SRI KRISHNA COLLEGE OF ENGINEERING AND TECHNOLOGY
An Autonomous Institution | Approved by AICTE | Affiliated to Anna University | Accredited by NAAC with A++ Grade
Kuniamuthur, Coimbatore – 641008
Phone : (0422)-2678001 (7 Lines) | Email : info@skcet.ac.in | Website : www.skcet.ac.in

Curriculum & Syllabi

Regulation 2022

2023-2027 Batch

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

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DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

(Batch 2023-2027)

VISION OF THE INSTITUTION

- To Produce Globally Competitive Engineers with High Ethical Values and Social Responsibilities.

MISSION OF THE INSTITUTION

- To impart the highest quality state-of-the-art technical education by providing impetus to innovation, research, and development and empowering students with entrepreneurship skills.
- To instill ethical values, imbibe a sense of social responsibility, and strive for societal well-being.
- To identify the needs of society and offer sustainable solutions through outreach programs.

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

VISION OF THE DEPARTMENT

- To equip future engineers with high academic knowledge, ethical values, leadership skills and a passion to contribute to the society.

MISSION OF THE DEPARTMENT

- To provide quality and contemporary education in Electronics and Communication Engineering through continuous upgradation of Curriculum and laboratory facilities, industrial collaboration and effective teaching learning process.
- To facilitate research activities and entrepreneurship skills to cope up with the changes in industrial demand and meet the global and societal needs.
- To inculcate professional attitude and ethical values.

I.	PROGRAMME EDUCATIONAL OBJECTIVES (PEOs)
PEO 1	Exhibit technical competence in Electronics and Communication Engineering by providing innovative engineering solutions and excel in professional career.
PEO 2	Indulge in problem identification, analysis and formulation to provide technically superior, economically feasible, environmentally compatible and socially acceptable design solutions.
PEO 3	Contribute towards entrepreneurship and research, and exercise leadership through effective communication, teamwork and knowledge upgradation through lifelong learning.

II.	PROGRAMME OUTCOMES (POs)
PO 1	**Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
PO 2	**Problem analysis**: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
PO 3	**Design/development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
PO 4	**Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
PO 5	**Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
PO 6	**The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
PO 7	**Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
PO 8	**Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
PO 9	**Individual and team work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
PO 10	**Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to

	comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
PO 11	**Project management and finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
PO 12	**Life-long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

III.PROGRAMME SPECIFIC OUTCOMES (PSOs)	
The Graduates of B.E – ELECTRONICS AND COMMUNICATION ENGINEERING programme will be able to:	
PSO 1	Potential to analyse, design, synthesize and provide technical solutions in the field of VLSI, Embedded Systems and Communication Networks.
PSO 2	Emerge as ethical leaders, excel in research, engage in lifelong learning, pursue entrepreneurship and contribute towards the field of Electronics and Communication Engineering.

IV. MAPPING OF PEOs WITH POs

PEO	**POs**											
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
1	**3**	**3**	**3**	**3**	**2**	**2**	**1**	**1**	**1**	**1**	**2**	**2**
2	**3**	**3**	**3**	**3**	**3**	**3**	**1**	**1**	**1**	**1**	**2**	**2**
3	**1**	**1**	**1**	**1**	**1**	**2**	**3**	**3**	**3**	**3**	**1**	**1**
	1- low, 2 - medium, 3 - high, '-' - no correlation											

V. MAPPING OF PEOs WITH PSOs

	PSO 1	**PSO 2**
PEO 1	3	2
PEO 2	2	2
PEO 3	2	3

AUTONOMOUS CURRICULUM AND SYLLABI

Regulations 2022
2023-2027 Batch

SEMESTER I							
S.No	**Course Code**	**Course Title**	**L/T/P**	**Contact Hrs/Wk**	**Credits**	**Ext/Int**	**Cat.**
Theory (Internal 40 Marks & External 60 Marks)							
1	23MA101	Mathematics I	3/1/0	4	4	60/40	BSC
2	23EC101	Circuit Theory and Electron Devices	3/0/0	3	3	60/40	ESC
3	23AS101	Applied Science	4/0/0	4	4	60/40	BSC
4	23SB101	Engineering Biology	3/0/0	3	3	60/40	BSC
Theory with Practical (Internal 50 Marks & External 50 Marks)							
5	23CS101	Problem Solving using C++	1/0/4	5	3	50/50	ESC
6	23IT101	Application Development Practices	1/0/4	5	3	50/50	ESC
Practical (Internal 60 Marks & External 40 Marks)							
7	23AS102	Applied Science Laboratory	0/0/4	4	2	40/60	BSC
Indian Knowledge System - Blended Learning							
8	23TA101	Heritage of Tamils	1/0/0	1	1	60/40	HSMC
Mandatory Course (Internal 100 Marks)							
9	23MC101	Mandatory Course I: Induction Programme	3 Weeks		0	0/100	MC
			TOTAL	**29**	**23**	**900**	

SEMESTER II							
S. No	**Course Code**	**Course Title**	**L/T/P**	**Contact Hrs/Wk**	**Credits**	**Ext/Int**	**Cat.**
Theory (Internal 40 Marks & External 60 Marks)							
1	23MA201	Mathematics II	3/1/0	4	4	60/40	BSC
2	23EC202	Digital System Design	3/0/0	3	3	60/40	PCC
3	23EC201	Electronic Circuits	3/0/0	3	3	60/40	PCC

Theory with Practical (Internal 50 Marks & External 50 Marks)							
4	23CD201	Database Management Systems	1/0/4	5	3	50/50	ESC
5	23CY201	Java Programming	1/0/4	5	3	50/50	ESC
6	23EN101	Oral and Written Communication Skills	2/0/2	4	3	50/50	HSMC
Practical (Internal 60 Marks & External 40 Marks)							
7	23EC204	Digital System Design Laboratory	0/0/2	2	1	40/60	PCC
8	23EC203	Circuits Laboratory	0/0/3	3	1.5	40/60	PCC
Indian Knowledge System - Blended Learning							
9	23TA201	Tamils and Technology	1/0/0	1	1	60/40	HSMC
Mandatory Course (Internal 100 Marks)							
10	23MC102	Mandatory Course II: Environmental Sciences	1/0/0	1	0	0/100	MC
			TOTAL	**31**	**22.5**	**1000**	

SEMESTER III							
S.No	**Course Code**	**Course Title**	**L/T/P**	**Contact Hrs/Wk**	**Credits**	**Ext/Int**	**Cat.**
Theory - Blended Learning (Internal 40 Marks & External 60 Marks)							
1	23GE301	Universal Human Values	3/0/0	3	3	60/40	HSMC
Theory (Internal 40 Marks & External 60 Marks)							
2	23EC301	Signals and Systems	4/0/0	4	4	60/40	PCC
3	23MA302	Mathematics III	3/1/0	4	4	60/40	BSC
Theory with Practical (Internal 50 Marks & External 50 Marks)							
4	23EC302	Operating Systems for Electronic Devices	3/0/2	5	4	50/50	PCC
5	23CS201	Data Structures and Algorithms	1/0/4	5	3	50/50	PCC
6	23CS301	Advanced Java Programming	1/0/4	5	3	50/50	PCC
Practical (Internal 60 Marks & External 40 Marks)							
7	23EC303	IDEA Laboratory	0/0/2	2	1	40/60	ESC
Mandatory Course (Internal 100 Marks)							
8	23MCXX	Mandatory Course III	1/0/0	3 Weeks	0	0/100	MC
			TOTAL	**28**	**22**	**800**	

SEMESTER IV							
S.No	**Course Code**	**Course Title**	**L/T/P**	**Contact Hrs/Wk**	**Credits**	**Ext/Int**	**Cat.**
Theory (Internal 40 Marks & External 60 Marks)							
1	23EC402	Electromagnetic Fields	4/0/0	4	4	60/40	PCC
2	23EC404	Analog and Digital Communication	3/0/0	3	3	60/40	PCC
3	23EC401	Analog Integrated Circuits	3/0/0	3	3	60/40	PCC
Theory with Practical (Internal 50 Marks & External 50 Marks)							
4	23EC403	Embedded C++	3/0/2	5	4	50/50	PCC
5	23IT004	Open Elective-I (Fundamentals of Python Programming)	1/0/4	5	3	50/50	OEC
6	23EC405	Analog Integrated Circuits Laboratory	0/0/3	3	1.5	40/60	PCC
Mini Project (Internal 100 Marks)							
7	23EC406	Mini Project I (MERN Stack)	0/0/4	4	2	40/60	PROJ
Mandatory Course (Internal 100 Marks)							
8	23MC1XX	Mandatory Course IV	1/0/0	3 Weeks	0	0/100	MC
			TOTAL	**27**	**20.5**	**800**	

SEMESTER V							
S.No	**Course Code**	**Course Title**	**L/T/P**	**Contact Hrs/Wk**	**Credits**	**Ext/Int**	**Cat.**
Theory (Internal 40 Marks & External 60 Marks)							
1	23EC501	Control Engineering	3/1/0	4	4	60/40	PCC
2	23EC502	Antenna and Wave Propagation	3/0/0	3	3	60/40	PCC
3	23EC503	Wireless communication	3/0/0	3	3	60/40	PCC
Theory with Practical (Internal 50 Marks & External 50 Marks)							
4	23EC504	VLSI Design	3/0/2	5	4	50/50	PCC
5	23EC505	Digital Signal Processing	3/0/2	5	4	50/50	PCC
6	23EC506	Computer Networks	2/0/2	4	3	50/50	PCC
Mini Project (Internal 100 Marks)							
7	23EC507	Mini Project II	0/0/4	4	2	0/100	PROJ
			TOTAL	**28**	**23**	**800**	

SEMESTER VI							
S.No	Course Code	Course Title	L/T/P	Contact Hrs/Wk	Credits	Ext/Int	Cat.
Theory - Blended Learning (Internal 100 Marks)							
1	23GEC01	Entrepreneurship and Startups	3/0/0	3	3	0/100	HSMC
Theory (Internal 40 Marks & External 60 Marks)							
2	23EC601	Green communication and Networks	3/0/0	3	3	60/40	PCC
3	23EC9XX	Professional Elective - I	3/0/0	3	3	60/40	PEC
4	23EC0XX	Open / Emerging/Industrial Elective- II	3/0/0	3	3	60/40	OEC/ EEC
5	23EC9XX	Professional Elective-II	3/0/0	3	3	60/40	PEC
Theory with Practical (Internal 50 Marks & External 50 Marks)							
6	23EC602	Microwave and Optical Communication	3/0/2	5	4	50/50	PCC
Practical's (Internal 60 Marks & External 40 Marks)							
8	23EC603	Prototype Lab	0/0/2	2	1	40/60	PROJ
			TOTAL	**22**	**20**		

SEMESTER VII							
S.No	**Course Code**	**Course Title**	**L/T/P**	**Contact Hrs/Wk**	**Credits**	**Ext/Int**	**Cat.**
Theory (Internal 40 Marks & External 60 Marks)							
1	23EC0XX	Open / Emerging/Industrial Elective- III	3/0/0	3	3	60/40	OEC/ EEC
2	23EC9XX	Professional Elective - III	3/0/0	3	3	60/40	PEC
3	23EC9XX	Professional Elective – IV	3/0/0	3	3	60/40	PEC
4	23EC9XX	Professional Elective - V	3/0/0	3	3	60/40	PEC
5	23EC9XX	Professional Elective - VI	3/0/0	3	3	60/40	PEC
Project (Internal 60 Marks & External 40 Marks)							
6	23EC701	Project - I	0/0/6	6	3	0/100	PROJ
Internship (Internal 100 marks)							
7	23EES01	Employability Enhancement Skills (Internship)	28 days		2	0/100	EES
			TOTAL	**21**	**20**		

SEMESTER VIII							
S.No	**Course Code**	**Course Title**	**L/T/P**	**Contact Hrs/Wk**	**Credits**	**Ext/Int**	**Cat.**
Project Work							
1	23EC801	Project - II	0/0/24	24	12	40/60	PROJ
			TOTAL	**24**	**12**		
				Total Credits		**163**	

SCHEME OF CREDIT DISTRIBUTION – SUMMARY											
Sl. No.	Stream	Credits/Semester								Credits	%
		I	II	III	IV	V	VI	VII	VIII		
1	Humanities and Social Sciences Including Management (HSMC)	1	4	3			3			11	6.75
2	Basic Science Courses (BSC)	13	4	4						21	12.88
3	Engineering Science Courses (ESC)	9	6	1						16	9.81
4	Professional Core Courses (PCC)		8.5	14	15.5	21	7			66	40.49
5	Professional Elective Courses (PEC)						6	12		18	11.04
6	Open Elective Course (OEC) /Emerging Elective Course (EEC)				3		3	3		9	5.52
7	Project work				2	2	1	3	12	20	12.26
8	Employability Enhancement Skills (EES)							2		2	1.22
9	Mandatory Courses (MC)	-	-	-	-	-	-	-	-	-	-
Total		23	22.5	22	20.5	23	20	20	12	163	100

STRUCTURE FOR UNDERGRADUATE ENGINEERING PROGRAM			
S. No.	**Course Work - Subject Area**	**AICTE Suggested Credits**	**SKCET Credits (163)**
1.	Humanities and Social Sciences (HS), including Management Courses	15*	**11**
2.	Basic Sciences (BS) including Mathematics, Physics, Chemistry, Biology	23*	**21**
3.	Engineering Sciences (ES) including Materials, Workshop, Drawing, Basics of Electrical/Electronics/Mechanical/Computer Engineering, Instrumentation	17*	**16**
4.	Professional Subjects-Core (PC), relevant to the chosen specialization/branch	61*	**66**
5.	Professional Subjects -Electives (PE), relevant to the chosen specialization/ branch;	12*	**18**
6.	Open Subjects- Electives (OE), from other technical and/or emerging subject areas	12*	**9**
7.	Project Work, Seminar and/or Internship in Industry or elsewhere	20*	**22**
9.	Mandatory Courses (MC)	Non-credit	Non-credit
Total		**160***	**163**
**Minor Variations is allowed as per need of the respective disciplines*			

HUMANITIES & SOCIAL SCIENCES INCLUDING MANAGEMENT (11 Credits)						
SL. No.	**Course Code**	**Course Title**	**L/T/P**	**Contact Hrs/Wk**	**C**	**Ext/Int**
1.	23TA101	Heritage of Tamils	1/0/0	1	1	60/40
2.	23TA201	Tamils and Technology	1/0/0	1	1	60/40
3.	23EN101	Oral and Written Communication Skills	2/0/2	4	3	50/50
4.	23GE301	Universal Human Values	3/0/0	3	3	60/40
5.	23GEC01	Entrepreneurship and Startups	3/0/0	3	3	0/100

BASIC SCIENCE COURSES (21 Credits)						
S.No	**Course Code**	**Course Title**	**L/T/P**	**Contact Hrs/Wk**	**C**	**Ext/Int**
1.	23AS101	Applied Sciences	4/0/0	4	4	60/40
2.	23MA101	Mathematics I	3/1/0	4	4	60/40
3.	23SB101	Engineering Biology	3/0/0	3	3	60/40
4.	23AS102	Applied Sciences Laboratory	0/0/4	4	2	40/60
5.	23MA201	Mathematics II	3/1/0	4	4	60/40
6	23MA302	Mathematics III	3/1/0	4	4	60/40

ENGINEERING SCIENCE COURSES (16 Credits)						
S.No	**Course Code**	**Course Title**	**L/T/P**	**Contact Hrs/Wk**	**C**	**Ext/Int**
1.	23EC101	Circuit Theory and Electron Devices	3/0/0	3	3	60/40
2.	23IT101	Application Development Practices	1/0/4	5	3	50/50
3.	23CS101	Problem Solving using C++	1/0/4	5	3	50/50
4.	23CD201	Database Management Systems	1/0/4	5	3	50/50
5.	23CY201	Java Programming	1/0/4	5	3	50/50
6.	23EC303	IDEA Laboratory	0/0/2	2	1	50/50

PROFESSIONAL CORE COURSES (66 Credits)						
S.No	Course Code	Course Title	L/T/P	Contact Hrs/Wk	C	Ext/Int
1.	23EC201	Electronic Circuits	3/0/0	3	3	60/40
2.	23EC202	Digital System Design	3/0/0	3	3	60/40
3.	23EC203	Circuits Laboratory	0/0/3	3	1,5	40/60
4.	23EC204	Digital System Design Laboratory	0/0/2	2	1	40/60
5.	23EC301	Signals and Systems	4/0/0	4	4	60/40
6.	23EC302	Operating Systems for Electronic Devices	3/0/2	5	4	50/50
7.	23CS201	Data Structures and Algorithms	1/0/4	5	3	50/50
8.	23CS301	Advanced Java Programming	1/0/4	5	3	50/50
9.	23EC401	Analog Integrated Circuits	3/0/0	3	3	60/40
10.	23EC402	Electromagnetic Fields	4/0/0	4	4	60/40
11.	23EC403	Embedded C++	3/0/2	5	4	50/50
12.	23EC404	Analog and Digital Communication	3/0/0	3	3	60/40
13.	23EC405	Analog Integrated Circuits Laboratory	0/0/3	3	1.5	40/60
14.	23EC501	Control Engineering	3/1/0	4	4	60/40
15.	23EC502	Antennas and wave propagation	3/0/0	3	3	60/40
16.	23EC503	Wireless Communication	3/0/0	3	3	60/40
17.	23EC504	VLSI Design	3/0/2	5	4	60/40
18.	23EC505	Digital Signal Processing	3/0/2	5	4	60/40
19.	23EC506	Computer Networks	2/0/2	4	3	60/40
20.	23EC602	Microwave and Optical Communication	3/0/2	5	4	50/40
21.	23EC601	Green Communication and Networks	3/0/0	3	3	60/40

PROFESSIONAL ELECTIVE COURSES (18 Credits)						
S.No	**Course Code**	**Course Title**	**L/T/P**	**Contact hrs./Wk.**	**C**	**Ext/Int**
ELECTIVE STREAM I – EMBEDDED SYSTEMS						
1.	23EC901	Real-Time Operating Systems and Applications	3/0/0	3	3	60/40
2.	23EC902	Automotive Embedded System	3/0/0	3	3	60/40
3.	23EC903	Hardware-Software Co-Design	3/0/0	3	3	60/40
4.	23EC904	Computational Intelligence	3/0/0	3	3	60/40
5.	23EC905	Embedded System Design using IoT	3/0/0	3	3	60/40
6.	23EC906	Embedded Processors and Architecture	3/0/0	3	3	60/40
7.	23EC907	Embedded Programming	3/0/0	3	3	60/40
8.	23EC908	Industrial IoT	3/0/0	3	3	60/40
9.	23EC909	Embedded Robotics	3/0/0	3	3	60/40
ELECTIVE STREAM II – VLSI						
1.	23EC910	Reconfigurable Architecture	3/0/0	3	3	60/40
2.	23EC911	VLSI Architectures for AI Algorithms	3/0/0	3	3	60/40
3.	23EC912	Low Power VLSI Design	3/0/0	3	3	60/40
4.	23EC913	Testing of VLSI Circuits	3/0/0	3	3	60/40
5.	23EC914	Digital CMOS VLSI Design	3/0/0	3	3	60/40
6.	23EC915	Analog VLSI Design	3/0/0	3	3	60/40
7.	23EC916	System on Chip Design	3/0/0	3	3	60/40
8.	23EC917	ASIC Design	3/0/0	3	3	60/40
9.	23EC918	Design of Semiconductor Memories	3/0/0	3	3	60/40
ELECTIVE STREAM III - NETWORKS, IMAGE AND VIDEO PROCESSING						
1.	23EC919	Network Engineering for IoT and Constrained Devices	3/0/0	3	3	60/40
2.	23EC920	Advanced Computer Network Architectures	3/0/0	3	3	60/40
3.	23EC921	Python Programming for Image and Video Processing	3/0/0	3	3	60/40
4.	23EC922	R Programming for Image and Video Data Analysis	3/0/0	3	3	60/40
5.	23EC923	Digital Image Processing	3/0/0	3	3	60/40
6.	23EC924	Computer Vision Techniques	3/0/0	3	3	60/40
7.	23EC925	Deep Learning for Image and Video Analysis	3/0/0	3	3	60/40
8.	23EC926	Video Analytics and Surveillance Systems	3/0/0	3	3	60/40
9.	23EC927	Network Integration for IoT and Multimedia Applications	3/0/0	3	3	60/40
ELECTIVE STREAM IV – NEXT GENERATION COMMUNICATION SYSTEMS						
1.	23EC928	RF System Design	3/0/0	3	3	60/40
2.	23EC929	Microwave integrated circuits	3/0/0	3	3	60/40
3.	23EC930	CAN and CAN Open Protocols	3/0/0	3	3	60/40
4.	23EC931	Software Defined Networking	3/0/0	3	3	60/40
5.	23EC932	Satellite Communication and GPS	3/0/0	3	3	60/40
6.	23EC933	High Frequency Communication Systems	3/0/0	3	3	60/40
7.	23EC934	Smart Antennas	3/0/0	3	3	60/40
8.	23EC935	Radar Systems	3/0/0	3	3	60/40
9.	23EC936	Wireless Broadband Networks	3/0/0	3	3	60/40

ELECTIVE STREAM V – MICROELECTRONICS, IC DESIGN AND PHOTONICS						
1.	23EC937	Electromagnetic Interference and Compatibility	3/0/0	3	3	60/40
2.	23EC938	Nanophotonics	3/0/0	3	3	60/40
3.	23EC939	SOI Devices Modeling and Simulation	3/0/0	3	3	60/40
4.	23EC940	Modeling of Microelectronic Devices	3/0/0	3	3	60/40
5.	23EC941	IC Design and Technology	3/0/0	3	3	60/40
6.	23EC942	RF Microelectronics	3/0/0	3	3	60/40
7.	23EC943	Photonic Integrated Circuits	3/0/0	3	3	60/40
8.	23EC944	RF and MEMS	3/0/0	3	3	60/40
9.	23EC945	E-Waste Management and Recycling	3/0/0	3	3	60/40
ELECTIVE STREAM VI – SMART SENSOR TECHNOLOGIES AND BIOMEDICAL ENGINEERING						
1.	23EC946	Artificial Intelligence in Healthcare	3/0/0	3	3	60/40
2.	23EC947	Automotive Sensors	3/0/0	3	3	60/40
3.	23EC948	Data Acquisition and Hardware Interfaces	3/0/0	3	3	60/40
4.	23EC949	Flexible and Wearable Sensors	3/0/0	3	3	60/40
5.	23EC950	Medical Sensors and MEMS Technology	3/0/0	3	3	60/40
6.	23EC951	Bio Signal Processing	3/0/0	3	3	60/40
7.	23EC952	Emerging Applications of Biosensors	3/0/0	3	3	60/40
8.	23EC953	Micro Systems & Hybrid Technology	3/0/0	3	3	60/40
9.	23EC954	Medical Robotics	3/0/0	3	3	60/40

OPEN/EMERGING ELECTIVE COURSES (9 Credits)						
SL. No.	**Course Code**	**Course Title**	**L/T/P**	**Contact hrs./Wk.**	**C**	**Ext/Int**
1.	23EC001	Principles of Cyber Physical Systems	3/0/0	3	3	60/40
2.	23EC002	Introduction to Raspberry Pi and Arduino	3/0/0	3	3	60/40
3.	23EC003	IT Workshop SCILAB/MATLAB	3/0/0	3	3	60/40
4.	23EC004	Brain Computer Interface and its Applications	3/0/0	3	3	60/40
5.	23EC005	Wireless wearable Sensors	3/0/0	3	3	60/40
6.	23EC006	Organizational Behavior	3/0/0	3	3	60/40
7.	23EC007	Fundamentals of Digital Signal Processing	3/0/0	3	3	60/40
8.	23EC008	Principles of Embedded Systems	3/0/0	3	3	60/40
9.	23EC009	Edge AI and TinyML	3/0/0	3	3	60/40
10.	23EC010	6G and Future Wireless Networks	3/0/0	3	3	60/40
11.	23EC011	Neuromorphic Computing and Design	3/0/0	3	3	60/40
12.	23EC012	Quantum Electronics	3/0/0	3	3	60/40
13	23EC013	Cyber-Physical Systems and Security	3/0/0	3	3	60/40
14	23EC014	Quantum Computing and Information	3/0/0	3	3	60/40

PROJECT WORK (20 Credits)							
SL. No.	**Course Code**	**Course Title**	**L/T/P**	**Contact hrs./Wk.**	**C**	**Ext/Int**	**Cat.**
1.	23EC406	Mini Project I - MERN Stack	0/0/4	4	2	0/100	PROJ
2.	23EC507	Mini Project II	0/0/4	4	2	0/100	PROJ
3.	23EC603	Prototype Lab	0/0/2	2	1	40/60	PROJ
4.	23EC701	Project - I	0/0/6	6	3	0/100	PROJ
5.	23EC801	Project - II	0/0/24	24	12	40/60	PROJ

Internship (2 Credits)							
S.No	**Course Code**	**Name of the Course**	**L/T/P**	**Contact Hrs/Wk**	**C**	**Ext/Int**	**Cat**
1.	23EES01	Employability Enhancement Skills (Internship)	3 weeks		2	40/60	EES

MANDATORY COURSES (0 Credits)						
S.No	**Course Code**	**Course Title**	**L/T/P**	**Contact Hrs/Wk**	**C**	**Ext/Int**
1.	23MC101	Induction Programme	3 weeks		0	0/100
2.	23MC102	Environmental Sciences	1/0/0	1	0	0/100
3.	23MC103	Soft Skills	1/0/0	1	0	0/100
4.	23MC104	Management Organizational Behaviour	1/0/0	1	0	0/100
5.	23MC105	General Aptitude	1/0/0	1	0	0/100
6.	23MC106	Life Skills and Ethics	1/0/0	1	0	0/100
7.	23MC107	Stress Management	1/0/0	1	0	0/100
8.	23MC108	Constitution of India	1/0/0	1	0	0/100
9.	23MC109	Essence of Indian Traditional Knowledge	1/0/0	1	0	0/100

PROFESSIONAL ELECTIVE COURSES: VERTICALS					
Vertical I **Embedded Systems**	**Vertical II** **VLSI**	**Vertical III** **Networks, Image And Video Processing**	**Vertical IV** **Next Generation Communication Systems**	**Vertical V** **Microelectronics, IC Design And Photonics**	**Vertical VI** **Smart Sensor Technologies And Biomedical Engineering**
Real-Time Operating Systems and Applications	Reconfigurable Architecture	Network Engineering for IoT and Constrained Devices	RF System Design	Electromagnetic Interference and Compatibility	Artificial Intelligence in Healthcare
Automotive Embedded System	VLSI Architectures for AI Algorithms	Advanced Computer Network Architectures	Microwave integrated circuits	Nanophotonics	Automotive Sensors
Hardware-Software Co-Design	Low Power VLSI Design	Python Programming for Image and Video Processing	CAN and CAN Open Protocols	SOI Devices Modeling and Simulation	Data Acquisition and Hardware Interfaces
Computational Intelligence	Testing of VLSI Circuits	R Programming for Image and Video Data Analysis	Software Defined Networking	Modeling of Microelectronic Devices	Flexible and Wearable Sensors
Embedded System Design using IoT	Digital CMOS VLSI Design	Digital Image Processing	Satellite Communication and GPS	IC Design and Technology	Medical Sensors and MEMS Technology
Embedded Processors and Architecture	Analog VLSI Design	Computer Vision Techniques	High Frequency Communication Systems	RF Microelectronics	Bio Signal Processing
Embedded Programming	System on Chip Design	Deep Learning for Image and Video Analysis	Smart Antennas	Photonic Integrated Circuits	Emerging Applications of Biosensors
Industrial IoT	ASIC Design	Video Analytics and Surveillance Systems	Radar Systems	RF and MEMS	Micro Systems & Hybrid Technology
Embedded Robotics	Design of Semiconductor Memories	Network Integration for IoT and Multimedia Applications	Wireless Broadband Networks	E-Waste Management and Recycling	Medical Robotics

VALUE ADDED COURSES (Based on student's interest)			
S.No	**Course Code**	**Course Title**	**Credits**
1.	23VA401	Antenna Design using Ansys HFSS Tool Flow	1
2.	23VA402	Mastering in MATLAB-Math and Optimization	1
3.	23VA403	The Agriculture in Industry 4.0	1
4.	23VA404	Connecting Technologies with Real World	1
5.	23VA405	Arduino Programming model	1
6.	23VA406	PCB Design for Electronic Circuits	1
7.	23VA407	Energy Harvesting and Security Issues in Cognitive Networks	1
8.	23VA408	System Design using IoT	1
9.	23VA409	UAV and UGV Technologies	1
10.	23VA410	Mobile Application Development	1
11.	23VA411	Embedded Software Engineering	1

L: Lecture **T:** Tutorial **P:** Practical **C:** Credit **O:** Outside Class hours **Cat.:** Category

HSMC : Humanities and Social Sciences including Management
BSC : Basic Science Courses
ESC : Engineering Science Courses
PCC : Professional Core Courses
PEC : Professional Elective Courses
OEC : Open and Emerging Elective Courses
PROJ : Project Work
EES : Employability Enhancement Skills
MC : Mandatory Course

Definition of Credit:

L – Lecture	1 Hr. Lecture (L) per week	1 credit
T – Tutorial	1 Hr. Tutorial (T) per week	1 credit
P - Practical/Practice (Project and Industry based Courses)	1 Hr. Practical (P) per week	0.5 credit

SEMESTER – V

23EC501	CONTROL ENGINEERING	3/1/0/4
Nature of Course	G (Theory Analytical)	
Course Objectives:		
1	To understand electrical and mechanical systems with its transfer function	
2	To provide an adequate knowledge of systems in time domain and steady state error analysis	
3	To understand the frequency response and stability of systems	
4	To introduce the concept of compensators and design of lag compensator	
5	To impart the concept of state variable representation of physical systems.	
Course Outcomes: **Upon completion of the course, students shall have ability to**		
C501.1	Understand the importance of mathematical modelling of systems	[U]
C501.2	Analyze the control systems with respect to time domain response and steady state error	[A]
C501.3	Analyze the frequency response and examine the stability of systems	[A]
C501.4	Analyze lag compensator using Bode plot to meet the desired specifications	[A]
C501.5	Construct state space model of a system and test its controllability and observability	[AP]

Course Contents:

Systems Modelling and Time Response Analysis **20**

Basic elements of control systems - Open and closed loop systems – Transfer function - Mathematical modelling of electrical and mechanical systems – Block diagram reduction techniques – Signal flow graphs. Time response analysis: Time domain specifications – Types of test input, First and Second order system response – Error coefficients – Generalized error series – Steady state error. Controllers: Introduction to P, PI, PD and PID controllers

Frequency Response and Stability Analysis **20**

Frequency response - Bode plot - Polar plot - Gain margin and Phase margin. Stability analysis: Concept of stability - Routh Hurwitz criterion - Root locus technique

Compensator and State Variable Analysis **20**

Compensators: Introduction to Lag, Lead and Lag - Lead networks - Design of Lag compensator using Bode plot. Concept of state variables – State models for linear and time invariant Systems – Solution of state equation - State transition matrix - Jordon canonical form. Concepts of controllability and observability.

Total Periods	**60**

Text Books:

1	I. J. Nagrath& M. Gopal, Control Systems Engineering, 6th Edition, New Age International Publishers, 2017.
2	Richard C. Dorf, Robert H.Bishop, „Modern Control Engineering", 13th Edition, Pearson Education, New Delhi, 2016.
3	Farid Golnaraghi & Benjamin C. Kuo, Automatic Control systems", 9th Edition, Wiley, 2014.

Reference Books:	
1	Norman S.Nise, Control Systems Engineering",Wiley,NewDelhi,2018.
2	Katsuhiko Ogata, Modern Control Engineering", 5th edition, Pearson, New Delhi, 2015.
3	A.Nagoorkani, "Control Systems Engineering", CBS Publishers, RBA Publications 2021
Web References:	
1	https://www.tutorialspoint.com/control_systems/index.htm
2	https://www.electronicsforu.com/technology-trends/learn-electronics/control-system
3	https://www.mathworks.com/help/overview/control-systems.html
4	https://www.halvorsen.blog/documents/teaching/courses/labview_automation/labview_control.php
Online Resources:	
1	http://www.nptel.ac.in/courses/108101037/
2	https://nptel.ac.in/courses/108101037/14
3	https://www.coursera.org/articles/controls-engineer
4	https://onlinecourses.nptel.ac.in/noc19_ee42/preview

23EC502	ANTENNAS AND WAVE PROPAGATION	3/0/0/3
Nature of Course	G (Theory & Analytical)	
Course Objectives:		
1	To gain knowledge in antenna parameters and the radiation principles of wire antennas	
2	To understand the design and operation of array and aperture antennas.	
3	To acquire knowledge on different types of antennas and its applications	
4	To understand the characteristics of transmission line and diversity techniques	
5	To gain knowledge in different wave propagation phenomenon	
Course Outcomes: **Upon completion of the course, students shall have ability to**		
C502.1	Explain antenna parameters, array patterns and its radiation characteristics	[U]
C502.2	Demonstrate the radiation mechanism of simple antennas to complex antenna structures	[AP]
C502.3	Analyse the performance of special antennas for different applications	[AN]
C502.4	Apply transmission line parameters and various diversity techniques in antenna design	[AP]
C502.5	Illustrate the different modes of wave propagation techniques	[U]

Course Contents:

FUNDAMENTAL PARAMETERS OF ANTENNAS AND ANTENNA ARRAYS **15**

Physical concept of radiation, Antenna parameters: Radiation pattern, gain, directivity, effective aperture, Baluns, Antenna noise temperature, Radiation from oscillating dipole, half wave dipole, folded dipole antenna. Linear Arrays: Two element array, Uniform N-element linear array, end fire and broadside arrays, pattern multiplication, synthesis of binomial array. Tschebyscheff array, Planar array antennas.

SPECIAL ANTENNAS **15**

Huygens' Principle, Aperture Antennas- Horn antennas, Reflector antennas, Slot antenna and feeding techniques. Microstrip patch antenna-Radiation from rectangular MSA, Circular MSA and feeding techniques, UWB-antenna, RFID-Antenna, Wearable-antenna. Applications of Antennas in 5G . Smart antenna: Historical development of smart antennas, phased array antennas, Beam steering: Fixed weight beamforming basics-Maximum signal to noise interference ratio, Minimum mean square error. Adaptive Beamforming-Least mean squares, Angle-of-Arrival Estimation: Array correlation matrix, AOA Estimation Methods- Bartlett AOA estimate, AI/ML role in AOA estimation.

