B.Tech.

IN

ELECTRONICS & COMMUNICATION ENGINEERING

CURRICULUM

AND

SYLLABI

(Applicable from 2023 Admission onwards)

Department of Electronics & Communication Engineering
NATIONAL INSTITUTE OF TECHNOLOGY CALICUT
Kozhikode - 673601, KERALA, INDIA

The Program Educational Objectives (PEOs) of B.Tech. in Electronics & Communication Engineering

PEO1	Provide solid foundations in mathematical and engineering fundamentals required to solve engineering problems so that the graduates are able to apply their understanding of science and engineering principles creatively to solve problems arising in whatever career path they choose, particularly in the domain of electronics and communication engineering.
PEO2	Make the graduates responsible and sensitive to social, environmental and economic issues in their profession and inculcate the sense of ethics and professionalism in their approach.
PEO3	Make the graduates capable to work in groups, lead teams engaged in system design and communicate their ideas clearly and precisely, both orally and in writing.
PEO4	Engage in lifelong learning of electronics and communication engineering and allied fields and face the challenges of the dynamic world by improving their skills through continuous learning.

Programme Outcomes (POs) and Programme Specific Outcomes (PSOs) of B.Tech. in Electronics & Communication Engineering

PO1	**Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
PO2	**Problem analysis**: Identify, formulate, research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
PO3	**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.
PO4	**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.
PO5	**Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling to complex engineering activities with an understanding of the limitations.
PO6	**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.
PO7	**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.
PO8	**Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
PO9	**Individual and team work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
PO10	**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.
PO11	**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.

PO12	**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.
PSO1	**Product development**: Identify, formulate, and analyze real life problems that are solvable using techniques in electronics and communication engineering and develop innovative, reliable, economic and eco-friendly solutions to such problems.
PSO2	**Research aptitude**: Research on the current problems and advance the knowledge further in the fields of semiconductor devices and circuits, signal processing, telecommunication, data science etc. using scientific knowledge acquired from the programme and state of the art software and hardware tools available.

CURRICULUM

Total credits for completing B.Tech. in Electronics & Communication Engineering is 150.

COURSE CATEGORIES AND CREDIT REQUIREMENTS:

The structure of B.Tech. programmes shall have the following Course Categories:

Sl. No.	Course Category	Number of Courses	Minimum Credits
1.	Institute Core (IC)	8	22
2.	Program Core (PC) and Program Electives (PE)	28 or 29	82
3.	Open Electives (OE)	8	24
4.	Institute Electives (IE) (Entrepreneurship Innovation (EI) + Digital / Automation Technologies (DA) + Humanities, Social Science, Management (HM))	6	18
5.	Activity Credits (AC)	--	4

COURSE REQUIREMENTS

The effort to be put in by the student is indicated in the tables below as follows:
L: Lecture (One unit is of 50 minute duration)
T: Tutorial (One unit is of 50 minute duration)
P: Practical (One unit is of one hour duration)
O: Outside the class effort / self-study (One unit is of one hour duration)

1. INSTITUTE CORE (IC)

a) Mathematics

Sl. No.	Course Code	Course Title	L	T	P	O	Credits
1.	MA1001E	Mathematics I	3	1*	0	5	3
2.	MA1011E	Mathematics II	3	1*	0	5	3
3.	MA2004E	Mathematics III	3	1*	0	5	3
4.	MA2014E	Mathematics IV	3	1*	0	5	3
Total			**12**	**4***	**0**	**20**	**12**

*Optional for Students (can be replaced by self-study)

b) Basic Sciences

Sl. No.	Course Code	Course Title	L	T	P	O	Credits
1.	PH1003E	Electricity and Magnetism	3	0	0	6	3
2.	BT1001E	Biology for Engineers	3	0	0	6	3

Total	**6**	**0**	**0**	**12**	**6**

c) Professional Communication and Professional Ethics

Sl. No.	Course Code	Course Title	L	T	P	O	Credits
1.	MS1001E	Professional Communication	3	1*	0	5	3
2.	EC1001E	Professional Ethics	1	0	0	2	1
		Total	**4**	**0**	**0**	**8**	**4**

2A. PROGRAMME CORE (PC)

Sl. No.	Course Code	Course Title	L	T	P	O	Credits
1	EC1002E	Introduction to Programming	2	0	2	5	3
2	EC1003E	Introduction to Electronics	3	0	0	6	3
3	EC1004E	Digital Circuits and Systems	3	0	0	6	3
4	EC1091E	Practical Electronics	1	0	2	3	2
5	EC1011E	Electric Circuits and Networks	3	1*	0	5	3
6	EC1012E	Semiconductor Devices	3	0	2	7	4
7	EC1092E	Digital Systems Lab	1	0	2	3	2
8	EC2001E	Signals and Systems	3	1*	0	5	3
9	EC2002E	Analog Circuits	3	1*	0	5	3
10	EC2003E	Computer Architecture and Processors	3	0	0	6	3
11	EC2004E	Engineering Electromagnetics	3	1*	0	5	3
12	EC2091E	Analog Circuits Lab	0	0	3	3	2
13	EC2011E	Foundations of Machine Learning	2	0	2	5	3
14	EC2012E	Communication Engineering I	3	1*	0	5	3
15	EC2013E	VLSI Design	3	0	0	6	3
16	EC2092E	Microcontroller Lab	1	0	2	3	2
17	EC3001E	Control Systems	3	1*	0	5	3
18	EC3002E	Digital Signal Processing	3	0	2	7	4
19	EC3003E	Communication Engineering II	3	1*	0	5	3
20	EC3091E	Communication Engineering Lab	0	0	3	3	2
21	EC3011E	Wireless Communication	2	0	2	5	3
22	EC3012E	Computer Networks	2	0	2	5	3
23	EC3092E	Project	0	0	0	9	3
24	EC3093E	Technical Seminar	0	0	3	3	2
25	EC4001E	Summer Internship	0	0	0	6	2

Total	**50**	**7***	**27**	**126**	**70**

2B. LIST OF ELECTIVES

Following courses may be credited under the categories mentioned in the table below, in addition to the Programme Electives.

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Additional Categories			
								PE	EI	DA	HM
		Digital / Automation Technologies									
1	EC2021E	Object Oriented Programming	2	0	2	5	3	✓		✓	
2	EC2022E	Data Structures	2	0	2	5	3	✓		✓	
3	EC2023E	Foundations of Data Science	2	0	2	5	3	✓		✓	
4	EC2024E	Hardware Modelling using HDL	2	0	2	5	3	✓		✓	
5	EC2025E	Introduction to C Programming	2	0	2	5	3	✓		✓	
		Entrepreneurship Innovation (EI)									
1	IE2001E	Innovation and Entrepreneurship	3	0	0	6	3		✓		
		Devices, Circuits and Systems									
1	EC3021E	Analog MOS Integrated Circuits	3	0	0	6	3	✓			
2	EC3022E	Architecture of Advanced Processors	3	0	0	6	3	✓			
3	EC3023E	Computer Organization	3	0	0	6	3	✓			
4	EC3024E	Design for Electromagnetic Compatibility	3	0	0	6	3	✓			
5	EC3025E	Electronic Instrumentation	3	0	0	6	3	✓			
6	EC3026E	Embedded Systems	2	0	2	5	3	✓			
7	EC3027E	High Speed Digital Circuits	3	0	0	6	3	✓			
8	EC3028E	Internet of Things	3	0	0	6	3	✓			
9	EC3029E	Micro-Nano Fabrication	3	0	0	6	3	✓			
10	EC3030E	VLSI Testing	3	0	0	6	3	✓			
11	EC3031E	Nanoelectronics	3	0	0	6	3	✓			
12	EC3032E	RF Integrated Circuits	3	0	0	6	3	✓			
13	EC3033E	Semiconductor Device Modelling	3	0	0	6	3	✓			
14	EC3034E	Sensors: Design and Fabrication	3	0	0	6	3	✓			
15	EC3035E	Design with OP-AMPS and Analog ICs	3	0	0	6	3	✓			

16	EC3036E	Compound Semiconductor Devices	3	0	0	6	3	✓			
17	EC3037E	Power Semiconductor Devices	3	0	0	6	3	✓			
18	EC3038E	Flexible Electronics	3	0	0	6	3	✓			
19	EC3039E	RF Computational Lab	1	0	3	5	3	✓			
20	EC3040E	Compact Modeling for IC Design	3	0	0	6	3	✓			
21	EC3041E	THz Electronics	3	0	0	6	3	✓			
22	EC3042E	Semiconductor Memory Technologies	3	0	0	6	3	✓			
23	EC3043E	Spintronic Devices	3	0	0	6	3	✓			
24	EC3044E	IC Hardware Security	3	0	0	6	3	✓			
25	EC3045E	Fundamentals of Photovoltaic Devices	3	0	0	6	3	✓			
26	EC3046E	Data Conversion Systems	3	0	0	6	3	✓			
27	EC3047E	VLSI Architectures for DSP	3	0	0	6	3	✓			
Signal Processing and Machine Learning											
1	EC3050E	Array Signal Processing	3	0	0	6	3	✓			
2	EC3051E	Artificial Intelligence	3	0	0	6	3	✓			
3	EC3052E	Introduction to Autonomous Intelligent Systems	3	0	0	6	3	✓			
4	EC3053E	Bases and Frames for Signal Processing	3	0	0	6	3	✓			
5	EC3054E	Compressed Sampling: Principles and Algorithms	3	0	0	6	3	✓			
6	EC3055E	Computer Vision: Algorithms and Applications	3	0	0	6	3	✓			
7	EC3056E	Natural Language Processing	3	0	0	6	3	✓			
8	EC3057E	Deep Learning for Computer Vision	3	0	0	6	3	✓			
9	EC3058E	Digital Image Processing	3	0	0	6	3	✓			
10	EC3059E	Reinforcement Learning	3	0	0	6	3	✓			
11	EC3060E	Mathematics for Machine Learning	3	0	0	6	3	✓			
12	EC3061E	Multi-rate Systems	3	0	0	6	3	✓			
13	EC3062E	Neural Networks and Deep Learning	3	0	0	6	3	✓			
14	EC3063E	Big Data Analytics	2	0	2	5	3	✓			
15	EC3064E	Optimization Techniques	3	0	0	6	3	✓			
16	EC3065E	Pattern Classification	3	0	0	6	3	✓			

