, *Handbook Of Neural Network Signal Processing.* The Electrical Engineering And Applied Signal Processing Series, CRC Press, 2002.

[3] Christopher M. Bishop, *Pattern Recognition and Machine Learning.* Springer - Information Science and Statistics, 2011.

[4] Ian Goodfellow, Aaron Courville, and Yoshua Bengio, *Deep learning.* MIT press, 2016.

[5] Christopher M. Bishop, *Neural Networks for Pattern Recognition.* Oxford University Press, 1996.

24-509-0X20 **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.
Course Outcome	:	After the completion of the course, the student will be able to

CO1	Use basic image processing algorithms in practical applications	Apply
CO2	Select a suitable transform for the analysis of images	Analyze
CO3	Model image restoration/degradation	Apply
CO4	Apply image representation schemes for various applications	Apply
CO5	Demonstrate various video modeling techniques	Apply

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	2	3	2			2	3	
CO2	3	2	3	2				3	2
CO3	3	3	3					3	2
CO4	3	2	2					3	2
CO5	3	2	2				2	3	

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Fundamentals of Image Processing:** 2D systems & mathematical preliminaries - Linear systems and shift invariance, Fourier transform, optical and modulation transfer functions, matrix notation, Toeplitz and Circulant matrices, orthogonal and unitary matrices, block matrices and kronecker products, Types of images – black & white, gray scale and color images, basic relationship between pixels, intensity transformations and spatial filtering, filtering in frequency domain
Module 2	**Image Transforms:** Two-dimensional orthogonal and unitary transforms, separable unitary transforms, basis images, Kronecker products and dimensionality, properties of unitary transformations, dimensionality of image transforms, two dimensional DFT, cosine transform, sine transform, Hadamard transform, Haar transform, the KL transform

Module 3	**Image Restoration and Reconstruction:** A model of image degradation/restoration process, noise models, restoration in the presence of noise only using spatial filtering, periodic noise reduction using frequency domain filtering, linear position invariant degradations, estimating the degradation function, inverse function, wiener filtering, image reconstruction from projections
Module 4	**Morphology, Segmentation and Representation:** Morphological operations - dilation, erosion, opening and closing, Image segmentation - point, line and edge detection, thresholding, region growing, region splitting and merging, boundary preprocessing - chain codes, boundary approximation using minimum perimeter polygons, signatures, boundary feature descriptors - shape numbers, Fourier descriptors, statistical moments, region feature descriptors - compactness, circularity, eccentricity, topological descriptors - Euler number, texture descriptor based on histogram, graylevel co-occurrence matrix
Module 5	**Video Processing:** Video formation, perception and representation - principles of color video imaging, video cameras, video display, composite versus component video, gamma correction, analog video raster - progressive and interlaced scans, characterization of a video raster, video modeling -camera model, illumination model, object models, scene models, 2D motion models, 2D motion estimation - optical flow, pixel based motion estimation

References:

[1] Rafael C. Gonzalez and Richard E. Woods, *Digital Image Processing*, 4th ed. Pearson, 2018.

[2] Anil K. Jain, *Fundamentals of Digital Image Processing*, 1st ed. Pearson, 2015.

[3] Yao Wang, Jörn Ostermann, and Ya-Qin Zhang, *Video Processing and Communications*, 1st ed. Prentice Hall Upper Saddle River, NJ, 2002.

[4] Bhabatosh Chanda and Dwijesh Dutta Majumder, *Digital Image Processing and Analysis*, 1st ed. PHI Learning Pvt. Ltd., 2011.

[5] Subramania Jayaraman, S. Esakkirajan, and T. Veerakumar, *Digital Image Processing*, 2nd ed. Tata McGraw Hill, 2020.

[6] Alan C. Bovik, *Handbook of Image and Video Processing.* Academic press, 2010.

[7] Kenneth R. Castleman, *Digital Image Processing*, 1st ed. Pearson, 2007.

[8] Bernd Jähne, *Digital Image Processing*, 6th ed. Springer, 2005.

[9] William K. Pratt, *Digital Image Processing: PIKS Scientific Inside*, 4th ed. Wiley Online Library, 2007.

[10] Wayne Niblack, *An Introduction to Digital Image Processing.* Strandberg Publishing Company, 1985.

24-509-0X21 **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.

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

CO1	Determine the discrete Fourier transform of a signal	Apply
CO2	Select a suitable digital filter based on the application	Analyze
CO3	Illustrate multidmensional signals	Apply
CO4	Model multirate digital systems	Apply
CO5	Demonstrate DSP real world problems in hardware	Apply

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	2	2				3	2	
CO2	3	3	2					2	3
CO3	3	2	2				3	2	
CO4	3	3	2				3	2	
CO5	3	2	2					2	3

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Discrete-time Signals and Systems:** Discrete-time signals, systems, analysis of discrete-time linear time invariant system, discrete-time system described by difference equation, correlation of discrete-time signals, z-transform, analysis of linear time invariant system in z-domain, linear time invariant systems as frequency-selective filters, Discrete Fourier Transform (DFT) and its properties, implementation of discrete-time systems
Module 2	**Digital Filters:** Design of Finite Impulse Response (FIR) filters - symmetric and antisymmetric FIR filters, design of linear-phase FIR filters using windows, design of linear-phase FIR filters by the frequency-sampling method, design of FIR differenti ators, design of Hilbert transformers, design of Infinite Impulse Response (IIR) filters - design by approximation of derivatives, impulse invariant technique, bilinear transformation, frequency transformations

Module 3	**Multidimensional Signal Processing:** Two dimensional discrete signals, multidimensional systems, Linear Shift Invariant (LSI) systems, separable systems, stable systems, regions of support, vector input-output systems, frequency response of 2D LSI systems, multidimensional Fourier transform, properties od 2D Fourier transform, periodic sampling with rectangular geometry, multidimensional discrete Fourier series and transform, multidimensional z-transforms
Module 4	**Multirate Signal Processing:** Basic multirate operations - decimation and interpolation, aliasing, decimation filters and interpolation filters, fractional sampling rate alteration, digital filter banks - DFT filter banks, uniform DFT banks, time-domain descriptions of multirate filters, interconnection of building blocks, Noble identities, the polyphase representation, efficient structures for decimation and interpolation filters, polyphase implementation
Module 5	**DSP Processors:** Features of DSP processors, Von Neumann architecture vs Harvard architecture, Very Long Instruction Word (VLIW) architecture, TMS320C6x Architecture, Functional units, Linear and circular addressing modes, TMS320C6x instruction set, OMAP-L138 development system - C6748 processor, code composer studio IDE, support files, TLV320AIC3106 (AIC3106) onboard stereo codec for analog input an output, real-time input and output using polling, interrupts, and direct memory access, real time sine wave generation

References:

[1] John G. Proakis and Dimitris G. Manolakis, *Digital Signal Processing: Principles, Algorithms, and Application*, 4th ed. Pearson Education India, 2007.

[2] Rulph Chassaing, *Digital Signal Processing and Applications with the C6713 and C6416 DSK*, 1st ed. John Wiley & Sons, 2005.

[3] Donald S. Reay, *Digital Signal Processing and Applications with the OMAP-L138 eXperimenter*, 1st ed. John Wiley & Sons, 2012.

[4] Parishwad P. Vaidyanathan, *Multirate Systems and Filter Banks*, 1st ed. Pearson Education India, 2006.

[5] Dan E. Dudgeon and Russell M. Merserau, *Multidimensional Digital Signal Processing*, 1st ed. Prentice Hall, 1984.

[6] Sanjit K. Mitra, *Digital Signal Processing: A Computer-Based Approach.* McGraw-Hill Higher Education, 2001.

[7] Alan V. Oppenheim and Ronald W. Schafer, *Discrete-time Signal Processing*, 2nd ed. Prentice Hall, 1999.

[8] Chi Tsong Chen, *Digital Signal Processing: Spectral Computation and Filter Design.* Oxford University Press, Inc., 2001.

[9] Emmanuel C. Ifeachor and Barrie W. Jervis, *Digital Signal Processing: A Practical Approach.* Pearson Education, 2004.

24-509-0X22 **Real Time Operating Systems**

L	T	P	C
3	1	0	3

Prerequisites	:	Programming basics
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, 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	Identify feasible schedules using various scheduling algorithms	Analyze
CO4	Discuss resource management and deadlock avoidance techniques	Understand
CO5	Explain various commercial RTOS flavors including Free RTOS	Understand

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3					3		
CO2	3						3		
CO3	3	3					3		
CO4	3						3		
CO5	3		2				3		

3-High; 2-Medium; 1-Low

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, 20004.

[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 μC/OS, "https://www.micrium.com/rtos/kernels/."

[9] Real Time Linux, "https://wiki.linuxfoundation.org/realtime/start/."

[10] Nicolas Melot, "Study of an Operating System: FreeRTOS," *CAPÍTULO XVIII*, vol. 115, pp. 1–39, 2009.

24-509-0X23 **Image & Video Processing Lab**

L	T	P	C
0	0	4	2

Prerequisites : Signals & Systems, Image Processing

Lab Description : This lab involves implementation of basic image and video processing techniques in Octave/MATLAB/Python.

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

CO1	Use basic image processing toolbox in Octave/MATLAB/Python	Apply
CO2	Apply basic image processing operations	Apply
CO3	Select necessary 2D transform based on application	Analyze
CO4	Illustrate the importance of high frequency components in an image	Analyse
CO5	Outline the steps involved in video processing	Analyse

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1			3	3	2	2	2	2	3
CO2			3	3	2	2	2	2	3
CO3			3	3	2	2	2	2	3
CO4			3	3	2	2	2	2	3
CO5			3	3	2	2	2	2	3

3-High; 2-Medium; 1-Low

Course Content:

Sample List of Experiments*	
1	Introduction to image processing toolbox
2	Implementation of 2D convolution and 2D DFT
3	Point operations & histogram Processing
4	To perform histogram equalisation
5	Implementation of smoothing filters
6	Perform Image Sharpening & Edge Detection
7	Implement frequency domain filtering
8	Compute 2D DCT and KL transform
9	Implement image segmentation algorithms
10	Compute motion estimation of videos

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

References:

[1] Rafael C. Gonzalez and Richard E. Woods, *Digital Image Processing*, 4th ed. Pearson, 2018.

[2] Subramania Jayaraman, S. Esakkirajan, and T. Veerakumar, *Digital Image Processing*, 2nd ed. Tata McGraw Hill, 2020.

[3] Anil K. Jain, *Fundamentals of Digital Image Processing*, 1st ed. Pearson, 2015.

[4] Alasdair McAndrew, *An Introduction to Digital Image Processing with MATLAB*, 1st ed. Course Technology Press, 2004.

24-509-0X24 **Robotics Lab**

L	T	P	C
0	0	4	2

Prerequisites : None

Lab Description : This lab includes experiments using SCARA robot, Raspberry pi and Jetson Nano-supported robots, Robot Operating System(ROS) and Robotics toolbox from MATLAB.

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

CO1	Program SCARA robot to perform tasks	Understand
CO2	Integrate and use ROS packages for various robotic applications	Apply
CO3	Demonstrate the robot‘s capability for autonomous mapping and localization	Apply
CO4	Navigate the robot through a cluttered environment without colliding with obstacles	Apply
CO5	Develop an optimized and efficient path that shows the intelligent navigation capability of the robot	Analyze

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3	3	3	3	3	3		3
CO2	3	3	3	3	3	3	3	3	3
CO3	3	3	3	3	3	3	3		3
CO4	3	3	3	3	3	3	3	3	3
CO5	3	3	3	3	3	3	3	3	3

3-High; 2-Medium; 1-Low

Course Content:

Sample List of Experiments*	
1	Program the SCARA robot for transfer of objects from one position to another
2	Learn and implement various ROS packages
3	Implement SLAM algorithms to enable the robots to map an unknown environment while simultaneously localizing themselves to that environment
4	Develop an obstacle avoidance algorithm that allows the robot to navigate around obstacles in its path
5	Experiment with different path planning algorithms and find the most efficient route from one point to another

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

References:

[1] Morgan Quigley, Brian Gerkey, and William D. Smart, *Programming Robots with ROS: A Practical Introduction to the Robot Operating System.* O'Reilly Media, 2015.

[2] Lentin Joseph, *Mastering ROS for Robotics Programming.* Packt, 2015.

[3] Carol Fairchild and Thomas L. Harman, *ROS Robotics By Example.* Packt, 2017.

[4] Roland Siegwart, Illah Reza Nourbakhsh, and Davide Scaramuzza, *Introduction to Autonomous Mobile Robots.* MIT Press, USA, 2011.

[5] Mobile Robtics resources from MATLAB , "https://in.mathworks.com/solutions/robotics /resources.html."

24-509-0X25 **Semiconductor Device Modeling Lab**

L	T	P	C
0	0	4	2

Prerequisites : Taken with Device Physics And Modeling for Integrated Circuits

Lab Description : This lab prepares students to use TCAD device simulation software for semiconductor device simulation, modeling and parameter extraction.

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

CO1	Use TCAD software for device characterization, modeling and simulation	Apply
CO2	Extract PN junction and MOSFET device parameters from characteristics	Apply
CO3	Use extracted MOSFET device parameters in ciruit simualtion models	Apply

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3		3	2	2	2	3		3
CO2	3		3	2	2	2	3		3
CO3	3		3	2	2	2	3		3

3-High; 2-Medium; 1-Low

Course Content:

Sample List of Experiments*	
1	Familiarization of TCAD software
2	PN junction I-V characteristics and parameter extraction
3	Study the effect of doping concentration on device characteristics
4	Model long channel MOSFETS, vary dimensions and doping and study how channel length modulation, body effect and subthreshold conduction affect device characteristics
5	Model MOSFETs at various gate lengths, study how short and narrow channel effects impact device performance
6	Extract MOSFET parameters from device characteristics, use the parameters in circuit simulation models
7	Model FINFETs and study the characteristics

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

References:

[1] Theodore I. Kamins and Richard S. Muller, *Device Electronics for Integrated Circuits*, 3rd ed. Wiley, 2002.

[2] Sentaurus TCAD Documentation from Synopsys Inc. , "https://www.synopsys.com/manufacturing/tcad/device-simulation/sentaurus-device.html."

24-509-0X26 **Processor Architecture Lab**

L	T	P	C
0	0	4	2

Prerequisites : Taken with 24-509-0X18, basic programming

Lab Description : The lab will include design and simulation of a simple RISC-V processor core. The lab will also provide a hands-on experience on simulator for evaluating the performance of various processor configurations.

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

CO1	Design basic buiding blocks for the design of a RISC-V processor pipeline	Analyze
CO2	Design RISC-V processors with performance optimization and hazard avoidance techniques	Analyze
CO3	Compare the performance of various processor configurations in a processor simulator using benchmarks	Evaluate

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3	3	3	3	3	3	3	3
CO2	3	3	3	3	3	3	3	3	3
CO3	3	3	3	3	3	3	3	3	3

3-High; 2-Medium; 1-Low

Course Content:

Sample List of Experiments*	
1	Design the components required for simple data path for RISC-V architecture in Verilog/BSV
2	Design the control path for for simple single cycle implementation of RISC-V architecture in Verilog/BSV
3	Design a simple pipelined RISC-V processor in Verilog/BSV
4	Implement a unicore system in processor simulator for a given memory hierarchy specification
5	Implement cache block replacement policy and analyse various parameters.
6	Build an ISA and for given specification, analyse performance parameters (like overall CPI, number of simulated CPU cycles, instruction issue rate, etc.)
7	Performance analysis of a given configuration for various benchmarks

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

References:

[1] John L. Hennessy and David A. Patterson, *Computer Architecture - A Quantitative Approach.* Morgan Kaufmann, 2017.

[2] David A. Patterson and John L. Hennessy, *Computer Organization and Design,The Hardware/Software interface: RISC-V Edition* . Morgan Kaufman, 2017.

[3] William Stallings, *Computer Organization and Architecture.* Pearson Ed, 2022.

[4] Arvind, Rishiyur S. Nikhil, James C. Hoe, and Silvina Hanono Wachman, "Introduction to digital design as cooperating sequential machines."

[5] "RISC-V International," https://riscv.org/.

[6] "Bluespec Reference Guide," https://web.ece.ucsb.edu/its/bluespec/doc/BSV/reference-guide.pdf.

[7] J. Bhasker, *A Verilog HDL Primer.* Star Galaxy Publishing, 2005.

[8] Shakthi Processors, " https://shakti.org.in/."

[9] Vega Processors, "https://vegaprocessors.in/."

[10] gem5 Simulator, "https://www.gem5.org/."

24-509-0X27 Deep Neural Network Signal Processing Lab

L	T	P	C
0	**0**	**4**	**2**

Prerequisites	:	Neural Networks
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, PyTorch etc.
Course Outcome	:	After the completion of the lab, the student will be able to

CO1	Model CNN for feature extraction and predictions	Apply
CO2	Model RNN for temporal and sequential signals	Apply
CO3	Model encoder-decoder based neural networks for spatial/temporal signals	Apply
CO4	Model generative networks to generate signals/images	Apply
CO5	Propose DNN solution for real world problems and analyse models/algorithms for performance improvement	Analyse

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1			3	3	2	2	3	2	3
CO2			3	3	2	2	3	2	3
CO3			3	3	2	2	3	2	3
CO4			3	3	2	2	3	2	3
CO5			3	3	2	2	3	3	3

3-High; 2-Medium; 1-Low

Course Content:

Sample List of Experiments*	
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 models for sequence/spatial signal
4	Implement generative adversarial network for signals/image 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.

References:

[1] Jon Krohn, *Deep Learning with TensorFlow, Keras, and PyTorch.* Pearson, 2020.

[2] Aurélien Géron, *Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow*, 3rd ed. O'Reilly Media, Inc., 2022.

[3] Documentations of python libraries.

24-509-0X28	FPGA System Design Lab

L	T	P	C
0	0	4	2

Prerequisites	:	Digital design basics
Lab Description	:	This lab equips students to build embedded systems using FPGA SOCs.
Course Outcome	:	After the completion of the lab, the student will be able to

CO1	Compare resource utilization, area and power for different implementations of digital logic blocks on FPGA	Evaluate
CO2	Demonstrate the functionality of different FPGA I/O interfaces	Apply
CO3	Integrate processor cores, memory and arithmetic blocks, transceivers and programmable logic in FPGA for practical applications	Evaluate

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3	3	2	2	2	3		3
CO2	3	3	3	2	2	2	3		3
CO3	3	3	3	2	2	2	3	2	3

3-High; 2-Medium; 1-Low

Course Content:

Sample List of Experiments*	
1	Familiarization of Xilinx Vivado software
2	Implement basic logic blocks like adders, counters, shift registers on FPGA
3	Implement different types of multipliers and compare speed and resource utilization
4	Write a C program and run it on a single processor system, based on a MicroBlaze soft core, using the available Xilinx FPGA platform
5	Implement AXI-Lite peripheral with a Cortex-A9 Processing System on FPGA and demonstrate using GPIOs
6	Demonstrate a functional HDMI output system using Cortex-A9 Processing System on FPGA
7	Boot any OS on Cortex-A9 Processing System on FPGA

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

References:

[1] Ron Sass and Andrew G. Schmidt, *Embedded Systems Design with Platform FPGAs, Principles and Practices.* Elsevier, 2007.

[2] Matlab Resources: Digital system design and FPGA system design , "https://content.mathworks.com/viewer/642a7100f19355331a3ea4c2."

[3] Xilinx FPGA user guides and documentation.

[4] Xilinx Vivado documentation.

[5] ARM Advanced System on Chip Design Education Kit.

L	T	P	C
0	**0**	**4**	**2**

24-509-0X29 **Analog IC Design Lab**

Prerequisites : Taken with Analog IC Design

Lab Description : This lab explores the different stages of custom IC design flow using EDA tools and employs these steps for implementing analog circuit components.

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

CO1	Simulate analog circuit components and estimate parameters like gain, bandwidth, power dissipation, noise figure etc.	Apply
CO2	Complete physically verified layouts from schematics for custom designs	Apply
CO3	Compare different implementations of analog integrated circuit components	Analyze

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3		3	2	2	2	3		3
CO2	3		3	2	2	2	3		3
CO3	3		3	2	2	2	3	2	3

3-High; 2-Medium; 1-Low

Course Content:

Sample List of Experiments*	
1	Cadence Spcetre circuit simulator familiarization
2	Learn the various steps of layout design like DRC, LVS and parasitic extraction using Cadence Virtouso layout editor
3	MOSFET characterization and parameter extraction
4	Design, simulate and compare various current mirror circuits
5	Design and simulate various inverting amplifier configurations
6	Design and simulate various differential amplifiers
7	Simulate operational transconductance amplifiers
8	Monte Carlo analysis

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

References:

[1] Behzad Razavi, *Design of Analog CMOS Integrated Circuit*, 2nd ed. McGraw Hill India, 2017.

[2] Documentation for Cadence Virtuoso custom IC simulation and layout suite.

24-509-0X30 **Neural Networks Lab**

L	T	P	C
0	0	4	2

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, PyTorch, 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	Analyse the models and improve the learning algorithms through parameter tuning	Analyse

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1			3	3	2	2	3	2	3
CO2			3	3	2	2	3	2	3
CO3			3	3	2	2	3	2	3
CO4			3	3	2	2	3	2	3
CO5			3	3	2	2	3	3	3

3-High; 2-Medium; 1-Low

Course Content:

Sample List of Experiments*	
1	Familiarisation of Python, Jupyter notebook and libraries like TensorFlow, Keras, PyTorch, etc.
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	Improve neural network model by fine tuning hyper-parameters, improve learning using heuristics and analyse training, validation and testing results
6	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.

References:

[1] Aurélien Géron, *Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow, 3rd Edition.* O'Reilly Media, Inc., 2022.

[2] Jon Krohn, *Deep Learning with TensorFlow, Keras, and PyTorch.* Pearson, 2020.

[3] Documentations of python libraries.

24-509-0X31 **Real Time Operating Systems Lab**

L	T	P	C
0	0	4	2

Prerequisites : Embedded Systems Lab

Lab Description : This lab will involve working on software tools and programming software for real time systems.

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	Illustrate porting an open source RTOS into development boards for demonstrating real world scenarios	Apply
CO4	Customize operation of an RTOS to desired specifications	Apply

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3		3	2	2	2	3		
CO2	3	2	3	2	2	2	3		
CO3	3	2	3	2	2	2	3	2	
CO4	3	2	3	2	2	2	3	2	

3-High; 2-Medium; 1-Low

Course Content:

Sample List of Experiments*	
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

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

References:

[1] David E. Simon, *An Embedded Software Primer.* Pearson Education, 2000.

[2] Abraham Silberschatz, *Operating Systems Concepts.* John Wiley & Sons, 20004.

[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 μC/OS, "https://www.micrium.com/rtos/kernels/."

[9] Real Time Linux, "https://wiki.linuxfoundation.org/realtime/start/."

[10] Nicolas Melot, "Study of an Operating System: FreeRTOS," *CAPÍTULO XVIII*, vol. 115, pp. 1–39, 2009.

Master of Technology

(M.Tech.) Degree Program

Microwave and Communication Engineering

Outcome Based Syllabus

DEPARTMENT OF ELECTRONICS
COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

MASTER OF TECHNOLOGY

in

MICROWAVE AND COMMUNICATION ENGINEERING

Syllabus

(2024 Admission Onwards)

DEPARTMENT OF ELECTRONICS

COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

Kochi - 682 022, India

Contents

1 Vision, Mission, PEO and PO 1

2 Course Structure 3

3 **Semester 1** 5

3.1 24-510-0101 : Signal Processing for Communication 7

3.2 24-510-0102 : Advanced Communication Systems 9

3.3 24-510-0103 : Microwave Devices and Circuits 11

3.4 24-510-0104 : Digital Communication Lab 13

3.5 24-510-0105 : Microwave Devices and Circuits Lab 15

4 **Semester 2** 17

4.1 24-510-0201 : Wireless Communications 19

4.2 24-510-0202 : Radar Systems 21

4.3 24-510-0203 : Wireless Communication Lab 23

5 **Semester 3** 25

5.1 24-510-0301 : Project Part 1 27

5.2 24-510-0302 : NPTEL/MOOC Course 29

6 **Semester 4** 31

6.1 24-510-0401 : Project Part 2 33

7 **Electives** 35

7.1 24-510-0X11 : Antennas for Communication Systems 37

7.2 24-510-0X12 : Machine Learning 39

7.3 24-510-0X13 : Electromagnetic Interference and Compatibility 41

7.4 24-510-0X14 : Software Defined Radio for Communication Engineers 43

7.5 24-510-0X15 : Information Theory and Coding 45

7.6 24-510-0X16 : Optimization Techniques 47

7.7 24-510-0X17 : Estimation and Detection Theory 49

7.8 24-510-0X18 : Signal Integrity for High-Speed Digital Design 51

7.9 24-510-0X19 : Software Defined Radio Lab 53

7.10 24-510-0X20 : Antennas Lab 55

7.11 24-510-0X21 : 5G Technologies and Standards 57

7.12 24-510-0X22 : Machine Learning Lab 59

7.13 24-510-0X23 : EMI/EMC Lab 61

7.14 24-509-0X15 : Analog & RF IC Design 63

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	Graduates apply their technical competence in theory, hardware, software and EDA tools to solve engineering problems in their chosen specialization
PEO2	Graduates apply their communication skill, leadership quality, reasearch aptitute and ethics to build a strong career in thier chosen areas of specialization through continous learning
PEO3	Graduates acquire the capacity for higher professional positions in academics/industry/research and entreprenuership

PEO-Mission Matrix:

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

Programme Outcomes: At the end of the programme, the student will be able to

PO1	Apply engineering knowledge to carry out research, and analysis of technical problems.
PO2	Develop solutions and design system components or processes that meet the specified needs considering all constraints.
PO3	Create, select, and apply appropriate techniques, resources, and modern engineering tools.
PO4	Ability to communicate effectively by preparing and presenting technical reports.
PO5	Apply professional ethics and responsibilities in engineering practice.
PO6	Engage in lifelong learning independently to enhance knowledge and skills that can contribute to the continuous improvement of individuals and society.

Programme Specific Outcomes: At the end of the programme, the student will be able to

PSO1	Acquire competency to design, analyze and evaluate the performance of a wireless communication system, using analytical skills, advanced simulation software and laboratory techniques.
PSO2	Be proficient in the industry standard simulation tools in 3DEM /circuit, wireless system design to develop/innovate in the field of RF / Microwave communication systems.
PSO3	Acquire the necessary skills to evaluate and innovate in building modern wireless communication systems.

PEO-PO Mapping:

	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
PEO1	✓	✓	✓				✓	✓	
PEO2				✓	✓	✓	✓	✓	✓
PEO3	✓	✓	✓	✓	✓	✓	✓	✓	✓

COURSE STRUCTURE

Semester 1

No.	Course Code	Course Title	L	T	P	Credits	C/E	CA	ES	Total
1	24-510-0101	Signal Processing for Communication	3	2	0	3	C	50	50	100
2	24-510-0102	Advanced Communication Systems	3	2	0	3	C	50	50	100
3	24-510-0103	Microwave Devices and Circuits	3	2	0	3	C	50	50	100
4	24-510-0104	Digital Communication Lab	0	0	4	2	C	100	0	100
5	24-510-0105	Microwave Devices and Circuits Lab	0	0	4	2	C	100	0	100
6	24-510-0106	Program Elective Lab	0	0	4	2	C	100	0	100
7	24-510-01XX	Program Elective	3	1	0	3	E	50	50	100
8	24-510-01XX	Program Elective	3	1	0	3	E	50	50	100
		Interdepartmental Elective*				3	E	50	50	100
		Total				21				

Semester 2

No.	Course Code	Course Title	L	T	P	Credits	C/E	CA	ES	Total
1	24-510-0201	Wireless Communications	3	2	0	3	C	50	50	100
2	24-510-0202	Radar Systems	3	2	0	3	C	50	50	100
3	24-510-0203	Wireless Communication Lab	0	0	4	2	C	50	50	100
4	24-510-02XX	Program Elective	3	0	0	3	E	50	50	100
5	24-510-02XX	Program Elective	3	1	0	3	E	50	50	100
6	24-510-02XX	Program Elective	3	1	0	3	E	50	50	100
		Interdepartmental Elective*				3	E	50	50	100
7	24-510-02XX	Program Elective Lab	0	0	4	2	E	100	0	100
		Total				19				

* At least one interdepartmental elective is mandatory. Need to compulsorily register for the same before third semester. This can be opted instead of a program elective in either first or second semester.

Semester 3

No.	Course Code	Course Title	L	T	P	Credits	C/E	CA	ES	Total
1	24-510-0301	Project Part 1	0	0	28	14	C	100	100	200
2	24-510-0302	Elective-MOOC/NPTEL Course#				2	E	0	100	100
		Total				16				

Need to compulsorily register for one MOOC/NPTEL course and one interdepartmental elective before registering for fourth semester exam.