TRANSMISSION LINE CHARACTERISTICS, DIVERSITY TECHNIQUES AND WAVE PROPAGATION **15**

Transmission line Parameters, Characteristic Impedance, Impedance matching, Propagation Constant. Diversity Techniques - Space diversity, Frequency diversity, Time diversity. Modes of propagation: Ground wave, surface wave, and space wave propagation; Tropospheric and duct propagation; Multipath fading and ray bending, Flat earth and curved earth concept, Virtual height, Critical frequency, Maximum usable frequency, Skip distance,

Total Periods:	**45**

Text Books:	
1	K D Prasad, “Antenna and Wave Propagation”, Fourth Edition (Reprint), Satya Prakashan, 2021.
2	Constantine A. Balanis, “Antenna Theory and Design”, Fifth Edition, John Wiley & Sons, 2020.
3	T. K. Sarkar, Michael C. Wicks, M. Salazar-Palma, Robert J. Bonneau, “Smart Antenna”, John Wiley & Sons, 2019.
Reference Books:	
1	John D Rider, “Neworks, Lines and Fields”, Prentice-Hall of India (PHI), Second Edition, 2020.
2	Theodore S Rappaport, “Wireless Communication: Principles and Practice, Second Edition, Prentice Hall of India, 2010.
3	John D Krauss, Ronald J Marhefka and Ahmad S. Khan, Antennas and Wave Propagation, Tata McGraw-Hill, Fourth Edition, 2016.
Web References:	
1	http://www.antenna-theory.com
2	https://www.tutorialspoint.com/antenna_theory
3	http://www.amanogawa.com/archive/antennaA.html
4	https://www.ieeeaps.org
5	https://spectrum.ieee.org/topic/antennas
Online Resources:	
1	https://archive.nptel.ac.in/courses/108/101/108101092/
2	https://onlinecourses.nptel.ac.in/noc23_ee130/preview

23EC503	WIRELESS COMMUNICATION	3/0/0/3
Nature of Course	: F (Theory)	
Course Objectives:		
1	To obtain a broad understanding of wireless communications	
2	To teach students the fundamentals of multipath fading and propagation models.	
3	To understand wireless standards and modulation technique	
4	To describe the diversity and MIMO schemes used in wireless communication	
5	To understand the concepts of Multiple Access Techniques and Wireless technologies	
Course Outcomes: **Upon completion of the course, students shall have ability to**		
C503.1	Understand the basics of wireless communication and channel assignment strategies	[U]
C503.2	Examine the propagation mechanism and fading techniques	[U]
C503.3	Understand wireless system standards and the principles of OFDM technology.	[U]
C503.4	Identify suitable MIMO techniques to enhance the spectrum efficiency	[AP]
C503.5	Analyze the features of next generation wireless technologies	[A]

Course Contents:

MOBILE RADIO PROPAGATION **15**

Introduction: Wireless communication, importance and requirements, types and classifications; Cellular concept -Frequency reuse- Channel assignment strategies- Handoff strategies - Interference and system capacity. Wireless channels- characterization of wireless channel, Communication link, propagation phenomenon, LoS, NLoS; Mobile wireless channel- multipath propagation, ISI, fading, large scale-Friss free-space path- loss model, ray tracing model, two-ray tracing model, shadowing, small scale multipath measurements; Rayleigh, Rician model, Fading parameters

WIRELESS SYSTEM STANDARDS AND OFDM TECHNOLOGY
15

AMPS,GSM, GPRS, EDGE, UMTS, LTE, LTE-A, Introduction and Challenges in Multicarrier Systems, OFDM System Model - IFFT/ FFT Transceiver Mathematical Model - Cyclic Prefix, PAPR and reduction techniques - SNR and BER performance - ICI-SC-FDMA.

MIMO TECHNOLOGY AND NEXT GENERATION WIRELESS COMMUNICATION **15**

MIMO systems – spatial multiplexing -System model -Pre-coding - Beam forming - transmitter diversity, receiver diversity- Channel state information-capacity in fading and non-fading channels. 5G Wireless Technologies - NR Standard, filter bank multicarrier, Non-orthogonal multiple access, small cells, mmWave, Index Modulation - 6G Key enablers – Reconfigurable intelligent surfaces.

Total Periods:	**45**

Text Books:

1	Rappaport, T.S., Wireless Communications: Principles and Practice, 2018,

	(Reprint), Pearson Education, Noida, India.
2	Andreas.F. Molisch, —Wireless Communicationsll, John Wiley – India, 2006.
3	David Tse and Pramod Viswanath, “Fundamentals of wireless communication”, 2005.
Reference Books:	
1	Andrea Goldsmith, Wireless Communications, 2020, 2nd Edition, Cambridge University Press
2	T L Singal, Wireless Communications, 2014, (Reprint), Tata McGraw Hill Education, 1 st edition, New Delhi, India.
3	Van Nee, R. and Ramji Prasad, —OFDM for wireless multimedia communications, Artech House, 2000
Web References:	
1	https://www.tutorialspoint.com/search/Wireless%20Communication
2	https://www.mathworks.com/academia/student-competitions/resources/wireless-communications.html
3	https://www.ti.com/solution/smart-grid-wireless-communication
4	https://www.comsoc.org/publications/magazines/ieee-wireless-communications
Online Resources:	
1	https://www.edx.org/learn/telecommunications-networks
2	https://www.coursera.org/learn/wireless-communications
3	https://archive.nptel.ac.in/courses/117/102/117102062/
4	https://archive.nptel.ac.in/courses/108/106/106106167/

23EC504	VLSI DESIGN	3/0/2/4
Nature of Course:	G (Theory & Analytical)	
Course Objectives:		
1	To familiarize the basics of VLSI design and MOS fabrication process.	
2	To relate different characteristics of MOSFET with design parameters	
3	To gain knowledge on CMOS logic structures and ratioed logic structures	
4	To introduce concepts on clock design and its types	
5	To apply VHDL programming for combinational and sequential logic circuits.	
Course Outcomes: Upon completion of the course, students shall have ability to:		
C504.1	Illustrate the essentials of VLSI design abstractions	[U]
C504.2	Compare different CMOS fabrication techniques and articulate the layout diagrams	[U]
C504.3	Analyse MOSFET characteristics and its parasitic components for various CMOS logic Structures	[A]
C504.4	Analyse various clock phase designs for sequential logic circuits	[A]
C504.5	Apply VHDL programming for the designing combinational and sequential logic circuits.	[AP]

Course Contents:

VLSI SYSTEM DESIGN AND FABRICATION **15**

VLSI design flow - VLSI design Domains – Hierarchical Design Approach- Layers of abstraction - Integration density and Moore's law - MOS Transistor – Operation of NMOS, PMOS and CMOS Transistors - Second Order effects- MOSFET fabrication: NMOS, CMOS P-well and N-well process, Silicon on Insulator, CMOS Logic gates- Stick Diagram, Layout Diagram –Layout Design rules.

MOSFET CHARACTERISTICS **15**

MOSFET- Ids Vs. Vds Equations, CMOS Inverter- DC Characteristics - Estimation of Resistance and Capacitance - Elmore Constant - RC Equivalent circuit - RC Arrays - Logical Effort - Switching characteristics, MOS scaling techniques- Latch up- Power dissipation - Noise margin - Static CMOS - Ratioed Circuits - Pseudo-nMOS, Dynamic CMOS, Clocked CMOS, Domino Logic, Pass Transistor, Transmission gate, Cascade Voltage Switch Logic.

CLOCK DESIGN AND HDL PROGRAMMING **15**

Static Latches and Registers, Race Condition, Dynamic Latches and Registers, True Single Phase Clock Register (TSPCR) designs, Latch vs Register Based Pipelines, NORA CMOS - VHDL modelling for combinational and sequential circuits - Adders, Subtractors, Multiplexer, Demultiplexer, Multiplier, Comparator, Encoders and Decoders, Registers, Counters.

Lab Experiments:

1. Design and analyse the transient characteristics of CMOS logic gates (Inverter, NAND, NOR) using Tanner
2. Design and analyse the transient characteristics of Boolean equations using Pass transistor logic using Tanner.
3. Compare and Analyse the power and delay parameters of CMOS logic NAND with Pseudo-nMOS NAND using Tanner
4. Build a 4-bit Arithmetic and Logic Unit that can perform Addition, Subtraction, Logical AND and Logical OR.
5. Construct a 4-bit Parallel Adder circuit where carry from previous bit position propagates to the next consecutive bit.

6. Construct a of 4-Bit Array Multiplier that performs binary multiplication through Partial Product accumulation and addition processes
7. Implementation of a simple 4X1 Multiplexer using Xilinx/Vivado FPGA development boards.
8. Realize one – bit storage device and verify the results for Toggle, Delay and J-K devices.
9. Build a 4-bit synchronous counter that can count sequentially on every clock pulse upwards ranging from 0 (0000) to 15 (1111).
10. Design and simulate a digital circuit that can shift data in both directions (left and right) and load data in parallel using D-flip flops
11. Design a sequence detector using Mealy or Moore FSM
12. Write a VHDL code for constructing an efficient Four way- Traffic light Controller

Total Periods:	**45+30**

Text Books:

1	Neil Weste, David Harris, “CMOS VLSI Design: A Circuits and Systems Perspective”, Fourth Edition, Addision Wesley, 2023 (Reprint)
2	A. Pucknell, Kamran Eshraghian, “Basic VLSI Design”, Third Edition, Prentice Hall of India, 2017.
3	Douglas Perry,” VHDL Programming by Example”,4th edition, McGraw-Hill,2017

Reference Books:

1	J. P. Uyemura, Introduction to VLSI Circuits and Systems, John Wiley & Sons (Asia), 2015.
2	W. Wolf, “Modern VLSI Design - System on Chip design”, Third Edition, Pearson Education, 2015.

Web References:

1	https://www.tutorialspoint.com/vlsi_design/
2	https://electronicsforu.com/resources/learn-electronics/vlsi-developments-ic-fabrication
3	http://www.vlsi-expert.com/p/vlsi-basic.html

Online Resources:

1	https://www.youtube.com/watch?v=9SnR3M3CIm4
2	https://www.techopedia.com/definition/714/very-large-scale-integration-vlsi
3	www.techulator.com › Resources › Electronics › Circuits & Components

23EC505	DIGITAL SIGNAL PROCESSING	3/0/2/4
Nature of Course:	G (Theory Analytical)	

Course Objectives:

1	To familiarize the students about Discrete Fourier Transform techniques and its applications in filter design
2	To allow students to design and analyze digital IIR filters
3	To enable the students to design and analyze digital FIR filters
4	To enable students to understand the quantization process and applications of multi rate signal processing
5	To implement IIR and FIR filter techniques using MATLAB and TMS320C50 Processor.

Course Outcomes:

Upon completion of the course, students shall have ability to:

C505.1	Apply discrete Fourier transform for the analysis of discrete signals and systems	[AP]
C505.2	Design and analyse FIR filters and IIR filter using various techniques	[AN]
C505.3	Understand the concepts of quantization effects and the behavioral Changes in filter response	[U]
C505.4	Explore the concept of Multi rate digital signal processing and its applications	[U]
C505.5	Examine and simulate the discrete time signal using transform and different techniques for design of digital filters.	[AN]

Course Contents:

DISCRETE FOURIER TRANSFORM **15**

Computation of DFT– Properties – Circular convolution – Fast Fourier Transforms (FFT) algorithms – Decimation in Time algorithm – Decimation in Frequency algorithms – Filtering long data sequences - overlap save and overlap add method.

DESIGN AND IMPLEMENTATION OF DIGITAL FILTERS **15**

Analog filters – Butterworth and Chebyshev Type I filter – Frequency transformation in analog domain –LPF to HPF / BPF / BSF. Design of IIR filter from analog filter using impulse invariance technique and bilinear transformations – Realization Structures for IIR filter (Direct Form I and II, cascade form and Parallel form). Finite Impulse Response (FIR) filters - Symmetric and Anti symmetric FIR filter – Linear phase FIR filters – Design of Linear phase FIR filters using windowing technique – Rectangular, Hamming and Hanning windows – Frequency Sampling methods - Structures for FIR filter (Direct form, Linear phase structure).

FINITE WORD LENGTH EFFECTS AND APPLICATIONS OF DSP **15**

Representation of numbers – Quantization process – co-efficient quantization error – Input quantization error – Product quantization error –Limit Cycle Oscillations (LCO) - Multi rate signal processing – Decimation – Interpolation – sampling rate conversion by rational factor I/D – Poly phase filter structure. Application of DSP to speech and radar signal processing.

Lab Experiments:

Analysis and simulation using MATLAB software

1. Computation of DFT using discrete Fourier transform and Matrix method

2. Computation of Linear and circular convolution using DFT
3. Computation of N-Point DFT using DIT and DIF algorithm
4. Design and simulation of FIR filter using various windowing technique
5. Design and simulation of IIR filter using Impulse invariant and Bilinear transformation technique
6. Quantization effects in digital filter design
7. Implementation of Multirate Signal processing- Interpolation and Decimation
8. Analysis of ECG signal
9. Analysis of EEG signal

Experiments Using TMS320C50/6713 Processor

10. Implementation of FFT algorithm
11. Implementation of Linear Convolution
12 .Implementation of FIR filter

Total Periods:	**45+30**

Text Books:

1	John G. Proakis & Dimitris G. Manolakis, Digital Signal Processing, Pearson, 4thEdition, 2021.
2	Sanjit K. Mitra ,Digital Signal Processing : A Computer- Based Approach, The McGraw-Hill Education, 4th Edition 2019
3	Alan V Oppenheim; Ronald W Schafer, Digital Signal Processing, Pearson India, First edition, 2019

Reference Books:

1	B.P.Lathi, “Principles of Signal Processing and Linear Systems”, Cambridge University,2023
2	Emmanuel C.Ifeachor,& Barrie .W. Jervis, “Digital Signal Processing”, Second edition, Pearson Education,2022
3	Li Tan, Jean Jiang, Digital Signal Processing: Fundamentals and Applications, 3rd edition, Academic Press, 2019

Web References:

1	http://www.sqlcourse.com/
2	https://www.w3schools.com/sql/
3	https://www.geeksforgeeks.org/dbms/

Online Resources:

1	https://www.coursera.org/learn/database-management
2	https://www.udemy.com/database-management-system/
3	https://onlinecourses.swayam2.ac.in/cec22_cs18/preview

23EC506	COMPUTER NETWORKS	2/0/2/3
Nature of Course:	G (Theory & Analytical)	
Course Objectives:		
1	To study different layers of ISO/OSI reference models.	
2	To understand the Network Topologies.	
3	To apply the concepts of Data link layer and Network layer Protocols.	
4	To understand the types of protocols in the Transport layer.	
5	To study the advanced Application layer protocols.	
Course Outcomes: Upon completion of the course, students shall have ability to:		
C506.1	Understand the components of data communication, network topologies, layered models and protocols to evaluate their impact on efficient data transfer	[U]
C506.2	Relate the physical layer transmission media, network hardware and switching techniques to enhance communication performance and reliability	[U]
C506.3	Apply the concepts of using data link layer functionalities including flow control, error control mechanisms and LAN standards	[AP]
C506.4	Analyze the logical addressing schemes, routing protocols and optimize their use in various networking scenarios	[AN]
C506.5	Analyze the transport layer protocols, including TCP and UDP, process-to-process delivery, congestion control mechanisms and QoS techniques to optimize network performance and reliability	[AN]

Course Contents:

DATA COMMUNICATION AND PHYSICAL LAYER **15**

Components of data communication - Data Representation and Data flow - Categories of Networks - Network Topology - Protocols and Standards - Layers in OSI Model - TCP / IP protocol suite - Performance Metrics. **Physical Layer:** Transmission media - Transmission Impairment - Network Hardware: Repeaters - Hubs - Bridges - Switches - Routers and Gateways. Packet switching vs. circuit switching.

DATA LINK AND NETWORK LAYER **15**

Data Link Layer: Block Coding, CRC, Hamming code, Checksum. Flow Control Mechanism: Stop-and-Wait ARQ - Go-Back-N ARQ - Selective Repeat ARQ – IEEE802.3 - IEEE 802.11 - RFID - Bluetooth. **Network Layer:** IPv4: Addresses, Classful Addressing, Classless Addressing (Subnetting) - NAT. IPv6: Addresses, Packet Format – Routing Protocols: Distance Vector Routing and Link State Routing - ARP - RARP - DHCP - ICMP.

TRANSPORT AND APPLICATION LAYER **15**

Transport Layer: Elements of transport protocols - Process to Process delivery - UDP and TCP - Effects of Congestion - Congestion control in TCP - Congestion Avoidance Mechanisms - QoS parameters. **Application Layer:** Domain Name System - FTP - SMTP - HTTP - SNMP - Application layer Attacks - Firewalls. Case Study: Software Defined Networking for IoT, Application Layer in E - commerce.

Lab Experiments:

1. Demonstrate the working of network tools such as Ping, Traceroute, Netstat.
2. Build simple LANs, perform basic configurations for switches using a simulator.

3. Implement a network topology using wired media in Cisco Packet Tracer. 4. Implement IPv4 and IPv6 addressing schemes and test it with command. 5. Build Connected LANs different subnets with router and Test performance using simulator. 6. Performance analysis of IP addressing Classless addressing. 7. Simulation of Transport layer Protocols and analysis of congestion control techniques in network. 8. Performance analysis of routing protocols using a simulator. 9. Develop a DNS client server to resolve the given host name or IP address. 10. Analyze the network traffic using Wireshark tool/Packet tracer tool. 11. Simulate a wireless network using cisco packet tracer. 12. Implement email client server in packet tracer.	
Total Periods:	**45+30**
Text Books:	
1	Behrouz A. Forouzan, Data Communications and Networking with TCP/IP Protocol Suite, 6th Edition, TataMcGraw- Hill, 2022.
2	Andrew S. Tanenbaum, Nick Feamster, David J. Wetherall, Computer Networks, 6th Edition, Pearson, 2021.
3	Andrei Gurtov, Madhusanka Liyanage, Mika Ylianttila, and Software Defined Mobile Networks (SDMN) Beyond LTE Network Architecture, Wiley, 2021.
Reference Books:	
1	William Stallings 'Data and Computer Communications' 11th edition, Pearson Publication, 2022.
2	Xingqin Lin, Namyoon Lee 5G and Beyond Fundamentals and Standards, Springer, 2021.
3	James Pyles, Jeffrey L. Carrell, and Ed Tittel,'Guide to TCP/IP: IPv6 and IPv4' 5th edition, Cengage Learning Publication, 2022.
Web References:	
1	https://www.geeksforgeeks.org/network-and-communication/
2	https://www.britannica.com/science/computer-science/Networking-and communication
3	https://www.ibm.com/docs/en/aix/7.2?topic=management-network-communication-concepts
Online Resources:	
1	https://onlinecourses.nptel.ac.in/noc22_ee61/preview
2	https://www.iit.edu/academics/programs/networking-and-communications-certificate
3	https://www.shiksha.com/online-courses/network-security-associate-course-nsel13

23EC507	MINI PROJECT - II	0/0/4/2
Nature of Course	Practical	
Course Objectives:		
1	To demonstrate the interpersonal skills and technical abilities.	
2	To apply suitable tools and techniques to solve the practical problems.	
Course Outcomes: **Upon completion of the course, students shall have ability to**		
C406.1	Design and develop a working model.	[C]
C406.2	Develop technical skill, presentation skill and interpersonal behavior.	[Ap]
C406.3	Demonstrate interdisciplinary skill, ethical values and team work.	[Ap]
C406.4	Examine market trends in terms of economics and finance.	[Ap]

Course Guidelines:

Introduction: Identifying an Innovation Challenge, Needs Finding, Observation Techniques, Techniques for Organizing Data. **Ideate:** Rules of Brainstorming, Brainstorm Facilitation. **Prototype:** Role of DT in your work, Prototyping Techniques, Testing Prototypes. **Experiments:** Introduction to Experimental Design, Types of Experiments, Business model canvass. Introduction and need for intellectual property rights.

1. Each student is expected to do a project and form a team of 3 members.
2. Every team shall have a guide who is the member of the faculty of the institution. Identification of faculty guide has to be completed within a week from the day of beginning of sixth semester.
3. The student has to identify and fabricate his/her idea into the project working model by conducting literature survey and finalize it.
4. A project report to this effect has to be submitted by the team. Also, the complete design project report has to be submitted by team.
5. Three mid semester reviews and one end semester review of the progress of the project work have to be conducted by a team of faculty (minimum 3 and a maximum of 5) along with their faculty guide as a member of the faculty team.
6. During the end semester exam, one internal examiner, appointed by the COE will examine the project done by the students.

Summative assessment based on Continuous and End Semester Examination

Activity	Month	Continuous Assessment [60 marks]	End Semester Examination [40 marks]
Project Evaluation	September	30	100
Project Evaluation	October	30	
Project Evaluation + Presenting in International Conference/Journal	November	40	

SEMESTER – VI

23GEC01	Entrepreneurship and Startup	3/0/0/3
Nature of Course	G (Theory Analytical)	
Pre-requisites	Power System Analysis	

Course Objectives:

1	To provide a comprehensive understanding of the entrepreneurial process, from idea generation to startup growth.
2	To familiarize students with different startup funding mechanisms and legal frameworks.
3	To equip students with problem solving, innovation, and business decision-making skills.
4	To enhance students' ability to use technology, market research, and financial planning in their entrepreneurial journey.
5	To develop practical entrepreneurial skills through blended learning, real-world case studies, and project-based learning.

Course Outcomes:

Upon completion of the course, students shall have ability to

C601.1	Apply the knowledge of entrepreneurship and startup ecosystem concepts to identify potential business opportunities and suitable startup types.	[AP]
C601.2	Apply lean startup methodology and create a Business Model Canvas for a selected startup idea using brainstorming tools like Miro or Google Jamboard.	[AP]
C601.3	Analyze various startup financing options, legal compliance requirements, and value chain positioning to construct a feasible financial and go-to-market strategy.	[AN]
C601.4	Analyze real-world startup failures and crisis scenarios to identify root causes and recommend corrective strategies for future ventures.	[AN]
C601.5	Apply the principles of sustainable business practices and strategic scaling to design a socially impactful startup model and simulate a realistic exit strategy.	[AP]

Course Contents:

Introduction to entrepreneurship & startup ecosystem **12**

Overview of Entrepreneurship & Startups - Characteristics of Successful Entrepreneurs - Identifying Business Opportunities and Idea Generation - Types of Startups: Lifestyle, Scalable, Small Business, Social, etc.- Lean Startup Methodology & Business Model Canvas - The Role of Incubators, Accelerators, and Startup Ecosystems - Government Initiatives & Policies for Startups in India and Globally.

Blended Learning Components: Online Resources: TED Talks, YouTube case studies, startup success/failure analysis. Interactive Tools: Google Jamboard, Miro for brainstorming ideas. Peer Collaboration: Discussion forums, peer feedback on ideas.

Blended Learning Activities: Online Case Study & Discussion: Analyze Airbnb's startup journey and discuss key success factors, Post reflections in an LMS discussion forum. Business Idea Brainstorming & Validation: Use Google Jamboard/Miro for real-time ideation, Peer feedback & faculty guidance on feasibility Live Expert Q&A Session: Industry expert session (Incubator/Founder/Startup Mentor), Pre-session task: Students prepare 3-5 key questions. Mini Startup Pitch Challenge: Each student delivers a 2-minute elevator pitch to the class.

Startup finance, Legal framework & Business strategy **15**

Startup Financial Planning: Bootstrapping, Angel Investors, Venture Capital, Crowdfunding - Developing a Financial Model & Revenue Strategy - Legal Aspects of Startups: Business Registration, IP & Patent Protection, Taxation & Compliance Risk Analysis and Mitigation Strategies - Go-to-Market Strategy and Product-Market Fit - Digital Marketing & Branding Strategies for Startups - Growth Hacking & Scaling Strategies.

Blended Learning Components: Simulation-based Learning: Crowdfunding campaign simulation, Workshop-based Learning: Hands-on experience with legal forms, compliance, Industry Collaboration: Investor/VC guest lecture.

Blended Learning Activities: Crowdfunding Simulation: Develop a Kickstarter campaign for a startup idea, Create a video pitch, funding goal, and reward structure. Startup Legal Workshop: Draft a business contract or IP filing document in teams, Present the drafted document for peer review. Digital Marketing Challenge: Design a Google Ads or Social Media campaign for a startup, Run a dummy ad campaign and analyze engagement. Shark Tank-Style Investment Pitch: Teams pitch ideas to a panel of faculty/industry investors, Evaluation based on Business Model, Financial Viability, Market Potential.

Startup Sustainability, Scaling, and Exit Strategies **18**

Startup Growth Stages: Expansion, Scaling, Diversification - Sustainable Business Models and Social Entrepreneurship - Leadership and Team Building in Startups - Fail Fast, Learn Faster: Case Studies on Startup Failures - Mergers, Acquisitions, and IPOs - Ethical & Social Responsibilities of Entrepreneurs - Future Trends in Entrepreneurship & Startups (AI-driven Startups, Blockchain, Green Startups)

Blended Learning Components: Project-Based Learning: Startup failure analysis report, Role-Playing & Gamification: Crisis management simulation, Hackathons & Competitions: Sustainability-focused startup challenge.

Blended Learning Activities**:** Startup Failure Analysis Report: Study 3 failed startups (e.g., Quibi, Theranos, Juicero), Submit a failure report identifying key reasons & lessons learned. Crisis Management Role-Playing: Teams are given a real-world startup crisis (financial loss, leadership change, PR crisis), Create a crisis response plan & present solutions. Sustainability Hackathon: Design a social impact startup model, Pitch with impact assessment & business viability. Startup Exit Strategy Simulation: Teams simulate an IPO, merger, or acquisition, Prepare a strategic exit report & investor pitch.

Total Periods:	**45**

Text Books:

1	Steven Fisher, Ja-nae' Duane, The Startup Equation -A Visual Guidebook for Building Your Startup, Indian Edition, Mc Graw Hill Education India Pvt. Ltd, (2016)
2	Donald F Kuratko, Jeffrey S. Hornsby, New Venture Management: The Entrepreneur's Road Map, 2e, Routledge (2017)
3	David H. Hott, "Entrepreneurship New Venture Creation", PHI (2018)

Reference Books:

1	Greco, F. (2023). Startup Ecosystems: Components for an Interpretative Model and International Benchmarks. Germany: Springer Nature Switzerland.

2	Aulet, B. (2013). Disciplined Entrepreneurship: 24 Steps to a Successful Startup. Germany: Wiley.
3	Harris, T. (2018). Start-up: A Practical Guide to Starting and Running a New Business. Germany: Springer International Publishing.
Web References:	
1	https://onlinecourses.nptel.ac.in/noc20_mg35/preview
2	https://cloud.google.com/startup
3	https://startup.google.com/
4	https://www.startupindia.gov.in/

23EC601	GREEN COMMUNICATION AND NETWORKS	3/0/0/3
Nature of Course	: F (Theory)	
Course Objectives:		
1	To introduce green wireless communication concepts.	
2	To understand the evolving paradigm of cooperative and green wireless communication concepts and the challenges and trade-offs involved in such networks	
3	To study various Spectral Efficiency trade-offs in Cellular Systems.	
4	To understand the different power-saving strategies and energy-efficient signal, system, and network design.	
5	To expose the energy-saving techniques adopted in existing wireless components, protocols, and networks, and the evolution of green future wireless communication technologies.	
Course Outcomes: **Upon completion of the course, students shall have ability to**		
C601.1	Understand the need for green wireless communication	[U]
C601.2	Understand the challenges in energy efficiency and spectral efficiency for digital data transmission	[U]
C601.3	Apply the concepts of dynamic spectrum in mobile communications for energy saving	[AP]
C601.4	Analyse the design practices for power minimization at the cellular base station	[AN]
C601.5	Analyse the cell deployment strategies for efficient network management	[AN]

Course Contents:

GREEN WIRELESS COMMUNICATION **15**

Characteristics-Challenges of Embedded Systems –Categories of embedded systems, Introduction - Origins of Green Communications - Telecommunication System Model and Energy Efficiency - Broadband Access Evolution - Cell Site Power Consumption Modeling - Power and Energy Metrics - Energy and Throughput Efficiency in LTE Radio Access Networks.

ENERGY EFFICIENCY & SAVINGS **15**

Dynamic Spectrum and Traffic Load Management: Power Saving - Dynamically Powering Down Radio Network Equipment, Propagation Improvement, Channel Bandwidth Increase, or Better Balancing Performance Assessment. Explosive Traffic Growth - Cellular Scenarios - Energy Metrics; Energy Reduction Techniques for High Traffic Load Scenarios; Energy Reduction Techniques for Low Traffic Load Scenarios, Other Energy Reduction Techniques.

MINIMIZING POWER CONSUMPTION **15**

Green Wireless Access Networks: Energy Efficiency and Network Technologies; Cell Deployment Strategies; Relaying Techniques; Base Station Coordination and Cooperation; Adaptive Network Reconfiguration; Radio Resource Management; Future Architectures; Green Ad Hoc and Sensor Networks; Energy Harvesting Techniques.

Total Periods:	**45**

Text Books:	
1	F. Richard Yu, XI Zhang, Victor C. M. Leung, "Green Communications and Networking", CRC Press, 1st Edition, 2019.
2	Konstantinos Samdanis, Peter Rost, Andreas Maeder, Michela Meo, Christos Verikoukis, "Green Communications: Principles, Concepts and Practice", Wiley, 2015.
3	Himal A. Suraweera, Himal A. Jing Yang, Alessio A. Zappone, John A. Thompson, "Green Communications for Energy-Efficient Wireless Systems and Networks", IET,2020.
Reference Books:	
1	Jinsong Wu, Sundeep Rangan, and Honggang Zhang, "Green Communications: Theoretical Fundamentals, Algorithms and Applications", CRC Press, 2016.
2	Green Communications and Networking: F. Richard Yu, Xi Zhang, Victor C.M. Leung; CRC Press, 2012.
3	Mohammad Obaidat S, Alagan Anpalagan and Isaac Woungang, "Handbook of Green Information and Communication Systems", 1st Edition, Academic Press, 2012.
Web References:	
1	http://www.comsoc.org/webcasts/view/wireless-green-networking
2	http://home.ku.edu.tr/~nwcl/green.html
3	http://mypage.zju.edu.cn/en/honggangzhang/607861.html
Online Resources:	
1	https://www.researchgate.net/publication/281489301_Green_Communications_and_Networking
2	https://onlinelibrary.wiley.com/doi/toc/10.1155/6302.si.932815
3	https://www.mdpi.com/journal/electronics/special_issues/TNB4X30IB5

23EC602	MICROWAVE AND OPTICAL COMMUNICATION	3/0/2/4
Nature of Course:	G (Theory & Analytical)	
Course Objectives:		
1	To study the basics of Microwave network and characterization of passive microwave components.	
2	To enable the students to understand the principles and operations of Microwave tubes.	
3	To enable the students to understand the principles and operations of Microwave semiconductor devices.	
4	To enable the students to understand the fundamentals of optical fibre communication.	
5	To enable the students to understand characteristics of optical transmitters and receivers.	
Course Outcomes: Upon completion of the course, students shall have ability to:		
C602.1	Understand the concepts of microwave network characterization.	[U]
C602.2	Understanding microwave passive components and to apply for various design implementation.	[AP]
C602.3	Design and Implementation of semiconductor devices.	[AP]
C602.4	Understand the operation of optical fiber and their operational modes.	[U]
C602.5	Design and Implementation of optical transmitter and receiver in modern fiber optic systems.	[AP]

Course Contents:

NETWORK CHARACTERIZATION AND PASSIVE COMPONENTS **15**

Microwave Frequency band and RF Spectrum -S parameter representation of N ports- Losses in terms of S parameters- Properties of S parameters. Directional Coupler- Microwave Hybrid Circuits-Circulator and Isolator- branch line coupler (equal & unequal), Rat Race Coupler (180° hybrid coupler), Noise figure computations, Dynamic range - Millimeter Wave Techniques.

TUBES AND SEMICONDUCTOR DEVICES **15**

Two cavity klystron - Reflex Klystron- Travelling Wave Tube Gunn Diode, Avalanche Breakdown diodes (TRAPATT, IMPATT, BARITT)- Manley – Rowe Power Relations - Wilkinson power divider. Microwave Resonators: Series and Parallel Resonant Circuits, Microwave Radar (MR)- Applications of MR.

OPTICAL TRANSMITTERS AND RECEIVERS **15**

Optical Fibers: Optical Fiber Modes and Configuration, Fiber Loss, Dispersions. Power coupling: splices, connectors, coupler, Light Emitting diode and Laser diodes Operational principles of WDM-Passive optical coupler-2x2 Fiber coupler. PIN and APD, Erbium Doped Fiber Amplifier.

Lab Experiments:

1 Analyze the Mode characteristics of Reflex Klystron
2 Compute the V-I Characteristics of Gunn Diode.
3. Design and analyze the directivity, coupling coefficient, S-parameter of directional coupler using EM Simulation Software.
4 Design and analyze the scattering matrix parameters of co-axial transmission line using EM Simulation Software.
5 Design and analyze the array antenna characteristics using EM Simulation Software.
6 Design and analyze the microstrip patch antenna for 5G applications using EM Simulation

	Software.
7	Design and analyze the microstrip antenna for Wi–Fi applications using EM Simulation Software.
8	Design and analyze the helical and slot antenna performance using EM Simulation Software.
9	Design and analyze the performance of fiber optic analog and digital communication link using Virtual simulation software.
10	Design and analyze optical fiber losses and numerical aperture in optical fiber using Virtual simulation software.
11	Design and analyze the performance of Microwave E-Plane & H-Plane tees using EM Simulation Software.
12	Design and analyze the performance of Microwave Magic tee using EM Simulation Software.
Total Periods:	**45+30**

Text Books:	
1	Annapurna Das and Sisir K Das, Microwave Engineering, Third Edition, Tata McGraw Hill, Inc., 2017.
2	D.M. Pozar, Microwave Engineering,4th Edition, John Wiley & sons, Inc., 2013.
3	Gerd Keiser, Optical Fiber Communications, 5th Ed, McGraw-Hill, 2017.
Reference Books:	
1	Samuel Y Liao, Microwave Devices & Circuits, Third Edition, Pearson Education, 2011.
2	Robert E. Collin, Foundations for Microwave Engineering, Second Edition, Wiley IEEE Press,2007.
3	S. Kumar and M. J. Deen, Fiber Optic Communications, John Wiley & sons,2014.
Web References:	
1	https://radfiz.org.ua/.../Collin.%20Foundations%20for%20Microwave%20Engineering.p
2	https://www.slac.stanford.edu/slac/sass/talks/opticalfiber.pdf
3	https://www.utdallas.edu/~torlak/courses/ee4367/lectures/FIBEROPTICS.pdf
4	https://www.cse.wustl.edu/~jain/tutorials/ftp/t_3opt.pdf
Online Resources:	
1	https://onlinecourses.nptel.ac.in/noc20_ee91/preview
2	https://onlinecourses.nptel.ac.in/noc21_ee42/preview
3	https://nptel.ac.in/courses/108101112/
4	https://nptel.ac.in/courses/117101054/

23EC603	PROTOTYPE LAB	0/0/2/1
Nature of Course	Practical	
Course Objectives:		
1	To demonstrate the interpersonal skills and technical abilities.	
2	To apply suitable tools and techniques to solve the practical problems.	
Course Outcomes: **Upon completion of the course, students shall have ability to**		
C406.1	Design and develop a working model.	[C]
C406.2	Develop technical skill, presentation skill and interpersonal behavior.	[Ap]
C406.3	Demonstrate interdisciplinary skill, ethical values and team work.	[Ap]
C406.4	Examine market trends in terms of economics and finance.	[Ap]

Course Guidelines:

Introduction: Identifying an Innovation Challenge, Needs Finding, Observation Techniques, Techniques for Organizing Data. **Ideate:** Rules of Brainstorming, Brainstorm Facilitation. **Prototype:** Role of DT in your work, Prototyping Techniques, Testing Prototypes. **Experiments:** Introduction to Experimental Design, Types of Experiments, Business model canvass. Introduction and need for intellectual property rights.