17	EC3066E	Signal Compression	3	0	0	6	3	✓				
18	EC3067E	Wavelet Theory	3	0	0	6	3	✓				
19	EC3068E	Speech Processing	3	0	0	6	3	✓				
20	EC3069E	Biomedical Signal Processing	3	0	0	6	3	✓				
21	EC3070E	Inverse Problems in Imaging	3	0	0	6	3	✓				
22	EC3071E	Predictive AI and Generative AI	3	0	0	6	3	✓				
23	EC3072E	AI for Text, Image and Video Processing	3	0	0	6	3	✓				
24	EC3073E	AI for National Urban Growth and Smart Cities	3	0	0	6	3	✓				
Communication and Networks												
1	EC3075E	Antenna Theory	3	0	0	6	3	✓				
2	EC3076E	Cryptography: Theory and Practice	3	0	0	6	3	✓				
3	EC3077E	5G-6G Technologies and Standards	3	0	0	6	3	✓				
4	EC3078E	Opto-electronic Communication Systems	3	0	0	6	3	✓				
5	EC3079E	CAD of High Frequency Circuits	3	0	0	6	3	✓				
6	EC3080E	Signal Estimation and Detection	3	0	0	6	3	✓				
7	EC3081E	Wireless Technologies and Systems	3	0	0	6	3	✓				
8	EC3082E	Coding Schemes for Modern Communication Systems	3	0	0	6	3	✓				
9	EC3083E	Network Information Theory and Coding	3	0	0	6	3	✓				
10	EC3084E	Wireless Networks	3	0	0	6	3	✓				
11	EC3085E	Topics in Multi-user Communications	3	0	0	6	3	✓				
12	EC3086E	Telecom Network Management	3	0	0	6	3	✓				
13	EC3087E	Radar Engineering	3	0	0	6	3	✓				
14	EC3088E	Multicarrier and MIMO Techniques	3	0	0	6	3	✓				

3. OPEN ELECTIVES (OE)

Courses offered by Other Departments/Schools/Centres or Approved Online Platforms, with a limit on the maximum number of courses from such platforms specified as per B Tech Ordinances and Regulations. In addition, PE courses offered by the Parent department shall be included in this category for students of the Parent department.

4. INSTITUTE ELECTIVES (IE)

In case of the Institute Electives, courses in the appropriate categories offered by other departments/schools/centres also can be credited instead of the courses offered by the Department of Electronics & Communication Engineering, subject to the approval from the Course Faculty and Faculty Advisor.

Entrepreneurship / Innovation Basket (EI): Courses proposed by the Departments/Schools/Centres and approved by Institute Innovation Council. Total credits required is 3.

Digital Automation Technologies (DA): Courses related to programming / automation tools & techniques / Industry 4.0. Total credits required is 6.

Humanities, Social Science, Management (HM): Courses such as Indian and Foreign languages, Economics, Engineering Management, Financial Management and Design Thinking. Total credits required is 9.

5. ACTIVITY CREDITS (AC)

A minimum of 80 Activity Points are to be acquired for obtaining the 4 Activity Credits required in the curriculum.

Activity points acquired should be a minimum of 20 at the end of S4.
Activity points acquired should be a minimum of 40 at the end of S6.

PROGRAMME STRUCTURE

Semester I

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1	MA1001E	Mathematics I	3	1*	0	5	3	IC
2	BT1001E	Biology for Engineers	3	0	0	6	3	IC
3	EC1001E	Professional Ethics	1	0	0	2	1	IC
4	EC1002E	Introduction to Programming	2	0	2	5	3	PC
5	EC1003E	Introduction to Electronics	3	0	0	6	3	PC
6	EC1004E	Digital Circuits & Systems	3	0	0	6	3	PC
7	EC1091E	Practical Electronics	1	0	2	3	2	PC
		Total	**16**	**1***	**4**	**33**	**18**	**--**

Semester II

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1	MA1011E	Mathematics II	3	1*	0	5	3	IC
2	PH1003E	Electricity and Magnetism	3	0	0	6	3	IC
3	MS1001E	Professional Communication	3	1*	0	5	3	IC
4	EC1011E	Electric Circuits & Networks	3	1*	0	5	3	PC
5	EC1012E	Semiconductor Devices	3	0	2	7	4	PC
6	EC1092E	Digital Systems Lab	1	0	2	3	2	PC
		Total	**16**	**3***	**4**	**32**	**18**	**--**

Semester III

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1	MA2004E	Mathematics III	3	1*	0	5	3	IC
2	EC2001E	Signals & Systems	3	1*	0	5	3	PC
3	EC2002E	Analog Circuits	3	1*	0	5	3	PC
4	EC2003E	Computer Architecture & Processors	3	0	0	6	3	PC
5	EC2004E	Engineering Electromagnetics	3	1*	0	5	3	PC
6	EC2091E	Analog Circuits Lab	0	0	3	3	2	PC
7		DA Elective - 1	2	0	2	5	3	DA
		Total	**17**	**4***	**5**	**34**	**20**	**--**

*Optional for Students

Semester IV

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	MA2014E	Mathematics IV	3	1*	0	5	3	IC
2	EC2011E	Foundations of Machine Learning	2	0	2	5	3	PC
3	EC2012E	Communication Engineering I	3	1*	0	5	3	PC
4	EC2013E	VLSI Design	3	0	0	6	3	PC
5	EC2092E	Microcontroller Lab	1	0	2	3	2	PC
6		Entrepreneurship / Innovation Elective	3	0	0	6	3	EI
7		DA Elective - 2	2	0	2	5	3	DA
8		Minor Course - 1					3	MC
		Total (Excluding the Minor Courses)	**17**	**2***	**6**	**35**	**20**	**--**

Activity Points acquired should be a minimum of 20 at the end of fourth semester.

Semester V

Sl. No	Course Code	Course Title	L	T	P	O	Credits	Category
1	EC3001E	Control Systems	3	1*	0	5	3	PC
2	EC3002E	Digital Signal Processing	3	0	2	7	4	PC
3	EC3003E	Communication Engineering II	3	1*	0	5	3	PC
4	EC3091E	Communication Engineering Lab	0	0	3	3	2	PC
5		HM Elective (HM-1)	3	0	0	6	3	HM
6		Open Elective -1	3	0	0	6	3	OE
7		Open Elective -2	3	0	0	6	3	OE
8		Minor Course - 2					3	MC
		Total (Excluding the Minor Courses)	**18**	**2***	**5**	**38**	**21**	**--**

Semester VI

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1	EC3011E	Wireless Communication	2	0	2	5	3	PC
2	EC3012E	Computer Networks	2	0	2	5	3	PC
3	EC3092E	Project	0	0	0	9	3	PC
4	EC3093E	Technical Seminar	0	0	3	3	2	PC
5		Open Elective - 3	3	0	0	6	3	OE
6		Open Elective - 4	3	0	0	6	3	OE
7		HM Elective-2	3	0	0	6	3	HM
8		Minor Course - 3					3	MC
		Total (Excluding the Minor Courses)	**13**	**0**	**7**	**40**	**20**	**--**

Activity Points acquired should be a minimum of 40 at the end of sixth semester.

Semester VII

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1	EC4001E	Summer Internship	0	0	0	6	2	PC
2		Program Elective-1	3	0	0	6	3	PE
3	EC4091E	Project / Internship/ Program Elective-2	0/0/3	0/0/0	0/0/0	9/9/6	3	PE
4		HM Elective-3	3	0	0	6	3	HM
5		Open Elective - 5	3	0	0	6	3	OE
6		Open Elective - 6	3	0	0	6	3	OE
7		Open Elective - 7	3	0	0	6	3	OE
8		Minor Course - 4					3	MC
Total (Excluding the Minor Courses)			**15/ 15/ 18**	0/0/0	**0/0 /0**	**45/45/42**	**20**	**--**

Semester VIII

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1	EC4092E	Project / Internship Program/ Program Elective - 3 & Program Elective - 4	0/0/ 6	0/0/0	0/ 0/0	18//18/ 12	6	PE
2		Open Elective - 8	3	0	0	6	3	OE
3	EC4099E	Activity Credits (minimum of 80 points)				12	4	AC
Total			**3/3/ 9**	**0/0/ 0**	**0/ 0/0**	**36/36/3 0**	**13**	**--**

Detailed Syllabus

(2023 Admission onwards)

MA1001E MATHEMATICS I

L	T	P	O	C
3	1*	0	5	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Formulate some engineering problems as ODEs and hence solve such problems.
CO2 Solve linear ODEs with constant coefficients.
CO3: Find the limits, check for continuity and differentiability of real valued functions of two variables. CO4: Test for the convergence of sequences and series.
CO5: Find the Fourier series representing periodic functions.