Semester 4

No.	Course Code	Course Title	L	T	P	Credits	C/E	CA	ES	Total
1	24-510-0401	Project Part 2	0	0	32	16	C	100	100	200
		Total				16				

Electives

No.	Course Code	Course Title	L	T	P	Credits	C/E	CA	ES	Total
1	24-510-0X11	Antennas for Communication Systems	3	1	0	3	E	50	50	100
2	24-510-0X12	Machine Learning	3	1	0	3	E	50	50	100
3	24-510-0X13	Electromagnetic Interference and Compatibility	3	1	0	3	E	50	50	100
4	24-510-0X14	Software Defined Radio for Communication Engineers	3	1	0	3	E	50	50	100
5	24-510-0X15	Information Theory and Coding	3	1	0	3	E	50	50	100
6	24-510-0X16	Optimization Techniques	3	1	0	3	E	50	50	100
7	24-510-0X17	Estimation and Detection Theory	3	1	0	3	E	50	50	100
8	24-510-0X18	Signal Integrity for High-Speed Digital Design	3	1	0	3	E	50	50	100
9	24-510-0X19	Software Defined Radio Lab	0	0	4	2	E	100	0	100
10	24-510-0X20	Antennas Lab	0	0	4	2	E	100	0	100
11	24-510-0X21	5G Technologies and Standards	3	1	0	3	E	100	0	100
12	24-510-0X22	Machine Learning Lab	0	0	4	2	E	100	0	100
13	24-510-0X23	EMI/EMC Lab	0	0	4	2	E	100	0	100
14	24-509-0X15	Analog & RF IC Design **	3	1	0	3	E	50	50	100

** This elective course is mapped to MTech in VLSI and Embedded Systems specialisation.

MASTER OF TECHNOLOGY

in

MICROWAVE AND COMMUNICATION ENGINEERING

Semester 1

DEPARTMENT OF ELECTRONICS

COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

Kochi - 682 022, India

24-510-0101 **Signal Processing for Communication**

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

Prerequisites : Signals & Systems, Digital Signal Processing, Mathematics

Course Description : This course deals with the basic mathematical foundation needed for communication system design.

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

CO1	Use the concept of vector space in signal analysis	Apply
CO2	Demonstrate the importance of filtering	Apply
CO3	Select a suitable digital filter based on the application	Analyse
CO4	Illustrate the concept of sampling and interpolation	Apply
CO5	Apply multirate signal processing techniques in communication	Apply

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	2	2				3	2	
CO2	3	2	2				3	2	3
CO3	3	2	2				3	2	3
CO4	3	2	2					2	3
CO5	3	2	2					2	3

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Signals & Hilbert Spaces:** Discrete-time basic signals, digital frequency, elementary operations, classes of discrete-time signals, Euclidean Geometry - vectors and notation, inner product, norm, distance, bases, vector space, inner product space, Hilbert space, subspaces, bases and projections
Module 2	**Discrete-time Filters:** Linear Time-Invariant Systems, filtering in time domain, convolution and inner product, Finite Impulse Response (FIR) vs Infinite Impulse Response (IIR), filtering in frequency domain - LTI Eigenfunctions, properties of frequency response, ideal filters, realizable filters, solving Constant Coefficient Difference Equations (CCDEs) using z-transform, pole-zero patterns
Module 3	**Filter Design:** Design fundamentals, filter specifications and trade-offs, FIR filter design - FIR design by windowing, linear phase filters, IIR filter design - impulse invariant technique and bilinear transformation, filter structures

Module 4	**Interpolation and Sampling:** Sampling, inner product and convolution, the sinc function, zero order hold interpolation, first order hold, polynomial interpolations, sinc interpolation, sampling theorem, sampling as a basis expansion, aliasing, oversampling, critical sampling and under sampling, A/D and D/A conversions
Module 5	**Multirate Signal Processing:** Downsampling, properties, frequency domain representation, downsampling of a high pass signal, anti-aliasing filter, upsampling, rational sampling rate changes, multirate identities, multirate filtering

References:

[1] P. Prandoni and M. Vetterli, *Signal Processing for Communications*, 1st ed. EPFL press, 2008.

[2] A. Lapidoth, *A Foundation in Digital Communication*, 2nd ed. Cambridge University Press, 2017.

[3] J. G. Proakis and D. G. Manolakis, *Digital Signal Processing: Principles, Algorithms, and Application*, 4th ed. Pearson Education India, 2007.

[4] A. V. Oppenheim and R. W. Schafer, *Discrete-time Signal Processing*, 2nd ed. Prentice Hall, 1999.

[5] B. Porat, *A Course in Digital Signal Processing*, 1st ed. John Wiley & Sons, 1996.

[6] P. P. Vaidyanathan, *Multirate Systems and Filter Banks*, 1st ed. Pearson Education India, 2006.

[7] D. E. Dudgeon and R. M. Merserau, *Multidimensional Digital Signal Processing*, 1st ed. Prentice Hall, 1984.

[8] S. K. Mitra, *Digital Signal Processing: A Computer-Based Approach.* McGraw-Hill Higher Education, 2001.

[9] C. T. Chen, *Digital Signal Processing: Spectral Computation and Filter Design.* Oxford University Press, Inc., 2001.

[10] E. C. Ifeachor and B. W. Jervis, *Digital Signal Processing: A Practical Approach.* Pearson Education, 2004.

24-510-0102 **Advanced Communication Systems**

L	T	P	C
3	2	0	3

Prerequisites	:	Signals & Systems
Course Description	:	This course deals with the statistical modeling of communication systems.
Course Outcome	:	After the completion of the course, the student will be able to

CO1	Use signal analysis for communication	Apply
CO2	Apply the concept of probability in communication system design	Apply
CO3	Illustrate the geometric representation of signals	Apply
CO4	Analyse digital modulation techniques	Analyse
CO5	Examine the issues related with band-limited channels	Apply

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	2	2	2			2		2
CO2	3	2	2	2			3	2	
CO3	3	2	2	2			2		2
CO4	3	2	2	2			2	3	
CO5	3	2	2	2			2		2

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Fourier Analysis of Signals & Systems :** Fourier series, Fourier transform, inverse relationship between time domain and frequency domain representation, Dirac delta function, Fourier transform of periodic signals, transmission of signals through Linear Time Invariant (LTI) systems, Hilbert transform, pre-envelopes, complex envelopes of band-pass signals, canonical representation of band-pass signals, complex low-pass representations of band-pass systems, linear modulation theory, phase and group delays
Module 2	**Probability and Stochastic Process:** Set theory, probability theory, random variables, distribution functions, the concept of expectation, statistical averages, characteristic functions, Gaussian distribution, Markov and Chebyshev inequalities, central limit theorem, stochastic process - strictly stationary and weakly stationary, mean, correlation, and covariance functions of weakly stationary processes, ergodic processes, Transmission of a Weakly Stationary Process through a LTI filter, cross spectral densities, Poisson process, Gaussian process, noise

Module 3	**Signaling over AWGN Channels:** Geometric representation of signals, the Schwarz inequality, Gram-Schmidt Orthogonalization Procedure, conversion of continuous AWGN channel in to a vector channel, statistical characterization of the correlator outputs, likelihood function for an AWGN channel, Maximum Likelihood (ML) Decoding, correlation receivers, matched filter receiver, probability of error
Module 4	**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, Carrier phase synchronisation and symbol timing synchronisation
Module 5	**Signaling over Band-Limited Channels:** Error rate due to channel noise in a matched-filter receiver, intersymbol interference, 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

References:

[1] S. Haykin, *Digital Communication Systems*, 1st ed. John Wiley & Sons, 2014.

[2] S. Haykin and M. Moher, *Introduction to Analog and Digital Communications*, 2nd ed. John Wiley & Sons, Inc., 2012.

[3] S. Haykin, *Communication Systems*, 2nd ed. John Wiley & Sons, 2008.

[4] A. B. Carlson and P. B. Crilly, *Communication Systems An Introduction to Signals and Noise in Electrical Communication*, 5th ed. McGraw Hill Higher Education, 2010.

[5] B. Sklar, *Digital Communications: Fundamentals and Applications*, 3rd ed. Pearson, 2021.

[6] J. G. Proakis and M. Salehi, *Digital Communications*, 5th ed. McGraw Hill, 2014.

[7] H. Taub and D. L. Schilling, *Principles of Communication Systems*, 4th ed. McGraw Hill, 2017.

[8] J. G. Proakis, M. Salehi, N. Zhou, and X. Li, *Communication Systems Engineering*, 2nd ed. Prentice Hall of India, 2017.

[9] W. Feller, *An Introduction to Probability Theory and its Applications*, 3rd ed. John Wiley & Sons, 1991.

[10] S. M. Ross, *Introduction to Probability Models*, eleventh ed. Academic press, 2014.

24-510-0103 **Microwave Devices and Circuits**

L	T	P	C
3	0	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 anal- ysis and gives an overview of active and passive components and discusses the design of practical microwave circuits.

Course Outcome : After the completion of the course, 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 S-parameters in describing RF circuit characteristics and employ various networks for impedance matching	Apply
CO3	Design the various Microwave components	Analyze
CO4	Understand the various microwave passive and active devices and components	Understand
CO5	Design of various Microwave circuits: Amplifiers, Oscillators, Frequency Synthesizers and an understanding of high power sources	Apply

COs to POs & PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3					2	3		
CO2	3	3	2			2	3	3	3
CO3	3	3	2			2	3	3	3
CO4	3		2			2	3		
CO5	3	3	2			2	3	3	3

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Transmission Line Theory:** - Revision of Maxwells equations- Behavior of Materials and Components at microwave frequency, Transmission Line Theory, Practical Transmission Lines, Smith Charts- Uses and its Variants. **S Pa- rameters and Matching Networks:** - S Parameters - Signal Flow Graphs. Impedance Matching Networks- Lumped and Distributed Element Matching Networks

Module 2	**Microwave Components:-** Resonators – Transmission line, Cavity and Di- electric resonators; Power dividers and Directional couplers – Basic Properties, T Junction, Wilkinson, Waveguide Directional Couplers, 90^0 & 180^0 Hybrid; **Filters:-** Design, Transformation and Implementation
Module 3	**Passive Devices:** - Schottky Diodes and Detectors, Varactor Diodes, PIN Diode Parameters, Switches, Attenuators, Phase Shifters- diode and Ferrite Phase Shifters, Circulators and Isolators
Module 4	**Active Devices:-** Microwave BJT, HBT, FET & CMOS; MMIC- Technology, Elements & Applications. **Microwave Sources:-** Low power and High power Sources
Module 5	**Microwave Circuits Design:-** Amplifiers- Single stage, Multistage and Broadband; Oscillators, Mixers and Frequency Synthesizers

References:

[1] S. Haykin, *Digital Communication Systems*, 1st ed. John Wiley & Sons, 2014.

[2] S. Haykin and M. Moher, *Introduction to Analog and Digital Communications*, 2nd ed. John Wiley & Sons, Inc., 2012.

[3] S. Haykin, *Communication Systems*, 2nd ed. John Wiley & Sons, 2008.

[4] A. B. Carlson and P. B. Crilly, *Communication Systems An Introduction to Signals and Noise in Electrical Communication*, 5th ed. McGraw Hill Higher Education, 2010.

[5] B. Sklar, *Digital Communications: Fundamentals and Applications*, 3rd ed. Pearson, 2021.

[6] J. G. Proakis and M. Salehi, *Digital Communications*, 5th ed. McGraw Hill, 2014.

[7] H. Taub and D. L. Schilling, *Principles of Communication Systems*, 4th ed. McGraw Hill, 2017.

[8] J. G. Proakis, M. Salehi, N. Zhou, and X. Li, *Communication Systems Engineering*, 2nd ed. Prentice Hall of India, 2017.

[9] W. Feller, *An Introduction to Probability Theory and its Applications*, 3rd ed. John Wiley & Sons, 1991.

[10] S. M. Ross, *Introduction to Probability Models*, eleventh ed. Academic press, 2014.

24-510-0104 **Digital Communication Lab**

L	T	P	C
0	0	4	2

Prerequisites	:	Advanced Communication Systems
Lab Description	:	This lab deals with the basic implementation of a digital communication systems. The lab evaluates a particular modulation scheme and develops techniques to improve its performance. in MATLAB/Octave/Python
Lab Outcome	:	After the completion of the lab, the student will be able to

CO1	Familiarise the communication toolbox in MATLAB/OCTAVE	Understand
CO2	Implement a digital communication system and evaluate its performance and represent the result in different ways- Constellation diagram, BER plot, eye diagram	Apply
CO3	Innovate and develop new models to cater to modern communication systems	Evaluate

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3					2	2	
CO2	3	3	3				3	3	
CO3	3	3	3		3	3	3	3	3

3-High; 2-Medium; 1-Low

Course Content:

Sample List of Experiments*: Implementation and performance evaluation of the following experiments in MATLAB/Octave/Python software
1. PCM Modulation & Demodulation
2. Delta Modulation
3. Various digital modulation schemes
4. OFDM
∗ The list is not exhaustive. Additional experiments or projects based on the experiments can be included in the laboratory activity.

References:

[1] [Online:] https://docs.octave.org/latest/

[2] [Online:] https://in.mathworks.com/help/matlab/

24-510-0105	**Microwave Devices and Circuits Lab**	**L**	**T**	**P**	**C**
		0	**0**	**4**	**2**

Prerequisites	:	Microwave Devices and Circuits
Course Description	:	This lab familiarizes the student with the experimental set up for carrying out microwave measurements followed by characterising the various Microwave 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 course, student will be able to

CO1	Setup a X band microwave bench and carry out measurement of various RF parameters	Apply
CO2	Familiarization of measurement with Network Analyzer	Apply
CO3	Computer aided design and characterization of transmission lines, microwave transistors, matching networks and various passive and active components and circuits	Apply

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	2		3	3	3	3		3
CO2	3			3	3	3	3		3
CO3	3	3	3	3	3	3	3	3	3

3-High; 2-Medium; 1-Low

Sample List of Experiments* :
Part A:- Familiarisation of microwave components and measurements
1. Familiarisation of X band Bench set up and do the measurements of various RF parameters
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,QW transformer, network analyzer)
5. Cavity Resonators (resonant frequency, Q, frequency counter)
6 Directional Couplers, Circulators, Waveguide Tees, Isolators, Attenuators (insertion loss, coupling, directivity)
Part B:- Computer Aided Design and Testing
Computer-Aided Design using industry-standard software and Testing of
1. Planar Transmission Lines
2. Planar Filters
3. Microwave Transistors (Biasing and Layout) and Amplifiers - for maximum power transfer and low noise
4. Matching Network (Design and Layout)
5. Branch Line Couplers & Power Dividers
6. Planar antennas - Rectangular patch with different types of feeds
∗ The list is not exhaustive. Additional experiments or project based on the experiments can be included in the laboratory activity.

MASTER OF TECHNOLOGY

in

MICROWAVE AND COMMUNICATION ENGINEERING

Semester 2

DEPARTMENT OF ELECTRONICS

COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

Kochi - 682 022, India

24-510-0201 **Wireless Communications**

L	T	P	C
3	2	0	3

Prerequisites	:	Advanced Communication Systems
Course Description	:	This course reviews the various communication standards in wireless communication. The course will enable the students to understand the challenges in the wireless propagation medium and appreciate the use of advanced communication techniques to meet the rising demands of the telecom industry.
Course Outcome	:	After the completion of the course, the student will be able to

CO1	Analyse the type of wireless channel and identify the appropriate model for the same	Analyse
CO2	Apply appropriate techniques to mitigate the impact of channel impairments	Apply
CO3	Analyze the capacity and reliability of wireless communication systems	Analyse
CO4	Understand the latest techniques to appreciate the futuristic wireless systems and to be able to apply them to develop a new prototype	Apply

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3		2				3	3	
CO2	3	3	2				3	3	
CO3	3	3	2				3	3	
CO4	3	3	2				3	3	3

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Introduction to Wireless Channel Modeling:** Wireless Channel Models, Statistical fading models, time-varying channel impulse response, Narrowband and wideband fading models
Module 2	**Capacity of Wireless Channels:** Performance of digital modulation schemes over wireless channels, AWGN channel capacity, Capacity of flat and frequency selective fading channels
Module 3	**Cellular Concept:** Techniques to reduce interference and improve the capacity in cellular systems, **Fading Mitigation Techniques:** Different types of diversity techniques, Various diversity combining techniques, performance analysis for Rayleigh fading channels

Module 4	**Multiple Access Techniques:** Review of Random Multiple Access Protocols, Multiple Access protocols over different generations of cellular systems, Spread Spectrum Techniques, Techniques used in 4G - MIMO/OFDM technique
Module 5	**Modern Technology Standards:** Cellular wireless communication standards - LTE and LTE Advanced, 5G and 6G standards. Introduction to Massive MIMO, mmWave communication, Reconfigurable Intelligent Surfaces for coverage extension in mmWave and THz frequencies, Usage of NOMA among multiple users to improve spectral efficiency

References:

[1] T. S. Rappaport, *Wireless Communications: Principles and Practice*, 2nd ed. Cambridge University Press, 2024.

[2] A. Goldsmith, *Wireless CCommunications*. Cambridge University Press, 2005.

[3] A. F. Molisch, *Wireless Communications*, 2nd ed. John Wiley & Sons, 2011.

[4] G. L. Stüber, *Principles of Mobile Communications*, 2nd ed. Kluwer Academic Publishers, 2001.

[5] D. Tse and P. Viswanath, *Fundamentals of Wireless Communication*. Cambridge University Press, 2005.

[6] A. J. Viterbi, *CDMA: Principles of Spread Spectrum Communication*. Addison Wesley Longman Publishing Co., Inc., 1995.

[7] D. R. Koilpillai, "Introduction to Wireless and Cellular Communications," NPTEL Course, 2023.

[8] A. K. Jagannatham, "Advanced 3G and 4G Wireless Mobile Communications," NPTEL Course, 2014.

[9] A. K. Jagannatham, "Principles of Modern CDMA/ MIMO/ OFDM Wireless Communications (Course sponsored by Aricent)," NPTEL Course, 2021.

24-510-0202 **Radar Systems**

L	T	P	C
3	2	0	3

Prerequisites	:	A basic course in communication and microwave.
Course Description	:	In this course, the students are given an overview of different radars and the signal processing associated. Also gives an an insight in to different antennas used in radar applications.
Course Outcome	:	After the completion of the course, 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 ex- traction	Analyze
CO4	Understand the radar signal processing and the analysis using software tools	Analyze
CO5	Understand the different radar applications	Understand

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	2	2			3	2	2	2
CO2	3					3			
CO3	3	3	2			3	3	2	2
CO4	3	3	2			3	3	2	2
CO5	3					3			2

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Radar fundamentals and operation:** Introduction, principles, types of radar, transmitter functions, wave form spectra, receiver functions, Radar equation, Radar cross section
Module 2	**Radar Systems:** Pulse, CW, FM-CW, MTI, Doppler and multimode tech- niques, 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 (Software simulation)
Module 5	**Radar Applications:** Instrument landing systems, Electronic Warfare - ECM and ECCM, High resolution radar, range and Doppler resolution, Synthetic aperture radar, Radar in automobile - Movement Detection, Phased array Radar, millimeter wave radars

References:

[1] M. I. Skolnik, *Introduction to Radar Systems.* Tata Mcgraw Hill, 2001.

[2] B. Edde, *Radar: Principles, Technology and Applications.* Pearson Education Inc., 1995.

[3] D. C. Scheleher, *Introduction to Electronic Warfare.* Artech House Inc., 1986.

[4] G. J. Wheeler, *Radar Fundamentals.* Prentice Hall Inc, 1967.

[5] L. Nadav, *Radar Principles.* john Wiley and Sons, 1988.

[6] B. R. Mahafza, *Radar Systems Analysis and Design using MATLAB.* CRC Press, 2013.

[7] M. A. Richards, *Fundamentals of Radar Signal Processing*, 2nd ed. Tata Mcgraw Hill.

24-510-0203 **Wireless Communication Lab**

L	T	P	C
0	0	4	2

Prerequisites : Fundamentals of Wireless Communication
Lab Description : Modelling of a wireless channel and analysis of the performance of a modern wireless communication system using MATLAB/Octave/ Python
Lab Outcome : After the completion of the lab, the student will be able to

CO1	Understand the communication toolbox in MATLAB/OCTAVE	Understand
CO2	Implement a basic channel model in a wireless communication system	Apply
CO3	Compare the performance of BER and outage probability under various traditional and modern modulation schemes	Apply
CO4	Develop a wireless communication system and evaluate the performance of various diversity combining schemes	Evaluate

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3					3	3	
CO2	3	3					3	3	3
CO3	3	3				3	3	3	3
CO4	3	3				3	3	3	3

3-High; 2-Medium; 1-Low

Course Content:

Sample List of Experiments*	
Implementation of the following in MATLAB/Octave/Python	
1	Model a wireless channel using the Jakes Rayleigh fading channel model
2	Implement a BPSK communication system under additive white Gaussian noise (AWGN). Obtain the BER performance (Eb/N_o Vs Error rate) through Monte-Carlo simulations and compare the error performance with theoretical plots obtained using analysis
3	Simulate a wireless commutation system under flat Rayleigh fading using a digital modulation scheme for various diversity combining schemes. (i) Obtain the BER performance (BER Vs Average bit SNR) for the above schemes using 1×2 ($N_t \times N_r$) system and 1×4 ($N_t \times N_r$) system. (ii) Compare the BER curves in (i) with a SISO system. Measure the diversity gain in each case from the BER curves for a target probability of error of 10^{-3}

4	Plot the Outage Probability vs. average SNR normalized to the Threshold SNR for the system in Q3. and evaluate its performance for various Receiver diversity branches using Maximal ratio combining and Equal gain combining schemes
5	Develop a Rayleigh fading simulator for a mobile communications channel and plot the received signal amplitude for different Doppler frequencies

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

References:

[1] T. S. Rappaport, *Wireless Communications: Principles and Practice*, 2nd ed. Cambridge University Press, 2024.

[2] S. Haykin, *Communication systems.* John Wiley & Sons, 2008.

[3] A. Goldsmith, *Wireless Communications.* Cambridge university press, 2005.

[4] [Online]. Available: https://www.3gpp.org/specifications-technologies/releases/release-15

MASTER OF TECHNOLOGY

in

MICROWAVE AND COMMUNICATION ENGINEERING

Semester 3

DEPARTMENT OF ELECTRONICS

COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

Kochi - 682 022, India

24-510-0301 **Project Part 1**

L	T	P	C
0	0	28	14

Prerequisites : None
Lab Description : This is the first part of the final project.
Course Outcome : After the completion of the course, the student will be able to

CO1	Identify unresolved problems and challenges in the selected domain through literature survey	Analyze
CO2	Determine appropriate tools and procedures for design, development & verification	Evaluate
CO3	Develop practical solutions for the chosen problem for a given specification	Create
CO4	Develop the ability to write good technical report, to make oral presentation of the work, and to publish the work in reputed conferences/journals	Create

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3			3	3	3	3		
CO2	3	3	3			3	3		3
CO3	3	3	3	3		3	3	3	3
CO4	3			3	3	3	3		

3-High; 2-Medium; 1-Low

Course Content:

The major project in fourth semester offer the opportunity to apply and extend knowledge acquired in the three semesters of the M.Sc. program. The major project can be analytical work, simulation, hardware design or a combination of these in the emerging areas of electronics under the supervision of a faculty from the Dept. of Electronics or in R and D institutes/ Industry. The specific project topic undertaken will reflect the common interests and expertise of the student(s) and supervisor. Students doing their projects outside the department will be assigned an internal supervisor.

Students will be required to

- perform a literature search to review current knowledge and developments in the chosen technical area
- 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 project supervisor/internal supervisor shall do monthly evaluation of the progress. M.Sc project evaluation committee for the course shall evaluate the project work during the fourth semester in two stages. 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 progress in the chosen topic, write technical report of the study and results. They are expected to communicate their innovative ideas and results in reputed conferences and/or journals.

24-510-0302 **NPTEL/MOOC Course**

L	T	P	C
2	0	0	2

Prerequisites	:	None
Course Description	:	This course has to be completed through MOOC mode using NPTEL/SWAYAM or other university approved MOOC platforms.
Course Outcome	:	After the completion of the course, the student will be able to

CO1	Demonstrate the ability for independent learning	Apply
CO2	Follow ethical practices for timely submissions	Apply

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3			3	3	3	3		
CO2				3	3	3			

3-High; 2-Medium; 1-Low

Course Content:

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 2. The selection of the course will be dependent on their specialisation and should be approved by the committee constituted for the same. The modality of the course will be as per the university guidelines on MOOC courses.

MASTER OF TECHNOLOGY

in

MICROWAVE AND COMMUNICATION ENGINEERING

Semester 4

DEPARTMENT OF ELECTRONICS

COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

Kochi - 682 022, India

24-510-0401 **Project Part 2**

L	T	P	C
0	0	32	16

Prerequisites : Successful completion of 20-510-0301 Project: Part 1
Lab Description : This is the second and final part of the final project.
Course Outcome : After the completion of the course, the student will be able to

CO1	Identify unresolved problems and challenges in the selected domain through literature survey	Analyze
CO2	Determine appropriate tools and procedures for design, development & verification	Evaluate
CO3	Develop practical solutions for the chosen problem for a given specification	Create
CO4	Develop the ability to write good technical report, to make oral presentation of the work, and to publish the work in reputed conferences/journals	Create

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3			3	3	3	3		
CO2	3	3	3			3	3		3
CO3	3	3	3	3		3	3	3	3
CO4	3			3	3	3	3		

3-High; 2-Medium; 1-Low

Course Content:

Project: Part 2 is a continuation of Project: Part 1 in 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 project supervisor/internal supervisor shall do monthly evaluation of the progress. 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 middle of the semester. This shall be followed by the end semester evaluation by the committee.

MASTER OF TECHNOLOGY

in

MICROWAVE AND COMMUNICATION ENGINEERING

Electives

DEPARTMENT OF ELECTRONICS

COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

Kochi - 682 022, India

24-510-0X11 **Antennas for Communication Systems**

L	T	P	C
3	1	0	3

Prerequisites	:	Electromagnetic fields, General familiarity with transmission lines
Course Description	:	The objective of this course is to provide an understanding of antenna concepts, and modern antenna designs. Starting from the basic antenna parameters, the course will discuss various types of antennas including the planar antennas along with an in-depth study on the analysis and design of arrays. A brief glimpse to the design on antennas for the future wireless technologies is given at the end with a view that the student can further explore the topic, if interested.
Course Outcome	:	After the completion of the course, student will be able to

CO1	Apply mathematical fundamentals of the antenna theory to understand the basic principle of radiation, along with a physical understanding of how different types of antennas radiate and to measure their various figures of merit	Apply
CO2	Acquire an understanding of antenna arrays enabling them to analyse its different types and configuration	Analyse
CO3	Familiarise with the working of several conventional antennas as well as antennas for modern wireless systems	Understand
CO4	Evaluate an appropriate antenna/array type depending on the application and develop a preliminary design for a given frequency of operation	Evaluate

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3	3			2	3	2	2
CO2	3	3	3			2	3	3	2
CO3	3	3	2			2	3	2	2
CO4	3	3	3			3	3	3	3

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Preliminary Topics and Basic Definitions:** Review of Maxwell's Equations and Boundary conditions, Wave equations, Hertzian dipoles, Half-wave dipoles, Antenna radiation mechanism, Fundamental parameters and Figures of merit; Antenna measurements- Principle, Ranges, and Parameters

Module 2	**Wire Antennas:** Finite Length Dipoles, Monopoles, Inverted-F Antennas, Loop Antennas, Yagi-Uda and Log-periodic antennas
Module 3	**Types of Antennas:** Broadband Antennas- Helical, Bi-conical, Frequency Independent Antennas; Aperture Antennas- Radiation from apertures, Horn and Parabolic dish antennas, Microstrip patch antennas
Module 4	**Arrays:** Array Factor, Pattern Multiplication, Uniform and Non-uniform Excitation, Mutual Coupling, Phased Arrays and Array Feeding Techniques, Array synthesis approaches
Module 5	**Modern Antennas:** Antenna Design Requirements for Smartphones, Wireless Dongles, Wearable Devices, Base stations and Access points; MIMO Antenna configurations, Pattern and polarization diversity; mm-Wave Antennas and their feeding techniques; Terahertz Antenna Technologies for 6G Communication Systems

References:

[1] W. L. Stutzman and G. A. Thiele, *Antenna Theory and Design*, 3rd ed. John Wiley & Sons, 2012.

[2] C. A. Balanis, *Antenna Theory: Analysis and Design*, 4th ed. John wiley & sons, 2016.

[3] J. D. Kraus, R. J. Marhefka, and A. S. Khan, *Antennas and Wave Propagation*, 4th ed. Tata McGraw-Hill Education, 2017.

[4] S. K. Koul and G. Karthikeya, *Antenna Architectures for Future Wireless Devices.* Signals and Communication Technology, Springer, 2022.