1. Each student is expected to do a project and form a team of 3 members.
2. Every team shall have a guide who is the member of the faculty of the institution. Identification of faculty guide has to be completed within a week from the day of beginning of sixth semester.
3. The student has to identify and fabricate his/her idea into the project working model by conducting literature survey and finalize it.
4. A project report to this effect has to be submitted by the team. Also, the complete design project report has to be submitted by team.
5. Three mid semester reviews and one end semester review of the progress of the project work have to be conducted by a team of faculty (minimum 3 and a maximum of 5) along with their faculty guide as a member of the faculty team.
6. During the end semester exam, one internal examiner and one external examiner, appointed by the COE will examine the project done by the students.

Summative assessment based on Continuous and End Semester Examination

Activity	Month	Continuous Assessment [60 marks]	End Semester Examination [40 marks]
Project Evaluation	February	30	100
Project Evaluation	March	30	
Project Evaluation + Presenting in International Conference/Journal	April	40	

PROFESSIONAL ELECTIVE COURSES (PEC)

23EC901	REAL-TIME OPERATING SYSTEMS AND APPLICATIONS	3/0/0/3
Nature of Course	: F (Theory)	
Course Objectives:		
1	To provide a strong foundation on the principles and architecture of real-time operating systems.	
2	To explore the design and implementation of processes and inter-process communication.	
3	To understand synchronization mechanisms including semaphores, message queues, and pipes.	
4	To study task scheduling and interrupt handling techniques in real-time environments.	
5	To evaluate the performance and memory management of real-time kernels and systems.	
6	To enable students to apply RTOS concepts in practical domains such as image processing, VoIP, control systems, and fault-tolerant applications."	
Course Outcomes: **Upon completion of the course, students shall have ability to**		
C901.1	Understand the basic principles of operating system structures and the role of system calls in process management.	U
C901.2	Apply process communication and synchronization techniques to manage deadlocks and handle critical sections in real-time systems.	AP
C901.3	Interpret various real-time system models such as event-based, process-based, and graph-based approaches.	AP
C901.4	Apply design principles of real-time kernels and compare the features of various RTOS platforms.	AP
C901.5	Implement real-time operating system concepts in domains like image processing, voice-over-IP, and control systems.	AP

Course Contents:

Basic Principles of Operating Systems and Process Synchronization **15**

Basic Principles, Operating System structures, System Calls, Files, Processes, Design and Implementation of processes, Communication between processes, Introduction to Distributed operating system, Distributed scheduling. RTOS Task and Task state, Process Synchronization- Message queues, Mail boxes, pipes, Critical section, Semaphores, Classical synchronization problem, Deadlocks.

Real-Time Operating Systems (RTOS) and Scheduling **15**

Event Based – Process Based and Graph based Models, Real Time Languages, RTOS Tasks, RT scheduling, Interrupt processing, Synchronization, Control Blocks, Memory Requirements. REAL TIME KERNEL: Principles, Design issues, Polled Loop Systems, RTOS Porting to a Target, Comparison and study of various RTOS like QNX, VX works, PSOS, C Executive- Case studies.

Applications of RTOS **15**

RTOS for Image Processing, Embedded RTOS for voice over IP, RTOS for fault Tolerant Applications, RTOS for Control Systems.

Total Periods:	**45**

Text Books:	
1	Raj Kamal, “Embedded Systems- Architecture, Programming and Design” Tata

	McGraw Hill, 2020.
2	Herma K., “Real Time Systems – Design for distributed Embedded Applications”, Kluwer Academic, 2022.
3	Charles Crowley, “Operating Systems-A Design Oriented approach” McGraw Hill 1996.
4	Krishna.C.M, Kang, Shin.G, “Real Time Systems”, McGraw Hill, 1997.
Reference Books:	
1	Donald L.Bailey, “An Introduction to Real Time Systems”, PHI 1999.
2	Mukesh Sighal and Shi.N.G “Advanced Concepts in Operating System”, McGraw Hill 2001.
Web References:	
1	https://www.freertos.org/
2	chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://runtimerec.com/wp-content/uploads/2024/03/rtos-essentials-ebook.pdf
3	https://rtos.com
4	https://developer.arm.com/tools-and-software
Online Resources:	
1	https://www.ni.com/en-us/innovations/real-time-operating-systems.html
2	https://developer.arm.com/architectures/learn-the-architecture/real-time-operating-systems
3	https://www.freertos.org/

23EC902	AUTOMOTIVE EMBEDDED SYSTEM	3/0/0/3
Nature of Course	: F (Theory)	
Course Objectives:		
1	To introduce the fundamental structure and operational principles of automotive electronic systems.	
2	To describe the architecture and internal communication protocols used in modern vehicles.	
3	To expose students to key in-vehicle communication networks such as CAN, LIN, FlexRay, and Automotive Ethernet.	
4	To impart knowledge of fault tolerance, functional safety, and efficient data exchange in automotive networks.	
5	To provide foundational understanding of software modelling and testing methodologies for embedded automotive applications.	
6	To equip students with the ability to use modelling languages such as SysML and ADL for systematic design and analysis of automotive embedded systems.	
Course Outcomes: **Upon completion of the course, students shall have ability to**		
C902.1	Understand the basic architecture and electronic components of automotive embedded systems.	U
C902.2	Understand the system frameworks like AUTOSAR and emerging trends in automotive technologies.	U
C902.3	Understand the structure and functionalities of in-vehicle communication protocols such as CAN, LIN, FlexRay, and Ethernet.	U
C902.4	Apply strategies for fault tolerance, synchronization, and efficient data exchange in automotive communication systems.	AP
C902.5	Apply testing methods to evaluate the safety, reliability, and performance of automotive embedded systems	AP

Course Contents:

Automotive Embedded Systems and Architectures **15**

Automotive Systems Overview: Powertrain, Chassis, Body, Telematics, HMI, Safety, Diagnostics, In-Vehicle Networks, and Protocols, Operating Systems, Middleware, and AUTOSAR: Layered Architecture (BSW, RTE), Models, Templates, Exchange Formats, Fail-Safe, Intelligent Automotive Systems, and Automated Road Vehicles.

In-Vehicle Communication and Networking Technologies **15**

Embedded Automotive Communication: Point-to-Point vs Multiplexed Systems, Event-Triggered vs Time-Triggered Communication. Automotive Networks Overview: Types, Low-Cost & High-Reliability Networks, Flex Ray & CAN (including Fault Tolerance, Clock Synchronization). Dependable CAN Networks: Features, Limitations, Data Consistency Challenges, Fault-Tolerant Architectures (TTCAN, Flex CAN).

Automotive Software Development, Verification, and Testing **15**

Embedded Software Development: Basic Concepts, Feature Modelling, and Reuse, Modular Automotive Software Architecture, Automotive Software Analysis Languages: SysML and ADL for Automotive Systems, Testing and Verification of Automotive Systems: Dynamic, Functional, Structural, and Model-Based Testing, Test Planning and Execution: Exemplary Case Study on Battery Management System (BMS) Communication Network for EVs, Overview of MISRA C and functional safety (ISO 26262) in software development

Total Periods:	**45**

Text Books:	
1	Nicolas Navet, Francoise Simonot-Lion, Automotive Embedded Systems Handbook, CRC Press, 2017.
2	William Ribbens, Understanding Automotive Electronics, 8th Edition, Butterworth-Heinemann, 2017.
3	Kirsten Matheus and Thomas Königseder, Automotive Ethernet: The Definitive Guide, Cambridge University Press, 2021.
4	Konrad Etschberger, "Controller Area Network (CAN): Basics, Protocols, Chips and Applications", IXXAT Automation, 2021
Reference Books:	
1	Konrad Etschberger, Controller Area Network (CAN): Basics, Protocols, Chips and Applications, IXXAT Automation, 2001.
2	Wolfgang Kreutzer, Learning Automotive Embedded Systems Programming with ARM Cortex and CAN, Apress, 2020.
Web References:	
1	https://www.autosar.org/
2	https://www.vector.com/vi_can_basics_en.html
3	https://www.godaddy.com/forsale/flexray.com?utm_source=TDFS_BINNS2&utm_medium=parkedpages&utm_campaign=x_corp_tdfsbinns2_base&traffic_type=TDFS_BINNS2&traffic_id=binns2&
4	https://www.nxp.com/design
Online Resources:	
1	https://www.ptc.com/en/technologies/application-lifecycle-anagement/automotive-embedded-software
2	https://www.coursera.org/learn/automotive-embedded-systems
3	https://nptel.ac.in/courses/108/105/108105057

23EC903	HARDWARE-SOFTWARE CO-DESIGN	3/0/0/3
Nature of Course	: F (Theory)	
Course Objectives:		
1	To explain the role of hardware–software co-design in optimizing embedded systems for performance, power, and cost.	
2	To describe state-oriented, dataflow, and event-driven modeling techniques for embedded system applications.	
3	To identify the trade-offs involved in hardware/software partitioning using classical and machine learning–driven algorithms.	
4	To design hardware accelerators using High-Level Synthesis (HLS) and software components using RTOS-aware synthesis tools.	
5	To validate timing, power, and area metrics in embedded system design space exploration.	
6	To apply co-design concepts in real-world scenarios such as RISC-V SoCs and Edge AI deployments.	
Course Outcomes: **Upon completion of the course, students shall have ability to**		
C903.1	Describe the system-level design principles and models of computation used in embedded systems	U
C903.2	Analyze the trade-offs involving performance, power, and security in hardware-software co-design	AN
C903.3	Apply partitioning and optimization strategies in embedded system design using formal techniques	AP
C903.4	Analyze hardware/software synthesis methodologies using RISC-V and RTOS-aware architectures	AN
C903.5	Demonstrate co-verification, estimation, and deployment techniques using case studies like TinyML	AP
Course Contents:		
System Specification & Models of Computation **15** Co-Design: Need, Performance, power, and cost tradeoffs - Models of Computation (MoCs): State-oriented (FSMs), Data-oriented, Event-driven, Heterogeneous - Modern Extensions: Real-time constrains - Security-aware modeling		
HW/SW Partitioning & Optimization **15** Partitioning Fundamentals: Granularity (task-level, instruction-level) - Partitioning Techniques: Kernighan-Lin, GCLP, ML-driven partitioning - Real-time scheduling: static vs. dynamic - Co-Synthesis: Hardware Synthesis: C-to-RTL concepts, RISC-V custom extensions - Software Synthesis: RTOS-aware code generation (FreeRTOS, Zephyr) - Interface Synthesis: AXI, SPI, I2C protocol implementation		
Embedded System Verification & Deployment **15** Estimation & Optimization: Metrics - Timing, power, area (HW); memory, WCET (SW) - Energy-optimal design for battery-operated embedded systems - Co-Verification: Simulation: Transaction-Level Modeling (TLM) vs. Cycle-Accurate - Formal Verification: Model checking for safety-critical systems - Case Studies: RISC-V SoCs: Custom ISA for embedded applications - Edge AI: Deploying TinyML on microcontrollers		
	Total Periods:	**45**

Text Books:	
1	Felice Balarin, Massimiliano Chiodo, Paolo Giusto, Harry Hsieh, Attila Jurecska, Luciano Lavagno, Claudio Passerone, Alberto Sangiovanni-Vincentelli, Ellen Sentovich, Kei Suzuki, Bassam Tabbara, “Hardware-Software Co-Design of Embedded Systems: The POLIS Approach”, 2013
2	Peter Marwedel, “Embedded System Design”, 4th Edition, Springer, 2021.
3	Giovanni De Micheli and Rolf Ernst, “Reading in Hardware/Software Co-Design”, Morgan Kaufmann, 2020 Reprin
4	Raj Kamal, “Embedded Systems: Architecture, Programming and Design”, 3rd Edition, McGraw Hill Education, 2021
Reference Books:	
1	Russell John Rickford, Bernd Kleinjohann, “Design and Analysis of Distributed Embedded Systems”, Springer, 2002,
2	Achim Rettberg, Mauro C Zanella, Franz J Rammig, “From Specification to Embedded Systems Application”, Springer, 2005,
Web References:	
1	https://ieeexplore.ieee.org/document/8448578
2	https://riscv.org/specifications/ratified/
3	https://www.iso.org/standard/68383.html
4	https://riscv.org
Online Resources:	
1	https://www.oreilly.com/library/view/tinyml/9781492052036/
2	https://ocw.mit.edu/courses/6-858-computer-systems-security-fall-2014/
3	https://www.coursera.org/learn/introduction-embedded-systems

23EC904	COMPUTATIONAL INTELLIGENCE	3/0/0/3
Nature of Course	: F (Theory)	
Course Objectives:		
1	To introduce the concepts of Soft Computing and highlight how they differ from traditional computational approaches.	
2	To study the basics of Fuzzy Logic and its applications in decision-making systems.	
3	To understand and apply Fuzzy Inference Systems for modeling real-world problems.	
4	To explain the structure, learning methods, and applications of Artificial Neural Networks.	
5	To explore Unsupervised Learning and advanced Neural Network models.	
6	To integrate fuzzy logic and neural networks into control systems and embedded applications.	
Course Outcomes: **Upon completion of the course, students shall have ability to**		
C904.1	Explain the basic principles of fuzzy sets, membership functions, and fuzzy operations	U
C904.2	Apply fuzzy logic control techniques in rule-based decision-making systems	U
C904.3	Describe neural architectures, learning algorithms, and network models for pattern recognition	U
C904.4	Analyze and design supervised and unsupervised neural networks.	AN
C904.5	Implement and evaluate neuro-fuzzy systems for real-time applications like control and classification	AP

Course Contents:

Fundamentals of Soft Computing and Fuzzy Logic **15**

Classical Sets and Fuzzy Sets — Basics of Fuzzy Sets and Membership Functions — Set Operations: Union, Intersection, Complement — Fuzzy Relations — Fuzzification and Defuzzification — Fuzzy If-Then Rules — Rule-Based Systems: Knowledge Base, Data Base, Rule Base, and Decision-Making Logic — Fuzzy Logic Controllers: Mamdani Architecture and Sugeno-Takagi Architecture.

Foundations and Architectures of Neural Networks **15**

Biological Neurons and their Artificial Models — Neuron Modeling — Basic Learning Mechanisms and Learning Factors influencing Neural Networks — Single Layer Networks and Multi-Layer Feed Forward Networks — Supervised Learning Models: Perceptron, Adaline, Multi-Layer Neural Networks, Backpropagation Algorithm, Radial Basis Function (RBF) Networks, and Functional Link Artificial Neural Networks (FLANN) — Unsupervised Learning Models: Competitive Learning Networks, Kohonen Self-Organizing Maps (SOM), and Hopfield Networks.

Evolutionary Computation and Optimization Techniques **15**

Adaptive neuro-fuzzy inference systems (ANFIS), coactive neuro-fuzzy modelling, and neuro-fuzzy control. case studies: smart temperature control, handwritten digit recognition, and fault detection in industrial machines. Implementation challenges and integration of fuzzy logic and

neural networks in embedded controllers	
Total Periods:	**45**
Text Books:	
1	Jacek M. Zurada, Introduction to Artificial Neural Systems, Jaico Publishing House, New Delhi, 2006.
2	John Yen, Reza Langari, Fuzzy logic Intelligence, control and Information, Pearson Education,2011.
3	H.J. Zimmerman, Fuzzy Set Theory-and its Applications, Kluwer Academic Publishers, New Delhi 2014.
4	B. Kosko, Neural Networks and Fuzzy Systems, Prentice Hall of India Ltd., New Delhi 2009.
Reference Books:	
1	B. Yagnanarayanan, Artificial Neural Networks, Prentice Hall of India Ltd., New Delhi 2012.
2	G.J. Klir and T.A. Folger, Fuzzy Sets, Uncertainty and Information, Prentice-Hall of India Ltd.,2015
Web References:	
1	https://towardsdatascience.com
2	https://link.springer.com/series/7092
3	https://www.sciencedirect.com/topics/computer-science/evolutionary-algorithm
4	https://www.fuzzytech.com
Online Resources:	
1	https://www.coursera.org/learn/fuzzy-logic
2	https://nptel.ac.in/courses/106105173
3	https://www.udemy.com/course/artificial-neural-networks-for-beginners/

23EC905	EMBEDDED SYSTEM DESIGN USING IoT	3/0/0/3
Nature of Course	: F (Theory)	
Course Objectives:		
1	To Understand the fundamental concepts of embedded system design.	
2	Ability to Explain the architecture and working of microcontrollers used in embedded systems	
3	To Develop programming skills for embedded hardware interfacing.	
4	To Understand the basics of IoT and its integration with embedded system	
5	Enable the students to Apply IoT protocols and cloud services to build real-time applications	
6	To Understand the security challenges and testing techniques for embedded IoT systems.	
Course Outcomes: **Upon completion of the course, students shall have ability to**		
C905.1	Describe the architecture, components, and characteristics of embedded systems.	U
C905.2	Develop basic embedded C programs to interface input/output devices with microcontrollers.	U
C905.3	Interface sensors, actuators, and communication modules with embedded hardware for IoT applications.	AP
C905.4	Implement IoT protocols and send/receive data between embedded systems and cloud platforms	AN
C905.5	Apply security mechanisms to ensure safe communication and firmware updates in IoT systems	AP

Course Contents:

Fundamentals of Embedded System Design **15**

Introduction to Embedded Systems-Embedded System Architecture: Hardware and Software Components-Input/Output Devices, Memory Systems-Embedded C Programming Fundamentals-Basics of Real-Time Operating Systems (RTOS)-Design Methodology for-Embedded Systems-Development Tools: Compilers, Debuggers, IDEs

IoT Integration with Embedded Systems **15**

Introduction to Internet of Things (IoT)-Embedded Platforms for IoT (ESP32, Raspberry Pi, Arduino)-Sensor and Actuator Interfacing Techniques-IoT Communication Technologies: WiFi, BLE, Zigbee, LoRaWAN-Networking Protocols: MQTT, CoAP, HTTP-Cloud Platforms for IoT (AWS IoT, Google Cloud IoT, Thingspeak, Blynk)-Edge Computing and Local Data Processing Basics-Power Management for IoT Devices

Security, Testing and Applications of Embedded IoT Systems **15**

Security in IoT Embedded Systems: Encryption, Authentication, Secure Boot-Firmware Updates and Over-The-Air (OTA) Mechanisms-Testing Techniques: Unit Testing, Integration Testing, System Testing-Debugging Embedded IoT Systems-Case Studies and Applications: Smart Homes-Smart Agriculture- Healthcare-Industrial IoT (IIoT) Systems

Total Periods:	**45**

Text Books:	
1	Raj Kamal," Embedded Systems: Architecture, Programming and Design" McGraw Hill Education, 2020
2	Perry Lea, "Internet of Things for Architects", 1st edition, Packt Publishing, 2018
3	Raj Kamal," INTERNET OF THINGS Architecture and Design Principles," McGraw Hill Education, 2022
4	Rajkumar Buyya, Amir Vahid Dastjerdi," Internet of Things: Principles and Paradigm", Morgan Kaufmann (Elsevier), 2020 (2nd Edition)
Reference Books:	
1	Raj Kamal, "Internet of Things: Architecture and Design Principles", McGraw-Hill Education, 2021
2	Simone Cirani, Gianluigi Ferrari, Marco Picone, Marco Picone, "Internet of Things_ Architectures, Protocols and Standards" Wiley, 2019
Web References:	
1	https://www.tescaglobal.com/embedded-system-design/
2	https://www.ibm.com/internet-of-things
3	https://www.edx.org/course/embedded-systems-programming
4	https://www.iotforall.com/iot-security-challenges
Online Resources:	
1	https://create.arduino.cc/projecthub
2	https://projects.raspberrypi.org/en/projects?software%5B%5D=python
3	https://www.postscapes.com/internet-of-things-platforms/

23EC906	EMBEDDED PROCESSORS AND ARCHITECTURE	3/0/0/3
Nature of Course	: F (Theory)	
Course Objectives:		
1	Understand the fundamental architecture and features of the Cortex-M processor family	
2	Gain knowledge about the programming model of the Cortex-M processor, including memory systems, registers, and exceptions	
3	Develop proficiency in programming assembly language for Cortex-M processors.	
4	Learn how to handle interrupts and exceptions, optimizing system performance and power consumption	
5	Acquire skills in embedded system development, including system initialization, memory management, and real-time operating systems (RTOS)	
6	Interface with various peripherals (e.g., UART, ADC/DAC, SD cards) and manage I/O operations for embedded systems	
Course Outcomes: **Upon completion of the course, students shall have ability to**		
C906.1	Describe the architecture and core features of Cortex-M processors (Cortex-M3 and Cortex-M4).	U
C906.2	Explain the programming model of Cortex-M processors, including memory systems, registers, and interrupts	U
C906.3	Analyze and implement interrupt and exception handling techniques for efficient system management.	AN
C906.4	Develop embedded systems with RTOS concepts, managing task scheduling and context switching.	AP
C906.5	Interface peripherals with Cortex-M processors and implement I/O operations	AP

Course Contents:

Introduction to Cortex-M Processor Architecture **15**

Cortex-M Processor Family: Overview and Advantages -Cortex-M3 and Cortex-M4 Processors: Block diagram and architectural details-Programmer's Model: Registers, Program Status, and Memory Systems-Exceptions and Interrupts: Basic concepts and interrupt handling-Assembly Language for Cortex-M: Syntax, instruction set, and barrel shifter-Memory System: Connecting the processor to memory and peripherals.

Cortex-M Processor Features and Interrupt Management **15**

Exceptions and Interrupts: Types, management, and NVIC (Nested Vector Interrupt Controller)-Interrupt and Exception Handling: Priority, vector table, latency, fault exceptions-Low Power Features: Techniques for reducing power consumption-Support: Shadowed stack pointer, context switching, SVC exception, PendSV exception-Exception and Interrupt Optimization: Strategies for improving interrupt handling.

Embedded System Development and Peripheral Interfacing **15**

UART Interface, Debugging hardware with Target board, SSI Interface, Analog I/O, A/D converter interfacing, Communication system with Ethernet. Memory Management, Dynamic Memory Allocation in Embedded Systems, Fixed-Size Memory Management in Embedded Systems, Blocking vs. Non-Blocking Memory Functions, An Outside-In Approach to Decomposing Applications

Total Periods:	**45**

Text Books:	
1	Rajkamal, 'Embedded system-Architecture, Programming, Design', TMH, 2020
2	The Definitive Guide to the ARM Cortex-M3, Joseph Yiu, econd Edition, Elsevier Inc.2013
3	Arnold. S. Berger, "Embedded Systems Design -An introduction to Processes, Tools and Techniques", Easwer Press 2001
4	C. M. Krishna and K. G. Shin, Real-Time Systems, McGraw-Hill 2E,2010
Reference Books:	
1	Lyla B Das," Embedded Systems-An Integrated Approach",Pearson, 2024
2	Jonathan Valvano, "Embedded Systems: Introduction to ARM Cortex-M Microcontrollers", 5th Edition, 2022, CreateSpace
Web References:	
1	https://www.st.com/en/microcontrollers-microprocessors/stm32-32-bit-arm-cortex-mcus.html
2	https://www.tinyml.org/
3	https://www.embedded.com/
4	https://www.nxp.com/docs/en/application-note/AN10216.pdf
Online Resources:	
1	https://www.coursera.org/learn/introduction-embedded-systems
2	www.circuitstoday.com/embedded-systems-an-introduction
3	https://www.codrey.com/embedded-systems/embedded-systems-introduction/

23EC907`	EMBEDDED PROGRAMMING	3/0/0/3
Nature of Course	: F (Theory)	
Course Objectives:		
1	To understand the low-level concepts of programming such as memory layout, pointer usage, and bit manipulation in C.	
2	To learn how C language features and file handling are used in embedded systems	
3	To introduce students to Linux command-line tools and basic shell scripting techniques used in embedded development.	
4	To provide hands-on experience with real-time programming using POSIX threads and kernel timing tools	
5	To explain how device drivers interact with hardware through kernel modules and file operations	
6	To introduce debugging techniques, interrupt handling, and driver development using a mini project on virtual sensors	
Course Outcomes: **Upon completion of the course, students shall have ability to**		
C907.1	Understand the use of pointers, structures, file operations, and optimization techniques in embedded C programming.	U
C907.2	Use Linux CLI commands and scripting techniques to automate tasks and manage embedded Linux systems.	AP
C907.3	Implement real-time multi-threaded applications considering task scheduling and priority management on Linux-based systems.	AP
C907.4	Compute and test Linux character device drivers to enable communication between user-space applications and kernel modules.	AP
C907.5	Apply debugging and tracing techniques to optimize kernel modules and analyze performance in embedded Linux systems.	AP

Course Contents:

Introduction to Programming **15**

Low-Level Concepts: CPU registers, stack vs heap - Memory layout: .text, .data, .bss sections - Pointers & addresses: Pointer arithmetic, void pointers - Bit manipulation: Masking, shifting, bitfields - High-Level Abstraction: Functions vs macros, Structures/Unions: Memory alignment, padding, File I/O: Text vs binary modes, Basic data structures: Arrays vs linked lists - C for Embedded: volatile keyword (hardware registers) - const & static (ROM vs RAM usage) - Cross-compilation intro (host vs target).

Embedded Linux & Shell Scripting **15**

Linux CLI for Embedded: Basic commands, Pipes/redirection: Log filtering (dmesg | grep error), Process control: ps, kill, nice, systemd - Shell Scripting for Embedded: Looping, Conditionals, Pattern matching: sed/awk - Practical use case: Write a build script for a kernel module - Real-Time Programming: POSIX threads, RT priorities, cyclictest.

Linux Device Drivers & Kernel Programming **15**

Linux System Overview for Drivers: Kernel space vs User space, Device Driver basics - File operations: open(), read(), write(), ioctl() - copy_to_user, copy_from_user for User-Kernel Data Exchange - Interrupt Handling - Introduction to IRQs - Kernel Debugging and Performance: checking memory leaks, race conditions - Case Study: Mini Application — Virtual Sensor Driver Project.

Total Periods:	**45**

Text Books:	
1	Michael Barr, Anthony Massa, “Programming Embedded System with C and GNU
2	Development Tools” O'Reilly Media, 2006.
3	Neil Mathew, Richard stones, “Beginning Linux Programming” 3rd Edition, Wrox – Wiley Publishing.2004
4	C Programming language Brian W. Kernighan, Dennis Ritchie.2012
Reference Books:	
1	Advanced Linux Programming by Mark Mitchell, Jeffrey Oldham, and Alex Samuel.,2005
2	Linux Device Drivers by Alessandro Rubini, Elsevier 2005
Web References:	
1	https://embeddedartistry.com/
2	https://linuxcommand.org/
3	https://kernelnewbies.org/KernelDebuggingTips
4	https://elinux.org/Main_Page
Online Resources:	
1	https://archive.nptel.ac.in/courses/106/105/106105159/
2	https://www.coursera.org/specializations/embedded-software-development-with-c
3	https://www.coursera.org/learn/introduction-embedded-systems

23EC908	INDUSTRIAL IoT	3/0/0/3
Nature of Course	: F (Theory)	
Course Objectives:		
1	To introduce the fundamental principles of Industrial IoT and relevance to Industry 4.0	
2	To help students learn about key technologies and communication methods used in IIoT systems	
3	To explain how IIoT systems are built using different layers like sensors, processing units, and communication networks	
4	To explore various industrial IoT platforms and understand how they are used in real-world industries.	
5	To learn how industrial data is collected and analyzed using tools like big data and machine learning.	
6	To understand the importance of security in IIoT systems and explore methods to protect them.	
Course Outcomes: **Upon completion of the course, students shall have ability to**		
C908.1	Describe the ecosystem, hardware platforms, and protocols used in IIoT.	U
C908.2	Explain the layered architecture and reference models of Industrial IoT system	U
C908.3	Analyze key IIoT platforms such as AWS, Azure, and ThingWorx and their industrial applications.	AN
C908.4	Apply IIoT architecture and networking concepts	AP
C908.5	Design secure, scalable IIoT systems using Fog/Cloud/TinyML/Blockchain principles	AP

Course Contents:

Fundamentals of IIoT and Industry 4.0 **15**

Introduction to Industrial IoT (IIoT), Elements of an IoT Ecosystem: Technology Drivers, Business Drivers, Typical IIoT Applications and Trends, IoT Hardware Platforms Overview (Microcontrollers, Embedded PCs),M2M Communication, Web of Things (WoT),Internet and Web Layering Concepts,• Business Aspects of IoT and IIoT, REST Architecture and Challenges of IoT, Role of IoT and IIoT in Industry 4.0 Revolutions.

Industrial IoT Systems **15**

IIoT-Introduction, Digital Twin, Industrial IoT: Business Model and Reference Architecture: IIoT Business Models, Industrial IoT- Layers: IIoT Sensing, IIoT Processing, IIoT Communication, IIoT Networking, Edge Computing in IIoT, IoT Platforms for Industrial Applications: Overview of AWS IoT, Azure IoT Hub, PTC ThingWorx, OPC UA: Secure data exchange standards for industrial systems.

IIoT ANALYTICS & IoT SECURITY **15**

Big Data Analytics and Software Defined Networks, Machine Learning and Data Science, Julia Programming, Data Management with Hadoop, Industrial IoT: Security and Fog Computing – Cloud Computing in IIoT, Fog Computing in IIoT, Security in IIoT. Zero Trust Security Model for IIoT, TinyML: Machine Learning on Edge Devices, Blockchain for Securing IIoT Devices.

Total Periods:	**45**

Text Books:

1	M. Kranz, "Building the Internet of Things: Implement New Business Models, Disrupt Competitors, Transform Your Industry", Wiley, 2017.

2	S. Bhattacharjee and S. Kak, "Practical Industrial Internet of Things Security: A Practitioner's Guide to Securing Connected Industries", Apress, 2020.
3	P. Lea, "Internet of Things for Architects: Architecting IoT solutions by implementing sensors, communication infrastructure, edge computing, analytics, and security", Packt Publishing, 2018.
4	K. Schwab, "The Fourth Industrial Revolution", Crown Business, 2016.
Reference Books:	
1	B. Sinclair, "IoT Inc.: How Your Company Can Use the Internet of Things to Win in the Outcome Economy", International Society of Automation (ISA), 2017.
2	J. Biron and J. Follett, "Foundational Elements of an IoT Solution", O'Reilly Media, 2016. 7. Keysight Technologies, "The Internet of Things: Enabling Technologies and Solutions for Design and Test, Application Note", 2016.
Web References:	
1	https://www.iotforall.com
2	https://www.cisco.com/c/en/us/solutions/internet-of-things/overview.html
3	https://www.iiconsortium.org/
4	https://www.iiot-world.com/
Online Resources:	
1	https://www.coursera.org/specializations/industrial-internet-things
2	https://www.udemy.com/course/industrial-automation/
3	https://www.edx.org/course/industrial-internet-of-things-iiot-markets-and-security

23EC909	EMBEDDED ROBOTICS	3/0/0/3
Nature of Course	: F (Theory)	
Course Objectives:		
1	To Understand the fundamental concepts, history, laws, and the need for robotics,	
2	To Develop knowledge of different types of robot joints, links, wrist mechanisms, end effectors, and the role of microcontrollers in robotic systems.	
3	To understand the mathematical modeling of robot and homogeneous transformations in 2D/3D space	
4	To develop basic knowledge of control strategies and sensor integration in robotic manipulators and autonomous systems	
5	To Acquire knowledge about the application of computer vision and pattern recognition techniques in robotic systems.	
6	To Gain exposure to real-world robotic vision applications through case studies and basic image processing	
Course Outcomes: **Upon completion of the course, students shall have ability to**		
C909.1	Understand the different robot configurations, joint types, wrist mechanisms, and the basics of end effectors and microcontroller integration.	U
C909.2	Solve problems related to direct and inverse kinematics, homogeneous transformations, and robot trajectory planning.	AP
C909.3	Implement basic robot control strategies and demonstrate an understanding of robotic sensors and introductory programming techniques.	AP
C909.4	Apply computer vision techniques and pattern recognition methods to simple robotic tasks.	AP
C909.5	Analyze and evaluate vision-based robotic applications through case studies and perform basic image processing operations.	AN

Course Contents:

Introduction to Robotics **15**

Basics of Robotics: Definition, Basic Concepts, Need for Robots - History of Robotics - Laws of Robotics (Asimov's Laws) - Anatomy and Specifications of Robots - Robot Configurations: Cartesian, Cylindrical, Polar, Articulate Robots - Robot Wrist Mechanisms - Robot Joints and Links – Types and Characteristics - End Effectors: Classifications, Types of Mechanical Actuation - Basics of Gripper Design - Introduction to Microcontrollers in Robotics: Architectures, Addressing modes and Instruction sets.

Robot Kinematics and Control Systems **15**

Robot Kinematics: Direct and Inverse Kinematics - Robot Trajectories - 2D and 3D Transformations: Scaling, Rotation, Translation - Homogeneous transformations - Control of Robot Manipulators - Point-to-Point Control - Continuous Path Control - Basics of Robot Programming - Robot Sensors: Touch, Tactile, Proximity, Range, Force, Light, Pressure Sensors - Basics of Machine Vision and Artificial Intelligence.