Existence and uniqueness of solution of first order ODE, Methods of solutions of first order ODE, Linear ODE, Orthogonal Trajectories, Linear homogeneous second order ODEs with constant coefficients, Fundamental system of solutions, Existence and uniqueness of solutions, Wronskian, Method of undetermined coefficients, Solution by variation of parameters, Euler-Cauchy equations, Applications of first and second order ODEs, System of linear ODEs with constant coefficients.

Function of several variables: Limit, Continuity, Partial derivatives, Partial differentiation of composite functions, Directional derivatives, Gradient, Local maxima and local minima of functions of two variables, Critical point, Saddle point, Taylor's formula for two variables, Hessian, Second derivative test, Method of Lagrange multipliers, Parameterised curves in space, Arc length, Tangent and normal vectors, Curvature and torsion.

Sequences, Cauchy sequence, Convergence of sequences, Series, Convergence of series, Tests for convergence, Absolute convergence, Sequence of functions, Power series, Radius of convergence, Taylor series, Periodic functions and Fourier series expansions, Half-range expansions, Fourier integral, Fourier transforms and their properties.

References:

1. H. Anton, I. Bivens and S. Davis, *Calculus*, 10th Edn., New York: John Wiley & Sons, 2015.
2. G. B. Thomas, M.D. Weirand J. Hass, Thomas' *Calculus*, 12th Edn., New Delhi, India:Pearson Education, 2015.
3. E. Kreyszig, *Advanced Engineering Mathematics*, 10th Edn., New York: John Wiley & Sons, 2015.
4. Apostol, *Calculus* Vol 1, 1st Edn., New Delhi: Wiley, 2014.

BT1001E BIOLOGY FOR ENGINEERS

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Explain the evolutionary basis of life and the structure-function relationship of biomolecules.
CO2: Describe the characteristics of cellular composition, communication, and principles of genetics.
CO3: Evaluate and apply biological principles to solve real-world problems related to food, agriculture, and environmental sciences
CO4: Apply advanced engineering techniques and tools to create medical devices, diagnostics, and therapies.

Exploring Biology
Origin of life, Darwinian evolution, Historical perspectives – Structure and function of biomolecules: Carbohydrates (Mono-, Di-, and Poly- Saccharides), Lipids, Proteins (Amino acids, Peptides), and Nucleic acids (DNA & RNA) - Central dogma of molecular biology and gene regulation.

Cell Biology & Genetics
Cell structure and function: Prokaryotic & Eukaryotic cells – Bioenergetics - Cell communication: Signal transduction - Cell division: Cell cycle, Binary fission, Mitosis & Meiosis - Genetics & inheritance: Mendelian genetics, Chromosomal aberrations.

Human Organs & Bio-design
Brain: Nervous system, Brain-computer interfaces, EEG, Engineering solutions for neurological disorders – Eye: Vision physiology, Bionic eye – Heart: Cardiac function, ECG, stents and pacemakers – Lungs: Physiology, ventilators & spirometry, heart-lung machine – Stem cells and regenerative medicine.

Global Challenges in Medicine, Agriculture, and Environment
Human diseases, Disorders & drugs, Biosensors, Biomedical diagnostics, Vaccines & antibiotics - Genetic modification of crops, Precision farming and sustainable agriculture - Biodegradation and bioremediation of pollutants, Biofuels - Recent advances in biology.

References:

1. Reece, J. B., Urry, L. A., Cain, M. L., Wasserman, S. A., Minorsky, P. V., & Jackson, R. B. *Campbell biology* (Vol. 9). Boston: Pearson, 2014
2. S ThyagaRajan, N Selvamurugan, M P Rajesh, R A Nazeer, Rechard W Thilagaraj, S Barathi, M K Jaganathan, *Biology for Engineers*-McGraw Hill Education, 2013
3. William S. Klug, Charlotte A. Spencer, Michael A. Palladino and Darrell Killian, *Concepts of Genetics*, 12th Global Edn Michael R. Cummings,, 2019.
4. L Nelson, D., & Michael M, C , Lehninger. *Principles of Biochemistry*, 8th Edn. 2021.
5. Fox, S. I. *Human physiology*. 13th Edn. New York, NY: McGraw--Hill, 752, 57, 2011.
6. Webb, A. G. *Principles of biomedical instrumentation*. Cambridge University Press, 2018.
7. Johnson, A. T. *Biology for engineers*. CRC Press, 2011.

EC1001E PROFESSIONAL ETHICS

L	T	P	O	C
1	0	0	2	1

Total Lecture Sessions: 13

Course Outcomes:

CO1: Develop a clear understanding of human values and use it as the basis for all activities.
CO2: Understand and follow the ethical aspects of engineering profession.
CO3: Align with the Code of Ethics prescribed by IEEE in all professional activities.
CO4: Assimilate the elements of Academic Integrity and Honour Codes, and adopt them in all relevant activities.

Human Values
Morals, values and ethics, Integrity, Work ethic, Service learning, Civic virtue, Sharing, Honesty, Courage,Valuing time, Cooperation, Commitment, Empathy, Self-confidence, Character.

Ethics in Professional Practice
Ethics in professional context, Ethical basis of engineering activities, Ethical responsibilities to consumers and customers, Safety and risk, Ethics in management of intellectual property, Environmental matters and sustainability.

Code of Ethics and Academic Integrity
An overview about IEEE code of ethics, Integrity, responsible behavior, ethical conduct, Treating others fairly and respectfully, avoiding harassment, discrimination and injuries to others, Helping others to keep ethics in their life.
Elements of Academic Integrity: Honesty, trust, fairness, respect, responsibility, Plagiarism as a violation of academic integrity, Honour Codes: Specifying the expected ethical standards from the stakeholders of an organization.

References:

1. R.S. Naagarazan, *A Textbook on Professional Ethics and Human Values*, 3rd Edn. New Age International Pvt. Ltd., 2022.
2. A.F. Bainbridge, *Ethics for Engineers*: A Brief Introduction, CRC Press, 2021.
3. E.G. Seebauer and R.L. Barry, *Fundamentals of Ethics for Scientists and Engineers*.
4. IEEE Code of Ethics – available at ‘https://www.ieee.org/about/corporate/governance/p7-8.html’.
5. International Center for Academic Integrity – available at ‘https://academicintegrity.org/’.

EC1002E INTRODUCTION TO PROGRAMMING

L	T	P	O	C
2	0	2	5	3

Total Sessions: 26L + 26P

Course Outcomes:

CO1: Illustrate the use of algorithms to solve real-world problems.
CO2: Design and develop computer programs to implement the algorithms.
CO3: Apply concepts of object-oriented programming to implement real-world entities like inheritance, polymorphism etc. in programming.
CO4: Assess the performance of computer programs for basic algorithms.

Procedural Programming
Introduction to Computational thinking: Data, Algorithms, Programming, Abstraction.
Introduction to Python, Data types and Expressions, Variables and Assignment, Strings, Tuples, Lists, Dictionaries, Control flow statements in Python: if-else, for, while loops, Iterations and Comprehensions.
Functions, Local and Global variables, Decomposition, Abstraction and Recursive Functions in Python, Aliasing, Mutability and Cloning.
Introduction to Testing, Benchmarking and Debugging using Python.
Exception handling, concepts of Concurrency and Parallelism, Synchronization.

Object Oriented Programming
Introduction to Object Oriented Concepts, Features of Object-oriented programming (OOP).
Classes and Objects: Creating a Class, The Self Variable, Constructor, Types of Variables, Namespaces, Types of Methods, Encapsulation, Module Packages.
Inheritance and Polymorphism: Constructors in Inheritance, The Super Function, Types of Inheritance, Polymorphism, Abstract classes and Interfaces.

Algorithms and Algorithmic Complexity
Searching and Sorting algorithms in Python.
Algorithmic Complexity: Asymptotic Notation, Complexity of various Sort algorithms, Complexity of common operations on Python Data Structures.

References:

1. Lutz, M. Learning Python: *Powerful object-oriented programming*, O'Reilly Media, Inc., 2013.
2. Guttag, J. V, *Introduction to computation and programming using Python*: *With application to understanding data,* MIT Press, 2016.
3. Lott, S. F., Mastering Object-Oriented Python: *Build powerful applications with reusable code using OOP design patterns and Python 3.7*, Packt Publishing Ltd., 2019.
4. Phillips, D. *Python 3 object-oriented programming: Build robust and maintainable software with object-oriented design patterns in Python 3.8,* Packt Publishing Ltd., 2018.

EC1003E INTRODUCTION TO ELECTRONICS

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Outline the working of basic electronic components.
CO2: Analyze linear circuits using network theorems.
CO3: Evaluate the steady state performance of electric circuits.
CO4: Examine simple circuits involving diode, BJT and Op-amp.

A brief history of electronics - Motives, Timelines and Breakthroughs.
Electronics in the modern era - Applications in Consumer electronics, Industry, Space and Military, Health care, Agriculture, IoT, Automobile etc.
Elements in an electrical circuit: Resistor, Inductor, Mutual inductance, Capacitor, Voltage and current sources-independent and dependent sources.
DC circuits: Kirchoff laws, Mesh and nodal analysis.
Network theorems- Star-Delta transformation, Thevenin's theorem, Norton's theorem, Superposition theorem, Maximum power transfer theorem, Reciprocity Theorem, Millman's theorem.