[5] U. Nissanov and G. Singh, *Antenna Technology for Terahertz Wireless Communication.* Springer Nature, 2023.

[6] W. Hong and C.-Y. D. Sim, *Microwave and Millimeter-wave Antenna Design for 5G Smartphone Applications.* John Wiley & Sons, 2023.

24-510-0X12 **Machine Learning**

L	T	P	C
3	**1**	**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, student will be able to

CO1	Design linear, nonlinear regression and logistic regression models	Apply
CO2	Design Artificial Neural Network for solving ML problems	Apply
CO3	Design Support Vector Machine for solving ML problems	Apply
CO4	Design unsupervised learning methods like clustering algorithms and dimensionality reduction algorithms	Apply
CO5	Design ML system suitable to the problem and analyse the model performance	Analyse

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3	2	2			3	2	2
CO2	3	3	2	2			3	2	2
CO3	3	3	2	2			3	2	2
CO4	3	3	2	2			3	2	2
CO5	3	3	2	2			3	2	2

3-High; 2-Medium; 1-Low

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	**Artificial Neural Network:** Artificial Neural Network: Introduction, mathematical model of neuron, activation functions, network architectures, Learning-cost function, gradient descent, optimisation, XOR problem, multilayer perceptron, back propagation algorithm, differentiability, feature scaling, initialization, stopping criteria. Deep Learning, Universal function approximation, feature extraction, Pattern recognition and classification, Stochastic Gradient Descent and Batch Gradient Descent

Module 3	**Support Vector Machine:** Introduction, optimization objective, large margin classification, support vectors, Separating hyperplane approaches, support vector machine formulation, SVMs for Linearly Non Separable Data, SVM Kernels, Hinge Loss formulation
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
Module 5	**ML System Design and Evaluation Measures:** Learning with large datasets, stochastic gradient descent, batch and mini-batch gradient descent. Evaluating a Hypothesis, Model Selection, Regularisation, Training Validation Testing, Diagnosing Bias vs. Variance. Two Class Evaluation Measures, Confusion Matrix, Precision Recall curve, ROC Curve, Area Under Curve(AUC). Applications of machine learning and deep learning architectures in system design, Deep Learning in Communication Systems, Signal Classification and Pattern Recognition

References:

[1] T. Mitchell, *Machine Learning.* McGraw-Hill, 1997.

[2] S. Haykin, *Neural Networks and Learning Machines*, 3rd ed. Pearson Education India, 2016.

[3] T. Hastie, R. Tibshirani, and J. H. Friedman, *The Elements of Statistical Learning: Data Mining, Inference, and Prediction*, 2nd ed. Springer Series in Statistics, 2016.

[4] C. M. Bishop, *Pattern Recognition and Machine Learning.* Springer - Information Science and Statistics, 2011.

[5] S. S. Shwartz and S. B. David, *Understanding Machine Learning: From Theory to Algorithms.* Cambridge University Press, 2014.

[6] E. Alpaydin, *Introduction to Machine Learning*, 2nd ed. MIT Press, 2010.

[7] M. Mohri, A. Rostamizadeh, and A. Talwalkar, *Foundations of Machine Learning.* MIT Press, 2012.

24-510-0X13 Electromagnetic Interference and Compatibility

L	T	P	C
3	1	0	3

Prerequisites	:	General familiarity with EM fields, transmission lines and circuit theory
Course Description	:	The objective of this course is to provide an understanding of important concepts of Electromagnetic Compatibility which are fundamental for the design of electronics systems and devices in order to minimize electromagnetic interference. These concepts will be applied to a frequency range covering conduction and radiation, according the applicable standards.
Course Outcome	:	After the completion of the course, student will be able to

CO1	Implement the various measurement techniques for electromagnetic interference and for electromagnetic compatibility	Apply
CO2	Recognize the various agencies and standards associated with EMI/EMC	Understand
CO3	Analyse various EM compatibility issues with regard to the design of PCBs and ways to improve the overall system performance	Analyse
CO4	Apply real-world EMC design constraints and make appropriate trade-offs to achieve the most cost effective design that meets all requirements	Apply

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3	2				3		3
CO2	3	3	2				3		2
CO3	3	3	3				3	3	3
CO4	3	3	3			3	3	3	2

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Introduction to Aspects of EMC:** EMI Sources, EMC units, Signal source specification, Advantages of EMC Design, EMC Requirements for Electronic Systems, Measurement of Radiated and Conducted Emissions. **Signal Spectra:** Spectra of Digital Waveforms, Spectral Bounds for Trapezoidal Waveforms, Spectrum Analyzer principle

Module 2	**Signal Integrity:** Transmission-Line Equations, High-Speed Digital Interconnects, Effect of Terminations, Matching Schemes, Effects of Line Discontinuities. **Non-ideal Behavior of Components:** Wires, resistors, capacitors, inductors, Printed Circuit Board (PCB), Effect of Component Leads, Mechanical Switches
Module 3	**Conducted Emissions and Conducted Susceptibility:** Measurement, Power Supplies, Filters, Placement. **Radiated Emissions and Conducted Susceptibility:** Simple Emission Models for Wires and PCB Lands, Simple Susceptibility Models for Wires and PCB Lands
Module 4	**Crosstalk:** Three-Conductor Transmission Lines and Crosstalk, Shielded Wires, Twisted Wires. **Shielding:** Shielding Effectiveness- Far-Field Sources, Near-Field Sources; Low Frequency, Magnetic Field Shielding
Module 5	**System Design for EMC:** Shielding, Ground, PCB Design, System Configuration and Design, Common EMC Issues in Practice and Design Guidelines

References:

[1] C. R. Paul, *Introduction to Electromagnetic Compatibility*, three ed. John Wiley & Sons, 2022.

[2] H. W. Ott, *Electromagnetic Compatibility Engineering*, 2nd ed. John Wiley & Sons, 2009.

[3] W. D. Kimmel and D. Gerke, *Electromagnetic Compatibility in Medical Equipment*. IEEE & Interpharm Press, 1995.

[4] V. P. Kodali, *Engineering EMC Principles, Measurements and Technologies*, 2nd ed. Wiley-Blackwell, 2001.

24-510-0X14 Software Defined Radio for Communication Engineers

L	T	P	C
3	1	0	3

Prerequisites	:	Basic knowledge of Communication Systems, Digital Signal Processing
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.
Course Outcome	:	After the completion of the course, 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	Apply the insight to appreciate the usage of SDR for modern communication applications	Apply

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3					2	2		
CO2	3						2		
CO3	3					3	2	2	
CO4	3					3	3	2	

3-High; 2-Medium; 1-Low

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.**Multirate Signal Processing:** Introduction, Sample Rate Conversion Principles, Polyphase Filters, Digital Filter Banks
Module 4	**Case studies:** Software Defined Radio for Wi-Fi Jamming, Experimental study of OFDM implementation utilizing GNU Radio and USRP-SDR, Developing a generic software-defined radar transmitter using GNU Radio
Module 5	**Case studies :** 5G New Radio Prototype Implementation Based on SDR, Challenges of 5G testing using SDR, Characterisation of 5G using SDR platform

References:

[1] J. H. Reed, *Software Radio: A Modern Approach to Radio Engineering.* Prentice Hall Professional, 2002.

[2] T. J. Rouphael, *RF and Digital Signal Processing for Software-defined Radio.* Elsevier, 2008.

[3] C. R. Johnson Jr and W. A. Sethares, "Telecommunication breakdown," *Concepts of Communication Transmitted via Software-Defined Radio*, 2004.

[4] [Online]. Available: https://www.gnuradio.org/doc/doxygen-3.7.4.1/index.html

[5] [Online]. Available: https://pysdr.org/content/intro.html

[6] A. M. Wyglinski, R. Getz, T. Collins, and D. Pu, *Software-defined Radio for Engineers.* Artech House, 2018.

[7] L. Y. Hosni, A. Y. Farid, A. A. Elsaadany, M. A. Safwat *et al.*, "5G New Radio Prototype Implementation based on SDR," *Communications and Network*, vol. 12, no. 01, pp. 1–27, 2019.

24-510-0X15 **Information Theory and Coding**

L	T	P	C
3	**1**	**0**	**3**

Prerequisites	:	Advanced Communication Systems
Course Description	:	This course provides an introduction about the lossy and lossless compression techniques in coding theory. It also delves into the modern coding theory concepts that can be adopted for the relevant application based on the rate requirements.
Course Outcome	:	After the completion of the course, the student will be able to

CO1	Understand the basic theory behind compression algorithms for Lossless and Lossy Data Compression.	Understand
CO2	Apply channel capacity and coding techniques to achieve efficient and reliable communication.	Apply
CO3	Design encoders and decoders for a given error correcting capability	Apply
CO4	Analyse the problem and apply suitable signal compression methods that satisfy the rate constraints for various applications.	Analyse

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3								
CO2	3	3					3		
CO3	3	3	3	3	3	3	3	3	3
CO4	3	3	3	3	3	3	3	3	3

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Introduction to Information Theory:** Entropy, Memoryless sources, Markov sources, Entropy of a discrete Random variable, Joint, conditional and relative entropy, Mutual Information and conditional mutual information, Differential Entropy, Joint, relative and conditional differential entropy, Mutual information
Module 2	**Source Coding:** Shannon's Source Coding Theory and algorithms – Kraft inequality, Huffman algorithm, Arithmetic coding, Lempel Ziv coding, Coding for sources with memory

Module 3	**Error Correction Coding:** Channel coding theorem, Error Correction Codes – Introduction to Galois fields, polynomial arithmetic, linear block codes for error correction, Cyclic Codes, BCH codes, Reed Solomon Codes, Convolutional codes, Trellis coded Modulation, Codes for 4G and 5G - LDPC and Turbo Codes, Capacity achieving Polar Codes (proposed for the uplink control channels in 5G)
Module 4	**Lossy Compression:** Rate Distortion Theory: Calculation of rate-distortion function (Binary Source, Gaussian Source); Converse to the rate-distortion function; Computation of channel capacity and the rate distortion function, The Rate-Distortion-Accuracy Tradeoff: JPEG Case Study
Module 5	**Compression standards** Review of Transforms - Transform coding - Subband coding - Wavelet Based Compression, Data Compression standards: Speech Compression Standards, Audio Compression standards, Image Compression standards, Video Compression Standards, The role of compression standards in image processing

References

[1] T. M.Cover and J.A.Thomas, Elements of Information Theory, 2nd Ed., John Wiley & Sons, New Jersey, USA, 2006.

[2] RanjanBose, Information Theory, Coding and Cryptography, 2nd Ed.,Tata McGraw-Hill, 2008.

[3] Shu Lin and Daniel Costello, Error Control Coding, 2nd Ed., by Pearson, 2004.

[4] P.S. Satyanarayana, "Concepts of Information Theory and Coding", Dynaram Publication, 2005.

[5] Richard B. Wells, "Applied Coding and Information Theory for Engineers" Pearson Education, LPE 2004.

[6] Rudiger Urbanke and Thomas Richardson, Modern coding theory, Cambridge, 2008.

[7] Luo X, Talebi H, Yang F, Elad M, Milanfar P. The rate-distortion-accuracy tradeoff: Jpeg case study. arXiv preprint arXiv:2008.00605, 2020.

24-510-0X16 **Optimization Techniques**

L	T	P	C
3	1	0	3

Prerequisites : A basic course in Advanced mathematics

Course Description : Through problem solving and design and developement activities, the course facilitates the students to have an in depth understanding of the Optimization techniques, in various fields.

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

CO1	Achieve Knowledge of design and development of problem solving skills.	Apply
CO2	Understand the principles of optimization.	Understand
CO3	Design and develop analytical skills.	Analyze
CO4	Summarize the Linear, Non-linear and Geometric Programming	Apply
CO5	Understands the concept of Dynamic programming.	Understand

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3	1			2		2	1
CO2	3					2			1
CO3	3	3	1			2		2	1
CO4	3	3	1			2		2	1
CO5	3					2			1

Course Content:

Module 1	**Introduction:** -Introduction to optimization, engineering applications of optimization, Formulation of structural optimization problems as programming problems. Optimization Techniques: Classical optimization techniques, single variable optimization, multivariable optimization with no constraints, unconstrained minimization techniques and algorithms constrained optimization solutions by penalty function techniques, Lagrange multipliers techniques and feasibility techniques
Module 2	**Linear Programming:** - Linear programming, standard form of linear programming, geometry of linear programming problems, solution of a system of linear simultaneous equations, pivotal production of general systems of equations, simplex algorithms, revised simpler methods, duality in linear programming
Module 3	**Non-linear programming:**- Non-linear programming, one dimensional minimization methods, elimination methods, Fibonacci method, golden section method, interpolation methods, quadratic and cubic methods, Unconstrained optimization methods, direct search methods, random search methods, descent methods

Module 4	**Constrained optimization techniques:** - Constrained optimization techniques such as direct methods, the complex methods, cutting plane method, exterior penalty function methods for structural engineering problems. Formulation and solution of structural optimization problems by different technique. **Convex optimisation:-** Convex Sets, Convex Functions and Generalizations, Convex Optimization Problems, Semidefinite Programming
Module 5	**Geometric programming:-** Geometric programming, conversion of NLP as a sequence of LP/ geometric programming. Dynamic programming: Dynamic programming conversion of NLP as a sequence of LP/ Dynamic programming

References:

[1] L. Spunt, *Microwave Active Circuit Analysis and Design.* Prentice Hall, 1971.

[2] S. Rao, *Optimization – Theory and Practice*, 5th ed. Wiley Eastern Ltd, 2019.

[3] K. Uri, *Optimum structural design : concepts, methods, and applications.* McGraw-Hill, 1981.

[4] B. Richard, *Schaum's outline of theory and problems of operations research.* McGraw-Hill, 1997.

[5] B. S.S., *Structural optimization using sequential linear programming.* Vikas Publishing House Pvt. Ltd., 2003.

[6] S. H. Z. Edwin K. P. Chong, *An Introduction to Optimisation.* John Wiley & Sons, 2013.

[7] C. M. S. Mokhtar S. Bazaraa, Hanif D. Sherali, *Nonlinear Programming: Theory and Algorithms.* John Wiley & Sons, 2005.

[8] L. V. Stephen Boyd, *Convex Optimization.* Cambridge University Press, 2004.

24-510-0X17 **Estimation and Detection Theory**

L	T	P	C
3	1	0	3

Prerequisites	:	Basic probability theory, Basics of Linear Algebra, Basic Communication Theory
Course Description	:	The course outlines the basics of estimation and detection theory. It introduces the students to classical and Bayesian estimators, estimation bounds, hypothesis testing, and various detection methods to detect signals under noise.
Course Outcome	:	After the completion of the course, the student will be able to

CO1	Understand the classical estimation and detection techniques	Understand
CO2	Apply the various estimation techniques for modern wireless applications	Apply
CO3	Mathematically identify and solve practical detection and estimation problems and analyze their performance	Analyse

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3						2		
CO2	3	3				3	2		
CO3	3	3				3	3	3	3

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Introduction to Estimation Theory:** Minimum variance unbiased estimation, best linear unbiased estimation Cramer-Rao lower bound (CRLB) Maximum Likelihood estimation (MLE), Bayseaen estimation-Minimum Mean-square error (MMSE) , Maximum a Posteriori (MAP) estimation, Least Squares (LS) Estimation
Module 2	**Estimation and Filtering:** Recursive LS method Kalman filtering, Application: MIMO Wireless Channel Estimation, Error Covariance of Estimation, Equalization for Frequency Selective Channels, Kalman Filtering, Wiener filtering
Module 3	**Introduction to Signal Detection:** Formulation of the binary hypothesis testing problem, Maximum Likelihood-based Optimal Detection, Likelihood Ratio Test and Performance, Neyman Pearson Criterion for optimal detection, Minimum probability of error detector, Bayesian minimum risk detector

Module 4	**Detection of Deterministic/Random Signals:** Matched Filter Detector, Detection of signal under White noise and colored noise, Performance of Matched filter detection, Random signal detection- performance of Random signal detection, Detectors for MIMO
Module 5	**Signals with unknown parameters**. Deterministic Signals with unknown parameters, Generalized Log likelihood Ratio Test (GLRT), Bayesian Approach, GLRT for the Linear Model

References

[1] H. Vincent Poor, An Introduction to Signal Detection and Estimation (2nd Edition), Springer-Verlag, 1994.

[2] Steven M. Kay, Fundamentals of Statistical Signal Processing - Volume I: Estimation Theory, Prentice Hall, 1993.

[3] Steven M. Kay, Fundamentals of Statistical Signal Processing - Volume II: Detection Theory, Prentice Hall, 1993.

[4] Statistical Inference for Engineers and Data Scientists by Moulin and Veeravalli, Cambridge University Press, 2019.

24-510-0X18 Signal Integrity for High-Speed Digital Design

L	T	P	C
3	1	0	3

Prerequisites : This course will discuss the principles of signal integrity and its applications in the proper design of high-speed digital circuits. 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, student will be able to

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

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3	2				3	2	2
CO2	3	3	2				3	2	2
CO3	3	3	3				3	2	2
CO4	3	3	3			2	3	3	3

3-High; 2-Medium; 1-Low

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 and 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 and 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] E. Bogatin, *Signal and Power Integrity -Simplified, (3rd Edition),*. Prentice Hall, 2018.

[2] H. L. H. Stephen H. Hall, *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] G. H. S. Hall and J. McCall, *High Speed Digital Design: A Handbook for Interconnect Theory and Design Practices.* Wiley IEEE Press, 2000.

24-510-0X19	**Software Defined Radio Lab**	

L	T	P	C
0	**0**	**4**	**2**

Prerequisites	:	Advanced Communication Systems
Lab Description	:	Implementation of basic analog and digital communication systems in SDR using GNURadio/ Labview
Lab Outcome	:	After the completion of the lab, the student will be able to

CO1	Familiarize with the GNU Radio and Labview software	Understand
CO2	Generate the block schematic in GNU Radio/ Labview and test using software defined radio (SDR) transceivers	Apply
CO3	Implement and analyse basic analog and digital communication systems in SDR	Analyse
CO4	Implement and analyse an end-to-end communication system prototype using SDR	Analyse

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3		3					2	
CO2	3	3	3					3	
CO3	3	3	3	2	3	3		3	3
CO4	3	3	3	2	3	3		3	3

3-High; 2-Medium; 1-Low

Course Content:

Sample List of Experiments*	
Implementation of the following in MATLAB/Octave/Python	
1	To setup an FM Receiver
2	To setup an FM Transmitter and Receiver Station
3	To demonstrate BPSK/QPSK Modulation & Demodulation
4	To demonstrate DPSK Modulation & Demodulation
5	To setup a 2×2 MIMO system

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

References:

[1] [Online]. Available: https://www.gnuradio.org/doc/doxygen-3.7.4.1/index.html

[2] [Online]. Available: https://pysdr.org/content/intro.html

[3] A. M. Wyglinski, R. Getz, T. Collins, and D. Pu, *Software-defined Radio for Engineers*. Artech House, 2018.

24-510-0X20 **Antennas Lab**

L	T	P	C
0	0	4	2

Prerequisites	:	Taken with Antennas for Communication Systems
Course Description	:	The objective of this lab is to introduce the design, simulation and verification of performance of various antennas and arrays
Course Outcome	:	After the completion of the course, student will be able to

CO1	Characterise the performance of the various standard antenna/array designs using open source/licensed CAD tools	Apply
CO2	Measure the radiation performance different antennas using a Network Analyser and an anachoic chamber	Analyse
CO3	Develop an antenna design for a given set of design parameters and verify its performance	Apply

COs to POs Mapping

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3	3				3	3	3
CO2	3	2	3				3	2	2
CO3	3	3	3			2	3	3	3

3-High; 2-Medium; 1-Low

Course Content:

Sample List of Experiments*	
1	Familiarization with antenna simulation tools and measurement equipments
2	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 and the radiation patterns of standard antennas: Horn, Dipole, Vivaldi, Spiral etc
4	Design and simulation of different types of antenna arrays

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

24-510-0X21 **5G Technologies and Standards**

L	T	P	C
3	1	0	3

Prerequisites	:	Digital Communications, Advanced Communication Systems, Wireless Networks
Course Description	:	The aim of this course is to let the students understand that air Interface is one of the most important elements that differentiate between 2G, 3G, 4G and 5G. While 3G was CDMA based, 4G was OFDMA based; this course reveals the contents of air interface for 5G. This course gives an overview of 5G vision that aims to provide extremely low delay services, great service in crowd, enhanced mobile broadband, ultra-reliable and secure connectivity, ubiquitous QoS, and highly energy efficient networks.
Course Outcome	:	After the completion of the course, student will be able to

CO1	Understand the evolution of mobile communication standards developed over the years	Understand
CO2	Analyse the 5G potential and applications, case studies	Analyse
CO3	Interpretation of how virtualisation of network functions helps in scalability and ease of operations	Apply
CO4	Analyse the use of advanced techniques in cellular communications	Analyse
CO5	Appraise the current Status and future challenges for 5G and beyond	Analyse

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	2	2							
CO2	3	2					3		3
CO3	3					2	2		
CO4	3	2				2	3		3
CO5	3	2		2	2	2	3		3

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Evolution from 1G to 5G:** Analog voice systems in 1G; digital radio systems in 2G, voice and messaging services, TDMA based GSM,CDMA, 2.5G (GPRS), 2.75G (EDGE); IMT2000: 3G UMTS, W-CDMA, HSPA, HSPA+, 3G services and data rates; IMT Advanced: 4G, LTE, VoLTE, OFDM, MIMO, LTE Advanced Pro (3GPP Release 13+); IMT2020: 5G, enhancements in comparison to IMT Advanced

Module 2	**Basics of 5G :** 5G potential and applications; Usage scenarios: enhanced mobile broadband (eMBB), ultra reliable low latency communications (URLLC), massive machine type communications (MMTC), D2D communications, V2X communications, Massive MIMO
Module 3	**5G architecture:** Spectrum for 5G, spectrum access/sharing; millimetre Wave communication, channels and signals/waveforms in 5G, carrier aggregation, small cells, dual connectivity, NFV and SDN, Basics about RAN architecture, centralized RAN, open RAN, High-level requirements for the 5G architecture, Functional architecture and 5G flexibility, Physical architecture and 5G deployment
Module 4	**5G radio-access technologies:** Orthogonal multiple-access systems, Spread spectrum multiple-access systems, Capacity limits of multiple-access methods, Non-orthogonal multiple access (NOMA), Massive MIMO, beam formation, FAPI: PHY API Specification, user plane protocol- Service Data Adaptation Protocol (SDAP); multi-access edge computing (MEC); software defined networking (SDN), network function virtualization (NFV); network slicing; restful API for service-based interface; private networks
Module 5	**Current state and Challenges ahead :** 5G penetration in developed countries; deployment challenges in low-middle income countries, stronger backhaul requirements, dynamic spectrum access and usage of unlicensed spectrum, contrasting radio resource requirements; large cell usage: LMLC; possible solutions for connectivity in rural areas (BharatNet, TVWS, Long-range WiFi, FSO); non-terrestrial fronthaul/backhaul solutions: LEOs, HAP/UAV, Vision for 6G

References:

[1] [Online]. Available: https://www.3gpp.org/specifications-technologies/releases/release-15

[2] E. Dahlman, S. Parkvall, and J. Skold, *5G NR: The Next Generation Wireless Access Technology.* Academic Press, 2020.

[3] A. Osseiran, J. F. Monserrat, and P. Marsch, *5G Mobile and Wireless Communications Technology.* Cambridge University Press, 2016.

[4] S. Ahmadi, *5G NR: Architecture, Technology, Implementation, and Operation of 3GPP New Radio Standards.* Academic Press, 2019.

[5] E. Dahlman, S. Parkvall, and J. Skold, *4G, LTE-advanced Pro and the Road to 5G.* Academic Press, 2016.

24-510-0X22 **Machine Learning Lab**

L	T	P	C
0	0	4	2

Prerequisites : None

Lab Description : This lab provides experiments to implement machine learning algorithms using Python with the help of open source libraries such as sklearn, keras, pytorch, etc.

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

CO1	Design and implement linear, nonlinear regression and logistic regression models	Apply
CO2	Design and implement ANN for solving ML problems	Apply
CO3	Design and implement SVM for solving ML problems	Apply
CO4	Design and implement unsupervised learning methods like clustering algorithms and dimensionality reduction algorithms	Apply
CO5	Design ML system suitable to the problem, analyse and evaluate the model performance	Analyse

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1			3	3	2	2	3	2	3
CO2			3	3	2	2	3	2	3
CO3			3	3	2	2	3	2	3
CO4			3	3	2	2	3	2	3
CO5			3	3	2	2	3	3	3

3-High; 2-Medium; 1-Low

Course Content:

Sample List of Experiments*	
1	Familiarisation Python, Jupyter notebook, and libraries such as sklearn, keras and pytorch
2	Implement the Linear and Logistic Regression model with gradient descent optimisation
3	Implement Artificial Neural Network models and optimise using back propagation algorithm
4	Implement Support Vector Machines for classification tasks for linear and non-linear data
5	Implement k-means clustering algorithm and Principle Component Analysis algorithm

6	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.

References:

[1] A. Géron, *Hands-on Machine Learning with Scikit-Learn, Keras, and TensorFlow*, 3rd ed. " O'Reilly Media, Inc.", 2022.

[2] J. Krohn, *Deep Learning with TensorFlow, Keras, and PyTorch.* Pearson, 2020.

[3] Documentations of python libraries.

24-510-0X23 **EMI/EMC Lab**

L	T	P	C
0	0	4	2

Prerequisites : Taken with Electromagnetic Interference and Compatibility

Course Description : The objective of this lab is to familiarise the student with the significance of EMI/EMC and their impact in circuit design using appropriate experiments and simulation studies.

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

CO1	Measure the conducted emission, radiated emission and crosstalk.	Apply
CO2	Determine the EM compatibility of a device	Analyse
CO3	Apply EMI mitigation techniques such as shielding.	Apply

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	2	2				3	2	2
CO2	3	2	2			2	3	2	3
CO3	3	3	3			2	3	2	2

Sample List of Experiments*

1	Familiarise with conducted and radiated emission measurement and simulation setup
2	Study and simulate different crosstalk in the cable and its reduction technique
3	Measure crosstalk in a three conductor transmission line using VNA
4	tudy the characteristics and measure the conducted emission of a Current Probe
5	Measure board level emission using Magnetic Field loop Probes
6	Measure radiated emission from mobile tower and mobile phone
7	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.

24-509-0X15 **Analog & RF IC Design**

L	T	P	C
3	1	0	3

Prerequisites	:	Circuit analysis
Course Description	:	This course introduces students to the analysis and design of basic analog integrated circuit components like amplifiers, current mirrors and biasing circuits. Specifications and trade-offs involved in analog design are covered. The course also covers various factors involved in the design of RF integrated circuit components.
Course Outcome	:	After the completion of the course, student will be able to

CO1	Perform small signal analysis using MOSFET models	Apply
CO2	Design single stage and differential amplifiers for given specification	Apply
CO3	Discuss about appropriate current sources and voltage references for biasing	Undersatnd
CO4	Understand the basic building blocks of RF ICs and the trade-offs involved in RF designs	Understand
CO5	Explain the methodologies for designing RF IC components with given specifications	Undersatnd

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3					3		
CO2	3	3					3		
CO3	3						3		
CO4	3						3		
CO5	3						3		

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Introduction:** Review of 4 terminal MOSFET, small signal model and analysis, high frequency model **RF Basic Concepts:** Non linearity and its effects, noise, sensitivity & dynamic range, passive impedance transformation, scattering parameters, bandwidth estimation techniques
Module 2	**Single Stage Amplifiers:** Single stage amplifiers - common source, source follower, common gate, cascode amplifiers, frequency response, noise

Module 3	**Differential Amplifiers:** Basic differential pair, common mode response, frequency response, noise, MOS transistor mismatch, effect of transistor mismatch **Current Mirrors & Biasing:** Basic and cascode current mirrors, effect of transistor mismatch, biasing techniques, self biasing circuits, supply independent bias circuits, bandgap reference
Module 4	**Low Noise Amplifiers:** Input matching, LNA topologies, gain and band switching, non linearity calculations, power constrained design optimizations, design examples **Mixers:** Mixer fundamentals, mixing using non linear systems, multiplier based mixers
Module 5	**Oscillators:** Ring oscillators, LC oscillators, inductors and capacitors, voltage controlled oscillators **Phase Locked Loops**: Simple PLL, Type II PLL, Non-idealities, phase noise

References:

[1] Behzad Razavi, *Design of Analog CMOS Integrated Circuit*, 2nd ed. McGraw Hill India, 2017.

[2] Thomas H. Lee, *The Design of CMOS Radio-Frequency Integrated Circuits*, 2nd ed. Cambridge University Press, 2014.

[3] Behzad Razavi, *RF Microelectronics*, 2nd ed. Prentice Hall, 2012.

[4] Phillip E. Allen and Douglas R. Holberg, *CMOS Analog Circuit Design*, 3rd ed. Oxford University Press, 2013.