Robot Vision and Applications **15**

Robot Vision Applications: Pattern Recognition - Embedded Systems in Robotics - Computer Vision in Robotics - Case Studies: Automated Navigation Guidance, Vision-based Depalletizing, Line Tracking, Automatic Part Recognition - Image Processing for Robotics - Basic Techniques using MATLAB/OPENCV

Total Periods:	**45**
Text Books:	
1	Dr. Jisu Elsa Jacob, Manjunath N, Robotics Simplified: An Illustrative Guide to Learn Fundamentals of Robotics, Including Kinematics, Motion Control, and Trajectory Planning, Paperback, 2022
2	John J. Craig, “Introduction to Robotics: Mechanics and Control”, Fourth Edition, Pearson, 2022.
3	S. B. Niku, Introduction to Robotics – Analysis, Control, Applications, 3rd edition, John Wiley & Sons Ltd., (2024)
4	N.P. Bali and Manish Goyal, A textbook of Engineering Mathematics, Laxmi Publications, New Delhi, 10th edition,2020.
Reference Books:	
1	Anis Koubaa, “Robot Operating System (ROS) The Complete Reference”, First Volume,Springer, 2024
2	Richard D. Klafter, Thomas A. Chmielewski, Robotic Engineering: An Integrated Approach, 2nd Edition, PHI, 2018
Web References:	
1	https://wiki.ros.org/ROS/Tutorials
2	https://www.arm.com/products/silicon-ip-cpu/cortex-m/cortex-m4
3	https://www.robotshop.com/blog/en
4	https://www.mathworks.com/solutions/robotics.html
Online Resources:	
1	https://onlinecourses.nptel.ac.in/noc21_me76/preview
2	https://www.edx.org/learn/robotics/columbia-university-robotics
3	https://ocw.mit.edu/courses/mechanical-engineering/2-12-introduction-to-robotics-fall-2005/

23EC910	RECONFIGURABLE ARCHITECTURE	3/0/0/3
Nature of Course	: F (Theory)	
Course Objectives:		
1	The student shall develop an overview and deeper insight into the research and development that is underway to meet future needs of flexible processors	
2	To learn the concepts of implementation, synthesis and placement of modules in reconfigurable architectures	
3	To understand the communication techniques and System on Programmable Chip for reconfigurable architectures	
4	To learn the process of reconfiguration management	
5	To familiarize the applications of reconfigurable architectures	
6	To explore real-world case studies and performance optimization strategies in reconfigurable systems.	
Course Outcomes: **Upon completion of the course, students shall have ability to**		
C910.1	Interpret the different architecture principles relevant to reconfigurable computing systems	[U]
C910.2	Illustrate the necessary trade-offs to meet the area, power and timing criteria of reconfigurable systems	[AP]
C910.3	Infer the algorithms related to placement and partitioning	[AN]
C910.4	Illustrate the communication techniques and system on programmable chip for reconfigurable architectures	[AP]
C910.5	Apply the principles of Network and System on a Programmable Chip	[AP]

Course Contents:

IMPLEMENTATION, SYNTHESIS AND PLACEMENT **15**

General purpose computing – domain specific processors – Application Specific Processors – reconfigurable computing – fields of application – evolution of reconfigurable systems – simple Programmable Logic Devices – Complex Programmable Logic Devices – Field Programmable Gate Arrays – coarse grained reconfigurable devices- Integration – FPGA design flow – logic synthesis – LUT based technology mapping – modeling – temporal partitioning algorithms – offline and online temporal placement – managing device's free and occupied spaces.

COMMUNICATION TECHNIQUES AND RECONFIGURATION MANAGEMENT IN SoPCs **15**

Direct communication – communication over third party – bus-based communication – circuit switching – Network on Chip – dynamic Network on Chip – System on a Programmable Chip – adaptive multi-processing on chip- Reconfiguration – configuration architectures – managing the reconfiguration process – reducing configuration transfer time – configuration security.

REAL-WORLD APPLICATIONS OF FPGA AND RECONFIGURABLE ARCHITECTURES **15**

FPGA based parallel pattern matching – low power FPGA based architecture for microphone arrays in Wireless Sensor Networks – exploiting partial reconfiguration on a dynamic coarse grained reconfigurable architecture – parallel pipelined OFDM baseband modulator with dynamic frequency scaling for 5G systems.

Total Periods:	**45**

Text Books:	
1	Francesca Palumbo “Applied Reconfigurable Computing: Architectures, Tools, and Applications”, Springer 2023
2	Nikoloas Voros Et Al. “Applied Reconfigurable Computing: Architectures, Tools and Applications” Springer, 2018.
3	Christophe Bobda, “Introduction to Reconfigurable Computing: Architectures, Algorithms and Applications”, Springer 2007.
4	Koen Bertels, João M.P. Cardoso, Stamatis Vassiliadis, “Reconfigurable Computing: Architectures and Applications”, Springer 2006.
Reference Books:	
1	Scott Hauck and Andre Dehon, “Reconfigurable Computing: The Theory and Practice of FPGA Based Computation”, Elsevier 2008
2	M. Gokhale and P. Graham, “Reconfigurable Computing: Accelerating Computation with Field-Programmable Gate Arrays”, Springer, 2005
Web References:	
1	https://www.xilinx.com
2	https://www.intel.com/content/www/us/en/products/details/fpga.html
3	https://www.mentor.com
Online Resources:	
1	https://www.coursera.org/learn/fpga-computing-systems
2	https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-111-introductory-digital-systems-laboratory-fall-2014/
3	https://www.youtube.com/playlist?list=PLnRD4jCw2wFUMNJnRM-v6zvR29kT4ZMka

23EC911	VLSI ARCHITECTURES FOR AI ALGORITHMS	3/0/0/3
Nature of Course	: F (Theory)	
Course Objectives:		
1	To enable students to understand the basic concepts of VLSI architectures used in AI and machine learning.	
2	To teach techniques like parallelism, pipelining, and memory organization used in AI hardware.	
3	To explain different VLSI design methods for building efficient AI systems.	
4	To introduce hardware structures like systolic arrays and neural network accelerators used in deep learning.	
5	To provide an understanding of how hardware and software work together in AI-based VLSI systems.	
6	To expose students to the latest industry trends and research in AI hardware.	
Course Outcomes: **Upon completion of the course, students shall have ability to**		
C911.1	Understand and model AI algorithms suitable for VLSI hardware realization.	[U]
C911.2	Infer the specialized VLSI architectures for efficient AI algorithm execution.	[AN]
C911.3	Apply parallel and pipelined data path architectures like systolic arrays.	[AP]
C911.4	Infer various design trade-offs including performance, power, and area for AI hardware.	[AN]
C911.5	Analyze cutting-edge AI accelerators and co-design methods for future AI-based VLSI solutions.	[AN]

Course Contents:

FUNDAMENTALS OF VLSI FOR AI **15**

Overview of AI and Machine Learning Algorithms: Matrix operations, CNNs, RNNs- Computational characteristics of AI workloads- Basics of VLSI design: Area, Power, Speed trade-offs- Arithmetic units for AI: Adders, Multipliers, MAC units.

ARCHITECTURES AND ACCELERATORS **15**

Dataflow architectures: SIMD, MIMD- Systolic arrays and applications in matrix multiplications - Hardware implementation of Neural Networks: Fixed-point vs Floating-point processing- Memory-centric architectures for AI: Buffer design, Memory Hierarchy for AI.

EMERGING TRENDS IN AI HARDWARE **15**

AI-specific ASICs and SoCs: TPU, Eyeriss - FPGA-based AI acceleration- Low-power AI designs and energy-efficient computing- Hardware/Software Co-design for AI systems.

Total Periods:	**45**

Text Books:	
1	Sze, Vivienne, Efficient Processing of Deep Neural Networks: A Tutorial and Survey, Morgan & Claypool Publishers, 2020.
2	Mead, Carver and Conway, Lynn, Introduction to VLSI Systems, Addison-Wesley, 1980.
3	Bell, Alexander; Horowitz, Mark, Compiling Algorithms for Heterogeneous Systems, Morgan & Claypool Publishers, 2018.

Reference Books:	
1	Chen, Yu-Hsin; Yang, Tien-Ju; Sze, Vivienne, *Eyeriss: A Spatial Architecture for Energy-Efficient Dataflow for Convolutional Neural Networks*, Springer, 2020.
2	Murmann, Boris, *Mixed-Signal Circuits for Machine Learning Applications*, Springer, 2019.
3	Hennessy, John L. and Patterson, David A., *Computer Architecture: A Quantitative Approach*, 6th Edition, Morgan Kaufmann, 2024.
Web References:	
1	https://energy.mit.edu/research/ai-hardware/
2	https://cloud.google.com/tpu/docs/tpus
3	https://vlsi.stanford.edu/
4	https://ieeexplore.ieee.org/xpl/RecentIssue.jsp?punumber=92
Online Resources:	
1	https://developer.nvidia.com/deep-learning
2	https://openmlsys.github.io/
3	https://www.coursera.org/learn/ai-hardware

23EC912	LOW POWER VLSI DESIGN	3/0/0/3

Nature of Course	: F (Theory)

Course Objectives:

1	To enable students to understand the fundamental principles and key sources of power dissipation in CMOS circuits.
2	To facilitate students in analyzing and designing low-power VLSI systems across different abstraction levels.
3	To introduce synthesis and optimization methods for low-power digital and memory circuit design.
4	To explain the challenges of low-voltage CMOS design and approaches to reduce leakage power.
5	To develop student competency in designing energy-efficient VLSI architectures at device, circuit and system levels.
6	To expose students to current research directions and industry practices in low-power VLSI design methodologies.

Course Outcomes:
Upon completion of the course, students shall have ability to

C912.1	Analyze various sources of power consumption in CMOS technologies.	[AN]
C912.2	Apply effective design strategies to minimize both dynamic and static power dissipation in VLSI circuits.	[AP]
C912.3	Understand low-power SRAM architectures and memory optimization techniques.	[U]
C912.4	Illustrate low-voltage CMOS design techniques suitable for submicron technologies.	[U]
C912.5	Analyze recent innovations, industrial practices, and methodologies for low-power VLSI design.	[AN]

Course Contents:

POWER DISSIPATION MECHANISMS AND LOW-POWER CIRCUIT DESIGN **15**

Sources of power dissipation – Physics of power dissipation in MOSFET devices: The MIS structure, long channel MOSFET, Submicron MOSFET, gate induced drain leakage– Power dissipation in CMOS: short circuit dissipation, dynamic dissipation, load capacitance– Low power VLSI design: Limits – principles of low power design. Transistor and Gate Sizing: Sizing an Inverter Chain, Transistor and Gate Sizing for Dynamic Power Reduction, Transistor Sizing for Leakage Power Reduction - Network Restructuring and Reorganization: Transistor Network Restructuring, Transistor Network Partitioning and Reorganization - Special Latches and Flip-flops: Self-gating Flip-flop, Varieties of Boolean Functions, Adjustable Device Threshold Voltage

LOW-POWER SYNTHESIS AND SRAM ARCHITECTURE OPTIMIZATION **15**

Behavioral Level Transforms, Logic Level Optimization for Low power, Circuit Level Optimization. Organization of a static RAM, MOS Static RAM Memory cell, Banked organization of SRAMs, reducing voltage swings on bit lines, reducing power in write driver circuits, reducing power in sense amplifier circuits, method for achieving low core voltages from a single supply.

DESIGN AND TEST OF LOW VOLTAGE CMOS CIRCUITS **15**

Circuit Design style, Leakage current in deep submicrometer transistors, Deep submicrometer device design issues, Low voltage circuit design techniques, Designing deep submicrometer ics with elevated intrinsic leakage, multiple supply voltages.

Total Periods:	**45**
Text Books:	
1	Narang, Dipankar, Low-Power CMOS VLSI Design: A Comprehensive Guide, CRC Press, 2023.
2	Rabaey, Jan M., Low Power Design Essentials, Springer, 2017.
3	Roy, Kaushik and Prasad, Sharat C., Low Power CMOS VLSI Circuit Design, Wiley-Interscience, 2000.
Reference Books:	
1	**Murmann, Boris,** *Mixed-Signal Circuits for Machine Learning Applications*, Springer, 2019.
2	**Chandrakasan, Anantha P.; Bowhill, William J.; Fox, Frank**, *Design of High-Performance Microprocessor Circuits*, Wiley-Blackwell, 2001.
3	**Chandrakasan, Anantha P.; Brodersen, Robert W.**, *Low-Power CMOS Design,* IEEE Press, 1995.
Web References:	
1	https://ieeexplore.ieee.org/xpl/RecentIssue.jsp?punumber=92
2	https://pages.hmc.edu/harris/cmosvlsi/4e/index.html
3	https://www.islped.org/2025/
4	https://www.edaboard.com/forums/low-power-design.45/
Online Resources:	
1	https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-973-communication-system-design-spring-2006/
2	https://community.cadence.com/cadence_blogs_8/b/can
3	https://www.edaplayground.com/

23EC913	TESTING OF VLSI CIRCUITS	3/0/0/3
Nature of Course	: F (Theory)	
Course Objectives:		
1	To enable students to understand the fundamentals of VLSI circuit testing and the various fault models used in industry.	
2	To impart knowledge of effective test generation techniques for both combinational and sequential circuits.	
3	To introduce design-for-testability (DFT) concepts and built-in self-test (BIST) methodologies for reliable circuit testing.	
4	To expose students to memory and embedded system testing algorithms.	
5	To familiarize students with fault diagnosis techniques and self-checking logic designs.	
6	To equip students with knowledge on system-level diagnosis and approaches for achieving fault tolerance in VLSI systems.	
Course Outcomes: **Upon completion of the course, students shall have ability to**		
C913.1	Identify various types of faults in digital circuits and understand fault modeling techniques.	[U]
C913.2	Infer test patterns for combinational and sequential circuits to ensure fault coverage.	[AN]
C913.3	Apply design for testability techniques and understand scan-based design methodologies.	[AP]
C913.4	Discuss the built-in self-test (BIST) architectures for complex VLSI circuits and memories	[U]
C913.5	Analyze and perform fault diagnosis and self-checking design at the system level.	[AN]

Course Contents:

FUNDAMENTALS OF VLSI TESTING AND FAULT MODELING **15**

Introduction to Testing - Faults in digital circuits - Modeling of faults - Logical Fault Models - Fault detection - Fault location - Fault dominance - Logic Simulation - Types of simulation - Delay models - Gate level Event-driven simulation. Test generation for combinational logic circuits - Testable combinational logic circuit design - Test generation for sequential circuits - design of testable sequential circuits.

DESIGN FOR TESTABILITY AND BUILT-IN SELF-TEST TECHNIQUES **15**

Design for Testability - Ad-hoc design - Generic scan-based design - Classical scan-based design – System level DFT approaches. Built-In Self-Test - Test pattern generation for BIST - Circular BIST - BIST Architectures - Testable Memory Design - Test algorithms - Test generation for Embedded RAMs.

FAULT DIAGNOSIS AND SELF-CHECKING MECHANISMS **15**

Level Diagnosis - Diagnosis by UUT reduction - Fault Diagnosis for Combinational Circuits - Self-checking design - System Level Diagnosis.

Total Periods:	**45**

Text Books:

1	M. Abramovici, M.A. Breuer, and A.D. Friedman, Digital Systems and Testable Design, Jaico Publishing House, 2021.
2	Bushnell, M. L.; Agrawal, V. D., Essentials of Electronic Testing for Digital, Memory

	and Mixed-Signal VLSI Circuits, Springer, 2006.
Reference Books:	
1	P.K. Lala, "Digital Circuit Testing and Testability", Academic Press, 2002.
2	A.L. Crouch, Design for Test for Digital IC's and Embedded Core Systems, Prentice Hall International, 1999.
Web References:	
1	https://ieeexplore.ieee.org/xpl/RecentIssue.jsp?punumber=43
2	https://www.itctestweek.org/
3	https://www.edaboard.com/forums/ic-design-and-test.8/
4	https://www.crhc.illinois.edu/
Online Resources:	
1	https://nptel.ac.in/courses/117106092
2	https://www.cadence.com/en_US/home/training/academic-network.html
3	https://www.edaboard.com/forums/digital-design.16/

23EC914	DIGITAL CMOS VLSI DESIGN	3/0/0/3
Nature of Course	: F (Theory)	
Course Objectives:		
1	To enable students to understand the basic behavior of MOSFETs and CMOS inverters.	
2	To illustrate how secondary effects impact power, delay, and energy in CMOS circuits.	
3	To equip students with the ability to design combinational and sequential logic circuits using CMOS techniques.	
4	To facilitate analysis of timing and performance in static and dynamic sequential circuits.	
5	To develop student proficiency in designing arithmetic units and memory blocks like adders, multipliers, and SRAM.	
6	To introduce students to the use of Hardware Description Languages (HDL) for digital circuit modeling and synthesis.	
Course Outcomes: **Upon completion of the course, students shall have ability to**		
C914.1	Explain the static and dynamic behavior of MOSFET transistors and CMOS inverters.	[U]
C914.2	Analyze the influence of secondary effects on CMOS inverter performance metrics like power and delay.	[AN]
C914.3	Design combinational and sequential circuits using CMOS static and dynamic logic techniques.	[AP]
C914.4	Evaluate the performance and timing issues in sequential circuits like latches, registers, and pipelines.	[AN]
C914.5	Demonstrate the modeling of digital circuits using Verilog HDL and describe memory subsystem architectures.	[AP]

Course Contents:

MOS TRANSISTOR PRINCIPLES AND CMOS INVERTER **15**

MOSFET Transistor Characteristic under Static and Dynamic Conditions, MOS Transistor Secondary Effects, CMOS Inverter - Static Characteristic, Dynamic Characteristic, Power, Energy, and Energy Delay parameters.

COMBINATIONAL AND SEQUENTIAL CIRCUITS **15**

Static CMOS Design – Complementary CMOS, Ratioed Logic, Pass-Transistor Logic. Dynamic CMOS Design – Dynamic Logic: Basic Principles, Speed and Power Dissipation of Dynamic Logic, Issues in Dynamic Design, Cascading Dynamic Gates- Timing metrics for sequential circuits, Static Latches and Registers, Dynamic Latches and Registers, Pipelines, Pulse and sense amplifier-based Registers, Non-Bistable Sequential Circuits**.**

ARITHMETIC BUILDING BLOCKS AND MEMORY ARCHITECTURES **15**

Data path circuits, Architectures for Adders, Multipliers, Shifters, Speed and Area Tradeoffs, Array Subsystems: SRAM, DRAM, ROM. Introduction, Power distribution, Input/Output, Clock, Hardware Description Languages, Verilog HDL: Behavioral modeling, Structural gate modeling, Switch modeling, Basic constructs, FSM, High-level synthesis.

Total Periods:	**45**

Text Books:	
1	Jan M Rabaey, Anantha Chandrakasan, B Nikolic, Digital Integrated Circuits: A

	Design Perspective,Second Edition, 2023, Prentice Hall of India.
2	Niel H.E. Weste, David Harris, Ayan Banerjee, CMOS VLSI Design- A circuits and Systems Perspective, Third Edition, 2013, Pearson education.
3	Chris Spear, Systemverilog for Verification, Springer, 2006.
4	Wayne Wolf, Modern VLSI Design, PHI Learning Private Limited, New Delhi, 2011.
Reference Books:	
1	Douglas A. Pucknell, Kamran Eshraghian, Basic VLSI Design, Third Edition, Prentice Hall of India, 2005.
2	Chris Spear, SystemVerilog for Verification: A Guide to Learning the Testbench Language Features, Springer, 2006.
Web References:	
1	https://www.coursera.org/learn/vlsi-cad
2	https://nptel.ac.in/courses/117106092
3	https://www.eetimes.com/tag/vlsi/
4	https://www.ece.ucsb.edu/Faculty/rodriuez/VLSI/
Online Resources:	
1	https://www.edaplayground.com/
2	https://www.asic-world.com/
3	https://www.edaboard.com/forums/asic-design.110/

23EC915	ANALOG VLSI DESIGN	3/0/0/3

Nature of Course	: F (Theory)

Course Objectives:

1	To enable students to understand the fundamentals of MOS device physics and analog circuit building blocks.
2	To guide students in analyzing various noise sources and designing effective analog filters.
3	To facilitate the evaluation of data converters with respect to their performance parameters and architectures.
4	To equip students with strategies for testing and validating analog VLSI circuits.
5	To introduce analog VLSI systems applied to vision and sensory applications.
6	To develop the ability to design and test analog VLSI systems for specialized and emerging applications.

Course Outcomes:
Upon completion of the course, students shall have ability to

C915.1	Understand MOS device models and basic analog building blocks	[U]
C915.2	Analyze the performance of current mirrors, differential pairs, and gain stages.	[AN]
C915.3	Apply design principles to develop multistage amplifiers with specified gain and bandwidth.	[AP]
C915.4	Analyze frequency response and stability considerations in feedback amplifier circuits.	[AN]
C915.5	Design analog circuits such as op-amps, comparators, and oscillators, and analyze their performance.	[AP]

Course Contents:

MOS DEVICE PHYSICS AND BASIC ANALOG CIRCUITS **15**

MOS Device Models: Small Signal Models, Basic CMOS circuits, Gain stages. – BICMOS Technology: Fabrication and design rules. – Passive IC Components: Capacitor and resistor. – Analog Circuits and Amplifiers: Current mirrors, Voltage references, Comparators. – Amplifiers: Inverting and differential amplifiers. – Op-Amps: Two-stage op-amps (BJT and CMOS), Folded cascode op-amp, Instrumentation amplifier.

NOISE, FILTERS, AND DATA CONVERTERS **15**

Noise and Filters: Noise spectrum, Thermal and Flicker noise, Noise bandwidth, Noise figure. – Filters: Low pass, High pass, Band pass filters, Phase Locked Loops (PLL). – D/A and A/D Converters: Ideal converters, Quantization noise, Performance limitations. – D/A Converters: Current scaling, Charge scaling, Serial D/A converters. – A/D Converters: Serial and Parallel A/D converters.

ANALOG VLSI TESTING AND SYSTEMS **15**

Fault Modelling and Simulation – Built-In Self Test (BIST) Techniques – Analog VLSI for Vision: System design issues, Integrated Image Acquisition, Smoothing and Segmentation Focal Plane Processor.

Total Periods:	**45**

Text Books:

1	Behzad Razavi, Design of Analog CMOS Integrated Circuits, 2nd Edition, 2020.

2	Phillip E. Allen and Douglas R. Holberg, CMOS Analog Circuit Design, 3rd Edition, 2012.
3	Adel S. Sedra and Kenneth C. Smith, Microelectronic Circuits, 7th Edition, 2014.
4	Tony Chan Carusone, David A. Johns, Kenneth W. Martin, Analog Integrated Circuit Design, 2nd Edition, 2012.
Reference Books:	
1	Paul R. Gray, Paul J. Hurst, Stephen H. Lewis, Robert G. Meyer, Analysis and Design of Analog Integrated Circuits, 5th Edition, 2009.
2	R. Jacob Baker, CMOS: Circuit Design, Layout, and Simulation, 3rd Edition, 2010.
Web References:	
1	www.students.aiu.edu/submissions/profiles/resources/onlineBook/C6p9V6_CMOS_Analog_Circuit_Design.pdf
2	www.analog.com/en/resources/analog-dialogue/articles/understanding-and-eliminating-1-f-noise.html
3	www.mpflynngroup.com/uploads/7/3/4/9/73490609/08307411.pdf
4	eprints.soton.ac.uk/464497/1/822168.pdf
Online Resources:	
1	https://onlinecourses.nptel.ac.in/noc23_ee142/preview
2	https://people.csail.mit.edu/bkph/papers/Analog_VLSI_Systems.pdf
3	http://circuits-cloud.com/

23EC916	SYSTEM ON CHIP DESIGN	3/0/0/3

Nature of Course	: F (Theory)

Course Objectives:

1	To explain the principles of low-power design and the impact of resistive and inductive interconnects on delay in VLSI systems.
2	To develop the ability to design efficient combinational and sequential logic networks.
3	To impart knowledge on power optimization techniques for combinational and sequential logic circuits.
4	To introduce testing strategies for logic networks and methods to validate the functionality of sequential systems.
5	To enable the design of FPGA and PLA architectures and provide insights into floor planning methodologies for system design.
6	To explore on-chip communication architectures and apply low-power design techniques for efficient System-on-Chip (SoC) implementation.

Course Outcomes:
Upon completion of the course, students shall have ability to

C916.1	Explain the principles of logic gate design, including low-power techniques and delay effects in interconnects.	[U]
C916.2	Design combinational and sequential logic networks with attention to layout, delay, and power optimization.	[AP]
C916.3	Analyze the performance, timi ng, and validation strategies of sequential systems and logic testing.	[AN]
C916.4	Develop arithmetic and memory subsystems such as shifters, adders, ALUs, and high-density memories.	[AP]
C916.5	Apply floor planning techniques including block placement, global routing, and switchbox routing in subsystem design.	[AP]

Course Contents:

LOGIC GATES **15**

Combinational Logic Functions. Static Complementary Gates. Switch Logic. Alternative Gate Circuits. Low-Power Gates. Delay Through Resistive Interconnect. Delay Through Inductive Interconnect.

COMBINATIONAL AND SEQUENTIAL LOGIC NETWORKS **15**

Standard Cell-Based Layout. Simulation. Combinational Network Delay. Logic and interconnect Design. Power Optimization. Switch Logic Networks. Combinational Logic Testing. Latches and Flip-Flops. Sequential Systems and Clocking Disciplines. Sequential System Design. Power Optimization. Design Validation. Sequential Testing.

SUBSYSTEM DESIGN AND FLOORPLANNING **15**

Introduction. Subsystem Design Principles. Combinational Shifters. Adders. ALUs. Multipliers. High-Density Memory. Field Programmable Gate Arrays. Programmable Logic Arrays. References Problems. Floor-planning Methods – Block Placement & Channel Definition, Global Routing, switchbox Routing.

Total Periods:	**45**

Text Books:

1	Hubert Kaeslin, *Digital Integrated Circuit Design: From VLSI Architectures to CMOS Fabrication*, 2nd Edition, Cambridge University Press, 2018.

2	Mohammad Ismail and Terri S. Fiez, *Analog VLSI: Signal and Information Processing*, 2nd Edition, Springer, 2022.
Reference Books:	
1	Yuan Xie, *Design Automation of High-Level Synthesis: From Algorithm to Chip*, Springer, 2020.
2	Sudeep Pasricha and Nikil Dutt, *On-Chip Communication Architectures: System on Chip Interconnect*, 2nd Edition, Morgan Kaufmann, 2018.
3	Peter Wilson, *Design Recipes for FPGAs: Using Verilog and VHDL*, 3rd Edition, Newnes (Elsevier), 2022.
Web References:	
1	https://www.allaboutcircuits.com/technical-articles/introduction-to-digital-circuits
2	https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-111-introduction-to-digital-systems-fall-2006/
3	https://www.edaplayground.com/
4	https://www.vlsiencyclopedia.com/2021/02/floorplanning-in-vlsi-design.html
Online Resources:	
1	https://www.xilinx.com/products/design-tools/design-flows/soc.html
2	https://www.edaplayground.com/
3	https://www.tutorialspoint.com/system_design/index.htm

23EC917	ASIC DESIGN	3/0/0/3
Nature of Course	: F (Theory)	
Course Objectives:		
1	To help students understand the different types of ASICs and programmable technologies like Antifuse, SRAM, EPROM, and EEPROM.	
2	To explain the VLSI design flow and the role of logic cells, I/O cells, and interconnects in programmable ASICs.	
3	To enable students to apply partitioning and floor planning techniques for optimizing speed, area, and power in ASIC designs.	
4	To guide students in analyzing system-level trade-offs for low-power and asynchronous design.	
5	To introduce the SoC design flow and compare platform-based and IP-based SoC design methods.	
6	To explain on-chip communication methods and low-power techniques used in efficient SoC design.	
Course Outcomes: **Upon completion of the course, students shall have ability to**		
C917.1	Demonstrate the complete VLSI tool-flow and illustrate the internal architecture of FPGAs.	[AP]
C917.2	Analyze critical issues in ASIC design, including technology selection, design flow management, verification, debugging, and testing	[AN]
C917.3	Explain core algorithms used in ASIC construction, such as partitioning, placement, and routing.	[U]
C917.4	Understand the fundamentals of System on Chip (SoC) design and describe on-chip communication protocols such as AMBA and AXI.	[U]
C917.5	Apply high-performance algorithms and optimization strategies in ASIC and SoC design scenarios.	[AP]

Course Contents:

OVERVIEW OF ASIC AND PLD **15**

Types of ASICs – VLSI Design flow – Programmable ASICs: Antifuse, SRAM, EPROM, EEPROM-based ASICs – Programmable ASIC logic cells and I/O cells – Programmable interconnects – Latest trends in Programmable Devices: Modern SRAM-based FPGAs (Xilinx UltraScale+), Flash-based CPLDs (Lattice MachXO3) – Soft-core processors (MicroBlaze) – Embedded system integration using IP cores and on-chip communication interfaces.

ASIC PHYSICAL DESIGN **15**

Trade off issues at System Level: Optimization with regard to speed, area and power, asynchronous and low power system design. ASIC physical design issues, System Partitioning, Power Dissipation, Partitioning Methods. ASIC floor planning, Placement and Routing.

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SYSTEM ON CHIP DESIGN **15**

System-On-Chip Design - SoC Design Flow, Platform-based and IP based SoC Designs, Basic Concepts of Bus-Based Communication Architectures, On-Chip Communication Architecture Standards, Low-Power SoC Design High performance algorithms for ASICS/ SoCs as case studies – Canonic Signed Digit Arithmetic.

Total Periods:	**45**

Text Books:	
1	Michael J. S. Smith, *Application-Specific Integrated Circuits*, Addison-Wesley, 2021.
2	Vaibbhav Taraate, *ASIC Design and Synthesis: RTL Design Using Verilog*, Springer, 2021.
Reference Books:	
1	David J. Greaves, *Modern System-on-Chip Design on Arm*, Arm Education, 2020.
2	Veena S. Chakravarthi and Shivananda R. Koteshwar, *System on Chip (SoC) Architecture: A Practical Approach*, Springer, 2023.
3	Khaled Salah Mohamed, *Heterogeneous SoC Design and Verification*, Springer, 2024.
Web References:	
1	https://www.ansys.com/en-in/simulation-topics/what-is-asic-design
2	https://teamvlsi.com/2020/05/asic-design-flow-overview-v1.html
3	https://anysilicon.com/asic-design-flow-ultimate-guide/
4	https://personal.utdallas.edu/~zhoud/Lecture3.pdf
Online Resources:	
1	https://www.youtube.com/playlist?list=PLfGJEQLQIDBN0VsXQ68_FEYyqcym8CTDN
2	https://www.zerotoasiccourse.com/
3	https://github.com/mattvenn/awesome-opensource-asic-resources/blob/main/README.md

23EC918	DESIGN OF SEMICONDUCTOR MEMORIES	3/0/0/3

Nature of Course	: F (Theory)

Course Objectives:

1	To introduce the fundamental concepts, classifications, and working principles of semiconductor memory technologies.
2	To enable students to understand the architecture and operation of SRAM, DRAM, ROM, and Flash memories.
3	To familiarize students with peripheral circuit components such as sense amplifiers, decoders, and address buffers in memory design.
4	To expose students to testing techniques, fault models, and reliability considerations in memory systems.
5	To explore emerging memory technologies and their relevance in embedded and SoC applications.
6	To bridge the gap between academic memory designs and industry-standard interface protocols and use cases.

Course Outcomes:
Upon completion of the course, students shall have ability to

C918.1	Classify and explain the various types of semiconductor memories and their timing characteristics.	[U]
C918.2	Design memory arrays and peripheral circuits considering power, area, and performance trade-offs.	[AP]
C918.3	Apply fault models and analyze testability using BIST and redundancy techniques.	[AN]
C918.4	Explain the operation and use cases of emerging memory technologies in embedded systems.	[U]
C918.5	Apply interface standards and evaluate memory hierarchy in real-world SoC memory subsystems.	[AP]

Course Contents:

FUNDAMENTALS OF SEMICONDUCTOR MEMORIES **15**

Classification of Memories: Volatile and Non-Volatile Memories – SRAM: 6T, 8T Cells – DRAM: 1T-1C, 3T Cells – ROM, PROM, EPROM, EEPROM – Flash Memory Basics – Timing Parameters (tRC, tRCD, tCAS, tWR) – Access Time, Cycle Time, Bandwidth – Memory Hierarchy: Registers to Secondary Storage.

MEMORY DESIGN AND PERIPHERAL CIRCUITS **15**

Memory Array Design: Word Line and Bit Line – Sense Amplifiers – Column Selectors – Row Decoders – Address Buffers – Power and Area Optimization – Redundancy: Row and Column Spares – Built-In Self-Test (BIST) Architectures – Fault Modeling: Stuck-at, Coupling, Transition Faults – Reliability Issues: Soft Errors, Retention Failures.

ADVANCED AND EMERGING MEMORIES **15**

Flash Memory Scaling – FRAM – MRAM – PCM – ReRAM – High Bandwidth Memory (HBM) – 3D Memory Architecture – Embedded Memories in SoCs – Memory IP Core Integration – Interface Standards: DDR4, LPDDR5 – Case Studies: Cache Memory, Scratchpad Memory, SoC Memory Subsystem.

Total Periods:	**45**

Text Books:

1	Ashok K. Sharma, Semiconductor Memories: Technology, Testing and Reliability,

	Wiley-IEEE Press, 2nd Edition, 2022.
2	Kiyoo Itoh, VLSI Memory Chip Design, Springer (Advanced Microelectronics Ser.), Softcover reprint 1st Edition, 2010.
Reference Books:	
1	Betty Prince**,** *Emerging Memories: Technologies and Trends*, Springer**,** Softcover reprint of 1st Edition, 2013**.**
2	Betty Prince, High Performance Memories: New Architecture DRAMs and SRAMs – Evolution and Function, Wiley-IEEE Press, Revised Edition, 1996.
3	Rino Micheloni et al., Inside NAND Flash Memories, Springer, 1st Edition, 2010.
Web References:	
1	https://nptel.ac.in/courses/117106114
2	https://www.ee.iitb.ac.in/course/~dek/DE/
3	https://nptel.ac.in/courses/117106058
4	https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-004-computation-structures-spring-2017/pages/unit-4-memory/
Online Resources:	
1	https://www.allaboutcircuits.com/technical-articles/memory-types-volatile-and-non-volatile/
2	https://www.edaplayground.com/index.jsp
3	https://www.vlsiencyclopedia.com/p/memory-architecture.html

23EC919	NETWORK ENGINEERING FOR IOT AND CONSTRAINED DEVICES	3/0/0/3

Nature of Course	: F (Theory)

Course Objectives:

1	To introduce key concepts in IoT-specific network design.
2	To explain communication models for constrained devices.
3	To illustrate networking standards such as 6LoWPAN, CoAP, and MQTT.
4	To design efficient protocols suitable for low-power and lossy networks.
5	To explore integration techniques for cloud and edge computing.
6	To analyze case studies on smart city, industrial IoT networks.