Steady state AC circuit analysis: Sinusoidal steady state response using complex exponential input, Voltage and current phasors, Impedance, Transformation of a circuit into phasor equivalent circuit, Network theorems Application to AC, Frequency response of AC circuits, Active power, Reactive power, Apparent power, Power factor.

Diodes and applications: Diode characteristics, Voltage and current relationship, Diode circuits-Rectifiers, Peak and envelope detectors, Wave shaping circuits, Voltage regulators.
BJT: Principle of operation, Transistor operating regions, Current-voltage characteristics, Transistor in DC, Current mirrors, Switch and amplifier circuits with biasing.
Operational amplifier: Properties and equivalent circuit model of op-amp, Open loop operation, Properties of negative feedback and virtual short, Analysis of op-amp circuits with negative feedback, Inverting and non-inverting amplifiers, Voltage follower, Input and output impedances, Summing and difference amplifiers, Integrator, Differentiator.

References:

1. Paul Horowitz, Winfield Hill, *The Art of Electronics*, 3rd Edn., Cambridge university press, 2015.
2. S. Sedra, K C Smith, *Microelectronic Circuits*, 7th Edn., Oxford University Press. 2017.
3. D. A. Neamen, *Electronic Circuit Analysis and Design*, 3rd Edn., McGraw-Hill India, 2006.
4. Anant Agarwal, Jeffrey H. Lang, *Foundations of Analog and Digital Electronic Circuits*, Elsevier, 2005.
5. Jacob Millman, Herbert Taub, Suryaprakash Rao Mothiki, *Pulse Digital and Switching Waveforms*, McGraw Hill Education; 3rd Edn., 2017.

EC1004E DIGITAL CIRCUITS AND SYSTEMS

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Apply Boolean Algebra in digital circuit design.
CO2: Illustrate various building blocks of combinational and sequential circuits.
CO3: Design combinational and synchronous sequential circuits.

Number system and Boolean algebra
Introduction to digital circuits, Importance of digital circuits in the modern world.
Number systems and conversion, Arithmetic, Signed and unsigned numbers, Complements, Binary codes.
Boolean algebra- Theorems and postulates, Boolean functions- Truth table, Logic gates, Canonical and standard forms, Complement of a function, Simplification of functions using Karnaugh map – Minimization of SoP and PoS forms, Don't care conditions, Quine McCluskey method. NAND and NOR implementation of Boolean functions

Combinational and Sequential circuits
Combinational circuits - Arithmetic circuits (Half adder/subtractor, Full adder/subtractor), Code converters, Magnitude comparators, Decoders and encoders, Multiplexers and demultiplexers.
Sequential circuits - Latches and flip flops (RS, JK, D, T and Master Slave) - Flip-flop conversion - Set-up time, Hold Time, and Clock skew.
Counters- Ripple counters - Synchronous counters - Shift registers - Random sequence generators.

Design and Analysis of Combinational and Sequential circuits
Design of combinational circuits - Boolean function realisation using multiplexers, Design considerations - Fan-in, Fan-out. Noise margin, Timing diagram, Hazards and Hazard free realisation.
Analysis of synchronous sequential circuits - Derivation of state graphs and state tables, General model of sequential networks.
Design of synchronous sequential circuits - Finite state machines - Mealy and Moore models - State graphs - State assignment - State table - State reduction.

References:

1. M Morris, M. and Michael, D., *Digital Design with an Introduction to the Verilog HDL*, 5th Edn., Pearson, 2013.
2. Roth Jr, C.H., Kinney, L.L. and John, E.B., *Fundamentals of logic design*, 6th Edn., Cengage Learning, 2020.
3. Brown, S.D. and Vranesic, Z.G., *Fundamentals of digital logic with Verilog design*, 3rd Edn., McGraw-Hill, 2014

EC1091E PRACTICAL ELECTRONICS

L	T	P	O	C
1	0	2	3	2

Total Sessions: 13L + 26P

Course Outcomes:

CO1: Choose appropriate components for designing an electronic circuit for a specific functionality.
CO2: Make use of suitable equipment for analysing different parameters in an electronic circuit.
CO3: Design and assemble electronic circuits for various applications.

Lecture Sessions:

(Qualitative/Intuitive explanations are envisaged).
Basic functionality of various electronic components - Resistors, Capacitor, Inductor, Transformer, Switch, Diode, Transistor, IC, LED, LDR, Potentiometer, Battery, Relay etc.
Diode circuits- Halfwave and full wave rectifiers, Clipper and clamper circuits.
Transistor as an amplifier - Biasing, Gain, Frequency response, Power, Loading, Impedance matching, Power amplifier.
Battery - Basic characteristics – Charging and discharging - Simple circuits used for charging – Protection circuits.
555 IC – Internal structure - Working – Astable and monostable operation.

Suggested Topics for Practical Sessions:

1. Familiarisation of electronic components and equipment
2. Component assembly methods
3. Regulated power supply
4. Wave shaping circuits
5. Audio amplifiers
6. Battery charging circuits
7. 555 timer circuits
8. Reverse engineering of an existing electronic product

References:

1. Paul Horowitz, Winfield Hill, *The Art of Electronics*, 3rd Edn., Cambridge university press, 2015.
2. Jacob Millman, Herbert Taub, Suryaprakash Rao Mothiki, *Pulse Digital and Switching Waveforms*, McGraw Hill Education; 3rd Edn., 2017.
3. Data sheets of various electronic components

MA1011E MATHEMATICS II

L	T	P	O	C
3	1*	0	5	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Find the parametric representation of curves and surfaces in space and evaluate integrals over curves and surfaces.
CO2: Use Laplace transform and its properties to solve differential equations and integral equations.
CO3: Test the consistency of a system of linear equations and solve it.
CO4: Diagonalise symmetric matrices and use it to find the nature of quadratic forms.

Vector field, Divergence, Curl, Identities involving divergence and curl, Scalar potential, Line integral, Independence of path, Conservative field, Evaluation of double integral, Improper integrals, Change of variables, Jacobian, Polar coordinates, Green's theorem for plane, Finding areas using Green's theorem, Triple integral, Cylindrical and spherical coordinates, Mass of a lamina, Centre of gravity, Moments of inertia, Parameterized surface, Surface area and surface integral, Flux, Gauss' divergence theorem, Stokes' theorem.

Laplace transform, Necessary condition for existence, Linearity, Inverse Laplace transform, Transforms of derivatives and integrals, Shifting theorems, Convolution, Differentiation and integration of transform, Solution of differential equations and integral equations using Laplace transform.

System of linear equations, Augmented matrix, Existence and uniqueness of solution, Gauss elimination method, Elementary row operations, LU decomposition, Row-equivalent systems, Row echelon form, Rank of a matrix, Linear dependence, Consistency of a linear system, Linear combination of solutions, General solution, Types of matrices and their properties, Eigenvalues, Eigen vectors, Eigenvalue problems, Cayley- Hamilton theorem, Similarity of matrices, Diagonalisation, Quadratic form, Reduction to canonical form.

References:

1. E. Kreyszig, *Advanced Engineering Mathematics*, 10th Edn., New Delhi, India: Wiley, 2015.
2. H. Anton, I. Bivens and S. Davis, *Calculus*, 10th Edn., New York: John Wiley & Sons, 2015.
3. V. I. Arnold, *Ordinary Differential Equations*, New York: Springer, 2006.
4. P. Dyke, *An Introduction to Laplace Transforms and Fourier Series*, New York: Springer,2014.

PH1003E ELECTRICITY AND MAGNETISM

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Apply knowledge of vector calculus to describe Electric and Magnetic fields.
CO2: Identify simplifying principles like symmetry to compute Electric and Magnetic fields.
CO3: Formulate and solve problems involving time dependent electromagnetic fields using Maxwell's equations.
CO4: Analyze propagation of electromagnetic waves in vacuum and dielectric media.

Electrostatics
Electric field – Charge density: Line, surface and volume. Coulomb's law, Coordinate systems and vector fields: Rectangular, cylindrical and spherical coordinates, Divergence and curl of electric field, Gauss' law, Potential, Gradient of the potential, Poisson and Laplace equation, Electrostatic work and energy, Conductors and electric fields, Field and potential of dipoles, Electric polarization vector, Gauss' law for a dielectric medium, Electrostatic boundary conditions.

Magnetostatics
Electric current, Current density, Surface and volume currents, Continuity equation, Magnetic field, Biot-Savart law, Divergence and curl of magnetic field, Ampere's law, Field due to a magnetic dipole, Magnetic dipole in external magnetic field, Magnetostatic energy, Magnetized materials, Magnetostatic boundary conditions.

Time varying Fields
Electromotive force, Faraday's law, Lenz's law, Electromagnetic induction, Mutual and self-inductance, Maxwell's equations, Maxwell's correction to Ampere's law, Displacement current, Electromagnetic field, Energy density, Poynting's theorem.

Electromagnetic Waves
Maxwell's equations in free space, Wave equation, Plane wave solution, Structure of the electromagnetic wave, Spherical waves, Propagation in dielectric medium and refractive index.

References:

1. D. J. Griffiths, *Introduction to Electrodynamics* 4th Edn. PHI Learning, New Delhi, 2012.
2. E. Purcell and D. Morin, *Electricity and Magnetism* 3rd Edn, Cambridge University Press, 2013.
3. M. O. Sadiku, *Elements of Electromagnetics* 4th Edn, Oxford, 2009.
4. D. J. Cheng, *Field and Wave Electromagnetics* 2nd Edn. Pearson, 2014.
5. R. P. Feynman, R. Leighton and M. Sands, Feynman *Lectures on Physics Vol.-II* Millenium Edn., Pearson, 2012.
6. J. Edminister, Schaum's Outline: T*heory and Problems in Electromagnetics*, 2nd Edn., McGraw-Hill, 1979.