[5] Jacob Baker R., *CMOS Circuit Design, Layout and Simulation*, 3rd ed. Wiley-Blackwell, 2010.

Master of Science

(M.Sc.) Degree Program

ELECTRONIC SCIENCE

Outcome Based Syllabus

DEPARTMENT OF ELECTRONICS
COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

MASTER OF SCIENCE

in

ELECTRONIC SCIENCE

Syllabus

(2024 Admission Onwards)

DEPARTMENT OF ELECTRONICS

COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

Kochi - 682 022, India

Contents

1 Vision, Mission, PEO and PO 1

2 Course Structure 3

3 **Semester 1** 7

3.1 24-305-0101 : Electronic Circuits 9

3.2 24-305-0102 : Signals and Systems 11

3.3 24-305-0103 : Digital System Design 13

3.4 24-305-0104 : RF Technology 15

3.5 24-305-0105 : Electronic Circuits Lab 17

3.6 24-305-0106 : Signals and Systems Lab 19

3.7 24-305-0107 : Digital System Design Lab 21

3.8 24-305-0107 : Digital Fabricaation 23

4 **Semester 2** 25

4.1 24-305-0101 : Programming for Embedded Systems 27

4.2 24-305-0102 : Digital Signal Processing 29

4.3 24-305-0103 : Control Systems 31

4.4 24-305-0104 : Programming Lab 33

4.5 24-305-0105 : Control Systems Lab 35

5 **Semester 3** 37

5.1 24-305-0301 : Seminar 39

5.2 24-305-0302 : Communication Systems 41

5.3 24-305-0303 : Embedded System Design 43

5.4 24-305-0304 : Embedded Systems Lab 45

6 **Semester 4** . . . 47
6.1 24-305-0401 : Project . . . 49
7 **Electives** . . . 51
7.1 24-305-0X11 : Robotics & Automation . . . 53
7.2 24-305-0X12 : Mobile Robotics . . . 55
7.3 24-305-0X13 : Microwave Integrated Circuits . . . 57
7.4 24-305-0X14 : FPGA Based System Design . . . 59
7.5 24-305-0X15 : Data Structures . . . 61
7.6 24-305-0X16 : Embedded Software and Real Time Systems . . . 63
7.7 24-305-0X17 : NPTEL/MOOC Course . . . 65
7.8 24-305-0X21 : Robotics & Automation Lab . . . 67
7.9 24-305-0X22 : Mobile Robotics Lab . . . 69
7.10 24-305-0X23 : Microwave Integrated Circuits Lab . . . 71
7.11 24-305-0X24 : Data Structure Lab . . . 73
7.12 24-305-0X25 : Embedded Software Lab . . . 75
7.13 24-305-0X26 : Communication Systems Lab . . . 77
7.14 24-305-0305 : Mini Project . . . 79
8 **Electives Mapped from VLSI and Embedded Systems** . . . 81
8.1 24-509-0101 : Digital System Design using HDLs . . . 83
8.2 24-509-0102 : Digital Integrated Circuits . . . 85
8.3 24-509-0201 : Digital Verification and Testing . . . 87
8.4 24-509-0202 : FPGA Based Embedded SoC Design . . . 89
8.5 24-509-0X14 : Neural Networks . . . 91
8.6 24-509-0X15 : Analog & RF Integrated Circuit Design . . . 93
8.7 24-509-0X17 : Device Physics and Modeling for Integrated Circuits . . . 95
8.8 24-509-0X20 : Image & Video Processing . . . 97
8.9 24-509-0104 : Digital System Design using HDLs Lab . . . 99
8.10 24-509-0105 : Digital Integrated Circuits Lab . . . 101

8.11 24-509-203: Digital Verification and Testing Lab 103

8.12 24-509-0X28: FPGA System Design Lab 105

9 **Electives Mapped from Microwave and Communication Engineering** 107

9.1 24-510-0201: Wireless Communications 109

9.2 24-510-0202: Radar Systems 111

9.3 24-510-0X11: Antennas for Communication Systems 113

9.4 24-510-0X12: Machine Learning 115

9.5 24-510-0X13: Electromagnetic Interference and Compatibility 117

9.6 24-510-0X14: Software Defined Radio for Communication Engineers 119

9.7 24-510-0X21: 5G Technologies and Standards 121

9.8 24-510-0203: Wireless Communication Lab 123

9.9 24-510-0X19: Software Defined Radio Lab 125

9.10 24-510-0X20: Antenna Lab 127

9.11 24-510-0X22: Machine Learning Lab 129

9.12 24-510-0X23: EMI/EMC Lab 131

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*

PROGRAMME EDUCATIONAL OBJECTIVES (PEO)

PEO1	Graduates apply their technical competence in theory, hardware, software and EDA tools to solve real-life problems in their chosen specialization
PEO2	Graduates apply their communication skill, leadership quality, research aptitude and ethics to build a strong career in their chosen areas of specialization through continuous learning
PEO3	Graduates develop capabilities for occupying prominent professional positions in academia, industry, research, and entrepreneurship

PEO-Mission Matrix:

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

Programme Outcomes: At the end of the programme, the student will be able to

PO1	Enhance knowledge by understanding, experimenting and comparing information (existing and new) to solve problems in the field of electronics
PO2	Demonstrate ability to model, simulate and evaluate the phenomenon and systems in the chosen areas of electronics
PO3	Use state-of-the-art tools to design, development and analysis problems and provide time bound and economical solutions
PO4	Work in collaborative and ethical manner with others in a team, contribute to the management, planning and implementations
PO5	Effectively communicate technical content through written reports/design documents, and presentations
PO6	Engage in lifelong learning independently to enhance knowledge and skills that can contribute to the continuous improvement of individuals and society

Programme Specific Outcomes:

PSO1	An ability to independently carry out research/investigation to solve real world technical problems
PSO2	Integrate electronic subsystems to develop communication/RF/intelligent/ VLSI systems
PSO3	Proficiency in usage of computer aided design and simulation tools system development

PEO-PO-PSO Mapping:

	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
PEO1	✓	✓	✓	✓					✓
PEO2	✓		✓		✓	✓	✓		
PEO3				✓	✓	✓		✓	

COURSE STRUCTURE

Semester 1

No.	Course Code	Course Title	L	T	P	Credits	C/E	CA	ES	Total
1	24-305-0101	Electronic Circuits	3	2	0	3	C	50	50	100
2	24-305-0102	Signals and Systems	3	2	0	3	C	50	50	100
3	24-305-0103	Digital System Design	3	2	0	3	C	50	50	100
4	24-305-0104	RF Technology	3	2	0	3	C	50	50	100
5	24-305-0105	Electronic Circuits Lab	0	0	4	2	C	100	0	100
6	24-305-0106	Signals and Systems Lab	0	0	4	2	C	100	0	100
7	24-305-0107	Digital System Design Lab	0	0	4	2	C	100	0	100
8	24-305-0108	Digital Fabrication	0	0	1	0	C			
		Total				18				

Semester 2

No.	Course Code	Course Title	L	T	P	Credits	C/E	CA	ES	Total
1	24-305-0201	Programming for Embedded Systems	3	2	0	3	C	50	50	100
2	24-305-0202	Digital Signal Processing	3	2	0	3	C	50	50	100
3	24-305-0203	Control Systems	3	2	0	3	C	50	50	100
4	24-305-02XX	Program Elective	3	1	0	3	E	50	50	100
		Interdepartmental Elective*				3	E	50	50	100
		Elective-MOOC/NPTEL Course*				2	E	0	100	100
5	24-305-0204	Programming Lab	0	0	4	2	C	100	0	100
6	24-305-0205	Control Systems Lab	0	0	4	2	C	100	0	100
7	24-305-02XX	Program Elective Lab	0	0	4	2	E	100	0	100
		Total				21/20				

* Need to compulsorily register for one MOOC/NPTEL course and one interdepartmental elective before registering for fourth semester exam.

Semester 3

No.	Course Code	Course Title	L	T	P	Credits	C/E	CA	ES	Total
1	24-305-0301	Seminar	0	0	2	1	C	100	0	100
2	24-305-0302	Communication Systems	3	2	0	3	C	50	50	100

3	24-305-0303	Embedded System Design	3	2	0	3	C	50	50	100
4	24-305-03XX	Program Elective	3	1	0	3	E	50	50	100
5	24-305-03XX	Program Elective	3	1	0	3	E	50	50	100
		Interdepartmental Elective*				3	E	50	50	100
		Elective-MOOC/NPTEL Course*				2	E	0	100	100
6	24-305-0304	Embedded Systems Lab	0	0	4	2	C	100	0	100
7	24-305-03XX	Program Elective Lab	0	0	4	2	E	100	0	100
		Total				17/16				

* Need to compulsorily register for one MOOC/NPTEL course and one interdepartmental elective before registering for fourth semester exam.

Semester 4

No.	Course Code	Course Title	L	T	P	Credits	C/E	CA	ES	Total
1	24-305-0401	Project				14	C	100	100	200
2	24-305-04XX	Program Elective	3	1	0	3	E	50	50	100
		Interdepartmental Elective*				3	E	50	50	100
		Elective-MOOC/NPTEL Course*				2	E	0	100	100
		Total				17/16				

* Need to compulsorily register for one MOOC/NPTEL course and one interdepartmental elective before registering for fourth semester exam.

Electives

No.	Course Code	Course Title	L	T	P	Credits	C/E	CA	ES	Total
1	24-305-0X11	Robotics & Automation	3	1	0	3	E	50	50	100
2	24-305-0X12	Mobile Robotics	3	1	0	3	E	50	50	100
3	24-305-0X13	Microwave Integrated Circuits	3	1	0	3	E	50	50	100
4	24-305-0X14	FPGA Based System Design	3	1	0	3	E	50	50	100
5	24-305-0X15	Data Structures	3	1	0	3	E	50	50	100
6	24-305-0X16	Embedded Software and Real Time Systems	3	1	0	3	E	50	50	100

7	24-305-0X17	NPTEL/MOOC Course	3	1	0	3	E	50	50	100
8	24-305-0X21	Robotics & Automation Lab	0	0	4	2	E	100	0	100
9	24-305-0X22	Mobile Robotics Lab	0	0	4	2	E	100	0	100
10	24-305-0X23	Microwave Integrated Circuits Lab	0	0	4	2	E	100	0	100
11	24-305-0X24	Data Structure Lab	0	0	4	2	E	100	0	100
12	24-305-0X25	Embedded Software Lab	0	0	4	2	E	100	0	100
13	24-305-0X26	Communication Systems Lab	0	0	4	2	E	100	0	100
14	24-305-0305	Mini Project	0	0	6	3	E	100	0	100

Electives Mapped from M.Tech VLSI and Embedded Systems

No.	Course Code	Course Title	L	T	P	Credits	C/E	CA	ES	Total
1	24-509-0101	Digital System Design using HDLs	3	1	0	3	E	50	50	100
2	24-509-0102	Digital Integrated Circuits	3	1	0	3	E	50	50	100
3	24-509-0201	Digital Verification and Testing	3	1	0	3	E	50	50	100
4	24-509-0202	FPGA Based Embedded SoC Design	3	1	0	3	E	50	50	100
5	24-509-0X14	Neural Networks	3	1	0	3	E	50	50	100
6	24-509-0X15	Analog & RF Integrated Circuit Design	3	1	0	3	E	50	50	100
7	24-509-0X17	Device Physics and Modeling for Integrated Circuits	3	1	0	3	E	50	50	100
8	24-509-0X20	Image & Video Processing	3	1	0	3	E	50	50	100
9	24-509-0104	Digital System Design using HDLs Lab	0	0	4	2	E	100	0	100
10	24-509-0105	Digital Integrated Circuits Lab	0	0	4	2	E	100	0	100
11	24-509-0203	Digital Verification and Testing Lab	0	0	4	2	E	100	0	100
12	24-509-0X28	FPGA System Design Lab	0	0	4	2	E	100	0	100

Electives Mapped from M.Tech Microwave and Communication Engineering

No.	Course Code	Course Title	L	T	P	Credits	C/E	CA	ES	Total
1	24-510-0201	Wireless Communications	3	1	0	3	E	50	50	100
2	24-510-0202	Radar Systems	3	1	0	3	E	50	50	100
3	24-510-0X11	Antennas for Communication Systems	3	1	0	3	E	50	50	100
4	24-510-0X12	Machine Learning	3	1	0	3	E	50	50	100
5	24-510-0X13	Electromagnetic Interference and Compatibility	3	1	0	3	E	50	50	100
6	24-510-0X14	Software Defined Radio for Communication Engineers	3	1	0	3	E	50	50	100
7	24-510-0X21	5G Technologies and Standards	3	1	0	3	E	50	50	100
8	24-510-0203	Wireless Communication Lab	0	0	4	2	E	100	0	100
9	24-510-0X19	Software Defined Radio Lab	0	0	4	2	E	100	0	100
10	24-510-0X20	Antenna Lab	0	0	4	2	E	100	0	100
11	24-510-0X22	Machine Learning Lab	0	0	4	2	E	100	0	100
12	24-510-0X23	EMI/EMC Lab	0	0	4	2	E	100	0	100

Electives with course code:
24-509-0*** are mapped from M.Tech VLSI and Embedded Systems
24-510-0*** are mapped from M.Tech Microwave and Communication Engineering

MASTER OF SCIENCE

in

ELECTRONIC SCIENCE

Semester 1

DEPARTMENT OF ELECTRONICS
COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY
Kochi - 682 022, India

24-305-0101 **Electronic Circuits**

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

Prerequisites	:	A course in Basic Electronics
Course Description	:	This course introduces the basic principles of electronic circuit operations, measurement of parameters, and the design and performance analysis of electronic circuits
Course Outcome	:	After the completion of the course, student will be able to

CO1	Understand the fundamental principles of linear electronic systems	Understand
CO2	Design of linear and non-linear op amp circuits	Apply
CO3	Analyze and design op amp based oscillators and negative feedback circuits	Analyze
CO4	Understand the concept of VCO, PLL, and timer IC operation	Understand
CO5	Analyze different types of power amplifiers	Analyze

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3					2		
CO2	3	3	3	3			3		
CO3	3	3		3			3	3	
CO4	3	3		3			2	2	
CO5	3	3					3		

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Review of active devices:** PN Junction diode: Principle of operation, V-I characteristics, Electrical Breakdown in PN junctions - Zener and avalanche break down. BJT-Working, comparison of three configurations Field effect Transistors: basic principles of JFET, MESFET and MOSFET, comparison with BJT. UJT, IGBT – Principles of operation and static characteristics.
Module 2	**Operational amplifiers:** Functional block diagram of operational amplifier, ideal operational amplifier, parameters, Inverting and non-inverting amplifier, summing amplifier, integrator, differentiator, Differential amplifiers, Instrumentation amplifiers, V to I and I to V converters, Comparators, precision rectifiers, multivibrators – Astable, Monostable, Schmitt Trigger, Square and triangular waveform generator. Active filters: Butterworth 1st order and Biquadratic filter of LPF and HPF , Simulation of circuits using LTSPICE.

Module 3	**Feedback and Stability:** Feedback amplifiers - Effect of positive and negative feedback on gain, frequency response and distortion, Feedback topologies and its effect on input and output impedance, Feedback amplifier circuits in each feedback topologies. Stability of feedback circuits. effect of feedback on amplifier poles, frequency compensation - Dominant pole and Pole-zero. Feedback oscillators; RC phase shift, Colpitts, Hartley, Wein bridge, crystal oscillators
Module 4	**VCO and PLL:** Basic concepts of Voltage Controlled Oscillator and application of VCO IC LM566, Phase Locked Loop – Operation, Closed loop analysis, Lock and capture range, Basic building blocks, PLL IC 565, Applications of PLL. Voltage Regulators – IC 723 and its Applications, Current boosting, short circuit and fold back protection. 555 Timer and its application. Timer IC 555- Functional diagram, Astable and monostable operations.
Module 5	**Power Amplifiers:** classification - class A , class B, Class AB, Class C and class D -Transformer coupled Power amplifiers – Transformer less class AB push-pull Power amplifier - complementary symmetry power amplifier - Harmonic distortion in Power amplifiers - Transistor rating -Heat sinks.

References:

[1] S. Franco, *Design with Operational Amplifiers and Analog Integrated Circuits.* McGraw Hill Book Company, 2017.

[2] R. E. Boylstead and L. Nashelsky, *Electronic Devices and Circuit Theory*, 10th ed. Pearson Education, 2009.

[3] A. S. Sedra and K. C. Smith, *Microelectronic Circuits.* New age international, 2017.

[4] M. N. Horenstein, *Micro Electronics Circuits and Devices.* PHI, 1995.

[5] B. Razavi, *Fundamentals of Microelectronics.* Wiley, 2021.

[6] R. A. Gayakwad, *Operational Amplifiers.* Pearson Education, 2015.

24-305-0102	Signals and Systems

L	T	P	C
3	2	0	3

Prerequisites	:	Basic Mathematics
Course Description	:	This course deals with the design and analysis of continuous and discrete time signals and systems
Course Outcome	:	After the completion of the course, the student will be able to

CO1	Illustrate the basic properties of signals and systems	Apply
CO2	Analyze continuous time systems using Fourier series and transform	Analyze
CO3	Analyze frequency domain analysis using discrete time Fourier Analysis	Analyze
CO4	Calculate Laplace transform of continuous time signals	Apply
CO5	Determine Z-transform of discrete time signals	Apply

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3	2				2		3
CO2	3	3	2				2	2	3
CO3	3	3	2					2	3
CO4	3	3	2				3		2
CO5	3	3	2				3		2

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Introduction:** Classification of signals, basic operations on signals, elementary signals, systems viewed as interconnections of operations, properties of systems, convolution: impulse response representation for LTI systems, properties of the impulse response representation for LTI systems, differential and difference equation representations for LTI systems.
Module 2	**Fourier analysis for continuous time signals:** Representation of periodic signals: Continuous Time Fourier Series, convergence of Fourier series, Gibbs phenomenon, Representation of aperiodic signals: Continuous Time Fourier Transform, The Fourier Transform for periodic signals, Properties of Fourier representations, Frequency response of LTI systems.
Module 3	**Fourier analysis for discrete time signals:** Discrete Time Fourier Series representation, properties of DTFS, Discrete Time Fourier Transform representation, Magnitude and Phase spectrum, Properties of DTFT, Frequency response of LSI systems.
Module 4	**Laplace Transform:** Bilateral Laplace transform, definition, Region of Convergence, properties, inversion of Laplace transform using partial fractions, transform analysis of systems.

Module 5	**z-transform:** z-transform, properties of Region of Convergence, properties of z-transform, Inversion of the z-transform, transform analysis of LSI system, stability and causality.

References:

[1] A. V. Oppenheim, A. S. Willsky, and S. H. Nawab, *Signals and Systems*, 2nd ed. Pearson Education India, 2015.

[2] S. Haykin and B. Van Veen, *Signals and Systems*, 2nd ed. John Wiley & Sons, 2007.

[3] B. P. Lathi and R. A. Green, *Linear Systems and Signals*.

[4] F. J. Taylor, *Principles of Signals and Systems*, ISE ed. McGraw-Hill, 1994.

[5] B. P. Lathi and Z. Ding, *Modern Digital and Analog Communication Systems*, 4th ed. Oxford University Press, 2011.

[6] R. E. Ziemer, W. H. Tranter, and D. R. Fannin, *Signals and Systems: Continuous and Discrete*, 4th ed. Prentice Hall, 1998.

[7] D. K. Lindner, *Introduction to Signals and Systems*, ISE ed. McGraw-Hill, 1999.

[8] R. A. Gabel and R. A. Roberts, *Signals and Linear Systems*, 3rd ed. John Wiley & Sons, 2009.

[9] M. J. Roberts, *Signals and Systems: Analysis Using Transform Methods and MATLAB*, 3rd ed. McGraw-Hill, 2019.

[10] A. Nagoor Kani, *Signals and Systems*, 1st ed. McGraw-Hill, 2010.

24-305-0103 **Digital System Design**

L	T	P	C
3	2	0	3

Prerequisites	:	None
Course Description	:	This course gives an overview of the design of digital systems. It introduces the basics of combinational and sequential circuits. It provides the concept of state machines and gives an idea of how to model real time scenarios and applications. The course also gives an idea of how to realise the digital system using hardware description language and also provides an overview of programmable logic devices.
Course Outcome	:	After the completion of the course, student will be able to

CO1	Apply Boolean algebra, Minimize the logic functions using Kmap and Quine McCluskey methods	Apply
CO2	Design combinational logic circuit and compare various programmable logic devices	Apply
CO3	Design sequential circuits using the various design techniques	Apply
CO4	Understand Verilog and describe the digital functions using Verilog hardware description language	Understand
CO5	Model combinational and sequential digital system using Verilog	Apply

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3	2				3		
CO2	3	3	2				3	3	
CO3	3	3	2				3	3	
CO4	3	3	2				3		2
CO5	3	3	2				3	3	2

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Review of Digital Systems:** Review of Digital Systems: Number Systems and Conversion, Binary Arithmetic, Boolean Algebra - Basic operations, Expressions and Truth tables, Theorems and Laws, Min-term and Max-term, Sum of Products and Product of Sums expression, K-maps, prime and essential prime implicants, Quine-McCluskey Methods

Module 2	**Combinational Logic Design:** NAND and NOR gates, Design of Two-level and Multi-level Gate Circuits, Circuit Conversion, Review of combinational logic circuit design - design of gates with limited fan-in, Gate delays and timing diagrams, hazards, Combinational Circuits - Multiplexers, decoders, encoders, buffers, code converters, adder, subtractor, Programmable Devices - Read Only Memory, Programmable Logic Array, Programmable Array Logic, Complex Programmable Logic Devices
Module 3	**Sequential Logic Design:** Sequential Circuits, Latches, Flip-Flops, Analysis of clocked sequential circuits, Mealy and Moore Models, state reduction and assignment, design procedures, excitation tables, state-transition table, state diagram, Finite State Machine design, Registers and Counters, Counter Design using flip flops
Module 4	**Introduction to HDL:** Hardware Description Languages, Verilog, Rules and Syntax, Modules, Ports, Variables, Datatypes, Operators, Assignments, Procedural Assignments, Always block, Delays, Dataflow modeling, Behavioral modeling, Structural modeling, Tasks and functions
Module 5	**System Design using Verilog:** Modeling combinational and sequential circuits using verilog – arithmetic and logic circuits, registers, counters, sequential machines, tristate buffers, Mealy and Moore finite state machines, Simulation and verification - Verilog testbench, Memory, file read and write

References:

[1] C. H. Roth, *Fundamentals of Logic Design*, 5th ed. Cengage Learning, 2009.

[2] C. H. Roth, L. K. John, and B. K. Lee, *Digital Systems Design Using Verilog*, 1st ed. CL Engineering, 2015.

[3] S. Palnitkar, *Verilog HDL*, 2nd ed. Pearson Education, 2004.

[4] M. Mano, *Digital Logic Design*, 4th ed. Pearson, 2008.

[5] N. N. Biswas, *Logic Design Theory.* Prentice Hall of India, 2001.

[6] P. K. Lala, *Digital system Design using PLD.* B S Publications, 2003.

[7] J. F. Wakerly, *Digital Design - Principles and Practices.* Pearson, 2008.

[8] V. P. Nelson, H. T. Nagle, J. D. Irvin, and B. D. Carol, *Digital Logic Analysis and Design*, 2nd ed. Pearson, 2020.

24-305-0104 **RF Technology**

L	T	P	C
3	2	0	3

Prerequisites	:	A basic course in Electromagnetic Theory
Course Description	:	In this course, the students are given an overview of basic concepts involved in an RF Communication system.
Course Outcome	:	After the completion of the course, student will be able to

CO1	Understand the basic building blocks of wireless systems and basic transmission line theory	Understand
CO2	Evaluate the concept of distortion due to noise and fundamentals of antennas and Propagation	Apply
CO3	Understand the working and types of various microwave sources	Understand
CO4	Describe the various passive components	Understand
CO5	Describe the working and design of a microwave amplifier, an oscillator and a mixer and compare the performance of its various types	Understand
CO6	Evaluate the design of an RF system.	Apply

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	2	3			3	1	3	
CO2	3	3				3	1	3	
CO3	3					3		3	
CO4	3					3		3	
CO5	3	2	1			3		3	
CO6	3	2				3	1	3	

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Introduction to Wireless Systems:** - Overview of various systems and Block diagrams. **Transmission lines and Network Analysis** -. Transmission line theory, Smith Chart, S-parameters, Impedance matching
Module 2	**Noise and Distortion:** - Noise, Noise figure, Noise temperature, Friss equation, linearity calculation of RF system, Dynamic range, Intermodulation distortion. **Antennas and Propagation** - Antenna fundamentals, Propagation, Radar equation, Communications Link equations, Satellite fundamentals
Module 3	**Microwave devices:** Limitations of conventional tubes at microwave frequencies. Two cavity Klystron and reflex Klystrons, Magnetron and Travelling Wave Tubes, Microwave Solid State Devices, Transferred Electron devices, Gunn effect, PIN diode, YIG Devices

Module 4	**Passive RF Components:** Rf Filters, power dividers, directional couplers, switches, attenuators, circulators, phase shifters
Module 5	**Active RF Components:** Amplifiers- Design using S parameters, LNA, PAs, Mixers- Characteristics and types, Oscillators - types and frequency synthesizers **Receiver Design:** Architecture, Dynamic range and practical receivers

References:

[1] D. M. Pozar, *Microwave and RF Design of Wireless Systems.* John Wiley & Sons, 2001.

[2] S. C. Harsany, *Principles of Microwave Technology.* Prentice Hall, 1997.

[3] P. A. Rizzi, *Microwave Engineering: Passive Circuits.* Prentice Hall of India, 2001.

[4] E. C. Jordan, *Electromagnetic waves and Radiating Systems*, 2nd ed. Pearson, 2015.

[5] R. E. Collin, *Foundations for Microwave Engineering.* McGraw Hill, 1998.

[6] C. R. Paul and S. A. Nassar, *Introduction to Electromagnetic fields.* McGraw Hill, 1987.

24-305-0105 **Electronic Circuits Lab**

L	T	P	C
0	**0**	**4**	**2**

Prerequisites : Electronic Circuits
Lab Description : This lab introduces the design, and analysis of electronic circuits
Course Outcome : After the completion of the lab, the student will be able to

CO1	Demonstrate the working of active electronic components and equipments	Apply
CO2	Design and implementation of analog integrated circuits	Apply
CO3	Use simulation tools to design and simulate analog integrated circuits	Apply
CO4	Develop application circuits for PLL and Regulators	Analyze

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3	3	3	3	3	3		3
CO2	3	3	3	3	3	3	3	3	3
CO3	3	3	3	3	3	3	3		3
CO4	3	3	3	3	3	3	3	3	3

3-High; 2-Medium; 1-Low

Course Content:

Sample List of Experiments*	
1	Plot the frequency response of a Common Emitter BJT amplifier and find the cut off frequencies, Bandwidth and gain
2	Measurement of op amp parameters-CMRR, slew rate, open loop gain, unity gain bandwidth, input and output impedances
3	Inverting, non-inverting amplifiers, differentiators and integrators-frequency response
4	Design and implement active filter circuits using Op-amp.
5	Build and test voltage regulator circuit using Op-amp to stabilise output voltages.
6	Find lock range and capture range of NE 565 PLL
7	Astable and monostable multivibrators using 555
8	Introduction to circuit simulators

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

References:

[1] D. M. Buchla and T. L. Floyd, *Lab Manual for Electronics Fundamentals and Electronic Circuits Fundamentals.* Pearson, 2010.

[2] [online] https://www.orcad.com/pspice.

[3] S. Franco, *Design with Operational Amplifiers and Analog Integrated Circuits.* McGraw Hill Book Company, 2017.

[4] R. E. Boylstead and L. Nashelsky, *Electronic Devices and Circuit Theory.* 10/e, Pearson Education, 2009.

[5] D. R. Choudhary and S. B. Jain, *Linear Integrated Circuits.* New age international, 2017.

24-305-0106	**Signals and Systems Lab**	

L	**T**	**P**	**C**
0	**0**	**4**	**2**

Prerequisites : Signals & Systems

Lab Description : Implementation of basic signal processing techniques in Octave/ MATLAB/Python

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

CO1	Use basic programming environment for signal processing in Octave/ MATLAB/Python	Apply
CO2	Illustrate the basic signal processing operations in Octave/MATLAB/ Python	Apply
CO3	Analyse the frequency domain behaviour of signals	Analyze
CO4	s-domain analysis of continuous-time systems	Analyse
CO5	Analyse stability of discrete-time systems in z-domain	Analyse

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1			3	3	2	2	2	2	3
CO2			3	3	2	2	2	2	3
CO3			3	3	2	2	2	2	3
CO4			3	3	2	2	2	2	3
CO5			3	3	2	2	2	2	3

3-High; 2-Medium; 1-Low

Course Content:

Sample List of Experiments*	
1	Introduction to MATLAB/Octave/Python programming
2	Introduction to signal processing toolbox
3	Basic matrix and linear algebra operations
4	Generation and plotting of elementary signals
5	To perform basic operations on signals
6	To find the convolution of two signals
7	Find the step response of the LTI system
8	Implement Fourier series/ Fourier transform and plot the magnitude response
9	Implement Laplace transform for convolution of two signals, finding residue and poles of s-domain signal and to find impulse response of the given system
10	Implement z-transform for convolution of two signals, finding residue and poles of s-domain signal and to find impulse response of the given system

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

References:

[1] M. J. Roberts, *Signals and Systems: Analysis Using Transform Methods and MATLAB*, 3rd ed. McGraw-Hill, 2019.