Course Outcomes:
Upon completion of the course, students shall have ability to

C919.1	Understand the principles of IoT network architectures and protocols.	[U]
C919.2	Apply suitable network models for constrained environments.	[AP]
C919.3	Design solutions for real-world IoT networking challenges.	[AP]
C919.4	Integrate IoT networks with cloud/edge computing infrastructures.	[AP]
C919.5	Evaluate and optimize performance of IoT networks.	[AN]

Course Contents:

IOT NETWORKING MODELS AND REQUIREMENTS **15**

Internet of Things concepts and design patterns - Communication models: Request/Response, Publish/Subscribe, Event-driven architectures - Constrained Application Protocol (CoAP) design - Network architecture layers for IoT - Power optimization techniques for networking - Challenges in bandwidth-limited and latency-sensitive environments - IPv6 addressing for constrained networks - 6LoWPAN and IPv6 compression techniques - Ubiquitous computing and device connectivity - Role of Gateways in IoT architecture - Smart city and healthcare networking models - Introduction to Software-Defined Networking (SDN) for IoT - Basics of Fog and Edge Computing networking.

PROTOCOLS AND TECHNOLOGIES FOR CONSTRAINED DEVICES **15**

6LoWPAN adaptation layer and routing concepts - RPL (Routing Protocol for Low-Power and Lossy Networks) working principles - CoAP and MQTT for constrained environments - Wireless standards: ZigBee, LoRa, Wi-Fi, BLE, NB-IoT, LTE-M - Data encapsulation and protocol stack optimization - Medium Access Control (MAC) issues in IoT - Energy-efficient scheduling and duty-cycling techniques - IoT network security: TLS, DTLS, lightweight cryptography - Secure data transfer mechanisms for low-power devices - Protocol bridging and interoperability challenges - IoT device discovery and registration - Network slicing concepts in 5G for IoT - Emerging protocols: QUIC and SCHC (Static Context Header Compression).

IOT CLOUD AND EDGE INTEGRATION **15**

Architecture of Cloud-IoT integration - Edge Computing concepts and architecture for IoT - Data aggregation and data filtering at the edge - MQTT over Websockets and Edge analytics - Real-time streaming protocols for IoT - Application layer protocols comparison: CoAP, MQTT, HTTP - Virtualization technologies in IoT (Docker, Kubernetes) - Managing large-scale IoT networks - Fault tolerance and load balancing strategies - Cloud platforms: AWS IoT Core, Azure IoT Hub, Google Cloud IoT - Edge platform examples: Azure IoT Edge, AWS Greengrass - Industrial case study: Smart Manufacturing Networks - Smart Home case study: Networking Design and Optimization.

Total Periods:	**45**

Text Books:	
1	Daniel Minoli, Building the Internet of Things with IPv6 and MIPv6: The Evolving World of M2M Communications, Wiley, 2013.
2	Peter Waher, Learning Internet of Things, Packt Publishing, 2015.
Reference Books:	
1	Olivier Hersent, David Boswarthick, and Omar Elloumi, The Internet of Things: Key Applications and Protocols, Wiley, 2012.
2	Adrian McEwen, Designing the Internet of Things, Wiley, 2013.
3	Rajkumar Buyya and Satish Narayanan Srirama, Fog and Edge Computing – Principles and Paradigms, Wiley, 2019.
Web References:	
1	https://www.iotforall.com
2	https://openwsn.atlassian.net/wiki
3	https://www.postscapes.com/internet-of-things-protocols/
4	https://iotagenda.techtarget.com/definition/IoT-network
Online Resources:	
1	https://onlinecourses.nptel.ac.in/noc22_cs53/preview
2	https://www.coursera.org/specializations/iot
3	https://www.edx.org/learn/computer-architecture/waseda-university-iot-system-design-software-and-hardware-integration
4	https://www.futurelearn.com/info/courses/gettingstartedwiththeiot

23EC920	ADVANCED COMPUTER NETWORK ARCHITECTURES	3/0/0/3
Nature of Course	: F (Theory)	
Course Objectives:		
1	To help students understand the evolution of network architectures and networking models.	
2	To enable learners to analyze emerging networking paradigms such as Software Defined Networking (SDN) and Network Function Virtualization (NFV).	
3	To introduce high-speed networking technologies and performance-enhancing protocols.	
4	To provide a strong foundation in network security frameworks, including common threats and mitigation techniques.	
5	To familiarize students with the architecture and functionality of data centers, cloud networking, and edge computing systems.	
6	To develop the ability to design and evaluate scalable, secure, and efficient network architectures.	
Course Outcomes: **Upon completion of the course, students shall have ability to**		
C920.1	Understand traditional and modern network architecture models.	[U]
C920.2	Analyze software-defined networking and network function virtualization.	[AN]
C920.3	Explore emerging high-speed networking protocols and techniques.	[U]
C920.4	Implement secure, scalable cloud and data center networking solutions.	[AP]
C920.5	Design next-generation network architectures for real-world applications.	[AP]

Course Contents:

EVOLUTION OF COMPUTER NETWORK ARCHITECTURES **15**

Review of OSI and TCP/IP reference models Network - Ethernet and VLAN architectures - IP addressing (IPv4/IPv6) and subnetting - Routing protocols: OSPF, BGP, EIGRP - MPLS architecture and traffic engineering - QoS models: IntServ and DiffServ - Virtual LANs (VLANs) and Virtual Private Networks (VPNs) - IP Multicast Routing Architectures - Data center topologies: Spine-Leaf, Fat-tree architecture - Challenges in traditional networking.

MODERN NETWORKING PARADIGMS AND TECHNOLOGIES **15**

Software Defined Networking (SDN) principles – Open Flow protocol and controllers (ONOS, Open Daylight) - Network Function Virtualization (NFV) architecture - Service Function Chaining - Edge Computing architectures - IoT networking integration with SDN/NFV - Traffic engineering with SDN - Cloud Networking: Virtual Private Cloud (VPC), Direct Connect – Micro segmentation and network security using SDN - 5G network slicing and architecture - SD-WAN architectures and protocols.

SECURITY, CLOUD AND DATA CENTER NETWORK ARCHITECTURES **15**

Data center network designs - Public, Private and Hybrid cloud networking models - Virtualization in networking: Hypervisors and VNFs - Cloud-native networking (AWS, Azure, GCP) - Load balancing and application delivery networks - Zero Trust Network Architecture (ZTNA) – Cyber-security principles in modern networks - DDoS mitigation architectures - Multi-cloud network architecture designs - Case studies on real-world cloud networks.

Total Periods:	**45**

Text Books:

1	William Stallings, *Foundations of Modern Networking: SDN, NFV, QoE, IoT, and Cloud*, Addison-Wesley, 2015.
2	Thomas D. Nadeau, Ken Gray, *SDN: Software Defined Networks*, O'Reilly, 2013.
3	James F. Kurose, Keith W. Ross, *Computer Networking: A Top-Down Approach*, Pearson, 2021.
Reference Books:	
1	Behrouz A. Forouzan, *Data Communications and Networking*, McGraw Hill, 2017.
2	Tim Szigeti, Christina Hattingh, *QoS Design Best Practices for IP Networks*, Cisco Press, 2004.
3	Rajkumar Buyya, *Cloud Computing: Principles and Paradigms*, Wiley, 2011.
Web References:	
1	https://opennetworking.org/
2	https://www.sdxcentral.com/
3	https://www.networkcomputing.com/
4	https://www.cisco.com/c/en/us/solutions/cloud/what-is-cloud-networking.html
Online Resources:	
1	https://nptel.ac.in/courses/106105183
2	https://www.coursera.org/learn/cloud-networking
3	https://www.udemy.com/course/master-python-network-automation-for-network-engineers/
4	https://www.edx.org/learn/computer-networking/curtin-university-introduction-to-software-defined-networking

23EC921	PYTHON PROGRAMMING FOR IMAGE AND VIDEO PROCESSING	3/0/0/3

Nature of Course	: F (Theory)

Course Objectives:

1	To enable students to develop a strong foundation in Python programming relevant to image and video processing.
2	To introduce the fundamental concepts of image and video data, and train students in using Python libraries such as OpenCV and Pillow for image processing.
3	To help students understand and apply various image enhancement and manipulation techniques including contrast adjustment, noise removal, and sharpening.
4	To guide students in using filtering, histogram equalization, and morphological operations for practical image enhancement applications.
5	To train students in feature extraction methods and segmentation techniques for detecting and analyzing objects within images.
6	To provide an introduction to video processing principles, emphasizing moving object detection, motion tracking, and frame-based analysis.

Course Outcomes:
Upon completion of the course, students shall have ability to

C921.1	*Apply* core Python programming constructs (variables, functions, modules) to solve image and video-related computational problems.	[AP]
C921.2	*Demonstrate* the ability to load, manipulate, and visualize digital images using Python libraries such as NumPy, OpenCV, and PIL.	[AP]
C921.3	*Implement* image enhancement techniques including intensity transformations, filtering, and histogram operations.	[AP]
C921.4	*Apply* morphological operations, edge detection, and segmentation methods to prepare images for feature extraction and analysis.	[AP]
C921.5	*Develop* basic video processing applications for moving object detection and tracking using Python.	[AP]

Course Contents:

PYTHON AND IMAGING **15**

Python, Python IDLE, Arithmetic Operators, Values and types, Variables, Expressions and Statements, Lists, Dictionaries, Tuples, Array, Functions – Function calls, Math Functions, Function types, Concept of local and global, Conditionals, Iteration and Recursion, Modules & Packages. Image, Image Acquisition, Color Images and Video. Python libraries for Image processing (NumPy, SciPy, scikit-image, PIL (Pillow), OpenCV, scikit-learn, SimpleITK, and Matplotlib)

IMAGE MANIPULATION AND ENHANCEMENT **15**

Image I/O and display, Image types and file formats, Basic image manipulations, Image Enhancement - Point-wise intensity transformations – pixel transformation, Histogram processing, Linear & Non-linear noise smoothing, Image Enhancement, Edge detection, Image pyramids, Morphological Image Processing.

IMAGE & VIDEO PROCESSING APPLICATION **15**

Extracting Image Features - Harris Corner Detector, Blob detectors (LoG, DoG, and DoH). Image Segmentation - Hough transform, Thresholding and Otsu's segmentation, Edges-based/region-based segmentation. Video processing - Moving Object Detection and Tracking.

Total Periods:	**45**
Text Books:	
1	Allen B. Downey, 'Think Python – How to think like a computer scientisit', O'Reilly Media, Inc., Second Edition, 2015.
2	Sandipan Dey, 'Hands-On Image Processing with Python', Packt Publishing, 2018.
3	Kenneth Dawson-Howe, 'A Practical Introduction to ComPuter VIsIon wIth OpenCV', John Wiley & Sons Ltd, First edition, 2014.
Reference Books:	
1	Adrian Rosebrock, 'Practical Python and OpenCV: An Introductory, Example
2	Driven Guide to Image Processing and Computer Vision', Pyimagesearch, Third edition, 2016.
3	Prateek Joshi, 'OpenCV with Python By Example', Packt Publishing, 2015..
Web References:	
1	https://www.python.org/
2	https://www.w3schools.com/python/
3	https://www.w3schools.com/python/python_intro.asp
4	https://developers.google.com/edu/python
Online Resources:	
1	https://onlinecourses.nptel.ac.in/noc25_cs69/preview
2	https://onlinecourses.swayam2.ac.in/nou25_cs08/preview
3	https://onlinecourses.swayam2.ac.in/cec25_ma18/preview
4	https://onlinecourses.nptel.ac.in/noc25_ee13/preview

23EC922	R PROGRAMMING FOR IMAGE AND VIDEO DATA ANALYSIS	3/0/0/3

Nature of Course	: F (Theory)

Course Objectives:

1	To impart fundamental programming knowledge in R.
2	To familiarize students with R-based libraries and basics of image and image acquisition.
3	To enable students to understand various spatial and frequency domain techniques for image enhancement, restoration, and filtering.
4	To develop proficiency in implementing morphological and fuzzy-based operations for advanced image transformations
5	To introduce advanced concepts such as color image processing, wavelets, compression, segmentation, and object recognition.
6	To familiarize students with R for multiresolution analysis and feature extraction.

Course Outcomes:
Upon completion of the course, students shall have ability to

C922.1	Apply R programming constructs and basic functions for data manipulation and image/video input-output operations.	[AP]
C922.2	Utilize R libraries such as imager, terra, and raster to acquire, visualize, and preprocess image and video data.	[AP]
C922.3	Implement image enhancement and restoration techniques including intensity transformations, filtering, and fuzzy logic methods using R.	[AP]
C922.4	Analyze morphological operations and frequency domain filtering techniques for efficient image processing tasks.	[AN]
C922.5	Design segmentation and object recognition workflows incorporating advanced techniques like wavelet transform, color image analysis, and compression using R.	[AP]

Course Contents:

R AND IMAGING **15**

R, RStudio, Arithmetic Operators, Vectors, Character Strings, Matrices and Arrays, Lists, Data Frames, Classes, Functions, Factors and Tables, R programming structures, Input/Output, file handling, packages. Image, Image Acquisition, Color Images and Video. Python libraries for Image processing (ggplot2, dplyr, tidyr, caret, shiny, imager, forecast, randomForest, gdalUtils, raster, RStoolbox, rgdal, mapview, gridExtra, and terra).

SPATIAL AND FREQUENCY OPERATIONS **15**

Intensity Transformations and Spatial Filtering, Spatial Enhancement Method, Fuzzy Techniques for Intensity Transformations and Spatial Filtering, Image Restoration and Reconstruction, Morphological Image Processing, Filtering in the Frequency Domain.

ADVANCED IMAGE PROCESSING APPLICATIONS **15**

Color Image Processing, Wavelets and Multiresolution Processing, Image Compression, Image Segmentation, Image Representation and Description, Object Recognition.

Total Periods:	**45**

Text Books:

1	Norman Matloff, 'The Art of R Programming', No Starch Press, 2011.
2	Rafael C. Gonzalez, Richard E. Woods, 'Digital Image Processing', Pearson

	Education,Third Edition.
Reference Books:	
1	Winston Chang, 'R Graphics Cookbook', O'Reilly, First edition, 2012.
2	Marcelo de Carvalho Alves, Luciana Sanches, 'Remote Sensing and Digital Image Processing with R - Lab Manual', CRC Press, First Edition, 2024.
3	Alejandro C. Frery, Talita Perciano, 'Introduction to Image Processing Using R', Springer.
Web References:	
1	https://www.r-project.org/
2	https://www.w3schools.com/r/
3	https://www.coursera.org/learn/r-programming
4	https://www.geeksforgeeks.org/r-programming-language-introduction/
Online Resources:	
1	https://www.reddit.com/r/programming/?rdt=47157
2	https://onlinecourses.nptel.ac.in/noc25_cs69/preview
3	https://onlinecourses.swayam2.ac.in/nou25_cs08/preview
4	https://onlinecourses.swayam2.ac.in/cec25_ma18/preview
5	https://onlinecourses.nptel.ac.in/noc25_ee13/preview

23EC923	DIGITAL IMAGE PROCESSING	3/0/0/3

Nature of Course	: F (Theory)

Course Objectives:

1	To introduce fundamental concepts of digital image processing.
2	To explore image enhancement, restoration, and compression techniques.
3	To analyze image segmentation and morphological processing methods.
4	To apply transforms and feature extraction for image understanding.
5	To develop solutions for real-world image processing applications
6	To introduce fundamental concepts of digital image processing.

Course Outcomes:
Upon completion of the course, students shall have ability to

C923.1	Understand basic operations and models in digital image processing.	[U]
C923.2	Apply enhancement and filtering techniques in spatial and frequency domains.	[AP]
C923.3	Perform image segmentation and morphological transformations.	[AP]
C923.4	Utilize transforms and feature extraction for object recognition.	[AN]
C923.5	Design image processing systems for industrial and research applications.	[AN]

Course Contents:

FUNDAMENTALS AND IMAGE ENHANCEMENT **15**

Introduction to digital image processing - Image formation and sensing - Image sampling and quantization - Basic intensity transformation functions - Histogram processing - Spatial filtering (smoothing, sharpening) - Frequency domain filtering - Introduction to Fourier Transform - Discrete Cosine Transform (DCT).

IMAGE RESTORATION, SEGMENTATION, AND COMPRESSION **15**

Noise models - Restoration techniques (inverse filtering, Wiener filtering) - Edge detection techniques (Sobel, Prewitt, Canny) - Thresholding and region-based segmentation - Morphological image processing (dilation, erosion, opening, closing) - Basics of compression - JPEG, JPEG2000 standards - Wavelet-based compression.

ADVANCED TOPICS AND APPLICATIONS **15**

Feature extraction: edges, corners, blobs - Image classification basics - Pattern recognition methods - Motion detection - 3D imaging basics - Case study: Medical imaging - Case study: Satellite image processing - Industrial project: Defect detection in manufacturing.

Total Periods:	**45**

Text Books:

1	Rafael C. Gonzalez and Richard E. Woods, *Digital Image Processing*, Pearson, 4th Edition, 2018.
2	Anil K. Jain, *Fundamentals of Digital Image Processing*, Prentice Hall, 1989.

Reference Books:

1	Bernd Jähne, *Digital Image Processing*, Springer, 6th Edition, 2005.
2	William K. Pratt, *Digital Image Processing: PIKS Scientific Inside*, Wiley-

	Interscience, 2007.
3	Milan Sonka, Vaclav Hlavac, and Roger Boyle, *Image Processing, Analysis, and Machine Vision*, Cengage Learning, 2014.
Web References:	
1	https://www.imageprocessingplace.com/
2	https://homepages.inf.ed.ac.uk/rbf/HIPR2/
3	https://nptel.ac.in/courses/117105079
Online Resources:	
1	https://www.coursera.org/learn/digital
2	https://www.coursera.org/learn/image-processing

23EC924	COMPUTER VISION TECHNIQUES	3/0/0/3

Nature of Course	: F (Theory)

Course Objectives:

1	To introduce basic concepts and techniques in computer vision.
2	To explore methods for feature extraction, matching, and object detection.
3	To apply image segmentation and 3D vision techniques.
4	To understand machine learning models for vision applications.
5	To develop end-to-end vision-based systems for practical use cases.
6	To introduce basic concepts and techniques in computer vision.

Course Outcomes:
Upon completion of the course, students shall have ability to

C924.1	Understand fundamental principles of computer vision.	[U]
C924.2	Apply feature detection, extraction, and matching techniques.	[AP]
C924.3	Perform image segmentation and object recognition.	[AP]
C924.4	Develop 3D reconstruction and depth estimation solutions.	[AP]
C924.5	Implement machine learning models for vision applications.	[AP]

Course Contents:

INTRODUCTION TO COMPUTER VISION AND FEATURE EXTRACTION **15**

Computer vision overview - Camera models and imaging geometry - Color models and image formation - Edge detection (Sobel, Canny) - Keypoint detection (Harris Corner Detector) - Feature extraction and matching (SIFT, SURF, ORB) - Optical flow basics - Applications in tracking and motion analysis.

OBJECT DETECTION, SEGMENTATION, AND 3D VISION **15**

Object detection techniques: Haar cascades, HOG + SVM - Semantic segmentation and instance segmentation basics - Mean-Shift and Graph Cut segmentation - 3D vision: Stereo imaging and disparity maps - Structure from Motion (SfM) concepts - Depth estimation using stereo vision - Application: 3D reconstruction from images.

MACHINE LEARNING AND DEEP LEARNING FOR VISION **15**

Introduction to supervised and unsupervised learning - CNN basics for vision - Transfer learning for vision tasks - Object detection frameworks: YOLO, SSD, Faster-RCNN - Model evaluation techniques - Applications: Face detection, pose estimation, gesture recognition - Mini-project: Building a real-time object recognition app.

Total Periods:	**45**

Text Books:

1	Richard Szeliski, *Computer Vision: Algorithms and Applications*, Springer, 2nd Edition, 2022.
2	Simon J. D. Prince, *Computer Vision: Models, Learning, and Inference*, Cambridge University Press, 2012.
3	Richard Szeliski, *Computer Vision: Algorithms and Applications*, Springer, 2nd Edition, 2022.

Reference Books:	
1	Forsyth and Ponce, *Computer Vision: A Modern Approach*, Pearson, 2nd Edition, 2011.
2	Adrian Kaehler and Gary Bradski, *Learning OpenCV 4*, O'Reilly Media, 2019.
3	Ian Goodfellow, Yoshua Bengio, and Aaron Courville, *Deep Learning*, MIT Press, 2016.
Web References:	
1	https://opencv.org/
2	https://scikit-image.org/
3	https://docs.tensorflow.org/
Online Resources:	
1	https://www.coursera.org/learn/computer-vision-basics
2	https://www.udacity.com/course/computer-vision-nanodegree--nd891
3	https://onlinecourses.nptel.ac.in/noc19_cs58/preview
4	https://www.edx.org/learn/computer-vision

23EC925	DEEP LEARNING FOR IMAGE AND VIDEO ANALYSIS	3/0/0/3

Nature of Course	: F (Theory)

Course Objectives:

1	To introduce deep learning foundations for image and video data analysis.
2	To explore neural network architectures including CNNs and RNNs.
3	To develop deep learning models for object detection and segmentation.
4	To analyze video sequences using advanced deep learning techniques.
5	To apply deep learning solutions to real-world multimedia applications.
6	To introduce deep learning foundations for image and video data analysis.

Course Outcomes:
Upon completion of the course, students shall have ability to

C925.1	Understand deep learning principles and architectures for image and video analysis.	[U]
C925.2	Implement convolutional neural networks (CNNs) for visual tasks.	[AP]
C925.3	Apply recurrent and 3D CNN models for video analysis.	[AP]
C925.4	Utilize advanced models for object detection and segmentation.	[AP]
C925.5	Design and deploy end-to-end deep learning systems for real-world multimedia problems.	[AP]

Course Contents:

FUNDAMENTALS OF DEEP LEARNING FOR VISUAL DATA **15**

Introduction to deep learning - Neural network basics - Loss functions and optimization techniques - Introduction to convolutional neural networks (CNNs) - CNN architecture: convolution, pooling, fully connected layers - Training deep networks - Data augmentation techniques for images.

DEEP ARCHITECTURES FOR IMAGE AND VIDEO TASKS **15**

Popular CNN models: AlexNet, VGGNet, ResNet - Transfer learning and fine-tuning - Object detection frameworks: R-CNN, Fast R-CNN, Faster R-CNN, YOLO, SSD - Semantic segmentation networks: U-Net, Mask R-CNN - Action recognition in videos - 3D convolutional neural networks - Recurrent Neural Networks (RNNs) and Long Short-Term Memory (LSTM) networks for video sequence modeling.

ADVANCED TOPICS AND APPLICATIONS **15**

Attention mechanisms and Vision Transformers (ViT) - Generative Adversarial Networks (GANs) for image synthesis - Deepfake detection - Video captioning using deep learning - Deployment of deep learning models on mobile and embedded platforms - Industrial case studies: autonomous driving, medical imaging, surveillance systems.

Total Periods:	**45**

Text Books:

1	Ian Goodfellow, Yoshua Bengio, and Aaron Courville, *Deep Learning*, MIT Press, 2016.
2	François Chollet, *Deep Learning with Python*, Manning Publications, 2nd Edition, 2021.

Reference Books:

1	Aurelien Géron, *Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow*, O'Reilly, 2022.
2	Rajalingappaa Shanmugamani, *Deep Learning for Computer Vision*, Packt Publishing, 2018.
3	Joseph Redmon and Santosh Divvala, *YOLO Object Detection Papers*, arXiv preprints.
Web References:	
1	https://keras.io/
2	https://pytorch.org/
3	https://tensorflow.org/
Online Resources:	
1	https://www.coursera.org/specializations/deep-learning
2	https://www.udacity.com/course/deep-learning-nanodegree--nd101
3	https://www.edx.org/learn/deep-learning
4	https://onlinecourses.nptel.ac.in/noc20_cs62/preview

23EC926	VIDEO ANALYTICS AND SURVEILLANCE SYSTEMS	3/0/0/3

Nature of Course	: F (Theory)

Course Objectives:

1	To introduce fundamental concepts of video analytics and surveillance.
2	To explore techniques for video preprocessing and event detection.
3	To develop algorithms for tracking, behavior analysis, and anomaly detection.
4	To understand architectures of smart surveillance systems.
5	To apply machine learning and deep learning techniques for video analytics.
6	To introduce fundamental concepts of video analytics and surveillance.

Course Outcomes:
Upon completion of the course, students shall have ability to

C926.1	Understand core concepts and challenges in video analytics.	[U]
C926.2	Apply preprocessing and feature extraction techniques for video data.	[AP]
C926.3	Design algorithms for tracking, behavior recognition, and anomaly detection.	[AP]
C926.4	Develop intelligent surveillance systems using modern frameworks.	[AP]
C926.5	Analyze real-world scenarios and implement smart video analytics solutions.	[AN]

Course Contents:

FUNDAMENTALS OF VIDEO ANALYTICS **15**

Introduction to video surveillance systems - Basics of video acquisition and formats - Frame differencing and background subtraction - Motion detection techniques - Object tracking: Kalman filter, Meanshift, Camshift - Visual surveillance and scene understanding - Challenges in surveillance: occlusion, illumination changes.

BEHAVIOR ANALYSIS AND EVENT DETECTION **15**

Action recognition techniques - Spatio-temporal feature extraction - Event detection in crowded scenes - Abnormal behavior detection - Multi-object tracking - Group activity recognition - Applications: Traffic monitoring, Retail analytics, Public safety surveillance - Datasets for video surveillance research.

INTELLIGENT SURVEILLANCE SYSTEMS **15**

Deep learning for video analytics: CNN, RNN, 3D CNN models - Person re-identification (Re-ID) - Face detection and recognition in surveillance - Edge-based video processing - Cloud-based video analytics platforms - Privacy issues and ethical considerations in surveillance - Industrial case study: Smart city surveillance systems.

Total Periods:	**45**

Text Books:

1	Maheshkumar H. Kolekar, *Intelligent Video Surveillance Systems*, Wiley, 2018.
2	Yunqian Ma and Gang Qian, *Intelligent Video Surveillance: Systems and Technology*, CRC Press, 2009.

Reference Books:

1	Borko Furht, *Handbook of Video Databases: Design and Applications*, CRC Press, 2003.

2	Amine Nait-ali, *Advanced Biosignal Processing for Video Surveillance*, Springer, 2019.
3	Richard Szeliski, *Computer Vision: Algorithms and Applications*, Springer, 2nd Edition, 2022.
Web References:	
1	https://openvinotoolkit.org/
2	https://opencv.org/
3	https://www.analyticsvidhya.com/
Online Resources:	
1	https://archive.nptel.ac.in/courses/106/106/106106238
2	https://archive.nptel.ac.in/courses/106/106/106106224
3	https://archive.nptel.ac.in/courses/106/107/106107220

23EC927	NETWORK INTEGRATION FOR IOT AND MULTIMEDIA APPLICATIONS	3/0/0/3

Nature of Course	: F (Theory)

Course Objectives:

1	To enable students to understand the fundamental architecture and protocols governing IoT and multimedia networks.
2	To introduce integration techniques for combining heterogeneous network systems effectively.
3	To guide students in developing robust communication frameworks that support seamless IoT and multimedia application delivery.
4	To help students address key challenges related to Quality of Service (QoS), security, and interoperability in integrated networks.
5	To train students in the design, deployment, and management of real-world network solutions involving IoT and multimedia convergence.
6	To provide insights into evolving standards and practices in unified network architectures supporting modern connected applications.

Course Outcomes:
Upon completion of the course, students shall have ability to

C927.1	Understand the networking fundamentals for IoT and multimedia integration.	[U]
C927.2	Analyze different communication protocols for heterogeneous systems.	[AN]
C927.3	Design frameworks ensuring quality of service and security.	[AP]
C927.4	Implement network solutions that integrate IoT and multimedia services.	[AP]
C927.5	Evaluate real-world applications and case studies of integrated systems.	[AN]

Course Contents:

NETWORKING BASICS FOR IOT AND MULTIMEDIA **15**

Overview of IoT and multimedia network requirements - Heterogeneous network models - Communication protocols: MQTT, CoAP, HTTP, RTP - Streaming protocols for multimedia: RTSP, HLS - Wireless technologies for IoT and multimedia: Wi-Fi, LoRa, 5G - Quality of Service (QoS) metrics - Delay, jitter, packet loss, and throughput considerations.

INTEGRATION ARCHITECTURES AND PROTOCOLS **15**

Edge computing and fog networking for IoT-multimedia applications - Cross-domain communication challenges - Protocol conversion and gateways - Service orchestration in heterogeneous environments - Resource allocation strategies - Network slicing in 5G for IoT/multimedia - Case study: Smart city communication infrastructure.

SECURITY, QOS, AND APPLICATIONS **15**

Security and privacy challenges in integrated networks - Lightweight encryption for IoT and multimedia - End-to-end QoS provisioning - Adaptive streaming and dynamic bandwidth management - IoT-multimedia fusion platforms: AWS IoT Core, Azure IoT Hub with Media Services - Case studies: Remote healthcare, Industrial monitoring, Smart transportation.

Total Periods:	**45**

Text Books:

1	Zaigham Mahmood, *IoT Applications, Security Threats, and Countermeasures*,

	Springer, 2022.
2	K. Chatterjee, *Multimedia Communications: Applications, Networks, Protocols and Standards*, Elsevier, 2020.
Reference Books:	
1	F. Hu, *Security and Privacy in Internet of Things (IoTs)*, CRC Press, 2016.
2	Adrian Farrel, *The Internet and Its Protocols: A Comparative Approach*, Morgan Kaufmann, 2004.
3	Rajkumar Buyya, *Fog and Edge Computing: Principles and Paradigms*, Wiley, 2019.
Web References:	
1	https://iotagenda.techtarget.com/
2	https://www.mediastreamingacademy.com/
3	https://aws.amazon.com/iot/
Online Resources:	
1	https://www.coursera.org/learn/internet-of-things-multimedia
2	https://www.edx.org/learn/computer-networking/curtin-university-iot-networks-and-protocols
3	https://nptel.ac.in/courses/117105083

23EC928	RF SYSTEM DESIGN	3/0/0/3
Nature of Course	: F (Theory)	
Course Objectives:		
1	To introduce students to the fundamental concepts and key principles of RF circuit design.	
2	To enable students to differentiate between various RF filters and resonator structures, and to guide them in their design.	
3	To teach students to design and analyze RF active components, highlighting their influence on circuit behavior.	
4	To provide students with the skills to design, match, and bias RF transistor amplifiers for diverse applications.	
5	To explain the operation and design considerations of RF oscillators and frequency synthesizers.	
6	To help students understand the working principles and practical applications of RF mixers used for frequency translation.	
Course Outcomes: **Upon completion of the course, students shall have ability to**		
C928.1	Understand the behavior and characteristics of RF passive and chip components in RF circuit applications.	[U]
C928.2	Analyze and design RF resonators, coupled filters, and mixer circuits used in frequency-selective and translation applications.	[AN]
C928.3	Apply impedance matching techniques and biasing methods in the design of RF transistor-based circuits.	[AP]
C928.4	Analyze the stability, gain characteristics, and noise performance of RF amplifiers, including low noise amplifier (LNA) design.	[AN]
C928.5	Apply the principles and configurations of RF oscillator and frequency synthesizer design for communication systems.	[AP]

Course Contents:

RF FUNDAMENTALS AND RF FILTER DESIGN **15**

Importance of RF Frequency Design, RF behaviour of Passive Components, Chip Components and Circuit Board Considerations, Basic Resonator and Filter Design, Filter Implementation-coupled filter.

IMPEDANCE MATCHING AND RF TRANSISTOR AMPLIFIER DESIGNS **15**

High electron mobility transistors, matching and biasing networks – impedance matching using discrete components, microstripline matching networks, amplifier – classes of operation and biasing networks. Characteristics of Amplifiers, Amplifier Power Relations, Stability Considerations, Constant Gain and VSWR Circles, Low noise Amplifier-Single ended and Differential LNAs.

RF OSCILLATORS AND MIXERS **15**

Basic Oscillator Model, High Frequency Oscillator Configurations – Fixed Frequency Oscillator, Dielectric Resonator Oscillator, Basics Concepts of Mixer and Frequency domain Considerations,Single balanced and double balanced mixers–subsampling mixers.

Total Periods:	**45**

Text Books:

1	Reinhold Ludwig, Gene Bogdanov, "RF circuit design, theory and applications", Pearson Asia Education, 2nd edition, 2009.

2	Joseph. J. Carr, “Secrets of RF Circuit Design “, McGraw Hill Publishers,Third Edition,2000.
Reference Books:	
1	Mathew M. Radmanesh, “Radio Frequency &Microwave Electronics”, Pearson Education Asia, Second Edition, 2002
2	Ulrich L. Rohde and David P. NewKirk, “RF / Microwave Circuit Design”, John Wiley & Sons USA, 2000.
Web References:	
1	https://www.ti.com/lit/an/snoa529a/snoa529a.pdf
2	https://www.electronics-tutorials.ws/oscillator/oscillators.html
Online Resources:	
1	https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-776-high-speed-communication-circuits-spring-2005/lecture-notes/
2	https://cds.cern.ch/record/1407402/files/p223.pdf

23EC929	MICROWAVE INTEGRATED CIRCUITS	3/0/0/3
Nature of Course	: F (Theory)	
Course Objectives:		
1	To facilitate students, understand planar transmission line structures and various microwave integrated circuit (MIC) technologies.	
2	To guide students in the design of basic lumped and quasi-lumped microwave passive components.	
3	To enable students to analyze and design different types of microwave resonators.	
4	To train students in developing microwave filters using both lumped and distributed design approaches.	
5	To teach students how to design microwave amplifiers and oscillators to meet specific performance criteria.	
6	To expose students to fabrication techniques used in MIC and monolithic microwave integrated circuit (MMIC) technologies.	
Course Outcomes: **Upon completion of the course, students shall have ability to**		
C929.1	Apply the concepts of planar transmission lines and passive microwave components in MIC design.	[AP]
C929.2	Apply the principles of microwave resonators in analysing and designing resonant circuits.	[AP]
C929.3	Design microwave filters using lumped and distributed techniques with impedance inverters and coupled line structures.	[AP]
C929.4	Analyze the performance characteristics of microwave amplifiers and oscillators based on key parameters.	[AN]
C929.5	Understand fabrication processes for MICs and MMICs using modern technologies and materials.	[U]

Course Contents:

PLANAR TRANSMISSION AND PASSIVE MICROWAVE COMPONENTS **15**

Types of MICs and their technology; Microstrip lines, strip lines, slotted lines, co-planar waveguides, coupled lines and SIW. Losses in microstrip transmission lines, Lumped microstrip components: Design of microstrip and chip inductors, capacitors, resistors, Quasi lumped microstrip elements: Open and short-circuited stubs (quarter wavelength, half wavelength). Interdigital capacitors, Approximate analysis.