MS1001E PROFESSIONAL COMMUNICATION

L	T	P	O	C
3	1*	0	5	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Distinguish the role and purpose of communication at the workplace and for academic purposes.
CO2: Decide strategies and modes for effective communication in a dynamic workplace.
CO3: Combine multiple approaches for successful and ethical information exchange.
CO4: Estimate best communication practices to assist productivity and congeniality at the workplace.

Listening and Reading Comprehension
Conversation starters: Introductions and small talk - Seek and provide information, clarification, polite enquiries, requests, congratulate people, apologise, give and respond to feedback - Describe graphs, tables, and charts - Words often confused: Lexicon and meaning - Sense groups - Listening for specific purposes: Listening to lectures, summarising academic lectures for note-taking - Appropriate language to request and respond - Public speaking.

Vocabulary and Speaking
Developing professional vocabulary - Basic sentence structures from reading texts - Concord - Functions of auxiliary verbs and modals - Strategies for effective reading - Skimming and scanning, Determining themes and main ideas, Predicting content using photos, images and titles - Critical reading: Discussing and summarising text points - Understanding text structures: Sequencing, Comparing and Contrasting, Relating cause and effect, Problems and problem-solving - Discussing rhetorical and cultural aspects in texts - Text Appreciation: Drawing inferences, Framing opinions, and Judgments on reading text.

Effective Writing
Note making and summarising: Prepare notes from reading texts, Paraphrasing - Use of multimedia for assistive purposes - Paragraph writing: Cohesive devices to connect sentences in a paragraph - Transitional devices - Use text structures in paragraphs: Sequencing, Comparing and contrasting, Relating cause and effect, Problems and problem-solving - Avoiding ambiguity and cleft sentences – Applications: Writing instructions, Descriptions and Explanations - Official letters of request and denial - Official e-mails - Abstract writing - Digital resources for effective communication.

Communication at Workplace
Communication theory - Process of communication - Modes of communication - Verbal and nonverbal communication - Tone in communication - Formal and informal communication at workplace - Passive, assertive and aggressive styles of communication - Positive body language - Group discussions - Presentation - Workplace communication - Active listening - Giving feedback - Communication etiquette - Persuasion - Negotiation - Tone and voice - Telephone etiquette - Establishing credibility in conversations - Digital communication and Etiquette: Conducting oneself in virtual interactions, Constructive use of social media - Ethical and culturally sensitive communication: Ethical considerations in professional communication, Addressing diversity, Inclusive communication practices**.**

References:
1. N. Bhatnagar and M. Bhatnagar, Communicative English for Engineers and Professionals. New Delhi: Dorling Kindersley, 2010.
2. M. Foley and D. Hall, *Longman Advanced Learners' Grammar: A Self-Study Reference & Practice Book with Answers.* Pearson Education, 2018.
3. B. A. Garner, *HBR Guide to Better Business Writing: Engage Readers Tighten and Brighten Make Your Case.* Harvard Business Review Press, 2012.
4. M. Hewings, *Advanced Grammar in Use: A Reference and Practice Book for Advanced Learners of English*. Cambridge University Press, 2013.
5. M. Ibbotson, *Cambridge English for Engineering Students*. Cambridge University Press, 2008.
6. S. Kumar, P Lata, *Communication Skills*. Oxford University Press, 2015.

7. N. Sudarshana, C. Savitha. *English for Technical Communication*. Cambridge English, 2016.

EC1011E ELECTRIC CIRCUITS AND NETWORKS

L	T	P	O	C
3	1*	0	5	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Evaluate the transient response and steady-state response of first- and second-order electric circuits.
CO2: Analyze electric circuits in s-domain and obtain the frequency response of linear circuits and systems.
CO3: Model two-port electric networks using two-port network parameters.

Time Domain Analysis of Circuits *77*
Review of network theorems - Transients in linear circuits: Initial conditions, Natural and forced response, Zero state response, Zero input response, Complete Response - Analysis of RC and RL circuits - Impulse and step responses - Time domain analysis of RLC circuits – RC and RL circuits as differentiator and integrator circuits, Compensated attenuator.

s-Domain Analysis of Circuits
Review of Laplace transform - Transformation of a circuit into s-domain: Transformed equivalent of inductance, capacitance and mutual inductance, Impedance and admittance in the transform domain - Node analysis and mesh analysis of the transformed circuit - Nodal admittance matrix and mesh impedance matrix in the s-domain – Analysis of transformed circuits with mutual inductance - Step response of an ideal transformer.

Network Functions and Frequency Response
Network functions - Impulse response and transfer function - Poles and zeros - Restriction of pole and zero locations of network functions.
Steady state response and frequency response from Laplace transform: Frequency response by transform evaluation on $j\omega$-axis, Frequency response from pole-zero plot by geometrical interpretation, Bode plots - Ideal frequency selective filter characteristics, Types of filters - Pole-zero location and frequency response of first and second order filter functions - First order RC and RL filters - Second order RLC filters, Q factor, Resonance.

Two Port Networks
Two port networks - Characterization in terms of impedance, admittance, hybrid, inverse hybrid and transmission parameters, Inter relationships among parameter sets, Interconnection of two port networks - Series, parallel and cascade. Symmetrical two port networks - T and π equivalent of a two-port network, Image impedance parameter description of a two-port network, Characteristic impedance and propagation constant of a symmetrical two port network.

References:

1. K. S. Suresh Kumar, *Electric Circuits and Networks*, Pearson India, 2015.
2. M.E. Van Valkenburg, *Network Analysis* 3rd Edn., Pearson India, 2015.
3. W.H. Hayt Jr , J. E. Kemmerly, J.D. Phillips, Steven M. Durbin *Engineering Circuit Analysis*, 9th Edn., McGraw Hill India, 2020.
4. C. A. Desoer, E. S. Kuh, *Basic Circuit Theory*, McGraw-Hill, 1969.
5. Jacob Millman, Herbert Taub, Suryaprakash Rao Mothiki, *Pulse Digital and Switching Waveforms*, McGraw Hill Education; 3rd Edn., 2017.

EC1012E SEMICONDUCTOR DEVICES

L	T	P	O	C
3	0	2	7	4

Total Sessions: 39L + 26P

Course Outcomes:

CO1: Apply the basic laws of solid state physics to understand the properties of semiconductor materials.
CO2: Analyze and model different types of semiconductor junctions, including homo junctions and heterojunctions.
CO3: Analyze and model the physics of Metal-Oxide-Semiconductor systems and MOSFETs.
CO4: Apply simulation tools for analyzing and evaluating various semiconductor devices.

Introduction to Quantum mechanics,Schrodinger equation,Particle in infinite potential well,Crystal structure of solids, Formation of energy bands, E-K diagram, Electron effective mass, Concept of hole ,Direct and indirect band gap semiconductors, Density of states, Fermi Dirac distribution, Maxwell Boltzmann distribution, Intrinsic and extrinsic semiconductors, Equilibrium carrier concentration, Mass action law , Carrier transport, Drift , Diffusion , Hall effect. Non-equilibrium carrier concentration, Recombination and generation of carriers , Life time ,Continuity equation - Quasi Fermi levels.

Semiconductor junction; P-N junction under equilibrium,Energy band diagram, Current under forward bias, Reverse bias, IV characteristics, Charge storage and transient behavior, Junction capacitance, Junction break down , Small signal model of P-N diode, Metal-Semiconductor contacts, Non-rectifying (ohmic) contacts, Schottky diodes.

Metal-Oxide-Silicon System: Ideal MOS structure ,Accumulation, Depletion, Inversion , Energy band diagram under bias, Threshold voltage, C-V characteristics, Effects of work function difference, Oxide and interface charges. MOSFET: Structure, Types, Threshold voltage, DC characteristics, Channel length modulation, Subthreshold conduction, Small signal models of MOSFET, Short channel effects (SCEs), Introduction to advanced MOS devices.

Simulation of semiconductor devices using SPICE/MATLAB/TCAD and Hardware experiments on device characteristics of diodes and BJTs , IV characteristics of MOSFETs, BJTs and diodes , CV characteristics of MOS capacitor.

References:

1. Donald A. Neamen, *Semiconductor Physics and Devices - Basic Principles*, McGraw Hill, 4th Edn., 2021.
2. Ben Streetman and Sanjay Banerjee, *Solid State Electronic Devices*, Pearson Education, 7th Edn., 2014.
3. Sm Sze, *Physics of Semiconductor Devices*, John Wiley & Sons, 3rd Edn., 2008
4. C. C. Hu, *Modern Semiconductor Devices for Integrated Circuits*, Pearson Education, 2nd Edn., 2010.
5. M. S. Tyagi, *Introduction to Semiconductor Materials and Devices*, John Wiley and Sons, 2004.

EC1092E DIGITAL SYSTEMS LAB

L	T	P	O	C
1	0	2	3	2

Total Sessions: 13L + 26P

Course Outcomes:

CO1: Design and implement combinational and sequential circuits using ICs.
CO2: Design basic logic circuits using hardware description language (HDL) at behavioural and gate levels and implement them in programmable devices.
CO3: Demonstrate the output of circuit design using technical reports.
CO4: Develop the ability to work in professional teams.