[2] L. F. Chaparro and A. Akan, *Signals and Systems using MATLAB.* Academic Press, 2018.

[3] S. Haykin and B. Van Veen, *Signals and Systems*, 2nd ed. John Wiley & Sons, 2007.

[4] A. Nagoor Kani, *Signals and Systems*, 1st ed. McGraw-Hill, 2010.

24-305-0107 **Digital System Design Lab**

L	T	P	C
0	0	4	2

Prerequisites : None

Lab Description : This lab provides experiments of simulation and synthesis of the digital systems using verilog hardware description language.

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

CO1	Familiarize verilog simulation tools, Model basic gates in verilog. simulation, synthesis and analysis using RTL schematic, waveforms and timing diagram	Apply
CO2	Design combinational logic circuits in verilog	Apply
CO3	Design sequential circuits in verilog	Apply
CO4	Design a digital system for real world problem in verilog	Apply
CO5	Identify test cases and build test bench for verification of design	Analyse

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1			3	3	2	2	3		3
CO2			3	3	2	2	3	2	3
CO3			3	3	2	2	3	2	3
CO4			3	3	2	2	3	2	3
CO5			3	3	2	2	3		3

3-High; 2-Medium; 1-Low

Course Content:

Sample List of Experiments*	
1	Familiarisation of EDA tools for simulation, synthesis and verification. Verilog modelling of logic gates using dataflow, behavioural and structural and analyse the RTL schematic, waveforms and timing diagram
2	Verilog modelling of combinational logic circuits
3	Verilog modelling of sequential logic circuits
4	Verilog modelling of state machines
5	Build Test bench programs for the identified test cases for the verification of designs
6	Digital System Solution proposal for a real world problem using combinational and sequential circuits. Simulate, Synthesise and analyse the circuit functionality

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

References:

[1] C. H. Roth, L. K. John, and B. K. Lee, *Digital Systems Design Using Verilog.* CL Engineering, 1st edition, 2015.

[2] J. Cavanagh, *Verilog HDL Design Examples.* CRC Press, 2017.

[3] S. Palnitkar, *Verilog® HDL: A Guide to Digital Design and Synthesis, Second Edition.* Pearson, 2003.

24-305-0108 **Digital Fabrication**

L	T	P	C
0	0	1	0

Prerequisites :

Lab Description : This lab introduces students to 3D printing and manufacturing including the materials, equipment and technology.

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

CO1	Understand the 3D printing technology	Understand
CO2	Write reports on the latest developments in digital fabrication	Understand
CO3	Discuss the types of material and equipment used for digital fabrication	Understand

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3		2			2			2
CO2				2	2				
CO3	3		2			2			2

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**3D Printing:** Introduction, process, classification, advantages, additive V/s conventional manufacturing processes, applications, CAD for additive manufacturing
Module 2	**Additive Manufacturing Techniques:** Stereo-lithography, LOM, FDM, SLS, SLM, binder jet technology, process, process parameter, process Selection for various applications
Module 3	**Materials:** Polymers, metals, non-metals, ceramics,various forms of raw material- liquid, solid, wire, powder; powder preparation and their desired properties, polymers and their properties, support materials
Module 4	**Equipment** Process equipment- design and process parameters, governing bonding mechanism, common faults, troubleshooting, process design **Product Quality:** Inspection and testing, defects and their causes

References:

[1] AICTE's Prescribed Textbook: Workshop / Manufacturing Practices (with Lab Manual), Khanna Book Publsihing Co .

[2] Lan Gibson, David W. Rosen, and Brent Stucker, *Additive Manufacturing Technologies: Rapid Prototyping to Direct Digital Manufacturing.* Springer, 2010.

[3] Andreas Gebhardt, *Understanding Additive Manufacturing: Rapid Prototyping, Rapid Tooling, Rapid Manufacturing.* Hanser Publisher, 2011.

MASTER OF SCIENCE

in

ELECTRONIC SCIENCE

Semester 2

DEPARTMENT OF ELECTRONICS

COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

Kochi - 682 022, India

24-305-0201 Programming for Embedded Systems

L	T	P	C
3	2	0	3

Prerequisites : None

Course Description : This course trains the students to program embedded systems using C programming language

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

CO1	Determine appropriate Linux commands for basic operations	Apply
CO2	Determine the functionality of C statements, expressions, functions and programs	Apply
CO3	Given a problem, understand the basic algorithm, determine the required program structure, identify the requirement for dynamic memory allocations and and develop C programs accordingly	Apply
CO4	Understand basic memory layout and memory management in C	Understand
CO5	Use fixed precision numbers and C language constructs in embedded programs	Apply
CO6	Explain different steps in embedded software development and different I/O programming techniques used	Understand

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3		3		2				3
CO2	3				2				3
CO3	3	3			2		3		3
CO4	3				2				
CO5	3				2				
CO6	3				2				

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Introduction:** Embedded systems- processors, programming languages, operating systems, applications. GNU/Linux OS, architecture, GNU C compiler. introduction to C, simple C programs, preprocessor directives, macros, library functions, multifile programs, linker. compile, link, debug and execute C programs using GNU compiler toolchain
Module 2	**Basics of C Programming:** Identifiers, keywords, data types, variables, scope, operators, operator precedence, expressions, statements, input and output, control statements, functions, arrays, multidimensional arrays, strings

Module 3	**Pointers & Structures:** Pointers, passing pointers to functions, pointers and arrays, operation on pointers, array of pointers, structures, unions, file handling **Memory layout and Memory management:** Memory layout, stack and heap. static and dynamic allocation, automatic, static and global variables, lifetime of variables
Module 4	**Data Representation:** Fixed-precision binary numbers, binary representation of integers, binary representation of real numbers - fixed-point and floating point **Introduction to Embedded C:** Data types, bit manipulation in memory and I/O ports, accessing memory mapped I/O, structures, variant access
Module 5	**Input/Output Programming:** Instructions, synchronization, transfer Rate, and latency, polled waiting loops, interrupt driven I/O, direct memory access **Embedded Software Development:** Host and target machines, linker and locator, getting software to target machines, debugging techniques, code optimizations

References:

[1] D. W. Lewis, *Fundamentals of Embedded Software: Where C and Assembly Meet, 1st Edition.* Prentice Hall, 2002.

[2] B. Gottfried, *Schaum's Outline of Programming with C, 2nd Edition.* McGraw-Hill Education, 1996.

[3] D. E. Simon, *An Embedded Software Primer.* Addison Wesley, 1999.

[4] B. Kernighan and D. Ritchie, *C Programming Language.* CreateSpace Independent Publishing Platform, 2017.

[5] M. Jones, *GNU/Linux Application Programming.* Charles River Media, 2008.

[6] M. Siegesmund, *Embedded C Programming: Techniques and Applications of C and PIC MCUs.* Elsevier Science, 2014.

[7] M. Barr, *Programming Embedded Systems in C and C++.* Shroff Publishers & Distributors, 2004.

24-305-0202 **Digital Signal Processing**

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

Prerequisites : Signals & Systems

Course Description : This course deals with analysis and design of various digital filters, various finite word length issues associated with DSPs and DSP processor architecture

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

CO1	Calculate linear and circular convolution	Apply
CO2	Analyse discrete time signals using DFT/FFT	Analyze
CO3	Illustrate the implementation of discrete-time systems	Apply
CO4	Select a suitable digital filter for any applications	Analyse
CO5	Use multi-rate signal processing techniques	Apply

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	2	2					3	3
CO2	3	2	2				3	2	
CO3	3	2	2					2	
CO4	3	3	2				3		3
CO5	3	2	2					2	3

Course Content:

Module 1	**Discrete-time Signals & Systems:** Basic classification of discrete-time signals and systems, resolution of a discrete-time signal into impulses, response of LTI systems to arbitrary inputs, causality and stability of linear time invariant system, finite duration and infinite duration impulse response, recursive and nonrecursive discrete-time systems, solution of linear constant coefficient difference equation, circular convolution, linear convolution via circular convolution, filtering of long data sequences - overlap add and overlap save method
Module 2	**Discrete Fourier Transform:** Frequency domain sampling - Discrete Fourier Transform (DFT), DFT as a linear transformation, relationship of DFT with other transforms, properties of DFT, use of DFT in linear filtering, efficient computation of DFT - Fast Fourier Transform (FFT), decimation-in-time FFT algorithm, decimation-in-frequency FFT algorithm

Module 3	**Implementation of Discrete-Time Systems:** Rational z-transform, analysis of linear time-invariant systems in z-domain, structures for realisation of linear time-invariant systems, direct form-1, direct form-2, cascade, parallel realisation of infinite-duration Impulse response (IIR) systems, direct form, cascade and linear phase realisation of finite-duration Impulse response (FIR) systems, recursive and nonrecursive realisation of FIR systems
Module 4	**Design of Digital Filters:** FIR filters - symmetric and antisymmetric FIR filters, design of linear phase FIR filters using windows and frequency sampling method, Design of IIR filters from analog filters, IIR filter design by approximation of derivatives, impulse invariant technique and bilinear transformation, characteristics of commonly used analog filters - Butterworth filters and Chebyshev filters, Frequency transformations
Module 5	**Multirate Signal Processing & DSP Processors:** Sampling rate conversion, Decimation by a factor D, interpolation by a factor I, sampling rate conversion by a rational factor I/D, features of DSP processors, Von Neumann architecture vs Harvard architecture, Very Long Instruction Word (VLIW) architecture, TMS320C6x Architecture, Functional units, Linear and circular addressing modes, TMS320C6x instruction set

References:

[1] J. G. Proakis and D. G. Manolakis, *Digital Signal Processing: Principles, Algorithms, and Application*, 4th ed. Pearson Education India, 2007.

[2] R. Chassaing, *Digital Signal Processing and Applications with the C6713 and C6416 DSK*. John Wiley & Sons, 2005.

[3] S. K. Mitra, *Digital Signal Processing: A Computer-Based Approach*. McGraw-Hill Higher Education, 2001.

[4] A. V. Oppenheim and R. W. Schafer, *Discrete-time Signal Processing*, 2nd ed. Prentice Hall, 1999.

[5] C.-T. Chen, *Digital Signal Processing: Spectral Computation and Filter Design*. Oxford University Press, Inc., 2001.

[6] L. C. Ludeman, *Fundamentals of Digital Signal Processing*. John Wiley & Sons, 1986.

[7] E. C. Ifeachor and B. W. Jervis, *Digital Signal Processing: A Practical Approach*. Pearson Education, 2004.

[8] B. Porat, *A Course in Digital Signal Processing*. John Wiley & Sons, 1996.

[9] A. Nagoor Kani, *Digital Signal Processing*, 2nd ed. McGraw-Hill Higher Education, 2012.

[10] P. Ramesh Babu, *Digital Signal Processing*. Scitech Publications (India) Pvt Ltd, 2011.

24-305-0203 **Control Systems**

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

Prerequisites : Signals & Systems

Course Description : This course deals with analysis and modeling of continuous time and discrete time control systems

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

CO1	Analyse control systems using block diagrams and signal flow graphs	Analyze
CO2	Categorize various techniques for analysis of control systems	Analyze
CO3	Demonstrate the need for sampled data systems	Apply
CO4	Determine the stability of discrete time systems	Apply
CO5	Solve the concepts of state space representation	Apply

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3		3				2	2	
CO2	3	3	3					2	2
CO3	3		3					3	2
CO4	3	3	3					3	2
CO5	3		3				3		

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Mathematical modeling of control systems:** Closed loop control versus open loop control, Review of Laplace transform, transfer function and impulse response, block diagrams, block diagram reduction, obtaining Cascaded, Parallel, and Feedback (Closed-Loop) Transfer Functions with MATLAB/Octave, Signal Flow Graphs, Mason's Rule, Mathematical modeling of mechanical and electrical systems - spring mass damper, RLC network, low pass RC filter
Module 2	**Analysis of continuous-time systems:** Typical test signals, Unit step response of first order systems, second order systems, transient-response specifications, transient-response analysis using MATLAB/Octave, steady state error, concept of stability, Routh-Hurwitz techniques, construction of bode diagrams, phase margin, gain margin, construction of root locus, theory of lag, lead and lag-lead compensator

Module 3	**z-plane analysis of discrete-time control systems:** Review of z-transform, Impulse sampling, data hold circuits - zero order hold, transfer function of a first order hold, reconstructing original signals from sampled signals - sampling theorem, pulse transfer function, pulse transfer function of cascaded elements, closed loop systems
Module 4	**Design of discrete-time control systems:** Mapping between s-plane and z-plane, primary strips and complementary strips, mapping of commonly used contours in the s-plane into the z-plane - constant attenuation loci, constant frequency loci, constant damping ratio loci, stability analysis of closed loop systems in z-plane, methods for testing absolute stability - Jury stability test, bilinear transformation and Routh stability criterion
Module 5	**Control system analysis in state space:** State-space formulation, state model of linear systems, state diagram representation, state-space representation using physical variables, state-space representation using phase variables - companion or controllable canonical form, observable canonical form, diagonal canonical form and Jordan canonical form

References:

[1] K. Ogata, *Modern Control Engineering*, 5th ed. Pearson, 2010.

[2] K. Ogata, *Discrete-time Control Systems*, 2nd ed. Prentice-Hall India, 2005.

[3] N. S. Nise, *Control Systems Engineering*, 8th ed. John Wiley & Sons, 2020.

[4] R. C. Bishop and R. H. Dorf, *Modern Control Systems*, 14th ed. Pearson, 2021.

[5] B. C. Kuo, *Digital Control Systems*, 2nd ed. Oxford University Press, 2012.

[6] I. J. Nagrath and M. Gopal, *Control Systems Engineering*, 7th ed. New Age International, 2022.

[7] M. Gopal, *Control Systems: Principles and Design*, 4th ed. McGraw-Hill, 2012.

[8] A. Nagoor Kani, *Control Systems.* RBA Publications, 2017.

[9] A. Nagoor Kani, *Advanced Control Theory*, 2nd ed. RBA Publications, 2009.

[10] D. Roy Choudhury, *Modern Control Engineering*, 1st ed. Prentice-Hall India, 2005.

24-305-0204 **Programming Lab**

L	T	P	C
0	0	4	2

Prerequisites : None

Lab Description : This lab enables students to develop C programs, compile, execute and debug them in Linux environment. It also introduces embedded programming using Keil IDE

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

CO1	Use Linux commands and utilities for basic operations	Apply
CO2	Use the GNU C compiler toolchain	Apply
CO3	Understand the basic algorithm for a problem, develop a C program, compile, execute and debug it	Analyze
CO4	Use Keil IDE to develop and debug embedded C Programs	Apply
CO5	Execute basic programs in an embedded platform	Apply

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3		3	3	3	3			3
CO2	3		3	3	3	3			3
CO3	3	3	3	3	3	3	3		3
CO4	3		3	3	3	3			3
CO5	3		3	3	3	3			3

3-High; 2-Medium; 1-Low

Course Content:

Sample List of Experiments*	
1	Linux commands for creating and entering folders, editing files, removing folder contents etc.
2	Use GCC to compile a multifile C program and debug it using GDB
3	Write a program to compare multiple pairs of numbers and display the results
4	Write a program to print all prime numbers less than a given number
5	Write a program which reads a sentence with uppercase and lowercase letters, numbers and symbols and outputs with the case reversed
6	Write a program which calculates the running average of a sequence of number. The average has to be calculated and displayed every time a new number is entered. Use a separate function for average
7	Write a recursive program to print the Fibonacci series
8	Compare different sorting algorithms

9	Write a C program that reads several different names and addresses into the computer, rearranges the names into alphabetical order, and then writes out the alphabetized list. Make use of structure variables within the program
10	Debug a buggy program using GNU Debugger
11	Familiarization with Keil IDE
12	Compile and execute hello world program in an Arm bBased platform
13	Study the behavior of a system with interrupt

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

References:

[1] B. S. Gottfried, *Schaum's Outline of Programming with C*, 2nd ed. McGraw-Hill Education, 1996.

[2] ARM. (2021) Efficient embedded education kit. 29/2/2024. [Online]. Available: https://compedulabs.org/583/efficient-embedded-education-kit/

24-305-0205 **Control Systems Lab**

L	T	P	C
0	0	4	2

Prerequisites	:	Signals & Systems, Control Systems
Lab Description	:	To model, simulate and analyze systems using MATLAB.
Course Outcome	:	After the completion of the lab, the student will be able to

CO1	Use basic programming environment for signal processing in Octave/ MATLAB/Python	Apply
CO2	Illustrate the basic signal processing operations in Octave/MATLAB/ Python	Apply
CO3	Analyse the frequency domain behaviour of signals	Analyze
CO4	s-domain analysis of continuous-time systems	Analyse
CO5	Analyse stability of discrete-time systems in z-domain	Analyse

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1			3	3	2	2	2	2	3
CO2			3	3	2	2	2	2	3
CO3			3	3	2	2	2	2	3
CO4			3	3	2	2	2	2	3
CO5			3	3	2	2	2	2	3

3-High; 2-Medium; 1-Low

Course Content:

Sample List of Experiments*	
1	Familiarizing with MATLAB/Octave/Python
2	Polynomials in MATLAB/Octave/Python
3	Scripts, Functions & Flow Control in MATLAB/Octave/Python
4	Mathematical modelling of Physical Systems
5	Modelling of Physical Systems using Simulink
6	Linear Time-invariant Systems and Representation
7	Block Diagram Reduction
8	Performance of First order and second order systems
9	Effect of Feedback on disturbance & Control System Design
10	Introduction to PID controller

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

References:

[1] K. Ogata, *Solving Control Engineering Problems with MATLAB.* Prentice-Hall, Inc., 1994.

[2] C. Lopez, *MATLAB Control Systems Engineering.* Apress, 2014.

[3] D.-W. Gu, P. Petkov, and M. M. Konstantinov, *Robust Control Design with MATLAB.* Springer Science & Business Media, 2005.

MASTER OF SCIENCE

in

ELECTRONIC SCIENCE

Semester 3

DEPARTMENT OF ELECTRONICS

COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

Kochi - 682 022, India

24-305-0301 **Seminar**

L	T	P	C
0	0	2	1

Prerequisites : None

Lab Description : Seminar allows to develop research and presentation skills by sharing work with peers and faculty, fostering critical thinking and effective communication in a professional setting

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

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3			3	3	3			
CO2	3		3			3			3
CO3	3	3	3	3	3	3	3	3	3

3-High; 2-Medium; 1-Low

Course Content:

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.Sc 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.

24-305-0302 **Communication Systems**

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

Prerequisites : Signals & Systems

Course Description : This course deals with the the fundamentals of communication systems.

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

CO1	Analyse signals in frequency domain	Analyze
CO2	Illustrate various continuous-wave modulation techniques	Analyze
CO3	Use pulse modulation techniques for communication	Apply
CO4	Demonstrate various digital modulation techniques	Apply
CO5	Apply the concept of probability into communication problems	Apply

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	2	3				3		
CO2	3	3			2			2	3
CO3	3				2			2	3
CO4	3	2			2			2	3
CO5	3		2				3		

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Fourier representation:** Fourier transform, spectrum, Inverse relationship between time and bandwidth, Dirac-delta function, Fourier transform of periodic signals, frequency response, autocorrelation function, energy spectral density, cross-correlation, power spectral density
Module 2	**Continuous-wave modulation:** Amplitude modulation, double sideband suppressed carrier modulation, single sideband modulation, vestigial sideband modulation, phase modulation, frequency modulation, relationship between PM and FM waves, transmission bandwidth of FM waves
Module 3	**Pulse modulation:** Sampling, ideal sampling and frequency domain representation, sampling theorem, aliasing, pulse-amplitude modulation, pulse-position modulation, Quantization, pulse-code modulation, delta modulation, quantization errors
Module 4	**Digital band-pass modulation techniques:** Band pass assumption, binary amplitude-shift keying, phase-shift keying, frequency-shift keying, M-array digital modulation schemes, mapping of digitally modulated waveforms onto constellations of signal points

Module 5	**Random signals and noise:** Probability, random variables, conditional probability, Gaussian random variable, Central limit theorem, random process, white noise, narrowband noise, noise equivalent bandwidth

References:

[1] S. Haykin and M. Moher, *Introduction to Analog and Digital Communications*, 2nd ed. John Wiley & Sons, Inc., 2012.

[2] S. Haykin, *Communication Systems*, 2nd ed. John Wiley & Sons, 2008.

[3] A. B. Carlson and P. B. Crilly, *Communication Systems An Introduction to Signals and Noise in Electrical Communication*, 5th ed. McGraw Hill Higher Education, 2010.

[4] B. Sklar, *Digital Communications: Fundamentals and Applications*, 3rd ed. Pearson, 2021.

[5] J. G. Proakis and M. Salehi, *Digital Communications*, 5th ed. McGraw Hill, 2014.

[6] H. Taub and D. L. Schilling, *Principles of Communication Systems*, 4th ed. McGraw Hill, 2017.

[7] G. Kennedy, B. Davis, and S. R. M. Prasanna, *Electronic Communication Systems*, 6th ed. McGraw Hill, 2017.

[8] R. E. Ziemer and W. H. Tranter, *Principles of Communication Systems, Modulation, and Noise*, 7th ed. John Wiley & Sons, 2015.

[9] D. Roddy and J. Coolen, *Electronic Communications*, 4th ed. Pearson, 2014.

[10] B. P. Lathi and Z. Ding, *Modern Digital and Analog Communication Systems*, 4th ed. Oxford University Press, 2011.

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

24-305-0303 **Embedded System Design**

Prerequisites : Digital design

Course Description : This course discusses the design of embedded system for a given task by interfacing various peripherals. This also gives a brief overview of operating system for embedded systems.

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

CO1	Summarize the general architecture of an embedded system	Understand
CO2	Analyze the performance of the processor based on optimizations in pipeline and memory hierarchy	Apply
CO3	Illustrate the architecture of VEGA processors	Understand
CO4	Design embedded system to perform a given task	Analyze
CO5	Outline the components of OS/RTOS and various scheduling algorithms	Understand

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	2	2			3	2			
CO2	3	3						2	2
CO3	2	2							2
CO4	3	3	3					3	3
CO5	2	2	2						2

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Introduction to Embedded Systems:** General architecture, Sensors and Actuators, characteristics, Real Life examples, Embedded Programming - IDE, Compiler/Assembler, Simulator/Emulator. Modern Applications of Embedded Systems – IoT, Edge computing, Electric vehicles, Health care, Cyber physical systems etc.
Module 2	**Processing elements:** CISC, RISC, Harvard, Von-Neumann Architectures, Processor Pipelining: Classic five stage pipelining in RISC processor, Pipeline Hazards, Branch prediction technique. Memory hierarchy: Locality of References, Cache memory principles, Cache architecture, Block Replacement Techniques and Write Strategy
Module 3	**RISC Architecture:** RISC-V Instruction set Architecture, Operating modes, Control status registers, Programmers' Model for Base Integer ISA, Exceptions, Traps, and Interrupts
Module 4	**VEGA THEJAS32 Microcontroller:** Functional Block diagram, Registers, GPIO, Timer, Memory Mapped I/O, Interrupt, Exception, ARIES Development board, ARIES IoT v2.0, Buses and Protocols – I2C, SPI, UART, USB, CAN, AMBA Ethernet/WLAN/ Bluetooth /Zigbee

Module 5	**Operating system in Embedded application:** Functions of Operating systems, The kernel, Task/Process, Thread, Inter Process Communication, Task synchronization, Semaphores, Priority inversion, Device drivers. Various Scheduling algorithms - Pre-emptive/Non-pre-emptive methods - RTOS. Real time scheduling algorithms

References:

[1] Lyla B. Das, *Embedded Systems, An Integrated Approach.* Pearson Ed, 2013.

[2] “Vega Processors,” https://vegaprocessors.in/.

[3] “Documents on CDAC Vega Processor ,” https://gitlab.com/cdac-vega .

[4] G. G. Abraham Shilbershartz, Peter Baer Galvin, *Operating System Concepts.* Wiley, 2013.

[5] D. E. Simon, *An Embedded Software Primer.* Pearson Education, 2012.

[6] P. A. Laplante, *Real- Time Systems Design and Analysis.* Wiley & Sons.

24-305-0304	**Embedded Systems Lab**

L	**T**	**P**	**C**
0	**0**	**4**	**2**

Prerequisites : Digital design

Lab Description : The lab will employ various software tools to interface peripherals like sensors, actuators, communication modules etc. to design an embedded system for a particular task.

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

CO1	Use software tools to program and debug embedded system	Apply
CO2	Interface various peripherals to the embedded platform to build system	Apply
CO3	Design embedded system to perform a given task	Analyze

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1				3	3	3	3		3
CO2	3	3	3	3	3	3	3	3	3
CO3	3	3	3	3	3	3	3	3	3

3-High; 2-Medium; 1-Low

Course Content:

Sample List of Experiments*	
1	Familiarization Vega Aries/MSP430/Raspberry Pi board using Hello world program
2	LED blinking with a 1 second delay
3	Interface sensors like temperature/pressure etc and display the measured value
4	Interfacing of real time clock module
5	Interfacing Servo Motors/ Stepper motor/RFID reader/Wifi Module
6	Booting freeRTOS in Aries/Raspberry Pi board
7	Implement a mini project - IoT system for healthcare/security etc. using appropriate embedded platform board

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

References:

[1] "Vega Processors," https://vegaprocessors.in/.

[2] "Vega Processors based Projects," https://vegaprocessors.in/blog/category/aries-with-arduinoide/.

[3] "Setting up Aries Board," https://cdac-vega.gitlab.io/boardsetup/setup.html.

[4] "Documents on CDAC Vega Processor ," https://gitlab.com/cdac-vega .

[5] Lyla B. Das, *Embedded Systems, An Integrated Approach.* Pearson Ed, 2013.

[6] "Introduction to Embdedded System Design," https://archive.nptel.ac.in/courses/108/102/108102169/.

[7] J. H. Davies, *MSP430 Microcontroller Basics.* Elsevier, 2008.

MASTER OF SCIENCE

in

ELECTRONIC SCIENCE

Semester 4

DEPARTMENT OF ELECTRONICS

COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

Kochi - 682 022, India

24-305-0401 **Project**

L	T	P	C
0	**0**	**28**	**14**

Prerequisites : None

Lab Description : Project work bridges the gap between theoretical knowledge and practical application, allowing to develop problem-solving skills and gain hands-on experiences.

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

CO1	Identify unresolved problems and challenges in the selected domain through literature survey	Analyze
CO2	Determine appropriate tools and procedures for design, development & verification	Evaluate
CO3	Develop practical solutions for the chosen problem for a given specification	Create
CO4	Develop the ability to write good technical report, to make oral presentation of the work, and to publish the work in reputed conferences/journals	Create

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3			3	3	3			
CO2	3		3			3			3
CO3	3	3	3	3	3	3	3	3	3
CO4	3			3	3	3			

3-High; 2-Medium; 1-Low

Course Content:

The major project in fourth semester offer the opportunity to apply and extend knowledge acquired in the three semesters of the M.Sc. program. The major project can be analytical work, simulation, hardware design or a combination of these in the emerging areas of electronics under the supervision of a faculty from the Dept. of Electronics or in R and D institutes/ Industry. The specific project topic undertaken will reflect the common interests and expertise of the student(s) and supervisor. Students doing their projects outside the department will be assigned an internal supervisor.

Students will be required to

- perform a literature search to review current knowledge and developments in the chosen technical area
- 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 project supervisor/internal supervisor shall do monthly evaluation of the progress. M.Sc project evaluation committee for the course shall evaluate the project work during the fourth semester in two stages. 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 progress in the chosen topic, write technical report of the study and results. They are expected to communicate their innovative ideas and results in reputed conferences and/or journals.