MICROWAVE RESONATORS AND FILTER DESIGN **15**

Analysis and Design of Quarter & Half wave length resonators, Ring resonators, Patch resonators and Slot resonators. Band pass filter: Insertion loss method, Conversion from low pass to band pass, Design of band pass filter using lumped elements, distributed elements, impedance inverters and coupled line filters.

MICROWAVE ACTIVE DEVICES AND MIC/MMIC FABRICATION **15**

Single stage amplifier design, Design of low noise amplifiers, Conditions for oscillations, one port oscillator, two port oscillator (Transistor oscillators), Characteristics of mixer, Single ended diode mixer, Single ended FET mixer. Hybrid MICs, Configuration, Dielectric substances, thick and thin film technology, Printed Circuit Board (PCB) Technology, Fabrication process of MMIC.

Total Periods:	**45**

Text Books:	
1	TC Edwards, MB Steer, “Foundations for Microstrip Circuit Design”, 4th Edition, John Wiley, 2022.
2	D. M. Pozar, “Microwave Engineering”, 4th Edition, John Wiley, 2020.
3	Ali A Behagi, “RF and Microwave Circuit Design: A Design Approach using ADS”, 1st Edition, Techno Search, 2021.
Reference Books:	
1	G Gonzalez, “Microwave Transistor Amplifiers”, 2nd Edition, PHI Inc., 2021.
2	Bharathi Bhat, Shiban K. Koul, “Stripline-Like Transmission Lines for Microwave Integrated Circuits”, Blackie Academic & Professional, 2017.
3	Hoffman R.K., “Hand Book of Microwave Integrated Circuits”, Artech House, Boston, 2019.
Web References:	
1	https://www.microwaves101.com/encyclopedias/microwave-integrated-circuits
2	https://resources.system-analysis.cadence.com/blog/msa2021-monolithic-and-hybrid-microwave-integrated-circuits-whats-the-difference
Online Resources:	
1	https://onlinecourses.nptel.ac.in/noc21_ee34/preview
2	https://innovationspace.ansys.com/courses/learning-track/microwave-integrated-circuits/?template=discovery

23EC930	CAN AND CAN OPEN PROTOCOLS	3/0/0/3
Nature of Course	: F (Theory)	
Course Objectives:		
1	To facilitate students, understand the basic concepts and significance of CAN and LIN protocols in automotive communication systems.	
2	To guide students in studying vehicle network architecture and CAN frame structures for effective in-vehicle communication design.	
3	To facilitate learning about data integrity in CAN, focusing on frame formats, bus arbitration, error detection mechanisms, and fault management.	
4	To provide an overview of satellite communication fundamentals, including key subsystems, modulation techniques, multiplexing, and multiple access methods.	
5	To enable students to analyze the functioning of the physical and data link layers within CAN bus systems.	
6	To train students in designing, simulating, and troubleshooting CAN-based communication networks for real-world applications.	
Course Outcomes: **Upon completion of the course, students shall have ability to**		
C930.1	Understand the concepts of CAN and LIN protocols and compare them with other serial communication standards.	[U]
C930.2	Analyze the architecture and frame structures of CAN protocol used in automotive communication systems.	[AN]
C930.3	Analyze the CAN communication process including arbitration, frame types, error detection, and fault confinement techniques.	[AN]
C930.4	Understand satellite communication subsystems, modulation schemes, multiplexing, and multiple access techniques applicable to space-based networks.	[U]
C930.5	Apply CAN protocol concepts to design reliable in-vehicle communication systems, focusing on bit timing, transceiver interfacing, and node communication.	[U]

Course Contents:

INTRODUCTION TO CAN AND LIN PROTOCOL **15**

Introduction to the Controller Area Network (CAN) & LIN protocol, Overview of Reasons for the development of Controller Area Network (CAN) & LIN, Comparison of Controller Area Network (CAN) with other serial communication protocols, Controller Area Network (CAN) vehicle network Architecture, Features of Controller Area Network (CAN) protocol, Frame formats of Controller Area Network (CAN).

DATA INTEGRITY AND ARBITRATION IN CAN **15**

Satellite subsystems - Attitude and orbit control electronics - Telemetry and tracking Power subsystems - Communication subsystems - Satellite antennas - Reliability and redundancy- Frequency modulation techniques. Modulation and Multiplexing -Multiple access techniques – FDMA, TDMA, CDMA, SDMA, ALOHA and its types – Onboard processing- Satellite switched TDMA – Spread spectrum transmission and reception for satellite networks.

PHYSICAL AND DATA LINK LAYER CONCEPTS IN CAN COMMUNICATION **15**

Differential voltage concept in Controller Area Network (CAN), Controller Area Network (CAN) node interfacing levels, Controller Area Network (CAN) transceivers, Controller Area Network (CAN) physical layer: CAN nodes, CAN Bus voltage levels and node interfacing techniques,

CAN bit timings and baud rate settings, Controller Area Network (CAN) data link layer: CAN Bus arbitration, CAN Bus Fault Confinement.	
Total Periods:	**45**
Text Books:	
1	Forouzan, B. A. (2007). *Data Communications and Networking (4th ed.).* New York, NY: McGraw-Hill.
2	Pratt, T., Bostian, C. W., & Allnutt, J. (2003). *Satellite Communications (2nd ed.).* Hoboken, NJ: Wiley.
3	Matheus, K., & Königseder, T. (2015). *Automotive Ethernet: The Definitive Guide.* Cambridge, MA: Cambridge University Press.
Reference Books:	
1	Maral, G., & Bousquet, M. (2009). Satellite Communications Systems: Systems, Techniques and Technology (6th ed.). Chichester, UK: Wiley.
2	Di Natale, M., Zeng, H., Giusto, P., & Ghosal, A. (2012). Understanding and Using the Controller Area Network Communication Protocol. New York, NY: Springer.
3	Etschberger, K. (2001). Controller Area Network: Basics, Protocols, Chips and Applications. Munich, Germany: IXXAT Automation GmbH.
Web References:	
1	https://www.bosch-semiconductors.com/can/
2	https://www.lin-subbus.org/
3	https://www.vector.com/int/en/know-how/can/can-overview/
Online Resources:	
1	https://www.tutorialspoint.com/can-protocol
2	https://www.csselectronics.com/pages/can-bus-simple-intro-tutorial
3	https://kvaser.com/can-protocol-tutorial/

23EC931	SOFTWARE DEFINED NETWORKING	3/0/0/3
Nature of Course	: F (Theory)	
Course Objectives:		
1	To help students understand the principles of traditional networking, identify its limitations, and recognize the motivation for adopting Software Defined Networks (SDN).	
2	To guide students in analyzing the fundamental concepts and planar architecture of SDN.	
3	To provide insights into the flexibility and design of multilevel pipeline processing within SDN environments.	
4	To examine the interaction between the SDN controller and data plane, with emphasis on flow table matching and packet processing.	
5	To train students in configuring SDN switches, designing networks by managing flow entries, and interpreting packet behavior through practical tools.	
6	To help students understand the principles of traditional networking, identify its limitations, and recognize the motivation for adopting Software Defined Networks (SDN).	
Course Outcomes: **Upon completion of the course, students shall have ability to**		
C931.1	Understand the architecture and limitations of traditional networks and explain the motivation for transitioning to Software Defined Networking (SDN).	[U]
C931.2	Analyze the structure and functioning of SDN planes—Data, Control, and Application—and evaluate the role of OpenFlow and related standards.	[AN]
C931.3	Apply SDN principles to solve performance-related problems in areas such as routing and traffic engineering optimization.	[AP]
C931.4	Demonstrate the configuration and use of OpenFlow components including flow tables, meter tables, and group tables within SDN environments.	[AP]
C931.5	Analyze real-world SDN applications such as data center networking, WAN optimization, and virtualization by configuring flow entries and interpreting packet behavior.	[AN]

Course Contents:

INTRODUCTION TO TRADITIONAL NETWORKS AND SDN **15**

Traditional networks, Control Plane, Data Plane and Management Plane, Flow table, Limitations of traditional networks- Need for simplification, lowering operating costs, Single flow table, Flexibility issues, Proprietary protocols and Destination based forwarding, Forces. Software defined networks, SDN Planes-Data-plane, Control Plane, Application Plane, OpenFlow, Open Network Foundation, Protocol-Encryption, Northbound & Southbound API, Multi-level flow table and pipeline processing, Group table, Meter table-Meter bands, OpenFlow version-1.0,1.1,1.2,1.3

SDN MESSAGES AND TABLE MATCHING **15**

Messages-Controller-Switch, Packet-In, Packet-Out, Flow-Mod, Flow-Removed, Port-Status and Error Messages, Symmetric & Asynchronous messages Counters, OpenFlow Port Concepts & Configuration, Table matching in SDN, Network Automation using SDN Controllers and Integration with Network Virtualization Tools.

MININET EMULATOR, SDN APPLICATIONS AND USE-CASES **15**

Introduction to Mininet, Custom topologies of OpenFlow and Legacy Networks, Flow table

manipulation-Adding & Deleting Flow entries, Packet Dissection via Wireshark, SDN Controllers-Ryu, POX, Floodlight, SDN Applications, SDN Use Cases, SDN in the Data Center and WAN, SDN-Open Source and its Features.	
Total Periods:	**45**
Text Books:	
1	Nadeau, Thomas D., and Ken Gray. SDN: Software Defined Networks: an authoritative review of network programmability technologies. " O'Reilly Media, Inc.", 2013.
2	Chuck Black and Paul Goransson, “Software Defined Networks: A Comprehensive Approach”, Morgan Kaufman.
3	Coker, Oswald, and Siamak Azodolmolky. Software-defined Networking with OpenFlow: Deliver Innovative Business Solutions. Packt Publishing Ltd, 2017.
Reference Books:	
1	Goransson, Paul, Chuck Black, and Timothy Culver. Software Defined Networks: A Comprehensive Approach. 2nd ed., Morgan Kaufmann, 2016.
2	Hu, Fei. Network Innovation through OpenFlow and SDN: Principles and Design. CRC Press, 2014.
3	Blaise, Pascal, and Doug Marschke. SDN and OpenFlow for Beginners with Hands-on Labs. Leanpub, 2015.
Web References:	
1	https://opennetworking.org
2	http://mininet.org
3	https://www.openvswitch.org
Online Resources:	
1	https://nptel.ac.in/courses/106/105/106105195/
2	https://www.coursera.org/specializations/computer-communications
3	https://github.com/mininet/mininet

23EC932	SATELLITE COMMUNICATIONS AND GPS	3/0/0/3
Nature of Course	: F (Theory)	
Course Objectives:		
1	To understand the fundamental concepts of satellite communication.	
2	To analyse the principles and components of satellite launch systems	
3	To provide a detailed understanding of navigation - both inertial and by navigation satellites.	
4	To examine digital transmission techniques and multiple access methods	
5	To analyse typical challenges of satellite-based GPS systems.	
6	To analyse modern satellite applications	
Course Outcomes: **Upon completion of the course, students shall have ability to**		
C932.1	Understand the concepts of satellite orbits, launch vehicles, and satellite classifications.	[U]
C932.2	Analyze the design and functioning of various satellite subsystems and their role in overall system performance.	[AN]
C932.3	Analyze satellite-based navigation systems and services, including their architecture and operational principles.	[AN]
C932.4	Understand digital transmission techniques and evaluate the influence of key parameters on satellite link design.	[U]
C932.5	Apply satellite communication systems in real-world applications such as broadcasting, remote sensing, and navigation.	[AP]

Course Contents:

ORBITAL MECHANICS & LAUNCHERS **15**

Overview of satellite communication - Orbital mechanics - Equations of the orbit - Kepler's laws of planetary motion - Orbital elements - Look angle determination - Orbital perturbation and determination Launches and launch vehicles- Launch vehicle selection factors - Satellite positioning into geostationary orbit - Orbital effects in communication systems performance - Doppler shift -Range variations - Solar eclipse and sun transit outage.

DESIGN ELEMENTS OF COMMUNICATION SATELLITE & DIGITAL TRANSMISSION **15**

Satellite subsystems - Attitude and orbit control electronics - Telemetry and tracking Power subsystems - Communication subsystems - Satellite antennas - Reliability and redundancy- Frequency modulation techniques. Modulation and Multiplexing -Multiple access techniques – FDMA, TDMA, CDMA, SDMA, ALOHA and its types – Onboard processing- Satellite switched TDMA – Spread spectrum transmission and reception for satellite networks.

SATELLITE LINK DESIGN & DIRECT BROADCAST SATELLITE GPS **15**

Transmission theory – System noise temperature and G/T Ratio- Noise figure and noise temperature- Calculation of system noise temperature – G/T ratio for earth stations - Link budgets - Uplink and downlink budget calculations - Error control for digital satellite links. DBS Satellite Systems: DVB-S2X Standards -System Design for High-Throughput Applications, Antenna Considerations, Modulation Scheme Considerations, Error Coding Considerations, Remote Sensing Application, Navigation Satellite Systems GPS-Position Calculations and Accuracy, Navigation Messages, Receiver Design- IRNSS.

Total Periods:	**45**

Text Books:	
1	Maral, G., & Bousquet, M. (2009). Satellite Communications Systems: Systems, Techniques and Technology (6th ed.). Chichester, UK: Wiley.
2	Pratt, C.W. Boastian and Jeremy Allnutt “Satellite Communication”, 2018, 2nd edition, John Wiley and Sons, Bangalore, India.
3	G. Maral, M. Bousquet, Z. Sun, “Satellite Communications Systems: Systems, Techniques and Technology”, 2020 (6th Edition), John Willy and sons, New York.
Reference Books:	
1	D.Roddy, “Satellite Communications”, 2011, 4th edition (sixth reprint), Tata McGraw Hill, New York.
2	Anil K. Maini, Varsha Agrawal, “Satellite Communications”, 2018, Wiley India Pvt. Ltd, New Delhi, India
3	Hofmann-Wellenhof, B., Lichtenegger, H., & Wasle, E. (2008). Global Navigation Satellite Systems: Insights Into GPS, GLONASS, Galileo, Compass, and Others. New York, USA: Springer.
Web References:	
1	https://solarsystem.nasa.gov/basics/
2	https://www.itu.int/en/ITU-R/space/Pages/default.aspx
3	https://www.gps.gov/
Online Resources:	
1	https://nptel.ac.in/
2	https://ocw.mit.edu
3	https://www.esa.int/Education

23EC933	HIGH FREQUENCY COMMUNICATION SYSTEMS	3/0/0/3
Nature of Course	: F (Theory)	
Course Objectives:		
1	To understand the characteristics of millimeter wave propagation in various environments.	
2	To explore antenna arrays and beamforming techniques for mmWave communication.	
3	To study light propagation and loss mechanisms in optical fibers.	
4	To understand the design principles of fiber optic communication systems and networks.	
5	To examine the and applications of free-space optical communication.	
6	To identify hybrid optical communication techniques used in modern wireless and wired systems.	
Course Outcomes: **Upon completion of the course, students shall have ability to**		
C933.1	Understand millimeter wave propagation models in outdoor, indoor, and vehicular environments.	[U]
C933.2	Apply beamforming and direction-finding techniques in mmWave communication systems.	[AP]
C933.3	Analyze fiber optic transmission characteristics including dispersion and attenuation.	[AN]
C933.4	Apply system design considerations for fiber optic networks and multiplexing technologies.	[AP]
C933.5	Understand the working of free-space optical communication systems under various conditions.	[U]

Course Contents:

MILLIMETER WAVE PROPAGATION AND COMMUNICATION **15**

Radio Wave Propagation for mmWave, Large-Scale and small-scale Propagation Effects of mmwaves, Outdoor Channel Models, Indoor Channel Models, Vehicle-to-Vehicle Models, Spatial Characterization of Multipath and Beam Combining. Adaptive Antenna Arrays — Beam Steering and Beamforming, ESPRIT and MUSIC, Emerging Applications of mmWave Communications.

FIBER OPTIC COMMUNICATION **15**

Transmission Characteristics of Fibres: Attenuation, material absorption and scattering loss, bending loss, intra-modal and inter-modal dispersion in step and graded fibres, FOC System description and design considerations, Analog & Digital broadband transmission.

OPTICAL NETWORKS AND FREE-SPACE COMMUNICATION SYSTEMS **15**

Principles of WDM, DWDM, telecommunications & broadband application, wavelength-routed networks - SONET/SDH, MUX. Propagation of light in unguided media, LASER beam characteristics, atmospheric effects on optical signals, FSO transceiver design, Point-to-Point FSO systems, point-to-point with transponder nodes, Hybrid FSO and RF, FSO applications, LIDAR.

Total Periods:	**45**

Text Books:

1	Theodore S. Rappaport, Robert W. Heath, Robert C. Daniels, and James N.

	Murdock, “Millimeter Wave Wireless Communications”, Prentice Hall of India, 2021.
2	Gerd Keiser, “Fiber Optic Communications”, Springer, 1st Edition, 2021.
3	John M. Senior, “Optical Fiber Communication”, PHI/Pearson, 2020.
Reference Books:	
1	Stamatios V. Kartalopoulos, “Free Space Optical Networks for Ultra-Broad Band Services”, John Wiley & Sons, Inc., 3rd Edition, 2020.
2	Rajiv Ramaswami, Kumar Sivarajan and Galen Sasaki, “Optical Networks: A Practical Perspective”, Morgan Kaufman Publishers, 5th Edition, 2021.
3	Agrawal G, “Fiber optic Communication Systems”, John Wiley and Sons, 2019.
Web References:	
1	https://www.rohde-schwarz.com/uk/solutions/aerospace-and-defense/sea/naval-systems/communications-systems/hf-communications_255935.html
2	https://www.afcea.org/signal-media/high-frequency-communications-features-highs-and-lows
3	https://dst.gov.in/new-model-improving-high-frequency-radio-communications-crucial-during-natural-disasters
Online Resources:	
1	https://onlinecourses.nptel.ac.in/noc21_ee76/preview
2	https://www.coursera.org/specializations/optical-engineering
3	https://www.coursera.org/learn/foundations-of-advanced-wireless-communication

23EC934	SMART ANTENNAS	3/0/0/3
Nature of Course	: G (Theory Analytical)	
Course Objectives:		
1	To gain knowledge in smart antenna radiation properties	
2	To analyze various narrow band signal processing techniques.	
3	To analyze various algorithms in estimating solution converges to optimal solution	
4	To acquire knowledge in broad band signal processing in time domain and frequency domain	
5	To enable students to understand and analyze direction of arrival estimation techniques	
6	To explore the application of massive MIMO, flexible antennas and reconfigurable intelligent surfaces in advanced 5G and 6G wireless communication systems	
Course Outcomes: **Upon completion of the course, students shall have ability to**		
C934.1	Understand the fundamental antenna parameters and their influence on the performance of wireless communication systems.	[U]
C934.2	Analyze smart antenna technologies and design antenna systems for advanced and emerging wireless applications.	[AN]
C934.3	Analyze adaptive filtering algorithms used in beamforming and direction of arrival (DOA) estimation.	[AN]
C934.4	Design optimized beamforming strategies tailored for real-world wireless communication scenarios.	[AP]
C934.5	Compare conventional and advanced DOA estimation techniques to evaluate and enhance smart antenna performance.	[AN]

Course Contents:

INTRODUCTION TO SMART ANTENNAS **15**

Antenna gain, wavelength, Directivity, beamwidth, phased array antenna, power pattern, beam steering, degree of freedom, optimal antenna, adaptive antennas, smart antenna – key benefits of smart antenna technology, wide band smart antennas, Digital radio receiver techniques and software radio for smart antennas, Narrow Band Processing**:** Signal model conventional beamformer, null steering beamformer, optimal beam former. Flexible /wearable antennas, Reconfigurable antennas/ Reconfigurable Intelligent surfaces(6G applications), Massive MIMO 5G Antennas.

ADAPTIVE PROCESSING AND BROADBAND PROCESSING **15**

Sample matrix inversion algorithm, unconstrained LMS algorithm, Gradient Estimate, Recursive Least Mean Square (RLS) Algorithm, normalized LMS algorithm, Constrained LMS algorithm, Neural network Approach. Tapped delay line structure, Digital beam forming, Broad band processing using DFT method.

DIRECTION OF ARRIVAL ESTIMATION METHODS **15**

Spectral estimation methods, linear prediction method, Maximum entropy method, Maximum likelihood method, Eigen structure methods, Conventional DOA Estimation Methods, Conventional Beam forming Method, Capon's Minimum Variance Method, MUSIC Algorithm, ESPRIT Algorithm, Uniqueness of DOA Estimates.

Total Periods:	**45**

Text Books:

1	Lal Chand Godara, “Smart Antennas” 1st edition, CRC press, 2004.
2	Balanis, “Antenna Theory”, 4th edition, John Wiley and Sons, 2016.
3	R. S. Elliot, “Antenna Theory and Design”, revised edition, Wiley-IEEE Press, 2003.
4	Constantine A. Balanis & Panayiotis I. Ioannides, “Introduction to Smart Antennas”, Morgan & Claypool Publishers’ series-2007.
Reference Books:	
1	T.S Rappaport, “Smart Antennas Adaptive Arrays Algorithms and Wireless Position Location”, IEEE press 1998, PTR – PH publishers 1999.
2	Robert A.Monzingo, R.L.Haupt, T.W. Miller, “Introduction to Adaptive Arrays”,Yesdee Publishing Pvt.Ltd.,Reprint, 2012.
3	Frank B.Gross,”Smart Antennas for wireless Communications”, 1st edition, Mcgraw Hill, 2005.
Web References:	
1	https://www.researchgate.net/publication/220696124_Introduction_to_Smart_Antennas
2	https://www.ieeeaps.org/ieee-tap/for-readers/special-issues/special-issue-on-adaptive-antennas
3	https://www.mdpi.com/1424-8220/20/10/2753
Online Resources:	
1	https://ocw.mit.edu/courses/6-450-principles-of-digital-communications-i-fall-2006/resources/lecture-20-introduction-of-wireless-communication/
2	https://www.sciencedirect.com/topics/computer-science/massive-mimo
3	https://my.avnet.com/abacus/solutions/markets/communications/5g-solutions/understanding-massive-mimo-technology/

23EC935	RADAR SYSTEMS	3/0/0/3
Nature of Course	: F (Theory)	
Course Objectives:		
1	To understand the fundamental principles and operating parameters of radar systems.	
2	To explore the radar signal characteristics, performance metrics, and range-related concepts.	
3	To study the architecture and functions of radar subsystems and signal processing techniques.	
4	To analyze the behaviour and design of various amplifiers and switching components in radar TRMs.	
5	To examine different radar types, their applications, and methods for signal detection in noise.	
6	To familiarize with stealth technologies and radar cross section reduction techniques.	
Course Outcomes: **Upon completion of the course, students shall have ability to**		
C935.1	Outlines the principles of radar operation, Doppler effect, and key system parameters.	[U]
C935.2	Compute radar range parameters, resolution, and signal-to-noise characteristics.	[AP]
C935.3	Identify and describe the roles of radar subsystems including TRMs and amplifiers.	[U]
C935.4	Analyze radar signal processing methods such as clutter removal and spectral analysis.	[AN]
C935.5	Compare and differentiate radar types and describe techniques used in stealth technology.	[AN]

Course Contents:

RADAR FUNDAMENTALS AND SYSTEM PARAMETERS **15**

Radar principles and Doppler Effect, Radar frequency bands and block diagram, Radar range equation and cross section, Radar clutter and scattering types, transmit pulse width, PRF, baud length, range resolution, Coherent and incoherent integration, Detectability, SNR, bandwidth, transmit power, Pulse compression techniques.

RADAR SUBSYSTEMS AND SIGNAL CHAIN **15**

Transmit and Receive Module (TRM): block schematic, Timing and signal generation, gain and phase control, Design of amplifiers (power, low-noise, solid-state), TR switches, circulators, blanking switches, band-pass filters, Digital receiver and signal processing flow, Clutter removal, spectral cleaning, velocity and range-SNR computation, Spectral moment computation, auto/cross correlation, Imaging methods: Capon and Maximum Entropy.

RADAR TYPES AND STEALTH TECHNOLOGIES **15**

Overview of Radar Types: CW and Frequency Modulated Radar, MTI and Pulse Doppler Radar, Tracking Radar, Detection of Radar Signals in Noise, Airborne Radar, Space borne Radar, Synthesis aperture radar, SHAR and MST radar. Principles of stealth technology, Radar cross section (RCS) reduction techniques, RF absorbers and stealth countermeasures.

Total Periods:	**45**

Text Books:

1	Merrill Skolnik, “Introduction to Radar Systems”, 3rd Edition, McGraw-Hill, USA,

	2017.
2	Habibur Rahman, “Fundamental Principles of Radar”, CRC Press, Taylor & Francis Group, USA, 2019.
3	G.S.N. Raju, “Radar Engineering and Fundamentals of Navigational Aids”, DreamTech Press (Wiley distribution), New Delhi, India, 2019.
Reference Books:	
1	Merrill Skolnik, “Radar Handbook”, 3rd Edition, McGraw-Hill, USA, 2018.
2	A.K. Sen and A.B. Battacharya, “Radar Systems and Radar Aids to Navigation”, Khanna Publications, 2019.
3	Mark A Richards, James A Scheer and William A Holm Yesdee, “Principles of Modern Radar: Basic Principles”, Scitech Publishing Inc, 1st Edition, 2019.
Web References:	
1	https://www.noaa.gov/jetstream/doppler/how-radar-works
2	https://www.mistralsolutions.com/blog/a-comprehensive-guide-on-radar-systems/
3	https://www.tutorialspoint.com/radar_systems/radar_systems_overview.htm
Online Resources:	
1	https://www.ll.mit.edu/outreach/online-course-radar-introduction-radar-systems
2	https://onlinecourses.nptel.ac.in/noc23_ee133/preview
3	https://www.udemy.com/course/radarengineering/?couponCode=LEARNNOWPLANS

23EC936	WIRELESS BROADBAND NETWORKS	3/0/0/3

Nature of Course	: F (Theory)

Course Objectives:

1	To understand the technical, economic and service advantages of next generation networks.
2	To analyze the basic architecture of a next generation network (NGN) with reference.
3	To understand and compare different methods of delivering connection-oriented services over Next Generation Networks (NGN).
4	To explore the role of Multimedia Sub-System (IMS), network attachment and admission control functions.
5	To design and simulate routing mechanisms to meet desired Quality of Service (QoS) in NGNs.
6	To compare various NGN virtual network services (VPNs, VLANs, VPLS) and understand their real-world applications.

Course Outcomes:
Upon completion of the course, students shall have ability to

C936.1	Understand the latest technologies and wireless components involved in broadband communication systems.	[U]
C965.2	Compare and evaluate various techniques and technologies essential for the development of broadband and next-generation networks (NGNs).	[AN]
C936.3	Analyze recent advancements in wireless communication and assess the role of next-generation Internet protocols in broadband networks.	[AN]
C936.4	Design efficient routing mechanisms to ensure Quality of Service (QoS) in broadband communication systems.	[AP]
C936.5	Compare and analyze NGN-based virtual network services and apply them in the context of real-time broadband applications.	[AN]

Course Contents:

WIRELESS PROTOCOLS **15**

Review of cellular standards, migration and advancement of GSM architecture and CDMA architecture, WLAN – IEEE 802.11and HIPERLAN, Bluetooth, Mobile network layer-Fundamentals of Mobile IP, data forwarding procedures in mobile IP, IPv4, IPv6, IP mobility management, IP addressing - DHCP, Mobile transport layer-Traditional TCP, congestion control, slow start, fast recovery/fast retransmission, classical TCP improvements- Indirect TCP, snooping TCP, Mobile TCP.

MANAGING WIRELESS NETWORKS AND TESTING **15**

Managing Wireless Broadband Operations Management of LMDS Systems and their Application, Principles of operations Management, LMDS Versus Other Access technologies, Applications, Testing Wireless Satellite Networks and Fixed Wireless Broadband Networks.

LAYER-LEVEL FUNCTIONS **15**

Characteristics of wireless channels - downlink physical layer, uplink physical layer, MAC scheme - frame structure, resource structure, mapping, synchronization, reference signals and channel estimation, SC-FDMA, interference cancellation –Comp, Carrier aggregation, Services - multimedia broadcast/multicast, location-based services.

Total Periods:	**45**

Text Books:

1	Kaveh Pahlavan, “Principles of wireless networks”, Prentice-Hall of India, 2002.
2	John R Vacca, Wireless Broadband Networks Handbook, Tata McGraw Hill, 2001.
3	John R. Vacca, “Wireless Broadband Networks Handbook 3G, LMDS and Wireless Internet” Tata McGraw-Hill, 2001.
Reference Books:	
1	William Stallings, ISDN and Broadband ISDN with Frame and ATM, Pearson 6th edition, 2002.
2	Robert C Newman, Broadband Communications, Prentice Hall, 2001.
3	William Stallings, Data and Computer Communications, Pearson 10th edition, 2013.
Web References:	
1	https://www.mona.uwi.edu/physics/physics/courses/elng3050/wireless-broadband-networks
2	www.techplayon.com/lte-a-lte
Online Resources:	
1	https://nptel.ac.in/courses/106105183
2	https://www.drdo.gov.in/drdo/labs-establishment/technologies/electronics-radar-development-establishment-lrde

23EC937	ELECTROMAGNETIC INTERFERENCE AND COMPATIBILITY	3/0/0/3

Nature of Course	: F (Theory)

Course Objectives:

1	To Introduce the fundamental concepts of EMI and EMC, including their sources and effects on electronic systems.
2	To Understand coupling mechanisms and mitigation techniques to ensure system compatibility.
3	To Familiarize with international EMC standards and testing procedures.
4	To Develop skills to design electronic systems with EMC considerations.
5	To Introduce the fundamental concepts of EMI and EMC, including their sources and effects on electronic systems.
6	To Understand coupling mechanisms and mitigation techniques to ensure system compatibility.

Course Outcomes:
Upon completion of the course, students shall have ability to

C937.1	Understand the basic concepts of electromagnetic interference (EMI) and electromagnetic compatibility (EMC).	[U]
C937.2	Understand the causes of conducted and radiated EMI emissions and describe the susceptibility of systems.	[U]
C937.3	Identify different coupling mechanisms in EMI such as common mode, differential mode, and ground loop coupling.	[U]
C937.4	Apply shielding and grounding techniques for minimizing EMI effects in electronic systems.	[AP]
C937.5	Apply EMI testing procedures using standard test methods and basic EMI measurement instruments.	[AP]

Course Contents:

FUNDAMENTALS OF EMI/EMC **15**

Introduction to Electromagnetic Environment -Sources and Types of EMI: Natural sources-Natural sources- Review of Maxwell's equations for EMC- Plane wave concepts, radiation, and field behavior- Reflection, refraction, absorption related to EMC- Narrowband vs. broadband interference- Continuous wave vs. impulsive noise- Effects on communication and control systems -Impact of EMI and EMC Requirements **:**Reliability issues-Regulatory needs (overview)-Introduction to basic protection techniques

COUPLING MECHANISMS AND MITIGATION TECHNIQUES **15**

Coupling paths and mechanisms: Conducted coupling-Radiative coupling-Ground loop coupling-Coupling via supply networks-Common mode vs Differential mode coupling-Cable-related emissions and coupling phenomena-Transient sources and Automotive transients-**Categorization of EMI:** Emission, Susceptibility, Transients, Crosstalk-Shielding and Signal Integrity Issues-**EMI Mitigation Techniques :Shielding Techniques:** LF (Low Frequency) Magnetic shielding-Apertures and Shielding Effectiveness- Choice of Materials for H-field, E-field, and Free-space field shielding- Gasketing and sealing techniques-PCB level shielding methods. Grounding Techniques

STANDARDS, REGULATIONS, EMI TEST METHODS AND BIO-EFFECTS **15**

Standards and Regulations: Need for EMI/EMC Standards-International and National Standards- EMI Standardization for different domain- **EMI Test Methods and Instrumentation:** Fundamental considerations for EMI testing-Shielding Effectiveness Test methods-Open-field

and Semi-Anechoic Chamber Tests -TEM cells for Immunity Tests-Shielded chambers and anechoic chambers-Test equipment: EMI Test receivers- Spectrum analyzers- Wave simulators- Coupling networks (EMI coupling via cables)-Line Impedance Stabilization Networks (LISN)- Feedthrough capacitors, Current probes, and Antennas- Basics of Biological Effects of EM Waves	
Total Periods:	**45**
Text Books:	
1	William Duff G., & Donald White R. J, “Series on Electromagnetic Interference and Compatibility”, Vol. 5, EMI Prediction and Analysis Technique – 1972.
2	V.P. Kodali, "Engineering Electromagnetic Compatibility", 2nd Edition, Wiley India, 2001.
3	Henry W. Ott, "Electromagnetic Compatibility Engineering", 1st Edition, Wiley, 2009.
4	Clayton R. Paul, "Introduction to Electromagnetic Compatibility", 2nd Edition, Wiley, 2006.
5	William R. Paul, "Electromagnetics for Engineers: With Applications to EMC", Wiley, 2001.
6	Rajeev Bansal, "Engineering Electromagnetic Fields and Waves", CRC Press, 2012.
Reference Books:	
1	Clayton R. Paul, "Analysis of Multiconductor Transmission Lines", 2nd Edition, Wiley-Interscience, 2008.
2	Henry W. Ott, "Noise Reduction Techniques in Electronic Systems", 2nd Edition, Wiley, 1988.
3	David Morgan, "A Handbook for EMC Testing and Measurement", IET (Institution of Engineering and Technology), 1994.
4	Reinaldo Perez, "Electromagnetic Compatibility Handbook", 1st Edition, CRC Press, 1995.
5	Bernhard Keiser, "Principles of Electromagnetic Compatibility", 3rd Edition, Artech House, 1987.
Web References:	
1	https://apps.dtic.mil/sti/tr/pdf/ADA018980.pdf
2	https://nvlpubs.nist.gov/nistpubs/Legacy/TN/nbstechnicalnote1099.pdf
3	https://interpro.wisc.edu/courses/emc-and-best-practices/
4	https://www.ansys.com/en-in/applications/emi-emc
Online Resources:	
1	https://archive.nptel.ac.in/courses/108/106/108106138/
2	https://www.youtube.com/playlist?list=PLLpZ1DoEuR9u4iLi82VLiL8oicpA7-wMC
3	https://www.youtube.com/watch?v=k4P_phchoT8
4	https://www.youtube.com/watch?v=RoCPFEHmtjk

23EC938	NANOPHOTONICS	3/0/0/3
Nature of Course	: F (Theory)	
Course Objectives:		
1	To introduce the fundamentals of photonics and nanophotonics, focusing on how light behaves at the nanoscale.	
2	To understand the interaction of electromagnetic waves with nanostructures and study optical properties of materials at the nanoscale.	
3	To explain basic phenomena such as surface plasmons, LSPR, and quantum dots, and their significance in nanophotonics.	
4	To study nanophotonic structures like photonic crystals, metamaterials, and metasurfaces.	
5	To explore nanofabrication and characterization techniques, including electron beam lithography, nanoimprint lithography, NSOM, SEM, AFM, and TEM.	
6	To discuss plasmonic circuits, emerging applications, and research trends in nanophotonics, especially in communication, sensing, and imaging.	
Course Outcomes: **Upon completion of the course, students shall have ability to**		
C938.1	Understand the behavior of light in photonics and nanophotonics, including concepts like surface plasmons and quantum dots at the nanoscale.	[U]
C938.2	Understand the working principles of photonic crystals, metamaterials, and metasurfaces, and identify their practical applications.	[U]
C938.3	Understand various nanofabrication techniques and testing methods employed in nanophotonic device development.	[U]
C938.4	Model the propagation of surface plasmons and explain their role in the design of nanoscale photonic circuits.	[U]
C938.5	Apply nanophotonic concepts to real-world applications such as communication, sensing, and imaging, and relate them to emerging research trends.	[AP]

Course Contents:

FUNDAMENTALS OF NANOPHOTONICS **15**

Introduction to Photonics and Nanophotonics - Light confinement and guiding at nanoscale- Interaction of electromagnetic waves with nanostructures- Optical properties of materials at nanoscale- Surface Plasmons: Principles and basic phenomena- Localized Surface Plasmon Resonance (LSPR)- Quantum Dots: Emission and absorption properties.