Lecture Sessions:

Introduction to logic design with Verilog, Modules, Ports, Wires, Registers, Behavioural and gate level modelling of logic circuits, Introduction to synthesis - Logic synthesis - RTL synthesis, Xilinx FPGA architectures.

Practical Sessions:

1. Transfer characteristics, Measurement of sinking and sourcing currents etc. of logic gates
2. Realisation of the following circuits using function specific ICs and/or FPGAs
    a. Combinational circuits (code converter, comparator etc.)
    b. Arithmetic circuits (Half/Full adder/subtractor, BCD adder etc.)
    c. Basic flip flops
    d. Synchronous counters
    e. Asynchronous counters
    f. Sequence detectors

References:

1. Roth Jr, C.H., Kinney, L.L. and John, E.B. *Fundamentals of logic design*, 6th Edn. Cengage Learning, 2020.
2. Brown, S.D. and Vranesic, Z.G., *Fundamentals of digital logic with Verilog design*, 3rd Edn., McGraw-Hill, 2014.
3. Palnitkar S., *Verilog HDL: A guide to digital design and synthesis*, Prentice Hall; 2nd Edn., 2003.
4. J. Bhasker,, *Verilog HDL Synthesis: A Practical Primer*, B. S. Publications, 2001.

MA2004E MATHEMATICS III

L	T	P	O	C
3	1*	0	5	3

Total Lecture Sessions: 39

Course Outcomes

CO1: Introduce the fundamentals of probability and random variables in continuous/discrete settings.
CO2: Identify the distribution and transformation of random variables.
CO3: Apply the concepts of correlation and stationarity in analysis of stochastic processes.
.

Probability distributions of a single random variable
Basics of probability, Axioms of Probability, Conditional probability, Independence; Random variables: Discrete and Continuous random variables, Probability Distribution functions, Cumulative Distribution function, Expectation, Variance, Moment Generating Function, Higher Order Moments; Special Distribution: Binomial, Geometric, Poisson, Hyper-geometric, Uniform, Gamma, Exponential distribution, and Normal distribution; Markov and Chebyshev inequalities; Law of large numbers; Central limit theorem and its significance.

Probability distributions of several random variables
Joint probability distribution function, Joint probability mass and density function, Marginal and Conditional distributions, Transformation of random variables, Joint probability distribution of functions of random variables, Independent random variables, Covariance, Correlation coefficient, Bivariate normal distribution.

Random processes:
Introduction and Specification, Mean and Auto-Correlation Function, Auto-Covariance Function, Cross-Correlation and Cross-Covariance Functions. Stationary processes: Strict-Sense Stationarity, Wide-Sense Stationarity (WSS), Stationarity, Auto-Correlation Function, Cross-Correlation Function, and Power Spectral Density of a WSS Random process, Wiener-Khinchine theorem, Low-pass and Band-pass processes, Power and Bandwidth calculations, Time averaging and Ergodicity: Time averages - interpretation, Mean and Variance; Ergodicity: general definition, Ergodicity of the mean, Ergodicity of the auto-correlation function.

References:

1. S. M. Ross, *Introduction to Probability and Statistics for Engineers and Scientists*, 5th Edn, Academic Press (Elseveir), 2014.
2. Richard A. Johnson, *Miller & Freund's - Probability and Statistics for Engineers*, 8th Edn, Prentice Hall India, 2011.
3. V. Krishnan, *Probability and Random Processes*, John Wiley & Sons, 2nd Edn, 2006.
4. S. Ross, *A First Course in Probability*, 9th Edition, Pearson, 2014.
5. Roy D Yates, David J Goodman, *Probability and Stochastic Processes*, 3rd Edn, Wiley, 2021.
6. Scott Miller, Donald Childers, *Probability and Random Processes*, 2nd Edn, Elsevier, 2007.

EC2001E SIGNALS AND SYSTEMS

L	T	P	O	C
3	1*	0	5	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Understand the foundational concepts in Signal Theory and System Theory.
CO2: Analyze the interaction between Signals and Systems.
CO3: Understand the basic principles of signal sampling.
CO4: Analyze the interaction between Discrete-time Signals and Systems.
CO5: Understand discrete Fourier theory and do Fourier analysis of discrete-time systems and signals.

Continuous-time Signals and Systems
Functions and Continuous-time systems: Functions on a real line, periodic functions; Linear time-invariant causal systems; System model: linear differential equations and their solutions as the system response, The Laplace transform: Region of convergence, Analysis of continuous-time systems, zero-input and zero-state responses, the Impulse response, convolution, the step response, the exponential response, the sinusoidal response and the transfer function of a system; The concept of poles and zeros of a system; stability of a system, Steady state analysis and the Fourier transform; Frequency response from pole-zero plot; Bandwidth of a continuous-time signal and a system; Fourier Series and the analysis of periodic functions.

Discrete-time Signals and Systems
Discrete-time sequences and systems: Sampling in time, Sampling theorems for lowpass and bandpass band-limited signals; Infinite and finite length sequences, Discrete-time systems and their properties; Linear difference equations and their solutions, Linear shift-invariant systems and convolution; responses of the discrete-time systems to impulse, step, exponential and sinusoidal inputs, and the transfer function of a discrete-time system; the z-transform and its relation to the Laplace transform, inverse z-transform, Linear difference equations and their solutions in the z-domain, Stability of discrete-time systems.

Fourier Analysis of discrete-time Signals and Systems
Fourier analysis of discrete-time sequences: Periodic discrete-time sequences and the Discrete-time Fourier series, and its properties; Discrete-time Fourier transform and its properties; Sampling in the Frequency domain: The discrete Fourier transform (DFT); The relation of the z-transform of a discrete-time sequence with its discrete-time Fourier transform and the discrete Fourier transform; Properties of the DFT matrix.

References:

1. B. P. Lathi, "*Linear Systems and Signals*," Oxford University Press, 2004.
2. Oppenheim A. V., Willsky A. S., and Nawab S. H., "*Signals and Systems*," 2nd Edition, PHI Learning Private Limited/Pearson Education, 2011.
3. R. F. Ziemer, W. H. Tranter and D. R. Fannin, "*Signals and Systems - Continuous and Discrete*," 4th Edition, Pearson Education, 2014.
4. M. Vetterli, J. Kovacevic and V. K. Goyal, "*Foundations of Signal Processing*," Cambridge University Press, 2015.

EC2002E ANALOG CIRCUITS

L	T	P	O	C
3	1*	0	5	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Analyze and design single stage amplifier circuits using transistors
CO2: Estimate frequency response of amplifiers using suitable transistor models
CO3: Design single stage and two stage operational amplifiers
CO4: Make use of feedback theory in the design and development of analog circuits

Signal amplification, circuit models for amplifiers, amplifier types, bandwidth, low pass and bandpass amplifiers. Circuit analysis with non-linear elements and two port network models - Large signal and small signal models of MOSFETs, common source amplifier, voltage gain, swing, bias stabilization, current-mirror biasing, source degeneration, source follower, common drain amplifier - High frequency MOSFET model, frequency response of single stage amplifiers, Miller effect, cascode amplifier.

Differential and common mode operations, CMOS differential amplifiers, single ended and differential outputs, common mode rejection ratio, differential amplifier as single stage op amp - Difference amplifier using op amps, Instrumentation amplifier, slew rate, offset voltage, bias current, non-ideal effects in op amp circuits.

Two stage op amp, op amp in negative feedback, properties of negative feedback, stability, phase margin and gain margin, dominant pole frequency compensation, impact of sensing and mixing techniques in feedback circuits - Condition for oscillation, RC phase shift oscillator and Wien bridge oscillator - PLL as negative feedback system, building blocks of PLL, applications of PLL.

References:

1. S. Sedra & K C Smith, *Microelectronic Circuits*, 7th Edition, Oxford University Press.2015.
2. D. A. Neamen, *Electronic Circuit Analysis and Design*, 3rd Edition, McGraw-Hill India, 2006.
3. Razavi, *Fundamentals of Microelectronics*. John Wiley India Pvt. Ltd. 2009.

EC2003E COMPUTER ARCHITECTURE AND PROCESSORS

Pre-requisites: A first level course in Digital Circuits

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Analyse the basic building blocks of a computer system and the role of the central processing unit, using 8086 as an example.
CO2: Develop assembly language programs to access the features provided by the 8086 CPU.
CO3: Examine the features of the 8051 CPU and peripherals from a programmer's point of view.

Basics of computer architecture: The Block Diagram of a Computer-The System Bus-Data bus, Address bus, and Control bus. The processor, System clock, Memory-Memory Read Cycle-Memory write cycle. Computer Languages-Machine Language, Assembly Language and High-Level Language- RISC and CISC Architectures- History of microprocessors-The x86 Philosophy. The first x86 processor: The architecture of 8086 —Block diagram, Execution Unit, Scratch Pad registers, Flag registers, Bus Interface Unit Memory Segmentation -Segment Registers, Memory Organization, Addressing modes and calculations of physical addresses. Programming concepts- Assembly Language Processing, Instructions and Directives-Assemblers for x86-Memory Models-com and Exe Files-Directives used in MASM- General Rules for Writing Assembly Language-Instruction Set Architecture (ISA)-Designing a code.

Instruction Set of 8086: Function calls, Data Transfer Instructions, Stack Operations, Branch Instructions, Arithmetic Instructions, Flag control Instructions, Logical Instructions, Shift and Rotate Instructions, String Instructions, Procedures-Call and Return Instructions, Passing Parameters to and from Procedures Macros, Signed Number Arithmetic, Programming Using High Level Language Constructs, Input -Output Programming, Memory mapped IO and peripheral IO.