MASTER OF SCIENCE

in

ELECTRONIC SCIENCE

List of Electives

DEPARTMENT OF ELECTRONICS

COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

Kochi - 682 022, India

24-305-0X11 **Robotics and Automation**

L	T	P	C
3	1	0	3

Prerequisites : None

Course Description : This course provides an introduction to robots and discusses the components of a robotic system

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

CO1	Discuss the basic classification and structure of a robot	Understand
CO2	Use spatial transformation to obtain forward kinematic equation of a robot manipulator	Apply
CO3	Illustrate the concept of singularity by calculating the Jacobian of a manipulator and Derive kinetic and potential energy in a robot manipulator	Apply
CO4	Understand the working and applications of various sensors and actuators used in robotics	Understand
CO5	Learn the various techniques involved in robot vision	Understand

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3							
CO2	3	3		3			3		
CO3	3	3					3	3	
CO4	3	3		3				3	
CO5	3	3							

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Introduction to robotics:** Definition, History , Growth, Laws of Robotics. Robot components, Degree of freedom, types of joints, robot coordinates, reference frames, workspace, grippers, robot characteristics, robot applications
Module 2	**Robot Kinematics:** Descriptions - positions, orientations, frames, Mapping and matrix representations - translations, rotations, transformations. representation of orientation using roll, pitch, and yaw angles, representation of orientation using Euler angles, D-H representation, forward and Inverse kinematics
Module 3	**Robot Dynamics:** Velocity propagation from link to link, Jacobian, singularities; static forces in manipulators; Jacobians in force domain, Newton-Euler dynamic formulation; Lagrange-Euler formulation, dynamic equations for multiple degrees of freedom robot

Module 4	**Sensors:**Proprioceptive/Exteroceptive and passive/active sensors, Performance measures of sensors, Encoders, Gyros, active and passive beacons, GPS, range sensors **Actuators:** DC motors, AC motors, Stepper motors, BLDC, Solenoids. Motor drives:. PWM and H-bridges, case study L298-based drive
Module 5	**Robotic Vision:** Vision-controlled robotic systems, architecture of robotic vision system, image acquisition, components of vision system, image representation, image processing techniques

References:

[1] K. S. Fu, *Robotics- Control, Sensing, Vision and Intelligence.* McGraw – Hill, 1987.

[2] J. J. Craig, *Introduction to Robotics- Mechanics and Control.* Addison-Wesley, 2004.

[3] R. Siegwart, I. Nourbakhsh, and D. Scaramuzza, *Introduction to Autonomous Mobile Robots.* MIT Press, USA, 2011.

[4] S. B. Niku, *Introduction to Robotics- Analysis,Systems,Applications.* Pearson, 2011.

[5] R. K. Mittal and I. J. Nagrath, *Robotics and Control*, 2017.

24-305-0X12 **Mobile Robotics**

L	T	P	C
3	**1**	**0**	**3**

Prerequisites : None

Course Description : This course provides an introduction to locomotion of robots and it provides an overview of various techniques for Robot Motion planning, Navigation, Localization and mapping

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

CO1	Understand various robot locomotion techniques	Understand
CO2	Discuss the Kinematics and dynamics of Wheeled Robots	Understand
CO3	Determine appropriate localization strategies for mobile robots	Apply
CO4	Use various motion planning, navigation schemes	Apply
CO5	Learn motion control techniques in robotics	Understand

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3					2		
CO2	3	3	3				3		
CO3	3	3					3	3	
CO4	3	3		3			2	2	
CO5	3	3					3		

3-High; 2-Medium; 1-Low

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	**Kinematics and Dynamics of mobile robots:**Kinematic Models and Constraints of wheeled mobile robot, Forward kinematic models, Wheel kinematic constraints, Robot kinematic constraints, Mobile Robot Maneuverability, Mobile Robot Workspace, Mobile Robot Workspace, Dynamics and motion controlling methods

Module 3	**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 4	**Motion Planning and Navigation:** Path planning, graph search methods, potential field planning, path planning algorithms based on Breadth-first, Depth-first, Dijkstra, A-star, rapidly exploring random trees, Obstacle avoidance
Module 5	**Motion Control:** Motion controlling methods, Control Architecture, Trajectory tracking in open loop and closed loop control, kinematic control, dynamic control, and cascaded control, Introduction to advanced control techniques

References:

[1] R. Siegwart, I. Nourbakhsh, and D. Scaramuzza, *Introduction to Autonomous Mobile Robots.* MIT Press, USA, 2011.

[2] S. B. Niku, *Introduction to Robotics- Analysis,Systems,Applications.* Pearson, 2011.

[3] R. K. Mittal and I. J. Nagrath, *Robotics and Control.* McGraw – Hill, 2017.

[4] S. G. Tzafestas, *Introduction to Mobile Robot Control.* Elsevier, USA,, 2013.

24-305-0X13	**Microwave Integrated Circuits**	**L**	**T**	**P**	**C**
		3	**1**	**0**	**3**

Prerequisites	:	A basic course in Electromagnetic Theory and Transmission Line Theory Fundamentals.
Course Description	:	In this course the basics of planar RF and microwave circuits are covered along with the various microwave integrated circuits components and fundamentals of monolithic microwave integrated circuits technology.
Course Outcome	:	After the completion of the course, student will be able to

CO1	Design of planar transmission line components	Analyze
CO2	Understand and design the behaviour of microwave passive components	Analyze
CO3	Describe the working of lumped elements in MICs, Analysis of circuits	Analyze
CO4	Explain the behaviour of non-reciprocal components in MICs	Understand
CO5	Appreciate the MMIC technology, fabrication and implementation	Understand

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3	3			3	2	2	2
CO2	3	3	3			3	2	2	2
CO3	3	3	3			3	2		2
CO4	3					3			
CO5	3					3		1	

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Planar Transmission lines:** Strip line, Microstrip line, coplanar line, quasi – static models of microstrip line, effective permittivity, characteristic impedance, dielectric and conductor losses, substrates for MIC, slot line and coplanar waveguide
Module 2	**Microstrip Passive Components:**- Discontinuities in Microstrip lines and coplanar lines, step, bent, T- junction, Hybrid line coupler, parallel coupled line and directional couplers, Even and odd mode analysis, Branch line couplers, impedance transformers
Module 3	**Lumped Elements for MICs:** Design and fabrication of lumped elements, circuits using lumped elements, Lumped constant Microstrip circuits, Filters- Design

Module 4	**Nonreciprocal components for MICs:** Microstrip on Ferromagnetic substrates, Microstrip circulators. Isolators and phase shifters, Design of microstrip circuits – high power and low power circuits
Module 5	**MMIC Technology:** – Thick film and Thin film technology, Hybrid MIC's. Monolithic MIC technology, fabrication process, testing methods, encapsulation and mounting of devices

References:

[1] D. M. Pozar, *Microwave Engineering*, 4th ed. Wiley, Hoboken, NJ, ISBN 9780470631553, 2011.

[2] T. H. Lee, *Planar Microwave Engineering: A Practical Guide to Theory, Measurements and Circuits.* Cambridge University Press, 2004.

[3] M. M. Radmanesh, *Radio Frequency and Microwave Electronics Illustrated.* Prentice Hall, 2001.

[4] R. L. . Bretchko, *RF Circuit Design, Theory and Applications.* Pearson Education Inc, 2011.

[5] T. C. Edwards, *Foundation for Microstrip Circuit Design.* Jone Willy & sons, 2000.

[6] E. H. Fooks and R. A. Zakarevicuis, *Microwave Engineering using Microstrip Circuits.* Prentice Hall, 2000.

[7] R. K. Hoffman, *Handbook of Microwave Integrated Circuits.* Artech House, Boston, 1987.

[8] K. C. Gupta and A. Singh, *Microwave Integrated circuits.* Wiley Eastern, 1974.

[9] B. Bhat and S. K. Koul, *Stripline-like Transmission Lines for Microwave Integrated Circuits.* New Age International, 2007.

24-305-0X14 **FPGA Based System Design**

L	T	P	C
3	**1**	**0**	**3**

Prerequisites	:	Digital Logic
Course Description	:	This course will provide an understanding of 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, student will be able to

CO1	Design basic digital building blocks	Apply
CO2	Use top down approach for designing digital systems	Apply
CO3	Summarize architectural features of various types of FPGAs	Understand
CO4	Explain different blocks in FPGA SoCs	Understand
CO5	Design and implement System-on-Chips on FPGA using system design methodologies	Apply

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3					3		
CO2	3	3					3		3
CO3	3								2
CO4	3								2
CO5	3	3	3				3	3	3

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Digital Building Blocks:** Decoder, multiplexers, code converters, counters, shift registers, FSMs, arithmetic circuits -adders, multipliers, dividers, sequential building blocks, memory arrays, logic arrays. modeling using Verilog
Module 2	**Digital System Design Approaches:** Top down approach to design, data path, control path, controller behaviour and design, design examples - BCD adder, traffic light controller, binary multiplier & divider
Module 3	**Programmable Devices:** Overview of programmable devices, CPLDs, FPGAs – implementing functions using PLDs, PLAs & FPGAs, architectures of commercial FPGAs Xilinx, Intel - Altera and Atmel,SRAM based FPGAs, permanently pro- grammable FPGAs, I/O, circuit design & architecture of FPGA fabrics, carry chains and cascade chains, design flow, Case study: Xilinx 7-series architecture

Module 4	**FPGA SoCs** Buses - AMBA & AXI, platform FPGA architectures, high speed transceivers, clocks, embedded memories & arithmetic blocks, creating IP blocks, soft core & hard core processors, Case Study: Xilinx Zync 7000 SOC
Module 5	**Embedded System Design Using FPGAs**: C-to-RTL high level synthesis, hardware software codesign, case study I: system design using Microblaze softcore processor and Xilinx embedded design kit (EDK), peripherals, developing software applications on microblaze. case study II: 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] C. H. Roth, L. K. John, and B. K. Lee, *Digital Systems Design Using Verilog.* Elsevier, 2007.

[2] S. Kilts, *Advanced FPGA Design Architecture, Implementation, and Optimization.* Wiley-IEEE Press, 2007.

[3] J. F. Wakerly, *Digital Design - Principles and Practices*, 4th ed. Pearson, 2008.

[4] W. Wayne, *FPGA Based System Design.* Prentice Hall PTR, 2004.

[5] R. Sass and A. G. Schmidt, *Embedded Systems Design with Platform FPGAs, Principles and Practices.* Elsevier, 2007.

[6] Xilinx FPGA user guides and documentation.

24-305-0X15	**Data Structures**	**L**	**T**	**P**	**C**
		3	**1**	**0**	**3**

Prerequisites : Basic C programming

Course Description : This course introduces object oriented programming using C++. It also discusses various data structures like stacks, queues, lists, trees and graphs. Various sorting and searching algorithms are also discussed

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

CO1	Determine the functionality of C++ statements, expressions, functions and programs	Apply
CO2	Develop object oriented C++ programs for solving practical problems	Apply
CO3	Compare the various searching sorting algorithms	Understand
CO4	Understand the various implementations of stacks, queues and lists, trees and graphs	Understand
CO5	Develop C++ implementations of stacks, queues and lists, trees and graphs for practical applications	Apply

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3								3
CO2	3	3					3		3
CO3	3								2
CO4	3								2
CO5	3	3					3		3

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Programming in C++:** C++ data types, simple data types, programmer defined data types, functions and parameters, pointers, dynamic memory allocation, static and dynamic arrays, structures, pointers to structures, input and output, classes, constructors and destructors, copy operation
Module 2	**Object oriented programming:** Overloading operators, overloading I/O operators, encapsulation, inheritance and operator oriented design, building derived classes, polymorphism and dynamic binding, virtual functions, standard template libraries, case study

Module 3	**Searching and Sorting:** Algorithm efficiency, linear and binary search implementation, bubble sort, selection sort, insertion sort, heap sort, quick sort and merge sort, time and space complexity for sorting algorithms
Module 4	**Lists, Stacks & Queues & Binary Trees:** Array based implementation of lists linked lists- pointer based implementation, stacks and queues- array based implementation. binary tree- in-order, pre-order and post-order traversals - representation and evaluation of arithmetic expressions using binary tree
Module 5	**Search Trees & Graphs:** Binary search trees - insertion, deletion and search graphs- directed graphs, adjacency-matrix and adjacency-list representation, depth first search, breadth first search, traversal and shortest path problems

References:

[1] L. R. Nyhoff, *ADTs, Data Structures and Problem Solving with C++*, 2nd ed. Pearson Education, 2012.

[2] S. Sartaj, *Data Structures, Algorithms and Applications in C++*, 2nd ed. Silicon Pr., 2004.

[3] Y. Langsam, M. J. Augenstein, and A. M. Tenenbaum, *Data Structures Using C and C++*, 2nd ed. Pearson Education India, 2015.

[4] T. H. Cormen, C. E. Leiserson, R. L. Rivest, and C. Stein, *Introduction to Algorithms*, 3rd International Edition ed. MIT Press, 2009.

[5] S. Dasgupta, C. H. Papadimitriou, and U. V. Vazirani, *Algorithms*, 1st ed. McGraw-Hill Higher Education, 2006.

24-305-0X16 **Embedded Software and Real Time Systems**

L	T	P	C
3	**1**	**0**	**3**

Prerequisites	:	Basic course on embedded systems
Course Description	:	This course provides an understanding to the students in the various aspects of embedded software and real time systems. It covers factors affecting embedded software along with methodologies in task scheduling, communication and resource management
Course Outcome	:	After the completion of the course, 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	Identify feasible schedules using various scheduling algorithms	Analyze
CO4	Discuss resource management and deadlock avoidance techniques	Understand
CO5	Explain various commercial RTOS flavors including Free RTOS	Understand

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	2	2				3		2
CO2	3								2
CO3	3	2					3		2
CO4	3								2
CO5	3		2						2

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Factors influencing Embedded system design:**CPU and memory types, Direct memory access, Interrupt basics, interrupt latency, disabling and masking interrupts, Shared data problems, atomicity, critical section
Module 2	**Software Architectures for Embedded System:** Round robin approach, round robin with interrupts, real time operating systems, soft and hard real time OS, tasks and task states, scheduler, reentrancy, semaphores, signaling, semaphore problems
Module 3	**Tasks Scheduling:** Interrupt driven systems, pre-emptive priority systems, hybrid systems, task control block model. process scheduling, fixed priority scheduling – rate monotonic approach, dynamic priority scheduling- earliest deadline first approach

Module 4	**Communication and resource management:** Message queue, mailbox, pipes. inter-task communication, blocking and non-blocking task synchronization. nested interrupts, resource management, deadlock, starvation, pre-emption, priority inversion, priority inheritance, priority ceiling protocol
Module 5	**Embedded software development tool:** Host and target machines, cross compilers, Linker, locator, emulators, in-circuit emulators, monitors. IEEE POSIX standard for programming, POSIX threads, POSIX semaphores and shared memory

References:

[1] D. E. Simon, *An Embedded Software Primer.* Pearson Education, 2000.

[2] A. Silberschatz, *Operating Systems Concepts.* John Wiley & Sons, 2004.

[3] H. Kopetz, *Real-Time systems, Design principles for distributed embedded applications.* Springer, 2011.

[4] P. A. Laplante, *Real - Time Systems Design and Analysis.* John Wiley & Sons, 2004.

[5] F. Vahid and T. Givargis, *Embedded System Design: A Unified Hardware/ Software Introduction.* John Wiley & Sons, 1999.

[6] W. Wolf, *Computers as Components: Principles of Embedded Computing System Design.* Elsevier, 2000.

[7] VxWorks, https://www.windriver.com/products/vxworks/.

[8] R. T. Linux, https://rt.wiki.kernel.org/index.php/Main_Page.

[9] N. Melot, “Study of an Operating System: FreeRTOS,” *CAPÍTULO XVIII*, vol. 115, pp. 1–39, 2009.

24-305-0X17	**NPTEL/MOOC Course**

L	T	P	C
2	0	0	2

Prerequisites : None

Lab Description : This course has to be completed through MOOC mode using NPTEL/SWAYAM or other university approved MOOC platforms .

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

CO1	Demonstrate the ability for independent learning	Apply
CO2	Follow ethical practices for timely submissions	Apply

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3			3	3	3	3		
CO2				3	3	3			

3-High; 2-Medium; 1-Low

Course Content:

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 2. The selection of the course will be dependent on their specialisation and should be approved by the committee constituted for the same. The modality of the course will be as per the university guidelines on MOOC courses.

24-305-0X21 **Robotics and Automation Lab**

L	T	P	C
0	0	4	2

Prerequisites : Robotics and Automation
Lab Description : This lab implements the kinematics, dynamics, and control of industrial robots
Course Outcome : After the completion of the lab, the student will be able to

CO1	Create kinematic and dynamic model of the robot	Apply
CO2	Simulate the robot's motion with the various controllers	Apply
CO3	Simulate the behavior of a robot and analyze joint torques and power consumption	Analyze

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3	3	3	3	3	3		3
CO2	3	3	3	3	3	3	3	3	3
CO3	3	3	3	3	3	3	3	3	3

3-High; 2-Medium; 1-Low

Course Content:

Sample List of Experiments*	
1	Program the SCARA robot to transfer objects from one position to another
2	DH parameters calculation
3	Kinematics of manipulators
4	Design of DC motor driver using L298 with speed, overload and direction control
5	Perform forward kinematics Using Robotics Toolbox from MATLAB

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

References:

[1] M. Quigley, B. Gerkey, and W. D. Smart, *Programming Robots with ROS: A Practical Introduction to the Robot Operating System.* O'Reilly Media, 2015.

[2] J. Lentin, *Mastering ROS for Robotics Programming.* Packt, 2015.

[3] C. Fairchild and T. L. Harman, *ROS Robotics By Example.* Packt, 2017.

[4] R. Siegwart, I. R. Nourbakhsh, and D. Scaramuzza, *Introduction to Autonomous Mobile Robots.* MIT Press, USA, 2011.

24-305-0X22	**Mobile Robotics Lab**

L	**T**	**P**	**C**
0	**0**	**4**	**2**

Prerequisites	:	Mobile Robotics
Lab Description	:	This course provides an introduction to locomotion of robots and it provides an overview of various techniques for Robot Motion planning, Navigation, Localization, and mapping
Course Outcome	:	After the completion of the lab, the student will be able to

CO1	Program SCARA robot to perform tasks	Understand
CO2	Integrate and use ROS packages for various robotic applications	Apply
CO3	Demonstrate the robot‘s capability for autonomous mapping and localization	Apply
CO4	Navigate the robot through a cluttered environment without colliding with obstacles	Apply
CO5	Develop an optimized and efficient path that shows the intelligent navigation capability of the robot	Analyze

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3	3	3	3	3	3		3
CO2	3	3	3	3	3	3	3		3
CO3	3	3	3	3	3	3	3	3	3
CO4	3	3	3	3	3	3	3	3	3
CO5	3	3	3	3	3	3	3	3	3

3-High; 2-Medium; 1-Low

Course Content:

Sample List of Experiments*	
1	Program the SCARA robot for transfer of objects from one position to another
2	Learn and implement various ROS packages
3	Implement SLAM algorithms to enable the robots to map an unknown environment while simultaneously localizing themselves to that environment
4	Develop an obstacle avoidance algorithm that allows the robot to navigate around obstacles in its path
5	Experiment with different path planning algorithms and find the most efficient route from one point to another

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

References:

[1] M. Quigley, B. Gerkey, and W. D. Smart, *Programming Robots with ROS: A Practical Introduction to the Robot Operating System.* O'Reilly Media, 2015.

[2] J. Lentin, *Mastering ROS for Robotics Programming.* Packt, 2015.

[3] C. Fairchild and T. L. Harman, *ROS Robotics By Example.* Packt, 2017.

[4] R. Siegwart, I. R. Nourbakhsh, and D. Scaramuzza, *Introduction to Autonomous Mobile Robots.* MIT Press, USA, 2011.

[5] https://in.mathworks.com/solutions/robotics/resources.html.

24-305-0X23 **Microwave Integrated Circuits Lab**

L	T	P	C
0	0	4	2

Prerequisites : 24-305-0X13

Course Description : This lab familiarizes the student with the experimental set up for carrying out microwave measurements followed by characterising the various Microwave/RF components. Also 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 course, student will be able to

CO1	Setup a X band microwave bench and carry out measurement of various RF parameters	Apply
CO2	Familiarization of measurement with Network Analyzer	Apply
CO3	Computer aided design and characterization of various microwave components	Apply
CO4	Understand the principle of radiation, measure the parameters	Understand

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3		3	3	3	2	3	
CO2	3	3		3	3	3	2	3	
CO3	3	3	3	3	3	3	2	3	3
CO4	3	3		3	3	3	2	3	

3-High; 2-Medium; 1-Low

Sample List of Experiments*	
1	Familiarisation of X band Bench set up and do the measurements of various RF parameters
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, QW transformer, network analyzer)
5	Cavity Resonators (resonant frequency, Q frequency counter)
6	Directional Couplers, Circulators, Waveguide Tees, Isolators, Attenuators (insertion loss, coupling, directivity)
7	Familiarization with antenna measurement setup
8	Computer Aided Design and Testing of Planar Transmission Lines, Planar Filters, Amplifiers, Oscillators

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

24-305-0X24 **Data Structure Lab**

L	T	P	C
0	0	4	2

Prerequisites	:	Basic C programming
Lab Description	:	This lab introduces object oriented programming in C++ and implementation of various data structures in C++
Course Outcome	:	After the completion of the lab, the student will be able to

CO1	Develop object oriented programs in C++ for real life problems	Analyze
CO2	Study programs with dynamic memory allocation and understand the concept of memory leaks	Understand
CO3	Compare different C++ implementations of the various sorting algorithms for large arrays in terms of execution time	Analyze
CO4	Implement linked lists, stacks and queues, bst with C++ and use these implementations for practical problems	Apply

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3	3	2	2	2	3		3
CO2	3		3	2	2	2			3
CO3	3		3	2	2	2			3
CO4	3	3	3	2	2	2	3		3

3-High; 2-Medium; 1-Low

Course Content:

Sample List of Experiments*	
1	Arrays: Write a program to add/multiply two large integers with more than 100 digits. The numbers are stored in arrays with each element storing a block of digits
2	Structures: Write a program to store and manage the details of students in a class
3	Develop a procedural program to implement a Time datatype
4	Develop an object oriented program to implement a Time datatype
5	Implement a class for complex numbers with methods for input and output, add, subtract, multiply, modulus, conjugate operators
6	Develop an object oriented program for managing payroll in a company. Use inheritance
7	Study programs with out of range indices for arrays, pointers and pointer dereferencing, memory allocation failures
8	Linked list for storing student records
9	Evaluating post fix expressions using stacks
10	BST inorder, preorder and post order traversals

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

References:

[1] L. R. Nyhoff, *ADTs, Data Structures and Problem Solving with C++*, 2nd ed. Pearson Education, 2012.

[2] S. Sartaj, *Data Structures, Algorithms and Applications in C++*, 2nd ed. Silicon Pr., 2004.

[3] Y. Langsam, M. J. Augenstein, and A. M. Tenenbaum, *Data Structures Using C and C++*, 2nd ed. Pearson Education India, 2015.

[4] T. H. Cormen, C. E. Leiserson, R. L. Rivest, and C. Stein, *Introduction to Algorithms*, 3rd International Edition ed. MIT Press, 2009.

[5] S. Dasgupta, C. H. Papadimitriou, and U. V. Vazirani, *Algorithms*, 1st ed. McGraw-Hill Higher Education, 2006.

24-305-0X25 **Embedded Software Lab**

L	T	P	C
0	0	4	2

Prerequisites : Basic programming

Lab Description : This lab will involve working on software tools and programming software for real time systems

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	Illustrate porting an open source RTOS into development boards for demonstrating real world scenarios	Apply
CO4	Customize operation of an RTOS to desired specifications	Apply

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3		3	2	2	2			3
CO2	3	2	3	2	2	2	3		3
CO3	3	2	3	2	2	2		2	3
CO4	3	2	3	3	3	3		2	3

3-High; 2-Medium; 1-Low

Course Content:

Sample List of Experiments*	
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

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

References:

[1] D. E. Simon, *An Embedded Software Primer.* Pearson Education, 2000.

[2] A. Silberschatz, *Operating Systems Concepts.* John Wiley & Sons, 2004.

[3] H. Kopetz, *Real-Time systems, Design principles for distributed embedded applications.* Springer, 2011.

[4] P. A. Laplante, *Real - Time Systems Design and Analysis.* John Wiley & Sons, 2004.

[5] F. Vahid and T. Givargis, *Embedded System Design: A Unified Hardware/ Software Introduction.* John Wiley & Sons, 1999.

[6] W. Wolf, *Computers as Components: Principles of Embedded Computing System Design.* Elsevier, 2000.

[7] VxWorks, https://www.windriver.com/products/vxworks/.

[8] R. T. Linux, https://rt.wiki.kernel.org/index.php/Main_Page.

[9] N. Melot, “Study of an Operating System: FreeRTOS,” *CAPÍTULO XVIII*, vol. 115, pp. 1–39, 2009.

24-305-0X26 **Communication Systems Lab**

L	T	P	C
0	0	4	2

Prerequisites	:	Signals and Systems
Lab Description	:	This lab deals with the implementation of basic analog and digital communication techniques in MATLAB/Labview
Course Outcome	:	After the completion of the lab, the student will be able to

CO1	Familiarize basic programming environment for communication in MATLAB/LabVIEW	Understand
CO2	Familiarize communication toolbox in MATLAB/LabVIEW	Understand
CO3	Implement basic analog and digital modulation techniques in MATLAB/LabVIEW	Apply
CO4	Analyse the effect of noise in digital communications system	Analyze

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3		3	2	2	2			3
CO2	3		3	2	2	2			3
CO3	3	2	3	2	2	2	2		3
CO4	3	2	3	2	2	2	2		3

3-High; 2-Medium; 1-Low

Course Content:

Sample List of Experiments*	
1	Signal Sampling and reconstruction
2	Time Division Multiplexing
3	AM Modulator and Demodulator
4	FM Modulator and Demodulator
5	Pulse Code Modulation and Demodulation
6	Delta Modulation and Demodulation
7	Signal constellations of BPSK, QPSK and QAM
8	Eye Diagram
9	FSK, PSK and DPSK schemes
10	Communication link simulation

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

References:

[1] S. Haykin, *Communication Systems*, 4th ed. John Wiley & Sons, 1996.

[2] https://www.mathworks.com/academia/courseware/digital-communication-laboratory.html.

24-305-0305 **Mini Project**

L	T	P	C
0	0	6	3

Prerequisites : None

Lab Description : This course enables students to work with a faculty member in finding solutions for practical problems which can be continued as their end-semester project work

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

CO1	Identify unresolved problems and challenges in the selected domain through literature survey	Analyze
CO2	Determine appropriate tools and procedures for design, development & verification	Evaluate
CO3	Develop practical solutions for the chosen problem for a given specification	Create
CO4	Develop the ability to write good technical report, to make oral presentation of the work	Apply

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3			3	3	3	3		
CO2	3	3	3	3	3	3	3		3
CO3	3	3	3	3	3	3	3	3	3
CO4				3	3				

3-High; 2-Medium; 1-Low

Course Content:

This course provides an option for exceptional students to start working with a faculty/industry for their final semester project from third semester onwards. Students can opt for this course only with the approval of a faculty supervisor or if they have got an offer for internship. The number of students from a batch, each faculty member can guide is limited to two. The project can be analytical work, simulation, hardware design or a combination of these in the emerging areas of electronics. The specific project topic undertaken will reflect the common interests and expertise of the student(s) and supervisor. Students doing their project outside the department will be assigned an internal supervisor.

Students will be required to

- perform a literature search to review current knowledge and developments in the chosen technical area
- undertake detailed technical work in the chosen area using one or more of the following:
    - Analytical models
    - Computer simulations
    - Hardware implementation

The project supervisor/internal supervisor shall do monthly evaluation of the progress. A project evaluation committee for the course shall evaluate the project work during the end of third semester.

MASTER OF SCIENCE

in

ELECTRONIC SCIENCE

Electives Mapped from M.Tech VLSI and Embedded Systems

DEPARTMENT OF ELECTRONICS
COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY
Kochi - 682 022, India

24-509-0101 **Digital System Design using HDLs**

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

Prerequisites : Digital design

Course Description : This course trains the students to design digital system using HDLs and provides an overview of building a processor using basic components.

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

CO1	Design combinational and sequential circuits	Apply
CO2	Design basic combinational/sequential building blocks of a digital system using Verilog/Bluespec HDLs	Apply
CO3	Compare different implementations in terms of timing and hardware resources	Analyze
CO4	Understand RISC processor pipeline and design a simple processor that support a subset of instruction	Apply

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	2	2					3	2	
CO2	3	3	3	2			3	3	3
CO3	3	3	3				3	3	3
CO4	3	3					3	3	3

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Review of Digital Design:** Combinational Logic - Karnaugh Maps, Sequential Circuits- Flip Flops and Latches, Mealy and Moore Circuits, State Reduction, Sequential Circuit Timing
Module 2	**Verilog HDL:** 4-Valued Logic System, Compilation, Simulations and Synthesis, Basic Constructs- Modules, Variables, Data types and Operators, Delays, Constants, Assignments, Initial and Always block, Blocking and Nonblocking Assignments, Statements – if, case, and casez, Constants arrays and loops, Structural model and Behavioral models, Testbench
Module 3	**Digital Building Blocks:** decoder, multiplexers, code converters, counters, shift registers, FSMs, Arithmetic Circuits -adders, multipliers, dividers, Number Systems (fixed and floating point), Sequential Building Blocks, Memory Arrays, Logic Arrays

Module 4	**Bluespec Verilog (BSV) HDL:** BSV's advantages over Verilog, Basic Syntax, Combinational Structures: Types and Type-checking, Parameterized Description, Sequential Design: Registers, Methods and method types, Rules and atomicity, Guarded interfaces, Iterative circuits: spatial and temporal unfolding, BSV to RTL: Interface, Registers, Ready-Enable interface protocol; Linearizability and Serializability, Concurrent execution of rules, rule scheduler
Module 5	**Processor Design:** MIPS ISA, Microarchitecture - Performance Analysis, Pipelined Processor- Data path, Control Path, HDL Representation-Instruction Encoding, Implementation of MIPS Subset

References:

[1] Charles H. Roth Jr., Lizy Kurian John, and Beyeong Kil Lee, *Digital Systems Design Using Verilog.* CL Engineering, 2015.