NANOPHOTONIC STRUCTURES AND FABRICATION **15**

Photonic Crystals: Concepts, bandgap formation, and applications- Metamaterials and negative refractive index- Plasmonic nanostructures and metasurfaces- Nanofabrication techniques: Electron Beam Lithography, Nanoimprint Lithography, Self-Assembly- Near-field optical microscopy (NSOM)- Characterization methods: SEM, AFM, TEM for nanophotonic devices.

PLASMONICS AND EMERGING TRENDS IN NANOPHOTONICS **15**

Introduction to Plasmonics-Fundamentals of Surface Plasmon-Polaritons-Plasmonic Wave Equations-Design of Plasmonic Photonic Circuits-Contemporary Issues in Nanophotonics-Recent Advances and Research Trends-Applications of Nanophotonics in Communication, Sensing, and Imaging-Future directions and challenges.

Total Periods:	**45**

Text Books:

1	Paras N. Prasad, "Nanophotonics", Wiley-Interscience, 2004.
2	John D. Joannopoulos, Steven G. Johnson, Joshua N. Winn, and Robert D. Meade, Photonic Crystals: Molding the Flow of Light Publisher: Princeton University Press, 2008
3	Lukas Novotny & Bert Hecht Principles of Nano-Optics, Cambridge University Press, 2006.
Reference Books:	
1	Motoichi Ohtsu, Kiyoshi Kobayashi, Tadashi Kawazoe, Takashi Yatsui, Makoto Naruse, Principles of Nanophotonics, CRC Press, Taylor & Francis Group, 2008.
2	J. R. Lakowicz, Principle of Fluorescence Spectroscopy, third Edition, Kluwer Academic Publisher, Newyork, 2007
3	Stefan A. Maier *Plasmonics: Fundamentals and Applications,Springer, 2007*.
Web References:	
1	https://spie.org
2	https://www.optica.org
3	https://www.nano.gov
4	https://www.nature.com/nnano/
Online Resources:	
1	https://onlinecourses.nptel.ac.in/noc23_ee141/preview
2	https://www.researchgate.net/publication/371341869_Basic_Concepts_Advances_and_Emerging_Applications_of_Nanophotonics
3	https://www.sciencedirect.com/book/9781782424642/fundamentals-and-applications-of-nanophotonics
4	https://www.youtube.com/user/StanfordOnline

23EC939	SOI DEVICES MODELING AND SIMULATION	3/0/0/3
Nature of Course	: F (Theory)	
Course Objectives:		
1	Explain the fundamental principles and fabrication techniques of Silicon-On-Insulator (SOI) devices.	
2	Analyze the electrical characteristics and modeling approaches of SOI devices.	
3	Interpret simulation results and evaluate the application of SOI devices in advanced semiconductor technologies.	
Course Outcomes: **Upon completion of the course, students shall have ability to**		
C939.1	Understand the fundamental concepts, structure, and advantages of SOI devices compared to bulk CMOS technology.	[U]
C939.2	Understand various fabrication techniques and process flows used for partially and fully depleted SOI structures.	[U]
C939.3	Understand the electrical behavior of SOI MOSFETs and identify performance benefits and challenges such as short-channel and floating body effects.	[U]
C939.4	Apply suitable device modeling techniques to analyze parasitic effects and non-idealities in SOI devices.	[AP]
C939.5	Apply compact modeling approaches to evaluate circuit-level performance in SOI-based digital and analog circuit applications.	[AP]

Course Contents:

INTRODUCTION TO SOI DEVICES **15**

Basics of SOI Technology: Motivation, History, and Evolution - Comparison of SOI and Bulk CMOS - Types of SOI structures: PDSOI (Partially Depleted) vs. FDSOI (Fully Depleted) - Fabrication Techniques: SIMOX (Separation by IMplanted OXygen), Smart-Cut, BESOI, ELTRAN, and others Thermal and mechanical properties of SOI wafers- Interface states, Buried Oxide (BOX) characteristics.

ELECTRICAL CHARACTERISTICS AND DEVICE MODELING **15**

I-V and C-V Characteristics of SOI MOSFETs - Threshold voltage models for PDSOI and FDSOI - Short-channel effects (SCEs) in SOI devices: DIBL, Punch-through, GIDL - Floating body effects: Hysteresis, Kink Effect - Self-heating effects and Thermal modelling - Back-gate biasing and body-contact schemes - Analytical Models vs. Compact Models for SOI MOSFETs.

SIMULATION TECHNIQUES AND APPLICATIONS **15**

Basics of TCAD simulation for SOI devices - Setup of 2D/3D simulations: Device structure definition, meshing, and boundary conditions - Calibration of simulation models with experimental data - Simulation of short-channel effects and body effects - Introduction to circuit-level modeling with SOI devices (BSIM-SOI models) - Applications of SOI Technology in RF, High-Speed Digital, and Low-Power Circuits - Emerging trends: UTB (Ultra-Thin Body) SOI, FD-SOI in advanced nodes.

Total Periods:	**45**

Text Books:

1	J.-P. Colinge, "Silicon-on-Insulator Technology: Materials to VLSI", 3rd Edition, Springer, 2004
2	Yannis Tsividis, "Operation and Modeling of the MOS Transistor", 3rd Edition, Oxford University Press, 2011.
3	Y. Taur and T. H. Ning, "Fundamentals of Modern VLSI Devices", 2nd Edition,

	Cambridge University Press, 2013.
Reference Books:	
1	David Esseni, Pierpaolo Palestri, Luca Selmi, *"Nanoscale MOS Transistors: Semi-Classical Transport and Applications"*, Cambridge University Press, 2011.
2	H.-S. P. Wong, *"Technology and Design of SOI Devices"*, Wiley-IEEE Press, 2009.
Web References:	
1	https://ieeexplore.ieee.org/
2	https://www.sciencedirect.com/
3	https://www.synopsys.com/
Online Resources:	
1	https://link.springer.com/book/10.1007/978-1-4419-8898-1
2	https://www.cambridge.org/core/books/fundamentals-of-modern-vlsi-devices/
3	https://link.springer.com/book/10.1007/978-1-4615-1229-7

23EC940	MODELING OF MICROELECTRONIC DEVICES	3/0/0/3
Nature of Course	: F (Theory)	
Course Objectives:		
1	To introduce the fundamental concepts of semiconductor physics, including charge carriers, band theory, and junction behavior.	
2	To explain the characteristics and operation of metal-semiconductor and p–n junctions under various biasing conditions.	
3	To understand the working principles of MOS capacitors and MOSFETs, focusing on threshold voltage and I–V characteristics.	
4	To apply knowledge of device physics to analyze short-channel effects and scaling challenges in advanced MOSFET technologies.	
5	To provide an overview of numerical simulation techniques and the structure of TCAD tools used in device modeling.	
6	To develop the ability to use TCAD simulations for evaluating and optimizing semiconductor devices such as MOSFETs and SOI structures.	
Course Outcomes: **Upon completion of the course, students shall have ability to**		
C940.1	Understand basic semiconductor physics, including carrier transport mechanisms, energy band models, and p-n junction behavior.	[U]
C940.2	Understand the characteristics and operation of metal-semiconductor junctions, p-n junctions, and MOS structures under various biasing conditions.	[U]
C940.3	Interpret the behavior of MOS capacitors and MOSFETs, including threshold voltage, current-voltage characteristics, and their dependence on device parameters.	[U]
C940.4	Apply theoretical concepts to analyze short-channel effects and scaling issues in advanced MOSFET technologies.	[AP]
C940.5	Use TCAD tools to simulate and evaluate semiconductor devices such as MOSFETs and SOI structures for design optimization.	[AP]

Course Contents:

SEMICONDUCTOR ELECTRONICS AND METAL-SEMICONDUCTOR CONTACTS **15**

Semiconductor Electronics – Physics of Semiconductor Materials – Band Model of Solids – Thermal-Equilibrium Statistics – Carriers in Semiconductors – Drift Velocity, Mobility, and Scattering – Drift & Diffusion Current – Device: Hall-Effect Metal-Semiconductor Contacts and P-N Junctions – Metal-Semiconductor Junctions: Current-Voltage Characteristics, Surface Effects – The pn Junction: Step Junction, Linearly Graded Junction, Heterojunctions – Reverse-Biased p-n Junctions and Breakdown Mechanism – Generation and Recombination.

FIELD-EFFECT TRANSISTORS (MOSFETS) AND DEVICE MODELING **15**

Field-Effect Transistors (MOSFETs): MOS capacitor – oxide & interface charge – basic MOSFET I–V behaviour – threshold voltage & body-effect – complementary MOSFETs (CMOS) – velocity saturation – channel-length modulation – leakage currents – sub-threshold conduction Short-Channel Effects & Device Modeling: limitations of long-channel models – mobility degradation – hot-carrier effects – threshold-voltage adjustment techniques – gate-coupling effects – overview of FDSOI & multi-gate MOSFETs – key challenges to scaling.

NUMERICAL SIMULATION AND TCAD TOOLS **15**

Basic Concepts of Simulations – Grids – Device Simulation and Challenges – Importance of Semiconductor Device Simulators – Key Elements of Physical Device Simulation – Historical

Development of Physical Device Modeling. Introduction to TCAD Simulation Tool – Examples of TCAD Simulations: MOSFETs and SOI – Application of TCAD in Modern Semiconductor Design.	
Total Periods:	**45**
Text Books:	
1	S. M. Sze and M.K. Lee, "Semiconductor devices- Physics and Technology", 3rd Edition, John Wiley & Sons, 2012
2	Dragica Vasileska, Stephen M. Goodnick," Computational Electronics: Semiclassical and Quantum Device Modeling and Simulation" CRC Press,2017.
3	Shunri Oda, David Ferry," Silicon Nanoelectronics" CRC Press, 2006.
Reference Books:	
1	S. M. Sze and Kwok K. Ng, "Physics of Semiconductor Devices" John Wiley & Sons, 3rd Edition, 2002.
2	Ben G. Steetman and Sanjay Banerjee, "Solid State Electronic Devices", Prentice Hall, 6th Edition, 2005
3	Robert F. Pierret, "Semiconductor Device Fundamentals", Addison-Wesley Publishing, 1996.
Web References:	
1	https://eng.libretexts.org/Bookshelves/Materials_Science/Supplemental_Modules_(Materials_Science)/Semiconductors/Metal-Semiconductors_Contacts
2	https://web.iitd.ac.in/~bkrishna/MLL738/Lecture16.pdf
3	https://www.sciencedirect.com/topics/engineering/metal-oxide-semiconductor-field-effect-transistor
4	https://www.sciencedirect.com/science/article/abs/pii/S0168900215009614
Online Resources:	
1	https://archive.nptel.ac.in/courses/108/108/108108122/
2	https://onlinecourses.nptel.ac.in/noc25_ee75/preview
3	https://onlinecourses.nptel.ac.in/noc23_ee35/preview
4	https://archive.nptel.ac.in/courses/108/105/108105188/

23EC941	IC DESIGN AND TECHNOLOGY	3/0/0/3
Nature of Course	: F (Theory)	
Course Objectives:		
1	To introduce the fundamentals of analog VLSI and understand mixed-signal design challenges in CMOS technologies.	
2	To study MOS transistor modeling, small-signal parameters, and their impact on analog circuit design.	
3	To design and analyze basic CMOS analog building blocks like current mirrors, differential amplifiers, and operational amplifiers.	
4	To understand the working principles of frequency synthesizers, phase-locked loops, and nonlinear analog blocks such as comparators and charge-pumps.	
5	To explore data converter basics, analog layout considerations, and low-power circuit design techniques	
6	To introduce the fundamentals of analog VLSI and understand mixed-signal design challenges in CMOS technologies.	
Course Outcomes: **Upon completion of the course, students shall have ability to**		
C941.1	Understand fundamental principles of analog and mixed-signal circuit design in CMOS technologies.	[U]
C941.2	Understand MOS device models, frequency-dependent parameters, and their impact on analog circuit performance.	[U]
C941.3	Apply the logic to build the CMOS analog building blocks like current sources, voltage references, differential amplifiers, and operational amplifiers.	[AP]
C941.4	Understand the working and design considerations of frequency synthesizers, PLLs, and basic data converters.	[U]
C941.5	Apply layout techniques and testing strategies for robust mixed-signal circuit design.	[AP]

Course Contents:

FUNDAMENTALS OF ANALOG VLSI AND CMOS CIRCUIT BUILDING BLOCKS **15**

Introduction to Analog VLSI and mixed-signal issues in CMOS technologies – Basic MOS models and their extensions – SPICE models for MOSFETs – Frequency-dependent parasitic parameters in MOS devices – Basic MNOS/CMOS gain stages – Cascade and Cascode amplifier circuits – Frequency response of analog circuits – Stability issues in amplifier design – Noise sources in analog amplifiers and their impact.

ANALOG CMOS BLOCKS AND OPERATIONAL AMPLIFIERS **15**

CMOS analog functional blocks: Current sources and voltage references – Design of Differential Amplifiers – Design of Operational Amplifiers (OPAMPs) – Frequency synthesizers: Design basics – Phase-Locked Loops (PLLs): Components and applications – Non-linear analog blocks: Comparators, Charge-pump circuits, Multipliers – Basics of data converters (ADC/DAC fundamentals).

ADVANCED TOPICS: TESTING, LAYOUT, LOW POWER, AND RF INTRODUCTION **15**

Analog testing strategies for mixed-signal circuits – Layout issues unique to analog and mixed-signal ICs – Techniques for minimizing mismatch and parasitic effects in layout – Low voltage and low power design considerations – Challenges in scaling analog circuits for low power operation – Introduction to RF electronics and RF circuit behavior at high frequencies.

Total Periods:	**45**

Text Books:	
1	B. Razavi, Design of Analog CMOS Integrated Circuits, McGraw Hill 2001
2	P. E. Allen and D. R. Holberg, CMOS Analog Circuit Design, 2nd edition, Oxford University Press, 1997
3	B. Razavi, RF Microelectronics, Prentice-Hall, 1998.
Reference Books:	
1	R. Jacob Baker, CMOS Circuit Design, Layout, and Simulation, IEEE Press, 1997.
2	P. R. Gray and R. G. Meyer, Analysis and design of Analog Integrated circuits 4th Edition, Wiley Student Edition, 2001.
3	D. A. Johns and K. Martin, Analog Integrated Circuit Design, Wiley Student Edition, 2002
Web References:	
1	https://community.cadence.com/cadence_blogs_8/b/cic/posts/from-concept-to-reality-understanding-the-cadence-analog-ic-design-flow
2	https://www.cadence.com/en_US/home/training/all-courses/86404.html
3	https://www.allaboutcircuits.com/technical-articles/introduction-to-analog-ic-design/
4	https://onlinecourses.nptel.ac.in/noc23_ee142/preview
Online Resources:	
1	https://archive.nptel.ac.in/courses/117/106/117106030/
2	https://ocw.tudelft.nl/courses/analog-integrated-circuit-design/
3	https://www.analog.com/en/resources/design-tools-and-calculators.html
4	https://www.udemy.com/course/integrated-circuit-learn-differential-amplifier-on-multisim/?couponCode=ST7MT290425G3

23EC942	RF MICROELECTRONICS	3/0/0/3
Nature of Course	: F (Theory)	
Course Objectives:		
1	To introduce the fundamental principles and components used in RF circuit design, including RLC networks and integrated passive devices.	
2	To explain supply-independent biasing techniques such as Bandgap Voltage Reference and Constant-gm biasing used in RF IC design.	
3	To describe feedback systems and various types of noise in RF circuits, and analyze how noise affects circuit performance.	
4	To develop an understanding of high-frequency amplifier design, including LNAs and power amplifiers, focusing on design trade-offs and performance optimization.	
5	To provide knowledge of oscillator design, phase-locked loops (PLLs), and mixer architectures used in RF signal generation and processing.	
6	To analyze the complete RF transceiver system architecture and apply concepts through a practical case study or design example.	
Course Outcomes: **Upon completion of the course, students shall have ability to**		
C942.1	Understand the fundamentals of RF circuits, including passive components, biasing techniques, and noise behavior.	[U]
C942.2	Analyze and design biasing and feedback networks in RF systems with emphasis on noise performance.	[AN]
C942.3	Understand the design of Low Noise Amplifiers (LNA), focusing on bandwidth, impedance matching, linearity, and noise figure.	[U]
C942.4	Understand and compare different RF power amplifier classes (A, B, AB, C) with respect to efficiency, linearity, and performance trade-offs.	[U]
C942.5	Describe the principles of RF oscillators, mixers, and PLLs, and apply system-level concepts in transceiver design.	[AP]

Course Contents:

FUNDAMENTALS OF RF CIRCUIT DESIGN AND NOISE ANALYSIS **15**

Fundamental concepts in RF circuit design - Basic concepts in RF design - Passive RLC networks - Characteristics of passive IC components such as resistors, capacitors, and inductors - Techniques for supply-independent biasing including Bandgap Voltage Reference and Constant-gm Biasing - Feedback systems: Desensitivity, Stability, Errors, and Compensation methods - Noise in RF circuits: Thermal noise, Shot noise, Flicker noise, Popcorn noise - Analysis of noise behavior in devices and its impact on RF performance.

RF AMPLIFIERS, LOW NOISE AMPLIFIERS (LNA), AND POWER AMPLIFIERS **15**

High-frequency amplifier design and optimization - Bandwidth enhancement techniques using zeros - Shunt-series amplifiers - Tuned amplifiers and cascaded amplifier structures - Low Noise Amplifier (LNA) design principles: Power Match and Noise Match topologies - Linearity and large-signal performance in LNA designs - RF Power Amplifiers: Design and characteristics of Class A, Class B, Class C, and Class AB amplifiers - Trade-offs between linearity, efficiency, and power output - Real-world considerations in amplifier design for RF circuits.

OSCILLATORS, PLLS, MIXERS, AND TRANSCEIVER ARCHITECTURES **15**

Generation and control of RF signals - RF Oscillators: Tuned oscillators, Negative resistance oscillators, and Phase Noise analysis - Phase-Locked Loops (PLLs): Design of phase detectors, loop filters, and frequency synthesizers - Mixer fundamentals: Non-linear behaviour, linearization of mixers, and various mixer architectures - Transceiver architectures: Overview and analysis of modern RF transceiver design - Practical case study example illustrating the

design of a complete RF transceiver.	
Total Periods:	**45**
Text Books:	
1	Behzad Razavi, “RF Microelectronics”, 2nd Edition, Pearson Education, Saddle River, New Jersey, USA, 2012.
2	John W. Rogers, Calvin Plett, “Radio Frequency Integrated Circuit Design”, 2nd Edition, Norwood, Massachusetts, USA, 2010.
3	Charles E. Free, Colin S. Aitchison,” RF and Microwave Circuit Design” Wiley 2021.
Reference Books:	
1	B. Razavi, “Design of Analog CMOS Integrated Circuits”, Tata McGraw-Hill, 2002.
2	Sorin Voinigescu, “High Frequency Integrated Circuits”, Cambridge University Press.
3	Reinhold Ludwig, Gene Bogdanov, “RF Circuit Design Theory and Applications”, Pearson Education
Web References:	
1	https://www.allaboutcircuits.com/textbook/radio-frequency-analysis-design/rf-principles-components/passive-components-in-rf-circuits/
2	https://rahsoft.com/2021/05/10/different-types-of-noise-in-rf-devices/
3	https://www.analog.com/en/resources/technical-articles/choosing-a-lownoise-amplifier.html
4	https://www.rfwireless-world.com/tutorials/rf-measurements/rf-mixer-basics
Online Resources:	
1	https://archive.nptel.ac.in/courses/117/102/117102012/
2	https://archive.nptel.ac.in/courses/117/105/117105138/
3	https://onlinecourses.nptel.ac.in/noc24_ee75/
4	https://onlinecourses.nptel.ac.in/noc24_ee100/

23EC943	PHOTONIC INTEGRATED CIRCUITS	3/0/0/3
Nature of Course	: F (Theory)	
Course Objectives:		
1	Understand the development of optical communication systems and explain the key benefits of integrated optics in modern photonic circuits.	
2	Identify and analyze guided modes (TE/TM) in various planar waveguide structures	
3	Explain the structure and operation of passive and active photonic devices	
4	Describe the working principles of advanced integrated photonic components	
5	List and compare different material platforms used in PIC fabrication	
6	Explain and apply characterization techniques for integrated photonic devices	
Course Outcomes: **Upon completion of the course, students shall have ability to**		
C943.1	Describe the principles of guided wave optics and analyze guided modes in planar, strip, and channel waveguides.	[U]
C943.2	Distinguish between TE and TM modes in symmetric and asymmetric waveguide structures using Beam Propagation Method (BPM).	[U]
C943.3	Understand the operation of passive and active photonic integrated circuit components such as directional couplers, Mach–Zehnder interferometers, and modulators.	[U]
C943.4	Understand the functions of advanced photonic components including waveguide filters, arrayed waveguide gratings (AWGs), and plasmonic devices.	[U]
C943.5	Describe the material platforms, fabrication methods, and characterization techniques used in integrated photonic device development.	[U]

Course Contents:

FUNDAMENTALS OF GUIDED WAVE OPTICS **15**

Brief history of optical communication – Advantages of integrated-optics configurations – Guided TE and TM modes in symmetric and anti-symmetric planar waveguides – Step-index versus graded-index slab waveguides – Strip and channel waveguides – Beam Propagation Method (BPM) for field profiling.

PASSIVE & ACTIVE PIC DEVICES **15**

Directional couplers and their use as power splitters – Y-junctions and basic on-chip optical switches – Mach–Zehnder interferometer structures – Integrated modulators and on-chip filters – A/D converters in PICs – Mode splitters and arrayed waveguide gratings (AWGs) – Acousto-optic waveguide devices – Nanophotonic elements: metal/dielectric plasmonic waveguides, surface-plasmon modes, and waveguide polarizers.

MATERIALS, FABRICATION & CHARACTERIZATION **15**

Photonic-material platforms: glass, lithium niobate, silicon, III–V compound semiconductors – Fabrication techniques: lithography, thin-film deposition, etching for integrated waveguides – Device characterization: prism coupling, grating couplers, tapered-fiber coupling – Nonlinear effects in integrated waveguides (Kerr, two-photon absorption, etc.) – Applications of on-chip nonlinear optics

Total Periods:	**45**

Text Books:	
1	José Capmany and Daniel Pérez, Photonic Integrated Circuits, Oxford Univversity Press, 2020
2	C. R. Pollock and M Lipson, Integrated photonics, Kluwer Pub, 2003.
3	H Nishihara, M Haruna and T Suhara, Optical Integrated Circuits; McGraw-Hill Book Company, New York, 1989.
Reference Books:	
1	K. Okamota, Fundamentals of Optical waveguides, Academic Press, 2006.
2	A Ghatak and K Thyagarajan, Optical Electronics, Cambridge University Press, 1989.
3	T. Tamir, Guided wave opto-electronics, Springer Verilag, 1990
Web References:	
1	https://www.sciencedirect.com/topics/physics-and-astronomy/guided-wave-optics
2	https://ebin.pub/fundamentals-of-optical-waveguides.html
3	https://www.opticsjournal.net/Articles/OJ4bdca8c5d0ec8a24/FullText
4	https://www.researchgate.net/publication/266865363_Silicon-based_Photonic_Devices_Design_Fabrication_and_Characterization
Online Resources:	
1	https://nptel.ac.in/courses/115105537
2	https://www.sciencedirect.com/book/9780120884810/guided-wave-optical-components-and-devices
3	https://archive.nptel.ac.in/courses/117/108/117108142/
4	https://ocw.mit.edu/courses/3-46-photonic-materials-and-devices-spring-2006/

23EC944	RF AND MEMS	3/0/0/3

Nature of Course	: F (Theory)

Course Objectives:

1	To introduce RF MEMS fundamentals, mechanical modeling, materials, fabrication, and MEMS switch design.
2	To understand MEMS-based inductors, capacitors, filters, and phase shifters with modeling and fabrication aspects.
3	To study RF MEMS interconnects, transmission lines, antennas, and micromachining techniques for performance improvement.
4	To learn RF MEMS packaging methods, material selection, integration strategies, and reliability considerations.

Course Outcomes:
Upon completion of the course, students shall have ability to

C944.1	Identify various types of RF MEMS devices, fabrication methods and packaging standard.	[U]
C944.2	Design MEMS inductors and tunable capacitors using micromachine techniques.	[U]
C944.3	Model MEMS filters and Phase shifters for various types of RF applications.	[U]
C944.4	Design and analyze Micro machined Transmission lines and Antennas forwireless applications.	[AP]
C944.5	Analyze the reliability and design related issues in MEMS structures.	[AP]

Course Contents:

RF MEMS DEVICES, FABRICATION AND SWITCHING MECHANISMS **15**

RF MEMS for microwave applications – overview of MEMS technology and fabrication – mechanical modeling of MEMS devices – key MEMS materials and their fabrication techniques – MEMS switches: introduction and applications in RF systems – capacitive shunt and series switches with physical description, circuit models, and electromagnetic modeling – fabrication and packaging techniques for MEMS switches – design considerations for high-performance MEMS switching elements.

MEMS PASSIVE COMPONENTS, FILTERS, AND PHASE SHIFTERS **15**

MEMS passives and tunable components – MEMS inductors: micromachined inductor structures, impact of layout on performance, modeling and design challenges for on-chip planar inductors – MEMS capacitors: gap-tuning and area-tuning capacitor concepts – dielectric-tunable capacitors for frequency agile RF circuits – RF MEMS filters: mechanical filter modeling, micromachined resonator filters, surface-acoustic-wave (SAW) filters, and millimeter-wave micromachined filters – phase shifters: MEMS-based and ferroelectric implementations, device types and their limitations.

RF MEMS INTERCONNECTS, ANTENNAS, AND PACKAGING TECHNIQUES **15**

RF MEMS interconnects, antennas, and packaging – micromachined transmission lines: design, loss mechanisms, coplanar transmission line structures, and micromachined waveguide components – micromachined antennas: key design parameters, micromachining techniques to boost performance, and reconfigurable antenna approaches – integration and packaging of RF MEMS: the role of MEMS packages, various package types, module-level packaging strategies, choice of packaging materials, and reliability considerations in RF environments.

Total Periods:	**45**

Text Books:	
1	RF MEMS and their Applications, Vijay K. Varadan, Wiley-India,2011.
2	RF MEMS: Theory, Design, and Technology, Gabriel M. Rebeiz, Wiley, 2003.
Reference Books:	
1	An Introduction to Microelectromechanical Systems Engineering, NadimMaluf, Artech House,2000. .
2	RF MEMS Circuit Design for Wireless Communications, De LosSantosH J, Artech House, 1999
Web References:	
1	https://en.wikipedia.org/wiki/Radio-frequency_microelectromechanical_system
2	https://eepower.com/technical-articles/rf-mems-switches-types-working-principle-and-applications/
3	https://www.mems-exchange.org/MEMS/
Online Resources:	
1	https://www.researchgate.net/publication/347862762_RF_MEMS_Switch_Fabrication_and_Packaging
2	https://www.las.inpe.br/~jrsenna/AerospaceMEMS/Comunicacoes/jmme-rf.pdf
3	https://www.researchgate.net/publication/347862762_RF_MEMS_Switch_Fabrication_and_Packaging

23EC945	E-WASTE MANAGEMENT AND RECYCLING	3/0/0/3
Nature of Course	: F (Theory)	
Course Objectives:		
1	To understand the sources, generation, and characteristics of e-waste and plastic waste from industrial and commercial activities.	
2	To study national and international regulatory frameworks and policy initiatives on e-waste and plastic waste management.	
3	To explore sustainable design strategies, circular economy approaches, and eco-friendly practices for managing electronic and plastic waste.	
4	To analyze advanced technologies for recycling and recovery, including nanotechnology, biotechnological, and smart system applications.	
5	To introduce digital innovations like IoT, blockchain, and AI for efficient and transparent waste management systems.	
6	To familiarize with global case studies, industry collaborations, and future trends in sustainable waste management.	
Course Outcomes: **Upon completion of the course, students shall have ability to**		
C945.1	Understand the fundamental concepts of e-waste and plastic waste generation, characteristics, and classification.	[U]
C945.2	Explain the regulatory frameworks, international agreements, and national policies governing e-waste and plastic waste management.	[U]
C945.3	Apply circular economy principles, sustainable design strategies, and eco-labeling techniques to enhance waste management practices.	[AP]
C945.4	Understand the various advanced recycling and recovery technologies including nanotechnology and biotechnology for valorization of e-waste.	[U]
C945.5	Apply emerging technologies like IoT, AI, and Blockchain for developing smart and traceable waste management systems.	[AP]

Course Contents:

CONCEPTS, CHALLENGES AND REGULATORY FRAMEWORK **15**

Introduction to E-Waste and Plastic Waste: Sources, generation, and characteristics from industrial and commercial activities – Current trends and challenges in e-waste and plastic waste management – Waste management practices: onsite handling, storage, collection, and transfer– E-Waste Processing Alternatives: Mechanical, thermal, chemical, and biological routes – Overview of E-Waste Management Rules and Plastic Waste Management Rules (2016) and subsequent amendments – International regulations and agreements on e-waste management– Policy development and implementation strategies – Extended Producer Responsibility (EPR) programs and their global impact.

SUSTAINABLE DESIGN, CIRCULAR ECONOMY, AND ADVANCED RECYCLING TECHNOLOGIES **15**

Circular Economy Approaches for E-Waste Recycling – Sustainable design strategies for electronic products – Eco-design principles and Life Cycle Assessment (LCA) for electronics – Green procurement policies and eco-labeling initiatives – Innovative recycling processes for complex e-waste streams – Nanotechnology applications in e-waste recovery – Biotechnological solutions for e-waste valorization – Sustainable processing and recovery approaches for plastics and e-waste.