The hardware Structure of 8086: Pin Diagram-Address demultiplexing Clock, Reset and ready pins, Power on Reset, Machine cycles, Clock-Read and Write Timing Diagrams-Other processor activities, Interrupts-DMA, Instruction cycles-delay loops. Memory and IO Decoding – Memory device pins, Address decoding using gates and block decoders-partial address decoding, Memory banks - IO Address Decoding. Interrupts of 8086: Interrupt Service Routine and Interrupt Vector–Interrupt vector Table, dedicated Interrupts, Hardware Interrupts-INTR and NMI, Interrupt Acknowledge Machine Cycle-Software interrupts –type number -priority

8051 Microcontroller: The Programmer's Perspective- architecture, Eight- and sixteen-bit Registers of 8051, Internal Memory, Flags, storing data in ROM Assembly Language Programming using Keil Microvision IDE, Instruction set, Addressing Modes, Ports of 8051, Port programming and generating square waves using software delays. Programming the Internal Peripherals of 8051: Generating square waves using timers – counting external events, Interrupt based operation of timers, Serial data transmission and reception using polling and interrupts.

References:

1. Lyla B. Das, *The x86 Microprocessors: 8086 to Pentium, Multicores, Atom, and the 8051 Microcontroller: Architecture, Programming and Interfacing*, Second Edition, Pearson Education, India 2014.
2. Muhammed Ali Mazidi, Janice GillispieMazidi ,Rolin D Mc Kinlay, *The 8051 Microcontroller and Embedded Systems Using Assembly and C* , Second Edition ,2008 , Pearson Education.
3. John L. Hennessy David A. Patterson, *Computer Architecture, A Quantitative Approach* ,5th Edition, 2012, Elsevier.

EC2004E ENGINEERING ELECTROMAGNETICS

Pre-requisites: A first level course in Electricity and Magnetism

L	T	P	O	C
3	1*	0	5	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Analyze the propagation of electromagnetic waves through transmission lines.
CO2: Analyze the propagation of plane waves in unbounded media and incidence of plane waves at interfaces.
CO3: Analyze two-port network/devices using S- parameters.
CO4: Design and simulation of matching network and other passive microwave components.

Transmission Lines: Voltage and current equations on a transmission line, Standing wave and impedance transformation, loss-less and lossy transmission line, Power transfer on a transmission line the Smith chart, impedance matching, different types of transmission lines, Microstrip line Quasi-TEM analysis, Discontinuities in Microstrip line. Bounce diagram and digital transmission lines.

Introduction to electromagnetic waves, review of Maxwell's equations and boundary conditions, Phase and group velocity, Polarizations, plane waves, and their propagations in free space; different mediums; skin depth, Reflection and transmission at interfaces: normal and oblique incidence of uniform plane electromagnetic waves at conducting boundaries, dielectric boundaries, and Brewster's angle.

Guided wave: rectangular and circular waveguides; transverse electric (TE) and transverse magnetic (TM) waves; cut-off wavelength and phase velocity; dominant mode, attenuation, wave impedances, excitation of modes. S-parameters for a two-port network, properties of the S-parameters. EM simulation Tool: design and simulation of waveguides, matching networks, tees, and couplers in electromagnetic simulation tools (open source and advanced tools).

References:

1. R K Shevgaonkar, *Electromagnetics Waves*, McGraw Hill, 1st Edn. 2016.
2. W H Hayt, J A buck, and M. J. Akthar, *Engineering Electromagnetics*, McGraw Hill, 8th Edn., 2020.
3. Matthew N. O. Sadiku, *Elements of Electromagnetics*, Oxford University Press, 4th Edn., 2006.
4. David K Cheng, *Field and wave electromagnetics*, Pearson Education, 2nd Edn., 2001.
5. Michael Steer, *Fundamentals of Microwave and RF Design*, NCSU Libraries, 2019.
6. David M. Pozar, *Microwave engineering*, John Wiley and Sons. Inc. 4th Edn. 2012.
7. Samuel Y. Liao, *Microwave devices and circuits*, Pearson Education India, 3rd Edn. 2003.

EC2091E ANALOG CIRCUITS LAB

L	T	P	O	C
0	0	3	3	2

Total Practical Sessions: 39

Course Outcomes:

CO1: Design signal conditioning blocks
CO2: Analyse circuits using suitable models and software simulations
CO3: Characterise the circuits and estimate the effects of parasitic components of circuit elements on the performance of circuits.
CO4: Develop the ability to prepare technical reports and oral presentation

Suggested Topics for Practical Sessions:

1. Op amp voltage follower, non-inverting amplifier, gain, frequency response, integrator, differentiator
2. Log/antilog amplifier and applications
3. Op amp as super diode and comparison
4. Extracting small signal model parameters of a transistor
5. Modeling and simulation of an amplifier using the obtained small signal parameters
6. Common drain amplifier as buffer with resistor and current source loads
7. Common source and cascode amplifiers
8. Instrumentation amplifier and CMRR
9. Characterization of an op amp
10. Oscillator/multivibrator circuits

References:

1. S. Sedra & K C Smith, *Microelectronic Circuits*, 7th Edition, Oxford University Press.2015.
2. D. A. Neamen, *Electronic Circuit Analysis and Design*, 3rd Edition, McGraw-Hill India, 2006.
3. Sergio Franco, '*Design with Operational Amplifiers and Analog Integrated Circuits*, 3rd Edition, Tata McGraw-Hill, 2017.
4. Data sheets of transistors and ICs.

MA2014E MATHEMATICS IV

L	T	P	O	C
3	1*	0	5	3

Total Lecture Sessions: 39

Course Outcomes

CO1: Characterise a linear system in terms of vectors, linear combinations, and span.
CO2: Understand the concepts of projection, orthogonality, and linear transformations of vectors.
CO3: Understand convergence, continuity, and differentiability of real valued functions.
CO4: Construct optimization problems for real world applications.
CO5: Understand the existence and uniqueness of the solutions for formulated optimization problems.

Linear Algebra: Vector spaces, Subspaces, Linear Independence, Basis, Dimension, Inner product spaces, Norms, Orthogonality, Gram-Schmidt Orthogonalization, Projection, Least squares approximations, Linear transformations, Kernel and Image, Rank-nullity theorem, Matrix representation of linear transformation, Change of Basis, Type of Matrices, Singular Value Decomposition.

Real Analysis: Real Line, Open and Closed Sets, Sequences and Sub-sequences, Compact and Connected Sets, Continuous Mapping, Boundedness on Compact Sets, Convergence, Differentiable Mapping, Chain Rule, Mean-Value Theorem, Taylor's Theorem and Higher Derivatives.

Fundamentals of Optimization: Convex sets and Convex cones, Affine sets, Convex and Concave functions, Global vs Local optimality, Quadratic Functions. Linear Programming: Introduction, Optimization model, Formulation, Geometric Ideas and applications. Nonlinear Programming, Unconstrained Optimization: Conditions of maxima and minima for unconstrained optimization. Numerical methods for unconstrained optimization: Line search methods; Method of Steepest Descent and Newton's method. Nonlinear Programming, Constrained Optimization: Conditions of maxima and minima for constrained optimization, Method of Lagrange Multipliers, Karush-Kuhn-Tucker theory.

References:

1. Jerrold E. Marsden and Michael J. Hoffman. *Elementary Classical Analysis*. Macmillan, 1993.
2. R. K. Jain and S. R. K. Iyengar, *Advanced Engineering Mathematics*, 5th Edn, Narosa Publication, 2016.
3. E. Kreyszig, H. Kreyszig, E. J. Norminton, *Advanced Engineering Mathematics*, 10th Edn, Wiley, New Delhi, 2015.
4. Edwin K. P. Chong and Stanislaw K. Zak, *An Introduction to Optimization,* 2nd Edn, Wiley, 2005.
5. David G. Luenberger and Yinyu Ye. *Linear and Nonlinear Programming*. Vol. 2. Reading, MA: Addison-Wesley, 1984.
6. G Mohan and Kusum Deep, *Optimization Techniques*, New age International Publishers, 2009

EC2011E FOUNDATIONS OF MACHINE LEARNING

L	T	P	O	C
2	0	2	5	3

Total Sessions: 26L + 26P

Course Outcomes:
CO1: Discuss the role of data in the future of computing and learn data processing, data exploration, feature extraction, training and testing ML models using the processed data.
CO2: Apply the principles of linear algebra, probability, statistics and optimization to analyze different machine learning algorithms.
CO3: Create machine learning algorithms for solving practical regression and classification problems.
CO4: Implement machine learning algorithms using a high-level programming language.