[2] David Money Harris and Sarah L Harris, *Digital Design and Computer Architecture.* Elsevier, 2019.

[3] Charles H. Roth Jr, *Fundamentals of Logic Design.* CL Engineering, 2013.

[4] Arvind, Rishiyur S. Nikhil, James C. Hoe, and Silvina Hanono Wachman, *Introduction to Digital Design as Cooperating Sequential Machines.*

[5] Bluespec Reference Guide, "https://web.ece.ucsb.edu/its/bluespec/doc/BSV/reference-guide.pdf."

[6] Rishiyur S. Nikhil and Kathy R. Czeck, *BSV by Example: The next-generation language for Electronic System Design,.* Bluespec, 2010.

[7] Stuart Sutherland, Simon Davidmann, and Peter Flake, *SystemVerilog for Design: A Guide to Using SystemVerilog for Hardware Design and Modeling.* Springer, 2006.

[8] John F. Wakerley, *Digital Design Principles and Practice.* Pearson Education, 2018.

[9] Samir Palnitkar, *Verilog HDL.* Pearson Education, 2004.

[10] J. Bhasker, *A Verilog HDL Primer.* Star Galaxy Publishing, 2005.

24-509-0102 **Digital Integrated Circuits**

L	T	P	C
3	2	0	3

Prerequisites : MOSFET basics, digital design

Course Description : This course introduces students to the analysis and design of digital integrated circuits along with the trade-offs involved in the design of combinational and sequential circuits.

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

CO1	Apply MOSFET characteristic equations to understand the design trade-offs in static CMOS inverters	Apply
CO2	Implement a combinational logic circuit for a given functionality with specific speed, area and power requirements	Apply
CO3	Analyze functionality, area, performance and power dissipation of combinational and sequential circuits	Analyze
CO4	Illustrate the use of combinational and sequential circuit design principles for building efficient arithmetic circuits	Apply
CO5	Summarize the different implementation strategies for digital circuits and the impact of interconnects on these circuits	Understand

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	2					3		
CO2	3	3					3		
CO3	3	3					3	2	
CO4	3	3					3	2	
CO5	3						3		

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Introduction:** Issues in digital integrated circuit design, quality metrics, manufacturing process, static & dynamic behavior of MOSFETs, interconnects. **Static CMOS Inverter:** CMOS inverter, static & dynamic behavior, robustness, performance, sizing, power dissipation
Module 2	**Combinational Logic:** Complementary CMOS, delay estimation, logical effort, sizing, delay optimization, ratioed logic, pass-transistor logic, dynamic logic

Module 3	**Sequential Logic:** Timing metrics, static latches & registers, dynamic latches & registers, delay constraints & violations, time borrowing, synchronous design, pipelining. **Memory:** Classification, architecture, static and dynamic RAMs, nonvolatile read-write RAMs, peripheral circuitry, power dissipation
Module 4	**Adders:** Definition, full adder circuit, inverting adder, carry save adder, carry select adder, carry look ahead adder. **Multipliers:** Definition, Booth and modified Booth encoding, array multiplier, carry save multiplier, signed multiplication, carry save implementation, final addition
Module 5	**Design flow:** Custom design, semicustom design, array based design. **Interconnects**: Capacitive parasitics, resistive parasitics, inductive parasitics

References:

[1] Jan M. Rabaey, Anantha P. Chandrakasan, and Borivoje Nikolić, *Digital Integrated Circuits: A Design Perspective*, 2nd ed. Pearson Education, 2003.

[2] Neil H.E. Weste and David Harris, *CMOS VLSI Design: A Circuits and Systems Perspective*, 4th ed. Addison Wesley, 2015.

[3] David A. Hodges, Horace G. Jackson, and Resve A. Saleh, *Analysis and Design of Digital Integrated Circuits: In Deep Submicron Technology*, Sp. Indian 3 ed. McGraw Hill, 2005.

[4] Ivan Sutherland, Robert F. Sproull, and David Harris, *Logical Effort: Designing Fast CMOS Circuits.* Elsevier Science, 1999.

[5] Sung-Mo Kang and Yusuf Leblebici, *CMOS Digital Integrated Circuits: Analysis and Design*, 4th ed. McGraw-Hill, 2003.

24-509-0201 **Design Verification and Testing**

L	T	P	C
3	2	0	3

Prerequisites	:	Digital design, Verilog
Course Description	:	This course deals with the design verification and testing stages of ASIC design flow. It provides an overview of the various components involved in the verification of a digital circuits. It also includes the basic testing and design for testability concepts.
Course Outcome	:	After the completion of the course, student will be able to

CO1	Summarize the components of design verification environment including coverage and assertion	Understand
CO2	Develop a self checking testbench to verify the given RTL design	Analyze
CO3	Generate test patterns for a circuit considering single-stuck-at fault model	Apply
CO4	Illustrate different design for testability techniques used for digital ICs	Understand

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3					3	3	2
CO2	3	3					3	3	2
CO3	3	3					3		2
CO4	3	3		3			3	3	2

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Introduction to Verification:** Functional verification versus Formal verification; Testbench; Verification versus Testing; Design and Verification Reuse, The Cost of Verification, Simulation, Waveform Viewers, Code Coverage, Functional Coverage, Assertions, Metrics
Module 2	**Verification Envirnment:** Verification Plan- Levels of Verification, Directed Testbenches Approach, Coverage-Driven Random-Based Approach; High-Level Modeling- Structure of High-Level Code, Race Conditions; Stimulus and Response- Reference Signals, Simple and Complex Stimulus, Bus-Functional Models, Response Monitor
Module 3	**Testbench Architecture:** Design Configuration, Self-Checking Testbenches, Directed Stimulus, Random Stimulus; Transaction-Level Model, Regression, Universal Verification Methodology (UVM)

Module 4	**Fundamentals of VLSI testing:** Fault modeling: Logical fault models, Single Stuck at Faults (SSF), Fault detection, Fault equivalence and fault dominance; Automatic test pattern generation - ATPG for SSF in combinational circuit, D-Algorithm, Sequential ATPG – Time Frame Expansion
Module 5	**Design for testability:** Controllability and Observability, Ad Hoc Design for testability, Generic scan based design, Test interface and boundary scan, Built-in-self- test (BIST)- BIST Architecture, Memory Test-MBIST

References:

[1] Janick Bergeron, *Writing Testbenches using System Verilog.* Springer, 2006.

[2] Charles H. Roth Jr., Lizy Kurian John, and Beyeong Kil Lee, *Digital Systems Design Using Verilog.* C L Engineering, 2015.

[3] Michael L. Bushnell and Vishwani D. Agrawal, *Essentials of Electronic Testing for Digital Memory and Mixed Signal VLSI Circuits.* Springer, 2005.

[4] Miron Abramovici, Melvin A. Breuer, and Arthur D. Friedman, *Digital System Testing and Testable Design.* IEEE Press, 1994.

[5] Chris Spear and Greg Tumbush, *System Verilog for Verification.* Springer, 2012.

[6] Stuart Sutherland, Simon Davidmann, and Peter Flake, *SystemVerilog for Design: A Guide to Using SystemVerilog for Hardware Design and Modeling.* Springer, 2006.

24-509-0202 **FPGA Based Embedded SoC Design**

L	T	P	C
3	2	0	3

Prerequisites : Digital design basics

Course Description : This course presents basic FPGA architectures and FPGA SoC architectures. Implementation of embedded systems on FPGA SoCs is also covered.

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

CO1	Summarize architectural features of various types of FPGAs	Understand
CO2	Model hardware blocks for optimized implementation on FPGAs	Apply
CO3	Explain different blocks in FPGA SoCs	Understand
CO4	Illustrate the concepts involved in system design on FPGAs	Apply
CO5	Discuss the different steps in SoC Design	Understand

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3						3		
CO2	3	3					3		
CO3	3						3		
CO4	3	3					3	2	
CO5	3		2				3		2

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**FPGA Overview:** Introduction, requirements & specification, hierarchical design, design abstraction **FPGA Architecture:** SRAM based FPGAs, permanently programmable FPGAs, I/O, circuit design & architecture of FPGA fabrics, carry chains and cascade chains, design flow, Case study: Xilinx 7-series architecture
Module 2	**Hardware Design & Optimization:** Modeling combinational logic using HDLs, combinational network delay, power and energy optimization, logic implementation, physical design, sequential design styles, clocking rules, architecting for speed, area and power, Case study - AES
Module 3	**FPGA SoCs:** Buses - AMBA & AXI, platform FPGA architectures, high speed transceivers, clocks, embedded memories & arithmetic blocks, creating IP blocks, soft core & hard core processors, Case Study: Xilinx Zync 7000 SOC **Clocks & Resets:** Crossing clock domains, gated clocks, asynchronous vs synchronous resets, Case study - I2S

Module 4	**System Design:** Principles, control flow graphs, hardware design, software design, debugging, Partitioning - analytical solution, communication, practical issues, Parallelism - principles, identifying parallelism, spatial parallelism, Bandwidth - techniques, scalable designs, on-chip and off-chip memory access
Module 5	**SoC Design:** SoC Overview, taxonomy of ICs, design abstraction, design flow, behavioral synthesis, scheduling, binding, resource sharing, on-chip communication architecture, modeling & co-simulation, hw/sw partitioning & co-synthesis, Case study - example using Xilinx Vivado HLS

References:

[1] Wayne Wolf, *FPGA Based System Design.* Prentice Hall PTR, 2004.

[2] Steve Kilts, *Advanced FPGA Design Architecture, Implementation, and Optimization.* Wiley-IEEE Press, 2007.

[3] Ron Sass and Andrew G. Schmidt, *Embedded Systems Design with Platform FPGAs, Principles and Practices.* Elsevier, 2007.

[4] Charles H. Roth Jr., Lizy Kurian John, and Beyeong Kil Lee, *Digital Systems Design Using Verilog.* Elsevier, 2007.

[5] Xilinx FPGA user guides and documentation.

24-509-0X14 **Neural Networks**

L	T	P	C
3	1	0	3

Prerequisites	:	None
Course Description	:	This course provides a broad overview to neural networks and its optimisation algorithm, heuristics and model analysis.
Course Outcome	:	After the completion of the course, student will be able to

CO1	Concept of learning, architectures and mathematical modelling of neuron	Understand
CO2	Model a linear regressor and classifier using a perceptron	Apply
CO3	Solve non-linear problems using multi-layer neural network	Apply
CO4	Analyse model performance and implement better training algorithms for neural network	Analyse
CO5	Understand RBFN networks and how to solve non-linear problems with kernel functions	Understand

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3						3		
CO2	3	2	2				3	2	2
CO3	3	2	2				3	2	2
CO4	3	2	2				3	2	2
CO5	3						3		

3-High; 2-Medium; 1-Low

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, batch perceptron algorithm. Model building through regression- linear regression model, Cost Function, learning rate, gradient descent algorithm, chain rule, optimization, Local minima, Global Minima, computer experiment: regression and pattern classification. Least-Mean-Square Algorithm

Module 3	**Multilayer Perceptron:** XOR problem, hidden layer, non-linearity, Back propagation algorithm, local error gradients, Back propagation and differentiation, Hessian matrix, optimal annealing and adaptive control of the learning rate, Approximations of function, Generalization, Cross validation, Network pruning Techniques, Optimal Brain Surgeon, Virtues and limitations of back propagation learning. computer experiment: pattern classification
Module 4	**Heuristics:** Heuristics for making the back-propagation algorithm perform better, batch learning and stochastic learning, activation functions, differentiability, symmetric, feature scaling, initialization, learning rate, momentum term, stopping criteria, Learning Curves, Early Stopping, Evaluation Measures: Training, Validation, Testing. Two class evaluation measures, Confusion Matrix
Module 5	**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*, 3rd ed. Pearson Education India, 2016.

[2] Martin T. Hagan, Howard B. Demuth, Mark H. Beale, and Orlando De Jesús, *Neural Network Design*, 2nd ed. Cengage Learning, 2014.

[3] Simon Haykin, *Neural Networks: A Comprehensive Foundation*, 2nd ed. Prentice Hall, 1999.

[4] Philip D. Wasserman, *Neural Computing: Theory and Practice.* Coriolis Group, 1989.

[5] B. Yegnanarayana, *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.

24-509-0X15 **Analog & RF IC Design**

L	T	P	C
3	1	0	3

Prerequisites : Circuit analysis

Course Description : This course introduces students to the analysis and design of basic analog integrated circuit components like amplifiers, current mirrors and biasing circuits. Specifications and trade-offs involved in analog design are covered. The course also covers various factors involved in the design of RF integrated circuit components.

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

CO1	Perform small signal analysis using MOSFET models	Apply
CO2	Design single stage and differential amplifiers for given specification	Apply
CO3	Discuss about appropriate current sources and voltage references for biasing	Undersatnd
CO4	Understand the basic building blocks of RF ICs and the trade-offs involved in RF designs	Understand
CO5	Explain the methodologies for designing RF IC components with given specifications	Undersatnd

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3					3		
CO2	3	3					3		
CO3	3						3		
CO4	3						3		
CO5	3						3		

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Introduction:** Review of 4 terminal MOSFET, small signal model and analysis, high frequency model **RF Basic Concepts:** Non linearity and its effects, noise, sensitivity & dynamic range, passive impedance transformation, scattering parameters, bandwidth estimation techniques
Module 2	**Single Stage Amplifiers:** Single stage amplifiers - common source, source follower, common gate, cascode amplifiers, frequency response, noise

Module 3	**Differential Amplifiers:** Basic differential pair, common mode response, frequency response, noise, MOS transistor mismatch, effect of transistor mismatch **Current Mirrors & Biasing:** Basic and cascode current mirrors, effect of transistor mismatch, biasing techniques, self biasing circuits, supply independent bias circuits, bandgap reference
Module 4	**Low Noise Amplifiers:** Input matching, LNA topologies, gain and band switching, non linearity calculations, power constrained design optimizations, design examples **Mixers:** Mixer fundamentals, mixing using non linear systems, multiplier based mixers
Module 5	**Oscillators:** Ring oscillators, LC oscillators, inductors and capacitors, voltage controlled oscillators **Phase Locked Loops**: Simple PLL, Type II PLL, Non-idealities, phase noise

References:

[1] Behzad Razavi, *Design of Analog CMOS Integrated Circuit*, 2nd ed. McGraw Hill India, 2017.

[2] Thomas H. Lee, *The Design of CMOS Radio-Frequency Integrated Circuits*, 2nd ed. Cambridge University Press, 2014.

[3] Behzad Razavi, *RF Microelectronics*, 2nd ed. Prentice Hall, 2012.

[4] Phillip E. Allen and Douglas R. Holberg, *CMOS Analog Circuit Design*, 3rd ed. Oxford University Press, 2013.

[5] Jacob Baker R., *CMOS Circuit Design, Layout and Simulation*, 3rd ed. Wiley-Blackwell, 2010.

24-509-0X17 Device Physics and Modeling for Integrated Circuits

L	T	P	C
3	1	0	3

Prerequisites : None

Course Description : This course reviews and strengthens the understanding of device physics studied at undergraduate level and provides indepth discussions on short channel MOSFETs and advanced MOS devices. The course also covers circuit level modeling of MOS devices.

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

CO1	Apply fundamental physics to model PN junctions and metal semiconductor junctions	Apply
CO2	Model the characteristics of MOS devices	Apply
CO3	Employ appropriate models to analyze and characterize MOSFET circuits	Apply
CO4	Explain the physics behind advanced FETs	Understand

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3	2				3		2
CO2	3	3	2				3		2
CO3	3	3	2				3		2
CO4	3						3		

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Semiconductor fundamentals:** Band model for solids, carrier concentrations, transport, generation-recombination, excess carriers **P-N junctions:** potential barrier, quasi-neutrality, reverse biased junction, breakdown, static and dynamic behavior, small signal and large signal models, SPICE model, simulation exercises using TCAD
Module 2	**Metal-semiconductor junction:** Band diagram, depletion region, capacitance, Schottky barrier, I-V characteristics, Ohmic contacts, TCAD exercises **MOS Capacitor:** Basic physics and analysis, equilibrium and non-equilibrium, C-V characteristics, oxide and surface charges, TCAD exercises
Module 3	**MOS Transistors:** Long-channel MOSFET - basic physics and models, channel-length modulation, body effect, sub threshold regime, small signal model, short and narrow channel effects, radiation and hot-carrier effects, parameter extraction, Spice Models, BSIM model, TCAD exercises

Module 4	**Complementary MOS:** Design considerations, latchup, digital design quality metrics, transient response, switch model, interconnect models, Elmore delay model, sequential circuit timing parameters, MOSFET Scaling
Module 5	**Modern MOSFETs:** High-k dielectrics, metal gates, strain, silicon-on-insulator, FINFETs **Nanoscale MOSFETs**: Basic theory, ballistic transport, scattering, nanowire and carbon nanotube transistors

References:

[1] Theodore I. Kamins and Richard S. Muller, *Device Electronics for Integrated Circuits*, 3rd ed. Wiley, 2002.

[2] Yannis Tsividis and Colin McAndrew, *Operation and Modeling of the MOS Transistor*, 3rd International ed. OUP USA, 2012.

[3] Jan M. Rabaey, Anantha P. Chandrakasan, and Borivoje Nikolić, *Digital Integrated Circuits: A Design Perspective*, 2nd ed. Pearson Education, 2003.

[4] Chenming Hu, *Modern Semiconductor Devices for Integrated Circuits*, 1st ed. Prentice Hall, 2010.

[5] Mark S. Lundstrom and Jing Guo, *Nanoscale Transistors: Device Physics, Modeling and Simulation*, 1st ed. Springer US, 2006.

[6] Sung-Mo (Steve) Kang and Yusuf Leblebici, *CMOS Digital Integrated Circuits: Analysis and Design*, 2nd ed. McGraw-Hill, 2003.

[7] J. P. Colinge, *FinFETs and Other Multi-Gate Transistors.* Springer, 2008.

[8] Mark Lundstrom. (2008) Physics of Nanoscale MOSFETs. 2/3/2024. [Online]. Available: https://nanohub.org/resources/5306#series

[9] Sentaurus TCAD Documentation Synopsys Inc. 2/3/2024. [Online]. Available: https://www.synopsys.com/manufacturing/tcad/device-simulation/sentaurus-device.html

24-509-0X20 **Image & 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.

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

CO1	Use basic image processing algorithms in practical applications	Apply
CO2	Select a suitable transform for the analysis of images	Analyze
CO3	Model image restoration/degradation	Apply
CO4	Apply image representation schemes for various applications	Apply
CO5	Demonstrate various video modeling techniques	Apply

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	2	3	2			2	3	
CO2	3	2	3	2				3	2
CO3	3	3	3					3	2
CO4	3	2	2					3	2
CO5	3	2	2				2	3	

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Fundamentals of Image Processing:** 2D systems & mathematical preliminaries - Linear systems and shift invariance, Fourier transform, optical and modulation transfer functions, matrix notation, Toeplitz and Circulant matrices, orthogonal and unitary matrices, block matrices and kronecker products, Types of images – black & white, gray scale and color images, basic relationship between pixels, intensity transformations and spatial filtering, filtering in frequency domain
Module 2	**Image Transforms:** Two-dimensional orthogonal and unitary transforms, separable unitary transforms, basis images, Kronecker products and dimensionality, properties of unitary transformations, dimensionality of image transforms, two dimensional DFT, cosine transform, sine transform, Hadamard transform, Haar transform, the KL transform

Module 3	**Image Restoration and Reconstruction:** A model of image degradation/restoration process, noise models, restoration in the presence of noise only using spatial filtering, periodic noise reduction using frequency domain filtering, linear position invariant degradations, estimating the degradation function, inverse function, wiener filtering, image reconstruction from projections
Module 4	**Morphology, Segmentation and Representation:** Morphological operations - dilation, erosion, opening and closing, Image segmentation - point, line and edge detection, thresholding, region growing, region splitting and merging, boundary preprocessing - chain codes, boundary approximation using minimum perimeter polygons, signatures, boundary feature descriptors - shape numbers, Fourier descriptors, statistical moments, region feature descriptors - compactness, circularity, eccentricity, topological descriptors - Euler number, texture descriptor based on histogram, graylevel co-occurrence matrix
Module 5	**Video Processing:** Video formation, perception and representation - principles of color video imaging, video cameras, video display, composite versus component video, gamma correction, analog video raster - progressive and interlaced scans, characterization of a video raster, video modeling -camera model, illumination model, object models, scene models, 2D motion models, 2D motion estimation - optical flow, pixel based motion estimation

References:

[1] Rafael C. Gonzalez and Richard E. Woods, *Digital Image Processing*, 4th ed. Pearson, 2018.

[2] Anil K. Jain, *Fundamentals of Digital Image Processing*, 1st ed. Pearson, 2015.

[3] Yao Wang, Jörn Ostermann, and Ya-Qin Zhang, *Video Processing and Communications*, 1st ed. Prentice Hall Upper Saddle River, NJ, 2002.

[4] Bhabatosh Chanda and Dwijesh Dutta Majumder, *Digital Image Processing and Analysis*, 1st ed. PHI Learning Pvt. Ltd., 2011.

[5] Subramania Jayaraman, S. Esakkirajan, and T. Veerakumar, *Digital Image Processing*, 2nd ed. Tata McGraw Hill, 2020.

[6] Alan C. Bovik, *Handbook of Image and Video Processing.* Academic press, 2010.

[7] Kenneth R. Castleman, *Digital Image Processing*, 1st ed. Pearson, 2007.

[8] Bernd Jähne, *Digital Image Processing*, 6th ed. Springer, 2005.

[9] William K. Pratt, *Digital Image Processing: PIKS Scientific Inside*, 4th ed. Wiley Online Library, 2007.

[10] Wayne Niblack, *An Introduction to Digital Image Processing.* Strandberg Publishing Company, 1985.

24-509-0104 **Digital System Design using HDLs Lab**

L	T	P	C
0	0	4	2

Prerequisites : Digital design

Lab Description : The lab focuses on design of digital system using HDLs like Verilog and Bluespec. Use front end tools for RTL design and simulations.

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

CO1	Develop basic testbench, simulate and debug Verilog/Bluespec designs using RTL simulation tools	Analyze
CO2	Design combinational and sequential using Verilog/Bluespec HDL	Apply
CO3	Design basic bulding blocks of a processor to realize a simple RISC processor using HDLs	Analyze

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3	3	3	3	3	3	2	3
CO2	3	2	3	3	3	3	3	2	3
CO3	3	3	3	3	3	3	3	3	3

3-High; 2-Medium; 1-Low

Course Content:

Sample List of Experiments*	
1	Design and simulate : full adder, multiplexer, priority encoder, code convertors, flipflops etc.
2	Design 4-bit adder/code converter using structural, data flow and behavioural models
3	Design of sequential circuits like: counter, shift registers, FIFO, pattern detection etc.
4	Implement 8 bit array multiplier and serial multiplier and compare area, power and delay
5	Design and simulate basic building blocks of processor like register file, ALU, decode unit etc.
6	Design of a simple RISC processor pipeline using the basic building blocks and debug the design using simulations

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

References:

[1] Charles H. Roth Jr., Lizy Kurian John, and Beyeong Kil Lee, *Digital Systems Design Using Verilog.* CL Engineering, 2015.

[2] David Money Harris and Sarah L Harris, *Digital Design and Computer Architecture.* Elsevier, 2019.

[3] Documentation for Cadence, Synopsis and Siemens Front end and Back end tools.

[4] Arvind, Rishiyur S. Nikhil, James C. Hoe, and Silvina Hanono Wachman, *Introduction to Digital Design as Cooperating Sequential Machines.*

[5] Bluespec Reference Guide, "https://web.ece.ucsb.edu/its/bluespec/doc/BSV/reference-guide.pdf."

[6] Stuart Sutherland, Simon Davidmann, and Peter Flake, *SystemVerilog for Design: A Guide to Using SystemVerilog for Hardware Design and Modeling.* Springer, 2006.

[7] J. Bhasker, *A Verilog HDL Primer.* Star Galaxy Publishing, 2005.

24-509-0105 **Digital Integrated Circuits Lab**

L	T	P	C
0	0	4	2

Prerequisites : Taken with Digital Integrated Circuit Design

Lab Description : This lab introduces the use of front-end and back-end tools for standard cell based designs.

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

CO1	Characterize speed, energy consumption, and robustness of combinational, sequential, and memory circuits using circuit simulation tools	Analyze
CO2	Draw optimized layouts for standard cells	Apply
CO3	Demonstrate the use of front-end and back-end design tools to obtain optimized layout from RTL models	Apply
CO4	Evaluate different implementation strategies for arithmetic circuits	Evaluate

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3		3	2	2	2	3		3
CO2	3	3	3	2	2	2	3		3
CO3	3		3	2	2	2	3		3
CO4	3	3	3	2	2	2	3	2	3

3-High; 2-Medium; 1-Low

Course Content:

Sample List of Experiments*	
1	MOSFET circuit simualtion and parameter extraction
2	Characterization of static CMOS inverter
3	Characterization of NAND/NOR logic gates
4	Design and analysis of chain of gates
5	Characterization of D flip flops
6	Layout of NAND/NOR standard cell
7	Front end and back end design and analysis of an 8 bit adder
8	Implement 8 bit ripple carry adder and carry look ahead adder and compare area, power and delay

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

References:

[1] Jan M. Rabaey, Anantha P. Chandrakasan, and Borivoje Nikolić, *Digital Integrated Circuits: A Design Perspective*, 2nd ed. Pearson Education, 2003.

[2] Documentation for Cadence, Synopsis and Siemens Front-end and Back-end tools.

24-509-0203 **Design Verification and Testing Lab**

L	T	P	C
0	0	4	2

Prerequisites	:	Digital design, Verilog
Lab Description	:	The lab will provide hands-on experience on implementing a test-bench to verifying a given digital design. This will also include exposure to testing tool for scan insertion and ATPG.
Course Outcome	:	After the completion of the lab, the student will be able to

CO1	Develop a test plan for a given specification	Analyze
CO2	Design functional verification environment for a Verilog RTL that can achieve the target coverage	Evaluate
CO3	Perform gate level timing simulation of netlist post and pre-layout	Apply
CO4	Stitch scan and generated test pattern for desired coverage using tools	Apply

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3	3	3	3	3	3	3	
CO2	3	3	3	3	3	3	3	3	3
CO3	3	3	3	3	3	3	3	3	3
CO4	3	3	3	3	3	3	3	3	3

3-High; 2-Medium; 1-Low

Course Content:

Sample List of Experiments*	
1	Familiarise the components of functional verification environment using simple components like full adder, multiplexer etc.
2	Functional verification of 4-bit adder with code/functional coverage
3	Functional verification of 8-bit counter with code/functional coverage
4	Functional verification of a simple RISC processor with code/functional coverage
5	Generate a gate level netlist of the given RTL and complete the physical design flow to extract timing parameters
6	Insert scan in the given netlist and generate test pattern to get 100% coverage
7	Gate level simulation post and pre-scan insertion

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

References:

[1] Janick Bergeron, *Writing Testbenches using System Verilog.* Springer, 2006.

[2] Charles H. Roth Jr. , Lizy Kurian John, and Beyeong Kil Lee, *Digital Systems Design Using Verilog.* C L Engineering, 2015.

[3] David Money Harris and Sarah L. Harris, *Digital Design and Computer Architecture.* Elsevier, 2019.

[4] Michael L. Bushnell and Vishwani D. Agrawal, *Essentials of Electronic Testing for Digital Memory and Mixed Signal VLSI Circuits.* Springer, 2005.

[5] Chris Spear and Greg Tumbush, *System Verilog for Verification.* Springer, 2012.

[6] Ray Salemi, *Python for RTL Verification: A complete course in Python, cocotb, and pyuvm.* Amazon Digital Services LLC, 2022.

[7] Documentation for Cadence, Synopsis and Siemens Front end and Back end tools.

24-509-0X28	**FPGA System Design Lab**

L	T	P	C
0	0	4	2

Prerequisites : Digital design basics

Lab Description : This lab equips students to build embedded systems using FPGA SOCs.