DIGITAL TRANSFORMATION, SMART SYSTEMS, AND FUTURE TRENDS **15**

Big Data Analytics and Artificial Intelligence applications in e-waste management – Blockchain technology for traceability and transparency in waste streams – Internet of Things (IoT) for smart

e-waste management systems – Case Studies: Successful global models in e-waste management – Industry collaborations and public-private partnerships for sustainable waste handling – Lessons learned from global practices – Future directions in advanced e-waste and plastic waste management	
Total Periods:	**45**
Text Books:	
1	Electronic Waste Management Rules 2016, Govt. of India, available online at CPCB website.
2	MSW Management Rules 2016, Govt. of India, available online at CPCB website
Reference Books:	
1	Ravi Agarwal, *"Waste of a Nation: Social Inequalities and Global Growth of Electronic Waste"*, Harvard University Press, 2018.
2	Kahhat, Ramzy, et al., *"E-Waste Management: From Waste to Resource"* (UNEP), Routledge, 2012.
3	Kumar, Sunil, et al., *"Electronic Waste Management: Approaches, Technology, and Trends"*, CRC Press, 2021.
4	Vishnupriya Singh, *"Plastic Waste and Its Management"*, AkiNik Publications, 2020.
5	R. Rajagopalan, *"Environmental Studies: From Crisis to Cure"*, 3rd Edition, Oxford University Press, 2016. *(Includes E-waste and Plastic Waste chapters)*
6	R. Widmer, H. Oswald-Krapf, D. Sinha-Khetriwal, M. Schnellmann, *"Global Perspectives on E-Waste"*, Environmental Impact Assessment Review, Elsevier, 2005.
Web References:	
1	https://wasteaid.org/wp-content/uploads/2022/06/Handbook-of-E-waste-management.pdf
2	https://greene.gov.in/wp-content/uploads/2018/01/E-waste-Vol-I-Inventory-Assessment-Manual.pdf
3	https://ewastemonitor.info/wp-content/uploads/2020/11/GEM_2020_def_july1_low.pdf
4	https://www.teriin.org/sites/default/files/files/White_paper_E-wasteEPR.pdf
Online Resources:	
1	https://onlinecourses.nptel.ac.in/noc21_ce03/preview
2	https://unccelearn.org/course/view.php?id=143&page=overview&lang=en
3	https://www.classcentral.com/course/ewaste-and-battery-recycling-technology-design-challenges-91569
4	https://nielit.gov.in/gangtok/content/paid-course-e-waste-management

23EC946	ARTIFICIAL INTELLIGENCE IN HEALTHCARE	3/0/0/3
Nature of Course	: F (Theory)	
Course Objectives:		
1	To learn the fundamental concepts, principles, and history of Artificial Intelligence.	
2	To Identify and summarize appropriate search algorithms for solving medical-related problems.	
3	To apply behavioral logic models to effectively represent and solve structured problems.	
4	To differentiate various AI problem-solving techniques and apply them to real-world scenarios.	
5	To analyze and evaluate the development and impact of AI applications in healthcare for societal benefits.	
6	To Design and develop simple intelligent systems for medical diagnosis using AI techniques.	
Course Outcomes: **Upon completion of the course, students shall have ability to**		
C946.1	Understand the fundamental concepts of Artificial Intelligence and its relevance in solving healthcare problems.	[U]
C946.2	Apply appropriate search algorithms and behavioral logic to model medical diagnostic problems.	[AP]
C946.3	Differentiate and apply AI problem-solving techniques to various healthcare scenarios.	[AP]
C946.4	Develop simple intelligent systems for medical diagnosis and healthcare decision support.	[AP]
C946.5	Analyze the development and impact of AI applications for solving real-world healthcare problems.	[AN]

Course Contents:

FOUNDATIONS OF ARTIFICIAL INTELLIGENCE AND PROBLEM-SOLVING TECHNIQUES **15**

Introduction to Artificial Intelligence, AI Approach to Healthcare Problem-Solving, Problem-Solving Methods in AI, Constraint-Based Problem Solving, Backtracking Search Algorithms, Applications of CSPs in Healthcare (Case Studies)

AI LEARNING METHODS AND KNOWLEDGE REPRESENTATION **15**

Learning methods in AI, Rule-based systems, Decision tree learning, Reinforcement learning, Application of AI in medical diagnosis. Knowledge representation techniques, First Order Predicate Logic (FOPL), Prolog programming, Unification, Forward and backward chaining, Resolution. Ontological engineering, Categories and objects, Events and mental objects, reasoning systems for categories, Default reasoning. Case studies on AI applications in healthcare.

INTELLIGENT AGENTS AND MEDICAL APPLICATIONS OF AI **15**

Architecture of intelligent agents, Agent communication, negotiation, and argumentation, Trust and reputation in multi-agent systems, Biomedical applications AI in blood pressure control, Speech recognition systems, Robotic control for surgical applications, Hardware, perception, planning, and moving image guidance in medical AI.

Total Periods:	**45**

Text Books:	
1	M. Tim Jones, “Artificial Intelligence: A Systems Approach ”, Jones and Bartlett Publishers, Inc.; First Edition, 2015 Reprint. ISBN-13: 978-9380298139.
2	Nils J. Nilsson, “The Quest for Artificial Intelligence”, Cambridge University Press, 2009. ISBN-13: 978- 0521122931
Reference Books:	
1	William F. Clocksin and, Christopher S. Mellish, “Programming in Prolog: Using the ISO Standard”, Fifth Edition, Springer, 2012 Reprint. ISBN 978-3-642-55481-0, DOI 10.1007/978- 3-642-5548.
2	Ian Millington, John Funge, “Artificial intelligence for Games”, Second edition, Morgan Kaufmann Publishers, CRC Press, 2012, ISBN: 978-0-12-374731-0.
3	S. Russell and P. Norvig, “Artificial Intelligence: A Modern Approach”, Prentice Hall, Third Edition, 2016. ISBN-1537600311, 97-81537600314.
4	David L. Poole and Alan K. Mackworth, “Artificial Intelligence: Foundations of Computational Agents”, Cambridge University Press, 2010. ISBN-13: 978-0521519007.
Web References:	
1	https://nptel.ac.in/courses/106102220
2	https://www.youtube.com/watch?v=t2G6u8GgUYE
Online Resources:	
1	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6616181/
2	https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-034-artificial-intelligence-fall-2020/

23EC947	AUTOMOTIVE SENSORS	3/0/0/3
Nature of Course	: F (Theory)	
Course Objectives:		
1	To introduce the basic principles and types of sensors used in automotive systems.	
2	To understand the operational characteristics and applications of various automotive sensors.	
3	To analyze the role of sensors in engine management, safety, and emission control systems.	
4	To develop diagnostic skills related to sensor faults and understand their impact on vehicle systems.	
5	To explore advancements in automotive sensor technologies for intelligent and autonomous vehicles.	
Course Outcomes: **Upon completion of the course, students shall have ability to**		
C947.1	Understand the fundamental principles, classifications, and characteristics of sensors used in automotive systems.	[U]
C947.2	Apply knowledge of sensor behavior to evaluate performance in engine management, emission control, and vehicle diagnostics.	[AP]
C947.3	Diagnose common sensor faults and analyze their impact on overall vehicle operation.	[AP]
C947.4	Apply sensor technologies in enhancing automotive safety, comfort, and driver-assist features.	[AP]
C947.5	Analyze recent advancements and emerging trends in automotive sensor technologies and their applications.	[AN]

Course Contents:

FUNDAMENTALS AND TYPES OF AUTOMOTIVE SENSORS **15**

Introduction to automotive sensors: purpose and applications, Sensor characteristics: sensitivity, accuracy, resolution, ranges. Classification: active/passive, contact/non-contact sensors. Overview of engine sensors: crankshaft, camshaft, knock, temperature, and pressure sensors (MAP, TPMS).AI Approach to Healthcare Problem-Solving, Problem-Solving Methods in AI, Constraint-Based Problem Solving, Backtracking Search Algorithms, Applications of CSPs in Healthcare (Case Studies)

SENSOR APPLICATIONS IN AUTOMOTIVE SYSTEMS **15**

Sensor applications in emission control (oxygen sensors, NOx sensors, PM sensors). Safety and comfort sensors: wheel speed, airbag impact, rain, light, parking sensors. Working of MAF, TPS, detonation sensors for fuel injection and ignition control. Introduction to OBD systems and sensor data fault diagnosis.

ADVANCED AUTOMOTIVE SENSOR TECHNOLOGIES **15**

Introduction to smart sensors and MEMS in automotive, Use of Lidar, Radar, and Ultrasonic sensors for ADAS and autonomous vehicles, Sensor fusion and predictive maintenance using sensor data, emerging trends: wireless sensors, IoT applications, and case studies on modern automotive sensors.

Total Periods:	**45**

Text Books:

1	Robert Bosch GmbH, “Automotive Electrics and Automotive Electronics”, 5th Edition, Springer Vieweg, 2014.

2	William Ribbens, “Understanding Automotive Electronics”, 8th Edition, Butterworth-Heinemann, 2017.
Reference Books:	
1	Tom Denton, “Automobile Electrical and Electronic Systems”, 5th Edition, Routledge, 2017.
2	Thomas Gillespie, “Fundamentals of Vehicle Dynamics”, SAE International, 1992.
Web References:	
1	https://archive.nptel.ac.in/courses/107/106/107106088/
2	https://archive.nptel.ac.in/courses/108/108/108108147/
3	https://www.youtube.com/watch?v=ECDVNAmcKFE
Online Resources:	
1	https://www.bosch-mobility.com/en/solutions/electrified-mobility/automotive-handbook/
2	https://www.allaboutcircuits.com/technical-articles/automotive-sensors-overview-and-trends/
3	https://www.ti.com/applications/automotive/sensor/products.html
4	https://ocw.mit.edu/courses/aeronautics-and-astronautics/16-405j-autonomous-vehicles-sensors-and-perception-spring-2020/

23EC948	DATA ACQUISITION AND HARDWARE INTERFACES	3/0/0/3
Nature of Course	: F (Theory)	
Course Objectives:		
1	To introduce students to the fundamental concepts of power supplies, amplifiers, and signal conditioning in automotive sensor systems.	
2	To familiarize students with the operation and characteristics of various automotive sensors and their signal processing techniques.	
3	To teach students the principles of signal conversion and communication standards such as RS232, S485, SPI, I2C, and CAN in automotive applications.	
4	To enable students to design and implement data acquisition systems for multi-channel automotive sensor networks.	
5	To equip students with the skills to interface automotive sensors with microcontrollers and develop real-time data transmission systems.	
6	To help students identify, diagnose, and rectify faults in automotive sensor systems, ensuring optimal performance and reliability in automotive applications.	
Course Outcomes: **Upon completion of the course, students shall have ability to**		
C948.1	Understand the basic principles of power supplies and signal conditioning circuits used in automotive sensor systems.	[U]
C948.2	Apply knowledge of data acquisition systems to implement sensor networks in automotive applications.	[AP]
C948.3	Apply serial communication protocols such as RS232, RS485, SPI, I²C, and CAN for efficient automotive data exchange.	[AP]
C948.4	Design and develop microcontroller-based interfaces for integrating sensors in automotive systems.	[AP]
C948.5	Analyze and troubleshoot sensor system faults to ensure real-time data transmission and accurate signal processing.	[AN]

Course Contents:

POWER SUPPLIES, FILTERS & SIGNAL CONDITIONING **15**

Overview of amplifiers: Instrumentation, isolation, chopper, low drift, lock-in, electrometer, and trans-impedance amplifiers, Introduction to modulation, filters, and voltage regulators: constant voltage, constant current, DC-DC converters, SMPS, Signal conditioning for resistive sensors, reactive variation sensors, and self-generating sensors; Error budget analysis.

SIGNAL CONVERSION, COMMUNICATION & DATA ACQUISITION **15**

Basic signal conversion methods: RS232, S485, and IEEE488 interface standards. Distributed vs. stand-alone data loggers, methods of frequency-to-code conversion, and indirect counting. Data acquisition systems: time-division and space-division-channelling, error protection in multi-channel systems, and data transmission techniques.

SERIAL COMMUNICATION & INTERFACING **15**

Serial data communication protocols: SPI, I2C, and CAN, Implementation examples on 8051-based microcontrollers, interfacing techniques for memory, LVDT, RPM meters, and digital thermometers.

Total Periods:	**45**

Text Books:

1	Automotive Technician Training, Tom Denton, Taylor and Francis, New York, 2015.

2	Automobile Electrical and Electronic Systems: Automotive Technology - Vehicle Maintenance and Repair, Tom Denton, Fourth Edition, Elsevier, New York, 2015.
3	Advanced Automotive Fault Diagnosis: Automotive Technology - Vehicle Maintenance and Repair, Tom Denton, Third Edition, Elsevier, New York, 2012.
Reference Books:	
1	Automotive Electrical and Electronic Systems, Tom Denton, Fourth Edition, Elsevier, New York, 2015.
2	Microcontroller Interfacing for Automotive Applications, William H. Collins, Wiley, 2018.
Web References:	
1	http://www.digimat.in/nptel/courses/video/108105088/L07
2	https://www.youtube.com/watch?v=WwQSfk6SSSo
Online Resources:	
1	https://nptel.ac.in/courses/108105088
2	https://www.ni.com/en-us/innovations/data-acquisition.html
3	https://www.microchip.com/design-centers/serial-communications
4	https://www.allaboutcircuits.com/technical-articles/introduction-to-data-acquisition-systems-daqs/

23EC949	FLEXIBLE AND WEARABLE SENSORS	3/0/0/3
Nature of Course	: F (Theory)	
Course Objectives:		
1	To understand the basics for the need of Wearable Devices	
2	To understand the operation of wearable devices and mobile sensing	
3	To learn how to use software programs to perform varying and complex tasks	
4	To expand upon the knowledge learned and apply it to solve real world problems	
5	To apply the wearable algorithms for developing wearable sensing	
Course Outcomes: **Upon completion of the course, students shall have ability to**		
C949.1	Understand the principles, categories, and social implications of wearable sensing technologies and their interaction modalities.	[U]
C949.2	Analyze various wearable wireless sensors, their placement, applications in health monitoring, and the role of sensor fusion in body-area networks.	[AN]
C949.3	Apply sensor integration techniques for real-time monitoring using smart fabrics, body-worn devices, and non-invasive textile sensors.	[AP]
C949.4	Evaluate the effectiveness of wearable sensing systems in tracking physiological and biomechanical parameters for health and fitness applications.	[AN]
C949.5	Analyze emerging trends in wearable and implantable sensor technologies through relevant case studies and real-world applications.	[AN]

Course Contents:

INTRODUCTION TO WEARABLE'S **15**

Fundamentals-wearable sensing technology, Social Aspects of Wear ability, Adoption of Innovation and Aesthetic Change, On-Body Interaction, Wearable Haptics, Categories of Wearable Haptic and Tactile Display, wearable Sensorimotor Enhancer, Wearable Bio and Chemical Sensors, Wearable Inertial Sensors and Their Applications, Cameras in wearable devices, Applications in safety and security, navigation.

WEARABLE WIRELESS SENSORS **15**

Overview of various wireless wearable sensors, Accelerometer, gyroscope, magnetometer, Smartphone orientation and heading detection, Health monitoring and fitness tracking, Wrist-worn wearable's, gesture and remote interaction, Sensor fusion in body-area networks, Application of Optical Heart Rate Monitoring, Measurement of Energy Expenditure by Body-worn Heat-flow Sensor, Biomechanical Sensing, Non-Invasive Sweat Monitoring by Textile Sensors, Smart Fabrics and Interactive Textile Platforms for Remote Monitoring, Physical Activity Body Sensor Technology.

FUTURE TRENDS OF WEARABLE SENSING ELEMENTS **15**

Channel Models for On-Body Communications, Establishment in Wireless Body Area Networks, Wearable Sensors for the Monitoring of Physical and Physiological Changes in Daily Life, Wearing Sensors Inside and Outside of the Human Body for the Early Detection of Diseases, Wearable and Non-Invasive Assistive Technologies, Wireless Tracking of Tongue Motion, Detection and Characterization of Food Intake by Wearable, future trends in wearable and implantable sensor technology :CASE STUDY: Wearable Event Device, Google Glass, Apple Watch.

	Total Periods:	**45**
Text Books:		
1	Edward Sazonov, Michael R. Neuman “Wearable Sensors: Fundamentals, Implementation and Applications”, 7th Edition, Academic Press/Elsevier, 2020.	
2	Woodrow Barfield “Fundamentals of Wearable Computers and Augmented Reality”, 2nd Edition, CRC Press, 2015.	
3	Annalisa Bonfiglo, Danilo De Rossi, “Wearable Monitoring Systems”, Springer Publishers, 4thEdition ,2014.	
Reference Books:		
1	Micheal, Katina “Wearable Technologies: Concepts, Methodologies, Tools, and Applications” 2nd Edition, IGI Global Engineering Publishers, 2018.	
2	Omesh Tickoo, Ravi Iyer “Making Sense of Sensors: End-to-End Algorithms and Infrastructure Design” ,2nd Edition, Apress Publishers, 2017.	
3	Kate Hartman, “Make: Wearable Electronics: Design, Prototype and wear your own interactive garments”, 3rd Edition, Maker Media, 2015.	
4	Guang Zhong Yang, “Body Sensor Networks”,4th Edition, Springer Publisher, 2016.	
Web References:		
1	https://www.sciencedirect.com/science/book/9780124186620	
2	https://pdfs.semanticscholar.org/.../4331017b99da992456c4a6e9b98bd2d54a41.pdf	
3	https://www.elsevier.com/books/wearable-sensors/sazonov/978-0-12-418662-0	
Online Resources:		
1	https://www.ncbi.nlm.nih.gov/books/NBK555956/	
2	https://ieeexplore.ieee.org/Xplore/home.jsp	
3	https://ocw.mit.edu/courses/media-arts-and-sciences/mas-963-wearable-computing-spring-2014/	
4	https://www.sciencedirect.com/book/9780124186620/wearable-sensors	

23EC950	MEDICAL SENSORS AND MEMS TECHNOLOGY	3/0/0/3

Nature of Course	: F (Theory)

Course Objectives:

1	Understand the fundamental concepts of medical sensors and their classifications.
2	Explain the working principles and applications of various medical sensors.
3	Apply modelling techniques to simulate the behaviour of piezoelectric MEMS devices and capacitive MEMS gyroscopes.
4	Assess the impact of packaging, testing, and calibration on MEMS device performance and reliability, and the selection of materials for MEMS applications
5	Find the tools to design and development of sensors for the medical applications
6	Analyse the integration of machine learning techniques in sensor design through case studies.

Course Outcomes:
Upon completion of the course, students shall have ability to

C950.1	Understand the classification, working principles, and interface design of medical sensors for measuring physiological parameters.	[U]
C950.2	Analyze the material properties, modeling techniques, and circuit interfaces used in MEMS and NEMS devices for biomedical applications.	[AN]
C950.3	Apply knowledge of MEMS fabrication, packaging, and calibration techniques in the design of smart sensor systems.	[AP]
C950.4	Utilize simulation tools like COMSOL, ANSYS, MATLAB, and Lumerical FDTD to model and design various biomedical sensors.	[AP]
C950.5	Evaluate sensor performance through simulations and apply machine learning techniques in sensor analysis using case studies.	[AN]

Course Contents:

MEDICAL SENSORS **15**

Introduction to medical sensors - Classification of Sensors: Sensors for Pressure Measurement- Sensors for Motion and Force Measurement - Sensors for Flow Measurement - Temperature Measurement - Sensors for speed, torque, vibration - smart sensors, design of interface system. Artificial intelligence in medical sensor technology.

MATERIAL FOR MEMS AND NEMS **15**

RF- MEMS- Modeling of Piezoelectric MEMS, Interface Circuits for Capacitive MEMS Gyroscope, Advanced MEMS Technologies for Tactile Sensing and Actuation, Packaging, test and calibration of MEMS, Dielectrics for Use in MEMS Applications, Piezoelectric Thin Films for MEMS Applications, future of smart structures and MEMS leading to NEMS.

SOFTWARE TOOLS **15**

Introduction to software tools: COMSOL Multiphysics, ANSYS, MATLAB, and Lumerical FDTD for sensor design and simulation - Modeling and design using MatLab - Design of sensors: pressure sensor, temperature sensor, motion sensor, MatLab - Machine learning tools in design and analysis, case study using medical sensors.

Total Periods:	**45**

Text Books:

1	VikasChoudhary, Krzysztof Iniewski, “MEMS: Fundamental Technology and Applications”, CRC Press, UK, 2017.
2	John G. Webster , “Medical Instrumentation: Application and Design”, Wiley, 2020.

3	Holly Moore" MATLAB for Engineers", Pearson Education Inc, 2022.
Reference Books:	
1	Octavian Adrian Postolache and Subhas Chandra Mukhopadhyay, "Sensors for Everyday Life: Healthcare Settings (Smart Sensors, Measurement and Instrumentation), CRC Press, 2017.
2	Albert Folch , Introduction to Bio MEMS, CRC Press, 2012.
3	Mohammad Ilyas, Imad Mahgoub, "Handbook of Sensor Networks Compact Wireless and Wired Sensing Systems" CRC Press, USA. 2005.
Web References:	
1	https://nptel.ac.in/courses/108105064
2	https://pmc.ncbi.nlm.nih.gov/articles/PMC4435109/
3	https://www.mathworks.com/solutions/medical-devices.html
Online Resources:	
1	https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-777j-design-and-fabrication-of-microelectromechanical-devices-spring-2007/
2	https://www.mathworks.com/solutions/medical-devices.html
3	https://nptel.ac.in/courses/108105064
4	https://www.comsol.com/stories/medical-device-design

23EC951	BIO SIGNAL PROCESSING	3/0/0/3
Nature of Course	: F (Theory)	
Course Objectives:		
1	To facilitate students to understand and apply various methods for analyzing biomedical signal characteristics.	
2	To make students able to analyse mathematical methods of biomedical signal and image processing.	
3	To make students able to design time domain filters for noise and artifact removal from biomedical signals.	
4	To make students able to design frequency domain filters for noise and artifact removal from biomedical signals.	
5	To motivate students to explore alternative techniques of analyzing biomedical signals in time and frequency domain.	
Course Outcomes: **Upon completion of the course, students shall have ability to**		
C951.1	Understand the fundamental concepts of biosignal and biomedical image processing, including key mathematical methods.	[U]
C951.2	Compare and contrast various noise analysis techniques used in biomedical signal and image processing.	[AN]
C951.3	Analyze the adaptability and integration of biomedical signal and image processing techniques into medical devices.	[AN]
C951.4	Apply signal representation and processing methods to EEG data for diverse biomedical applications.	[AP]
C951.5	Develop algorithms to detect physiological events from biomedical signals and images.	[AN]

Course Contents:

INTRODUCTION TO BIOMEDICAL SIGNALS **15**

Action Potential and Its Generation, Origin and Waveform Characteristics of Basic Biomedical Signals like: Electrocardiogram (ECG), Electroencephalogram (EEG), Electromyogram (EMG), Phonocardiogram (PCG), Electroneurogram (ENG), Event-Related Potentials (ERPS), Electrogastrogram (EGG), Objectives & Difficulties in Biomedical Signal Analysis, Computer-Aided Diagnosis.

REMOVAL OF NOISE AND ARTIFACTS FROM BIOMEDICAL SIGNAL **15**

Random and Structured Noise, Physiological Interference, Stationary and Nonstationary Processes, Advanced Denoising Methods: Wavelet denoising, Independent Component Analysis (ICA) and Principal Component Analysis (PCA) for artifact removal, EEG Artifact Removal - Eye blink, muscle artifacts, movement artifacts.

EEG SIGNAL PROCESSING AND EVENT DETECTION IN BIOMEDICAL SIGNAL **15**

EEG recording systems, Time and Frequency Domain Analysis of EEG, Feature Extraction from EEG, Seizures, Sleep stages, K-complexes, Machine learning-based detection (SVM, Random Forest, KNN), Future of EEG signal processing: AI and hybrid models.

Total Periods:	**45**

Text Books:

1	Rangayyan, R.M., 2015. Biomedical signal analysis (Vol. 33). John Wiley & Sons
2	Reddy, D.C., 2005. Biomedical signal processing: principles and techniques. McGraw-Hill

3	Saeid Sanei and J.A. Chambers, 2007, " EEG Signal Processing" Wiley
Reference Books:	
1	Tompkins, W.J., 1993. Biomedical digital signal processing. Editorial Prentice Hall
2	Sörnmo, L. and Laguna, P., 2005. Bioelectrical signal processing in cardiac and neurological applications (Vol. 8). Academic Press
3	Nilanjan Dey, Amira Ashour, Fuqian Shi, "Practical Guide for Biomedical Signal Analysis Using Machine Learning Techniques", Academic Press.
Web References:	
1	https://onlinecourses.nptel.ac.in/noc20_ee41/preview
2	https://www.coursera.org/courses?query=signal%20processing
3	https://www.mathworks.com/help/wavelet/gs/wavelet-applications-in biosignals.html
Online Resources:	
1	https://onlinecourses.nptel.ac.in/noc23_ee66/
2	https://www.coursera.org/learn/biomedical-signal-processing
3	https://www.mathworks.com/solutions/biomedical-devices.html
4	https://www.edx.org/course/biomedical-signal-processing

23EC952	EMERGING APPLICATIONS OF BIOSENSORS	3/0/0/3
Nature of Course	: F (Theory)	
Course Objectives:		
1	To learn the Fundamentals of biosensors.	
2	To acquaint the student with design and construction of biosensors.	
3	To expose recent advances in application of biosensors in health, environment, and agriculture.	
4	To differentiate types of transducers with their characteristics.	
5	To know the use of different nanomaterials in biosensors.	
Course Outcomes: **Upon completion of the course, students shall have ability to**		
C952.1	Understand the fundamental components of biosensors and the role of biomolecules in sensing mechanisms.	[U]
C952.2	Classify and differentiate various types of biosensors and transducers based on their operating principles and physiochemical characteristics.	[AN]
C952.3	Apply biosensing techniques in diverse domains including healthcare, environmental monitoring, and agriculture.	[AP]
C952.4	Analyze the integration of biosensors with nanomaterials and biomaterials for advanced sensing applications.	[AN]
C952.5	Examine the role of biosensors in signal amplification, detection mechanisms, and transducer fabrication.	[AN]

Course Contents:

INTRODUCTION TO BIOSENSORS **15**

Introduction to biosensor, General components of biosensor, Biomolecules in biosensors such as enzyme, DNA, antigen antibody, protein, Classification of biosensors based on principle: amperometric, potentiometric biosensors, optical, acoustic, piezoelectric, and calorimetric biosensors, scope of biosensors and its limitations.

APPLICATIONS OF BIOSENSORS IN HEALTH, ENVIRONMENT AND AGRICULTURE **15**

Biosensors and diabetes management, Micro fabricated biosensors and point-of-care diagnostics systems, Non-invasive biosensors in clinical analysis; Surface plasmon resonance and evanescent wave biosensors, Biosensor in cancer and HIV early diagnosis, Detection of crop diseases, pathogens in plants, Detection of soil nutrients, pesticide and its residual detection.

TRANSDUCERS AND NANOMATERIALS IN BIOSENSORS **15**

Types of Transducers; Fiber Optic, ECL, Surface Plasmon Resonance, Electro chemical; FET, Impedance, Piezoelectric; Cantileaver, Nano Materials in biosensors; Carbon based Nano Material, Metal oxide and nano particle, Quantumdots, Role of nano material in Signal Amplifications, Detection and Transducer Fabrication.

Total Periods:	**45**

Text Books:

1	Jeong-Yeol Yoon, Introduction to Biosensors, Springer-Verlag New York Ed., 2016
2	Mohammed Zourob,Recognition Receptors in Biosens; Publisher: Springer-Verlag New York Ed., 2010
3	B. D. Ratner, A. S. Hoffman, F. J. Schoen and J. E. Lemons, Biomaterials Science:

	An Introduction to Materials and Medicine, 3rd Edition, Academic Press, 2012.
4	Zhang X. ZuH. Wang J. Electrochemical Sensors, Biosensors and their Biomedical applications. Elsevier Science and Technology Books, 2018.
Reference Books:	
1	Zvi Liron,Novel Approaches in Biosensors and Rapid Diagnostic Assays; Publisher: Springer US Ed., 2001.
2	J. B. Park and J. D. Bronzino, Biomaterials: Principles and Applications, CRC Press, 2002.
3	Pierre R. C, and Loïc J.B,Biosensor Principles and Applications, CRC Press, 2019.
Web References:	
1	https://onlinecourses.nptel.ac.in/noc20_ph13/preview
2	https://nptel.ac.in/courses/102101054
3	https://www.youtube.com/watch?v=kQ6CY1qpGjY
Online Resources:	
1	https://nptel.ac.in/courses/102103044
2	https://www.futurelearn.com/courses/biosensors
3	https://ocw.mit.edu/courses/health-sciences-and-technology/hst-518j-cellular-and-molecular-immunology-fall-2004/related-resources/biosensors/
4	https://www.frontiersin.org/journals/bioengineering-and-biotechnology/sections/biosensors

23EC953	MICRO SYSTEMS & HYBRID TECHNOLOGY	3/0/0/3

Nature of Course	: F (Theory)

Course Objectives:

1	To introduce the fundamental concepts of microsystem design.
2	To provide comprehensive understanding of various micromachining techniques.
3	To acquaint the students with various materials and material properties for microsystem designing.
4	To expose to various scaling effects of Microsystems.
5	Enhancing the basics of thick film and hybrid technologies for sensor development.

Course Outcomes:
Upon completion of the course, students shall have ability to

C953.1	Understand the fundamental concepts and background of microsystems and their applications.	[U]
C953.2	Apply knowledge of micromachining techniques and material selection for microsystem design.	[AP]
C953.3	Determine the impact of scaling laws in the miniaturization of devices.	[AP]
C953.4	Analyze the use of thick film and hybrid technologies in the development of sensors.	[AN]
C953.5	Evaluate microsystem packaging techniques by analyzing performance parameters and integration challenges.	[AN]

Course Contents:

INTRODUCTION TO MICROSYSTEMS & MICROMACHINING TECHNOLOGIES **15**

Microsystems, Miniaturization, Benefits of Microsystems, Microsystems products, Evolution of Micro fabrication and Applications, Micro actuators, Design of Micro accelerometers, Overview of silicon processes techniques, Photolithography, Ion Implantation, Diffusion, Chemical Vapor Deposition, Physical vapor Deposition, Epitaxy, Etching, Bulk micromachining, Surface Micromachining, LIGA and other techniques.

MATERIALS & SCALING EFFECTS FOR MICROSYSTEMS **15**

Silicon compounds, Silicon Piezo resistors, Gallium Arsenide, Quartz, Piezoelectric materials, Polymers, Shape Memory Alloys, ferroelectric and rheological materials, Scaling, Scaling laws, Scaling in Geometry, Scaling in Rigid body dynamics, Scaling in Electromagnetic, Electrostatic, magnetic, optical and Thermal domains. Scaling in Fluid mechanics.

HYBRID TECHNOLOGY **15**

Thick-film and hybrid technology in sensor production. Basic materials, components, manufacturing Screen manufacturing, Screen printing, Parameters, Comparison: thick- vs. thin film technology Structure dimensions, Assembly and packaging Surface mount technology (SMT) Active and passive devices (SMD), Connection technologies, Packaging.

Total Periods:	**45**

Text Books:

1	G.K.Ananthasuresh, K J Vinoy, S Gopalakrishnan, KN Bhatt, V K Aatre," Micro and smart systems", 1 st ed., Wiley, New York, 2012.
2	Tai-Ran Hsu, “MEMS & Microsystem, Design and Manufacture”, 1 st ed., McGraw Hill India, New Delhi, 2017.

3	Wolfgang Menz, Jürgen Mohr, Oliver Paul, "Microsystem Technology", 2 nd ed., Wiley, New York, 2011.
Reference Books:	
1	Banks H.T. Smith R.C. and Wang Y.Smart, 'Material Structures – Modeling, Estimation and Control', 1st ed., John Wiley & Sons, NewYork, 2011.
2	Massood Tabib – Arar, 'Microactuators – Electrical, Magnetic Thermal, Optical, Mechanical, Chemical and Smart structures', 1 st ed., Kluwer Academic publishers, New York, 2014.
3	Marc Madau, Fundamentals of Microfabrication Science of Miniaturization, CRC Press, 2002.
Web References:	
1	https://benthamscience.com/public/journals/micro-and-nanosystems
2	https://www.ikts.fraunhofer.de/en/departments/electronics_microsystems_biomedicine/hybrid_micro_systems.html
3	https://archive.nptel.ac.in/courses/117/105/117105082/
Online Resources:	
1	https://nptel.ac.in/courses/117105082
2	https://ocw.mit.edu/courses/mechanical-engineering/2-77j-micro-nano-processing-technology-spring-2005/
3	https://www.elsevier.com/books/introduction-to-microsystem-packaging-technology/li/978-0-12-822584-6
4	https://www.researchgate.net/publication/264235034_Thick_Film_and_Hybrid_Technologies_for_Sensors

23EC954	MEDICAL ROBOTICS	3/0/0/3

Nature of Course	: F (Theory)

Course Objectives:

1	To impart basic understanding of robotics.
2	To provide knowledge on the application of robotics in the field of health care.
3	To overview the sensor requirements for localization and tracking in medical applications.
4	To understand the design aspects of medical robots.
5	To comprehend on the application of robotics in the field of healthcare.

Course Outcomes:
Upon completion of the course, students shall have ability to

C954.1	Understand the different types of robotic systems and their relevance to medical applications.	[U]
C954.2	Design kinematic models for specified robotic systems used in medical environments.	[AP]
C954.3	Analyze the design methodology, sensor integration, and technological choices in medical robot development.	[AN]
C954.4	Evaluate localization and tracking techniques using various sensors in medical robotic systems.	[AN]
C954.5	Summarize the role and impact of surgical robotics across different clinical procedures.	[U]

Course Contents:

INTRODUCTION TO ROBOTS **15**

Introduction to robots: Robots as mechanical devices, Classification of robotic manipulators, Robotic systems: Accuracy and repeatability, Wrists and end-effectors, Mathematical modelling of robots, Symbolic representation of robots, The configuration space, The state space, The workspace common kinematic arrangements of manipulators, Forward kinematics, Inverse kinematics, Velocity kinematics.

CONTROL MODES, LOCALIZATION AND TRACKING **15**

Medical robots: Robots for navigation, Movement replication, Robots for imaging, Rehabilitation and prosthetics, Describing spatial positioned orientation, Standardizing kinematic analysis, Computing joint angles, Quaternions, Robot kinematics, Three-joint robot, Six-joint robot, Position sensors requirements, Tracking, Mechanical linkages, Optical - Sound based, Electromagnetic - Impedance-based, In-bore MRI tracking.

DESIGN & APPLICATIONS OF ROBOTS IN MEDICAL CARE **15**

Assistive robots, types of assistive robots - case studies, Characterization of gestures to the design of robots, Design methodologies, Technological choices, Security, Application of medical robots: The learning curve of robot, Assisted laparoscopic surgery, Haptic feedback in robotic heart surgery, Robotic applications in neurosurgery, Miniature robotic guidance for spine surgery.

Total Periods:	**45**

Text Books:

1	AchimSchweikard, Floris Ernst, “Medical Robotics”, Springer, 2015.
2	Mark W. Spong, Seth Hutchinson, and M. Vidyasagar, “Robot Modeling and

	Control", Wiley Publishers, 2006.
3	VanjaBozovic, Medical Robotics, Springer, 2008.
Reference Books:	
1	Paula Gomes, "Medical robotics- Minimally Invasive surgery", Woodhead, 2012.
2	Jocelyne Troccaz, "Medical Robotics", Wiley, 2013.
3	Daniel Faust, "Medical Robots", Rosen Publishers, 2016.
Web References:	
1	https://r2surgical.com/blogs/news/how-much-is-a-new-surgical-robot
2	https://web.stanford.edu/class/me328/lectures/lecture1-intro.pdf
3	https://youtu.be/rYWJdZ5qg6M
Online Resources:	
1	https://web.stanford.edu/class/me328/
2	https://web.stanford.edu/~allisono/icra2016tutorial/ICRA2016TutorialIntro.pdf
3	https://www.utsouthwestern.edu/edumedia/edufiles/departments_centers/surgery/scmis/2.Robotic_System_Setup_Tutorial.pdf
4	https://www.classcentral.com/subject/surgical-robotics