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

CO1	Compare resource utilization, area and power for different implementations of digital logic blocks on FPGA	Evaluate
CO2	Demonstrate the functionality of different FPGA I/O interfaces	Apply
CO3	Integrate processor cores, memory and arithmetic blocks, transceivers and programmable logic in FPGA for practical applications	Evaluate

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3	3	2	2	2	3		3
CO2	3	3	3	2	2	2	3		3
CO3	3	3	3	2	2	2	3	2	3

3-High; 2-Medium; 1-Low

Course Content:

Sample List of Experiments*	
1	Familiarization of Xilinx Vivado software
2	Implement basic logic blocks like adders, counters, shift registers on FPGA
3	Implement different types of multipliers and compare speed and resource utilization
4	Write a C program and run it on a single processor system, based on a MicroBlaze soft core, using the available Xilinx FPGA platform
5	Implement AXI-Lite peripheral with a Cortex-A9 Processing System on FPGA and demonstrate using GPIOs
6	Demonstrate a functional HDMI output system using Cortex-A9 Processing System on FPGA
7	Boot any OS on Cortex-A9 Processing System on FPGA

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

References:

[1] Ron Sass and Andrew G. Schmidt, *Embedded Systems Design with Platform FPGAs, Principles and Practices*. Elsevier, 2007.

[2] Matlab Resources: Digital system design and FPGA system design , “https://content.mathworks.com/viewer/642a7100f19355331a3ea4c2.”

[3] Xilinx FPGA user guides and documentation.

[4] Xilinx Vivado documentation.

[5] ARM Advanced System on Chip Design Education Kit.

MASTER OF SCIENCE

in

ELECTRONIC SCIENCE

Electives Mapped from M.Tech Microwave and Communication Engineering

DEPARTMENT OF ELECTRONICS

COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

Kochi - 682 022, India

24-510-0201 **Wireless Communications**

L	T	P	C
3	2	0	3

Prerequisites	:	Advanced Communication Systems
Course Description	:	This course reviews the various communication standards in wireless communication. The course will enable the students to understand the challenges in the wireless propagation medium and appreciate the use of advanced communication techniques to meet the rising demands of the telecom industry.
Course Outcome	:	After the completion of the course, the student will be able to

CO1	Analyse the type of wireless channel and identify the appropriate model for the same	Analyse
CO2	Apply appropriate techniques to mitigate the impact of channel impairments	Apply
CO3	Analyze the capacity and reliability of wireless communication systems	Analyse
CO4	Understand the latest techniques to appreciate the futuristic wireless systems and to be able to apply them to develop a new prototype	Apply

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3		2				3	3	
CO2	3	3	2				3	3	
CO3	3	3	2				3	3	
CO4	3	3	2				3	3	3

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Introduction to Wireless Channel Modeling:** Wireless Channel Models, Statistical fading models, time-varying channel impulse response, Narrowband and wideband fading models
Module 2	**Capacity of Wireless Channels:** Performance of digital modulation schemes over wireless channels, AWGN channel capacity, Capacity of flat and frequency selective fading channels
Module 3	**Cellular Concept:** Techniques to reduce interference and improve the capacity in cellular systems, **Fading Mitigation Techniques:** Different types of diversity techniques, Various diversity combining techniques, performance analysis for Rayleigh fading channels

Module 4	**Multiple Access Techniques:** Review of Random Multiple Access Protocols, Multiple Access protocols over different generations of cellular systems, Spread Spectrum Techniques, Techniques used in 4G - MIMO/OFDM technique
Module 5	**Modern Technology Standards:** Cellular wireless communication standards - LTE and LTE Advanced, 5G and 6G standards. Introduction to Massive MIMO, mmWave communication, Reconfigurable Intelligent Surfaces for coverage extension in mmWave and THz frequencies, Usage of NOMA among multiple users to improve spectral efficiency

References:

[1] T. S. Rappaport, *Wireless Communications: Principles and Practice*, 2nd ed. Cambridge University Press, 2024.

[2] A. Goldsmith, *Wireless CCommunications*. Cambridge University Press, 2005.

[3] A. F. Molisch, *Wireless Communications*, 2nd ed. John Wiley & Sons, 2011.

[4] G. L. Stüber, *Principles of Mobile Communications*, 2nd ed. Kluwer Academic Publishers, 2001.

[5] D. Tse and P. Viswanath, *Fundamentals of Wireless Communication*. Cambridge University Press, 2005.

[6] A. J. Viterbi, *CDMA: Principles of Spread Spectrum Communication*. Addison Wesley Longman Publishing Co., Inc., 1995.

[7] D. R. Koilpillai, "Introduction to Wireless and Cellular Communications," NPTEL Course, 2023.

[8] A. K. Jagannatham, "Advanced 3G and 4G Wireless Mobile Communications," NPTEL Course, 2014.

[9] A. K. Jagannatham, "Principles of Modern CDMA/ MIMO/ OFDM Wireless Communications (Course sponsored by Aricent)," NPTEL Course, 2021.

24-510-0202 **Radar Systems**

L	T	P	C
3	2	0	3

Prerequisites : A basic course in communication and microwave.

Course Description : In this course, the students are given an overview of different radars and the signal processing associated. Also gives an an insight in to different antennas used in radar applications.

Course Outcome : After the completion of the course, 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 ex- traction	Analyze
CO4	Understand the radar signal processing and the analysis using software tools	Analyze
CO5	Understand the different radar applications	Understand

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	2	2			3	2	2	2
CO2	3					3			
CO3	3	3	2			3	3	2	2
CO4	3	3	2			3	3	2	2
CO5	3					3			2

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Radar fundamentals and operation:** Introduction, principles, types of radar, transmitter functions, wave form spectra, receiver functions, Radar equation, Radar cross section
Module 2	**Radar Systems:** Pulse, CW, FM-CW, MTI, Doppler and multimode tech- niques, 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 (Software simulation)
Module 5	**Radar Applications:** Instrument landing systems, Electronic Warfare - ECM and ECCM, High resolution radar, range and Doppler resolution, Synthetic aperture radar, Radar in automobile - Movement Detection, Phased array Radar, millimeter wave radars

References:

[1] M. I. Skolnik, *Introduction to Radar Systems.* Tata Mcgraw Hill, 2001.

[2] B. Edde, *Radar: Principles, Technology and Applications.* Pearson Education Inc., 1995.

[3] D. C. Scheleher, *Introduction to Electronic Warfare.* Artech House Inc., 1986.

[4] G. J. Wheeler, *Radar Fundamentals.* Prentice Hall Inc, 1967.

[5] L. Nadav, *Radar Principles.* john Wiley and Sons, 1988.

[6] B. R. Mahafza, *Radar Systems Analysis and Design using MATLAB.* CRC Press, 2013.

[7] M. A. Richards, *Fundamentals of Radar Signal Processing*, 2nd ed. Tata Mcgraw Hill.

24-510-0X11 **Antennas for Communication Systems**

L	T	P	C
3	1	0	3

Prerequisites	:	Electromagnetic fields, General familiarity with transmission lines
Course Description	:	The objective of this course is to provide an understanding of antenna concepts, and modern antenna designs. Starting from the basic antenna parameters, the course will discuss various types of antennas including the planar antennas along with an in-depth study on the analysis and design of arrays. A brief glimpse to the design on antennas for the future wireless technologies is given at the end with a view that the student can further explore the topic, if interested.
Course Outcome	:	After the completion of the course, student will be able to

CO1	Apply mathematical fundamentals of the antenna theory to understand the basic principle of radiation, along with a physical understanding of how different types of antennas radiate and to measure their various figures of merit	Apply
CO2	Acquire an understanding of antenna arrays enabling them to analyse its different types and configuration	Analyse
CO3	Familiarise with the working of several conventional antennas as well as antennas for modern wireless systems	Understand
CO4	Evaluate an appropriate antenna/array type depending on the application and develop a preliminary design for a given frequency of operation	Evaluate

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3	3			2	3	2	2
CO2	3	3	3			2	3	3	2
CO3	3	3	2			2	3	2	2
CO4	3	3	3			3	3	3	3

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Preliminary Topics and Basic Definitions:** Review of Maxwell's Equations and Boundary conditions, Wave equations, Hertzian dipoles, Half-wave dipoles, Antenna radiation mechanism, Fundamental parameters and Figures of merit; Antenna measurements- Principle, Ranges, and Parameters

Module 2	**Wire Antennas:** Finite Length Dipoles, Monopoles, Inverted-F Antennas, Loop Antennas, Yagi-Uda and Log-periodic antennas
Module 3	**Types of Antennas:** Broadband Antennas- Helical, Bi-conical, Frequency Independent Antennas; Aperture Antennas- Radiation from apertures, Horn and Parabolic dish antennas, Microstrip patch antennas
Module 4	**Arrays:** Array Factor, Pattern Multiplication, Uniform and Non-uniform Excitation, Mutual Coupling, Phased Arrays and Array Feeding Techniques, Array synthesis approaches
Module 5	**Modern Antennas:** Antenna Design Requirements for Smartphones, Wireless Dongles, Wearable Devices, Base stations and Access points; MIMO Antenna configurations, Pattern and polarization diversity; mm-Wave Antennas and their feeding techniques; Terahertz Antenna Technologies for 6G Communication Systems

References:

[1] W. L. Stutzman and G. A. Thiele, *Antenna Theory and Design*, 3rd ed. John Wiley & Sons, 2012.

[2] C. A. Balanis, *Antenna Theory: Analysis and Design*, 4th ed. John wiley & sons, 2016.

[3] J. D. Kraus, R. J. Marhefka, and A. S. Khan, *Antennas and Wave Propagation*, 4th ed. Tata McGraw-Hill Education, 2017.

[4] S. K. Koul and G. Karthikeya, *Antenna Architectures for Future Wireless Devices.* Signals and Communication Technology, Springer, 2022.

[5] U. Nissanov and G. Singh, *Antenna Technology for Terahertz Wireless Communication.* Springer Nature, 2023.

[6] W. Hong and C.-Y. D. Sim, *Microwave and Millimeter-wave Antenna Design for 5G Smartphone Applications.* John Wiley & Sons, 2023.

24-510-0X12 **Machine Learning**

L	T	P	C
3	**1**	**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, student will be able to

CO1	Design linear, nonlinear regression and logistic regression models	Apply
CO2	Design Artificial Neural Network for solving ML problems	Apply
CO3	Design Support Vector Machine for solving ML problems	Apply
CO4	Design unsupervised learning methods like clustering algorithms and dimensionality reduction algorithms	Apply
CO5	Design ML system suitable to the problem and analyse the model performance	Analyse

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3	2	2			3	2	2
CO2	3	3	2	2			3	2	2
CO3	3	3	2	2			3	2	2
CO4	3	3	2	2			3	2	2
CO5	3	3	2	2			3	2	2

3-High; 2-Medium; 1-Low

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	**Artificial Neural Network:** Artificial Neural Network: Introduction, mathematical model of neuron, activation functions, network architectures, Learning-cost function, gradient descent, optimisation, XOR problem, multilayer perceptron, back propagation algorithm, differentiability, feature scaling, initialization, stopping criteria. Deep Learning, Universal function approximation, feature extraction, Pattern recognition and classification, Stochastic Gradient Descent and Batch Gradient Descent

Module 3	**Support Vector Machine:** Introduction, optimization objective, large margin classification, support vectors, Separating hyperplane approaches, support vector machine formulation, SVMs for Linearly Non Separable Data, SVM Kernels, Hinge Loss formulation
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
Module 5	**ML System Design and Evaluation Measures:** Learning with large datasets, stochastic gradient descent, batch and mini-batch gradient descent. Evaluating a Hypothesis, Model Selection, Regularisation, Training Validation Testing, Diagnosing Bias vs. Variance. Two Class Evaluation Measures, Confusion Matrix, Precision Recall curve, ROC Curve, Area Under Curve(AUC). Applications of machine learning and deep learning architectures in system design, Deep Learning in Communication Systems, Signal Classification and Pattern Recognition

References:

[1] T. Mitchell, *Machine Learning.* McGraw-Hill, 1997.

[2] S. Haykin, *Neural Networks and Learning Machines*, 3rd ed. Pearson Education India, 2016.

[3] T. Hastie, R. Tibshirani, and J. H. Friedman, *The Elements of Statistical Learning: Data Mining, Inference, and Prediction*, 2nd ed. Springer Series in Statistics, 2016.

[4] C. M. Bishop, *Pattern Recognition and Machine Learning.* Springer - Information Science and Statistics, 2011.

[5] S. S. Shwartz and S. B. David, *Understanding Machine Learning: From Theory to Algorithms.* Cambridge University Press, 2014.

[6] E. Alpaydin, *Introduction to Machine Learning*, 2nd ed. MIT Press, 2010.

[7] M. Mohri, A. Rostamizadeh, and A. Talwalkar, *Foundations of Machine Learning.* MIT Press, 2012.

24-510-0X13 Electromagnetic Interference and Compatibility

L	T	P	C
3	1	0	3

Prerequisites : General familiarity with EM fields, transmission lines and circuit theory

Course Description : The objective of this course is to provide an understanding of important concepts of Electromagnetic Compatibility which are fundamental for the design of electronics systems and devices in order to minimize electromagnetic interference. These concepts will be applied to a frequency range covering conduction and radiation, according the applicable standards.

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

CO1	Implement the various measurement techniques for electromagnetic interference and for electromagnetic compatibility	Apply
CO2	Recognize the various agencies and standards associated with EMI/EMC	Understand
CO3	Analyse various EM compatibility issues with regard to the design of PCBs and ways to improve the overall system performance	Analyse
CO4	Apply real-world EMC design constraints and make appropriate trade-offs to achieve the most cost effective design that meets all requirements	Apply

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3	2				3		3
CO2	3	3	2				3		2
CO3	3	3	3				3	3	3
CO4	3	3	3			3	3	3	2

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Introduction to Aspects of EMC:** EMI Sources, EMC units, Signal source specification, Advantages of EMC Design, EMC Requirements for Electronic Systems, Measurement of Radiated and Conducted Emissions. **Signal Spectra:** Spectra of Digital Waveforms, Spectral Bounds for Trapezoidal Waveforms, Spectrum Analyzer principle.

Module 2	**Signal Integrity:** Transmission-Line Equations, High-Speed Digital Interconnects, Effect of Terminations, Matching Schemes, Effects of Line Discontinuities. **Non-ideal Behavior of Components:** Wires, resistors, capacitors, inductors, Printed Circuit Board (PCB), Effect of Component Leads, Mechanical Switches.
Module 3	**Conducted Emissions and Conducted Susceptibility:** Measurement, Power Supplies, Filters, Placement. **Radiated Emissions and Conducted Susceptibility:** Simple Emission Models for Wires and PCB Lands, Simple Susceptibility Models for Wires and PCB Lands.
Module 4	**Crosstalk:** Three-Conductor Transmission Lines and Crosstalk, Shielded Wires, Twisted Wires. **Shielding:** Shielding Effectiveness- Far-Field Sources, Near-Field Sources; Low Frequency, Magnetic Field Shielding.
Module 5	**System Design for EMC:** Shielding, Ground, PCB Design, System Configuration and Design, Common EMC Issues in Practice and Design Guidelines.

References:

[1] C. R. Paul, *Introduction to Electromagnetic Compatibility*, three ed. John Wiley & Sons, 2022.

[2] H. W. Ott, *Electromagnetic Compatibility Engineering*, 2nd ed. John Wiley & Sons, 2009.

[3] W. D. Kimmel and D. Gerke, *Electromagnetic Compatibility in Medical Equipment*. IEEE & Interpharm Press, 1995.

[4] V. P. Kodali, *Engineering EMC Principles, Measurements and Technologies*, 2nd ed. Wiley-Blackwell, 2001.

24-510-0X14 Software Defined Radio for Communication Engineers

L	T	P	C
3	**1**	**0**	**3**

Prerequisites	:	Basic knowledge of Communication Systems, Digital Signal Processing
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.
Course Outcome	:	After the completion of the course, 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	Apply the insight to appreciate the usage of SDR for modern communication applications	Apply

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3					2	2		
CO2	3						2		
CO3	3					3	2	2	
CO4	3					3	3	2	

3-High; 2-Medium; 1-Low

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.**Multirate Signal Processing:** Introduction, Sample Rate Conversion Principles, Polyphase Filters, Digital Filter Banks
Module 4	**Case studies:** Software Defined Radio for Wi-Fi Jamming, Experimental study of OFDM implementation utilizing GNU Radio and USRP-SDR, Developing a generic software-defined radar transmitter using GNU Radio
Module 5	**Case studies :** 5G New Radio Prototype Implementation Based on SDR, Challenges of 5G testing using SDR, Characterisation of 5G using SDR platform

References:

[1] J. H. Reed, *Software Radio: A Modern Approach to Radio Engineering.* Prentice Hall Professional, 2002.

[2] T. J. Rouphael, *RF and Digital Signal Processing for Software-defined Radio.* Elsevier, 2008.

[3] C. R. Johnson Jr and W. A. Sethares, "Telecommunication breakdown," *Concepts of Communication Transmitted via Software-Defined Radio*, 2004.

[4] [Online]. Available: https://www.gnuradio.org/doc/doxygen-3.7.4.1/index.html

[5] [Online]. Available: https://pysdr.org/content/intro.html

[6] A. M. Wyglinski, R. Getz, T. Collins, and D. Pu, *Software-defined Radio for Engineers.* Artech House, 2018.

[7] L. Y. Hosni, A. Y. Farid, A. A. Elsaadany, M. A. Safwat *et al.*, "5G New Radio Prototype Implementation based on SDR," *Communications and Network*, vol. 12, no. 01, pp. 1–27, 2019.

24-510-0X21 **5G Technologies and Standards**

L	T	P	C
3	1	0	3

Prerequisites	:	Digital Communications, Advanced Communication Systems, Wireless Networks
Course Description	:	The aim of this course is to let the students understand that air Interface is one of the most important elements that differentiate between 2G, 3G, 4G and 5G. While 3G was CDMA based, 4G was OFDMA based; this course reveals the contents of air interface for 5G. This course gives an overview of 5G vision that aims to provide extremely low delay services, great service in crowd, enhanced mobile broadband, ultra-reliable and secure connectivity, ubiquitous QoS, and highly energy efficient networks.
Course Outcome	:	After the completion of the course, student will be able to

CO1	Understand the evolution of mobile communication standards developed over the years	Understand
CO2	Analyse the 5G potential and applications, case studies	Analyse
CO3	Interpretation of how virtualisation of network functions helps in scalability and ease of operations	Apply
CO4	Analyse the use of advanced techniques in cellular communications	Analyse
CO5	Appraise the current Status and future challenges for 5G and beyond	Analyse

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	2	2							
CO2	3	2					3		3
CO3	3					2	2		
CO4	3	2				2	3		3
CO5	3	2		2	2	2	3		3

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Evolution from 1G to 5G:** Analog voice systems in 1G; digital radio systems in 2G, voice and messaging services, TDMA based GSM,CDMA, 2.5G (GPRS), 2.75G (EDGE); IMT2000: 3G UMTS, W-CDMA, HSPA, HSPA+, 3G services and data rates; IMT Advanced: 4G, LTE, VoLTE, OFDM, MIMO, LTE Advanced Pro (3GPP Release 13+); IMT2020: 5G, enhancements in comparison to IMT Advanced

Module 2	**Basics of 5G :** 5G potential and applications; Usage scenarios: enhanced mobile broadband (eMBB), ultra reliable low latency communications (URLLC), massive machine type communications (MMTC), D2D communications, V2X communications, Massive MIMO
Module 3	**5G architecture:** Spectrum for 5G, spectrum access/sharing; millimetre Wave communication, channels and signals/waveforms in 5G, carrier aggregation, small cells, dual connectivity, NFV and SDN, Basics about RAN architecture, centralized RAN, open RAN, High-level requirements for the 5G architecture, Functional architecture and 5G flexibility, Physical architecture and 5G deployment
Module 4	**5G radio-access technologies:** Orthogonal multiple-access systems, Spread spectrum multiple-access systems, Capacity limits of multiple-access methods, Non-orthogonal multiple access (NOMA), Massive MIMO, beam formation, FAPI: PHY API Specification, user plane protocol- Service Data Adaptation Protocol (SDAP); multi-access edge computing (MEC); software defined networking (SDN), network function virtualization (NFV); network slicing; restful API for service-based interface; private networks
Module 5	**Current state and Challenges ahead :** 5G penetration in developed countries; deployment challenges in low-middle income countries, stronger backhaul requirements, dynamic spectrum access and usage of unlicensed spectrum, contrasting radio resource requirements; large cell usage: LMLC; possible solutions for connectivity in rural areas (BharatNet, TVWS, Long-range WiFi, FSO); non-terrestrial fronthaul/backhaul solutions: LEOs, HAP/UAV, Vision for 6G

References:

[1] [Online]. Available: https://www.3gpp.org/specifications-technologies/releases/release-15

[2] E. Dahlman, S. Parkvall, and J. Skold, *5G NR: The Next Generation Wireless Access Technology.* Academic Press, 2020.

[3] A. Osseiran, J. F. Monserrat, and P. Marsch, *5G Mobile and Wireless Communications Technology.* Cambridge University Press, 2016.

[4] S. Ahmadi, *5G NR: Architecture, Technology, Implementation, and Operation of 3GPP New Radio Standards.* Academic Press, 2019.

[5] E. Dahlman, S. Parkvall, and J. Skold, *4G, LTE-advanced Pro and the Road to 5G.* Academic Press, 2016.

24-510-0203 **Wireless Communication Lab**

L	T	P	C
0	0	4	2

Prerequisites : Fundamentals of Wireless Communication

Lab Description : Modelling of a wireless channel and analysis of the performance of a modern wireless communication system using MATLAB/Octave/Python

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

CO1	Understand the communication toolbox in MATLAB/OCTAVE	Understand
CO2	Implement a basic channel model in a wireless communication system	Apply
CO3	Compare the performance of BER and outage probability under various traditional and modern modulation schemes	Apply
CO4	Develop a wireless communication system and evaluate the performance of various diversity combining schemes	Evaluate

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3					3	3	
CO2	3	3					3	3	3
CO3	3	3				3	3	3	3
CO4	3	3				3	3	3	3

3-High; 2-Medium; 1-Low

Course Content:

Sample List of Experiments*	
Implementation of the following in MATLAB/Octave/Python	
1	Model a wireless channel using the Jakes Rayleigh fading channel model
2	Implement a BPSK communication system under additive white Gaussian noise (AWGN). Obtain the BER performance (Eb/N_o Vs Error rate) through Monte-Carlo simulations and compare the error performance with theoretical plots obtained using analysis
3	Simulate a wireless commutation system under flat Rayleigh fading using a digital modulation scheme for various diversity combining schemes. (i) Obtain the BER performance (BER Vs Average bit SNR) for the above schemes using 1×2 ($N_t \times N_r$) system and 1×4 ($N_t \times N_r$) system. (ii) Compare the BER curves in (i) with a SISO system. Measure the diversity gain in each case from the BER curves for a target probability of error of 10^{-3}

4	Plot the Outage Probability vs. average SNR normalized to the Threshold SNR for the system in Q3. and evaluate its performance for various Receiver diversity branches using Maximal ratio combining and Equal gain combining schemes
5	Develop a Rayleigh fading simulator for a mobile communications channel and plot the received signal amplitude for different Doppler frequencies

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

References:

[1] T. S. Rappaport, *Wireless Communications: Principles and Practice*, 2nd ed. Cambridge University Press, 2024.

[2] S. Haykin, *Communication systems.* John Wiley & Sons, 2008.

[3] A. Goldsmith, *Wireless Communications.* Cambridge university press, 2005.

[4] [Online]. Available: https://www.3gpp.org/specifications-technologies/releases/release-15

24-510-0X19	**Software Defined Radio Lab**				
		L	**T**	**P**	**C**
		0	**0**	**4**	**2**

Prerequisites	:	Advanced Communication Systems
Lab Description	:	Implementation of basic analog and digital communication systems in SDR using GNURadio/ Labview
Lab Outcome	:	After the completion of the lab, the student will be able to

CO1	Familiarize with the GNU Radio and Labview software	Understand
CO2	Generate the block schematic in GNU Radio/ Labview and test using software defined radio (SDR) transceivers	Apply
CO3	Implement and analyse basic analog and digital communication systems in SDR	Analyse
CO4	Implement and analyse an end-to-end communication system prototype using SDR	Analyse

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3		3					2	
CO2	3	3	3					3	
CO3	3	3	3	2	3	3		3	3
CO4	3	3	3	2	3	3		3	3

3-High; 2-Medium; 1-Low

Course Content:

Sample List of Experiments*	
Implementation of the following in MATLAB/Octave/Python	
1	To setup an FM Receiver
2	To setup an FM Transmitter and Receiver Station
3	To demonstrate BPSK/QPSK Modulation & Demodulation
4	To demonstrate DPSK Modulation & Demodulation
5	To setup a 2×2 MIMO system

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

References:

[1] [Online]. Available: https://www.gnuradio.org/doc/doxygen-3.7.4.1/index.html

[2] [Online]. Available: https://pysdr.org/content/intro.html

[3] A. M. Wyglinski, R. Getz, T. Collins, and D. Pu, *Software-defined Radio for Engineers.* Artech House, 2018.

24-510-0X20 **Antennas Lab**

L	T	P	C
0	0	4	2

Prerequisites	:	Taken with Antennas for Communication Systems
Course Description	:	The objective of this lab is to introduce the design, simulation and verification of performance of various antennas and arrays
Course Outcome	:	After the completion of the course, student will be able to

CO1	Characterise the performance of the various standard antenna/array designs using open source/licensed CAD tools	Apply
CO2	Measure the radiation performance different antennas using a Network Analyser and an anachoic chamber	Analyse
CO3	Develop an antenna design for a given set of design parameters and verify its performance	Apply

COs to POs Mapping

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3	3				3	3	3
CO2	3	2	3				3	2	2
CO3	3	3	3			2	3	3	3

3-High; 2-Medium; 1-Low

Course Content:

Sample List of Experiments*	
1	Familiarization with antenna simulation tools and measurement equipments
2	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 and the radiation patterns of standard antennas: Horn, Dipole, Vivaldi, Spiral etc
4	Design and simulation of different types of antenna arrays

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

24-510-0X22 **Machine Learning Lab**

L	T	P	C
0	0	4	2

Prerequisites : None

Lab Description : This lab provides experiments to implement machine learning algorithms using Python with the help of open source libraries such as sklearn, keras, pytorch, etc.

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

CO1	Design and implement linear, nonlinear regression and logistic regression models	Apply
CO2	Design and implement ANN for solving ML problems	Apply
CO3	Design and implement SVM for solving ML problems	Apply
CO4	Design and implement unsupervised learning methods like clustering algorithms and dimensionality reduction algorithms	Apply
CO5	Design ML system suitable to the problem, analyse and evaluate the model performance	Analyse

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1			3	3	2	2	3	2	3
CO2			3	3	2	2	3	2	3
CO3			3	3	2	2	3	2	3
CO4			3	3	2	2	3	2	3
CO5			3	3	2	2	3	3	3

3-High; 2-Medium; 1-Low

Course Content:

Sample List of Experiments*	
1	Familiarisation Python, Jupyter notebook, and libraries such as sklearn, keras and pytorch
2	Implement the Linear and Logistic Regression model with gradient descent optimisation
3	Implement Artificial Neural Network models and optimise using back propagation algorithm
4	Implement Support Vector Machines for classification tasks for linear and non-linear data
5	Implement k-means clustering algorithm and Principle Component Analysis algorithm

6	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.

References:

[1] A. Géron, *Hands-on Machine Learning with Scikit-Learn, Keras, and TensorFlow*, 3rd ed. " O'Reilly Media, Inc.", 2022.

[2] J. Krohn, *Deep Learning with TensorFlow, Keras, and PyTorch.* Pearson, 2020.

[3] Documentations of python libraries.

24-510-0X23 **EMI/EMC Lab**

L	T	P	C
0	0	4	2

Prerequisites	:	Taken with Electromagnetic Interference and Compatibility
Course Description	:	The objective of this lab is to familiarise the student with the significance of EMI/EMC and their impact in circuit design using appropriate experiments and simulation studies.
Course Outcome	:	After the completion of the course, student will be able to

CO1	Measure the conducted emission, radiated emission and crosstalk	Apply
CO2	Determine the EM compatibility of a device	Analyse
CO3	Apply EMI mitigation techniques such as shielding	Apply

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	2	2				3	2	2
CO2	3	2	2			2	3	2	3
CO3	3	3	3			2	3	2	2

3-High; 2-Medium; 1-Low

Course Content:

Sample List of Experiments*	
1	Familiarise with conducted and radiated emission measurement and simulation setup
2	Study and simulate different crosstalk in the cable and its reduction technique
3	Measure crosstalk in a three conductor transmission line using VNA
4	Study the characteristics and measure the conducted emission of a Current Probe
5	Measure board level emission using Magnetic Field loop Probes
6	Measure radiated emission from mobile tower and mobile phone
7	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.