Mathematical Foundations
Reviews of Linear Algebra, Probability and Distributions, Decision Theory – the Bayes decision rule and optimal risk, Generative and Discriminative Models, Normal Density – Univariate and Multivariate. Optimization problems and algorithms – Constrained and Unconstrained optimization, Gradient descent, stochastic gradient descent, Batch and minibatch gradient descent, momentum.
Machine learning Terminology, Supervised learning: The design cycle - Data Exploration and Preparation, Model development, Model selection and Evaluation.
Linear Models for Regression and Classification
Linear models, Linear Regression - Simple Linear Regression, Multiple Linear Regression, and Nonlinear Least square regression. Logistic Regression. Introduction to Classification - Binary and Multiclass Classification. loss functions, Training, Validation and Testing. cross-validation, Confusion matrix. Underfitting and Overfitting, Bias and Variance, Regularization.
Nonlinear and statistical models
Classifier - Decision tree, Naive Bayes, Perceptron, MLP. Statistical models: Maximum likelihood estimation and Parametric density estimation, Non-parametric techniques -K Nearest Neighbor Estimation.
Unsupervised Learning and Clustering
Unsupervised learning: Dimensionality reduction - Principal Component Analysis, Linear Discriminant Analysis, Clustering- K-Means clustering algorithm.
Suggested List of Topics for Practical Sessions:
1. Introduction to Linear Algebra, Probability distribution using Python.
2. Implementation of gradient descent algorithm for optimization problems.
3. Build and train a linear regression model that takes multiple features as input.
4. Build and train a binary logistic regression using stochastic gradient and evaluating the classification performance.
5. Linear regression with regularization such as ridge regression, LASSO.
6. Cross-validation for penalization.
7. Maximum Likelihood Estimation.
8. Data visualization using PCA and LDA
9. K-means clustering algorithm and application to image compression
10. A Course project spanning 2 – 3 weeks based on the concepts learned in the laboratory is to be implemented and demonstrated**.**

References:

1. Deisenroth, Marc Peter, A. Aldo Faisal, and Cheng Soon Ong. *Mathematics for machine learning.* Cambridge University Press, 2020.
2. James, Gareth, et al. *An introduction to statistical learning*. Vol. 112. New York: springer, 2013.
3. Hastie, Trevor, et al. *The elements of statistical learning: data mining, inference, and prediction.* Vol. 2. New York: springer, 2009.
4. Lyla B. Das , Sudhish N. George & Anup Aprem *Artificial Intelligence and Machine Learning: Theory and Practice*, 1/e, I.K International, 2023.

EC2012E COMMUNICATION ENGINEERING I

Pre-requisites: A first level course in Signals and Systems

L	T	P	O	C
3	1*	0	5	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Demonstrate sound knowledge of approaches for analysis of random processes and signals.
CO2: Analyze techniques for generation and reception of signals used for analog communication.
CO3: Evaluate analog communication system in terms of performance, bandwidth and complexity.
CO4: Analyze the design of various processing blocks of a digital communication system.
CO5: Demonstrate sound knowledge of various pass band digital modulation schemes and the corresponding demodulation techniques.

Analog communication
Fundamentals of analog communication systems, Block schematic, Review of probability and random process, Function of random variables, Wiener Khinchine theorem, Filtering of random processes, Modulation and frequency translation, Lowpass and bandpass signals, Concept of complex envelope, Hilbert transform and phase shifting, Linear continuous wave (CW) modulation: AM, DSB/SC, SSB, VSB, methods of generation; Demodulation techniques of CW modulation, Nonlinear modulation techniques: FM and PM, narrowband FM, wideband FM, methods of generation, Demodulation techniques for FM, threshold effect in FM, pre-emphasis and de-emphasis, Radio transmitters and receivers, Noise in receivers, Noise figures, Performance of analog modulation schemes in AWGN: SNR and figure of merit for different schemes.

Digital baseband communication
Digital baseband communication, Sampling: sampling of lowpass and bandpass signals, Pulse Amplitude Modulation (PAM), Time division multiplexing with PAM, Quantization, Pulse Code Modulation (PCM), Differential PCM, Line coding schemes, Power and bandwidth efficiency, Inter symbol interference, Nyquist’s criteria, pulse shaping, Equalization, Digital baseband transmission in AWGN channel, Representation of a signal in signal space, Gram-Schmidt orthogonalization, Cauchy-Schwarz inequality, Matched filter receiver, Correlation receiver.

Digital bandpass communication
Digital bandpass communication, Bandpass modulation techniques: amplitude shift keying, phase shift keying, frequency shift keying, M-ary digital modulation schemes, quadrature phase shift keying, minimum shift keying, quadrature amplitude modulation, method of generation and detection, Signal constellation.

References:
1. Upamanyu Madhow, *Introduction to Communication Systems*, Cambridge University Press, 1st Edition, 2014.
2. R. E. Zeimer and W. H. Tranter, *Principles of Communications: System, Modulation, and Noise,* Wiley, 7th Edition, 2014.
3. J. G. Proakis, M. Salehi, and G. Bauch, *Contemporary Communication Systems using MATLAB,* Cengage Learning, 3rd Edition, 2013.
4. L.W. Couch, *Digital and Analog Communication Systems*, 8/e, Pearson, 2013.
5. B. P. Lathi and Zhi Ding, *Modern Digital and Analog Communication Systems*, Oxford University Press, 5th Edition, 2019.
6. J. G. Proakis and M. Salehi, *Communication System Engineering*, Pearson Education, 2nd Edition, 2013.

EC2013E VLSI DESIGN

Pre-requisites: A first level course in Digital Circuits & Systems

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Analyse static and dynamic characteristics of digital CMOS circuits.
CO2: Design static and dynamic CMOS logic circuits for a given functionality, speed, power consumption and area requirements.
CO3: Demonstrate the performance of CMOS logic circuits designed using various logic styles with the help of CAD tools.
CO4: Design arithmetic circuits and memories using CMOS.

Overview of VLSI Design flow: Review of MOS transistors, Threshold Voltage, MOSFET operation, MOSFET capacitances, Junction Capacitances, Oxide related capacitances, MOSFET scaling, constant-voltage and constant-field scaling, Short channel effects.
MOSFET as switch, Switch models of inverter, CMOS inverters, DC and Transient analysis, Area, power and noise margin considerations, stick diagram, design rules and layout of CMOS inverter, Simulation analysis of CMOS circuits using CAD tools.

Multiple input static CMOS logic circuits: DC and transient analysis, Area, power and noise margin considerations, Logical and Electrical effort, parasitic delay, Design of minimum delay, Sizing for optimal delay
Different Logic Styles, Pseudo-NMOS, DCVSL logic, Pass transistor, Complementary pass transistor and transmission gate.
Dynamic CMOS design-steady-state behaviour of dynamic gate circuits, noise considerations in dynamic design, charge sharing, cascading dynamic gates, domino logic, np-CMOS logic, designing of sequential circuits - static and dynamic latches and registers, clocked CMOS circuits, TSPC, C2MOS registers.

Timing issues in digital circuits: Introduction, Synchronous Timing basics, Clock Skew and Jitter, Clock distribution techniques, Clock Generation and Synchronization
Concept of Standard cells, Design of arithmetic building blocks: Different types of Adders, Multipliers - array and tree multipliers, Barrel and logarithmic shifters, area-time tradeoff, power consumption issues; 6T SRAM and DRAM cell design

References:

1. J.M. Rabaey, A. Chandrakasan and B. Nikolic, *Digital Integrated Circuits- A Design Perspective*, 2nd Edn., Pearson Education, 2016
2. N.H.E. Weste and David M. Harris, *CMOS VLSI Design - a Circuits and System Perspective*, 4th Edn., Pearson Education Asia, 2010
3. S.M. Kang, Y. Leblebici and Chul Woo Kim *CMOS Digital Integrated Circuits Analysis and Design*, 4th Edn., McGraw Hill, 2019
4. R. Jacob Baker, *CMOS Circuit Design, Layout, and Simulation*, 3rd edition, Wiley-IEEE Press, 2019
5. David A. Hodges, Horace G. Jackson, Resve Saleh, *Analysis and Design of Digital Integrated Circuits in Deep Submicron Technology*, 3rd Edn, McGraw Hill, 2004

EC2092E MICROCONTROLLER LAB

Pre-requisites: A first level course in Computer Organization and Processors

L	T	P	O	C
1	0	2	3	2

Total Sessions: 13L + 26P

Course Outcomes:

CO1: Build small electronic systems using 8051/MSP430 for given applications
CO2: Choose appropriate designs for managing constraints in different designs
CO3: Demonstrate the output of the design using technical reports
CO4: Develop the ability to work in professional teams

Embedded C programming using Keil Micro vision IDE, Interfacing external peripherals to 8051

MSP 430 pinout functional block diagram, memory map CPU peripheral overview clock generator interrupts Interfacing peripherals with MSP 430

Lab experiments need to be prepared as a standalone complete system so that students will get the experience of designing electronic systems for specific applications. Half of the experiments have to be designed using 8051 microcontrollers and the other half using MSP430.

Suggested Topics for Lab Sessions

1. Configuring GPIO pin as an output and drive a particular logic output through this pin
2. Configuring GPIO pin as an input and sense the state of the input pin
3. Use of Timer modules
4. Use of Interrupts
5. Analog signal interfacing
6. Interfacing of Relay/display devices/Motor drivers
7. Designing simple embedded systems

References:

1. Muhammed Ali Mazidi, Gillispie Mazidi, Rolin D Mc Kinlay, *The 8051 Microcontroller and Embedded Systems Using Assembly and C* , Second Edition ,2008 , Pearson Education
2. John Davies, *MSP 430 Microcontroller Basics*, Elsevier Publications,2008

EC3001E CONTROL SYSTEMS

Pre-requisites: A first level course in Signals and Systems

L	T	P	O	C
3	1*	0	5	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Deduce the model of a system using block diagram / system matrix and estimate its performance parameters
CO2: Analyse stability of systems using time domain and frequency domain methods
CO3: Design controllers for systems using time domain and frequency domain methods

Modeling of systems: Introduction to control systems - Open-loop and Closed-loop systems
Review of LTI systems - Transfer function- Poles and zeroes- Transient and Steady state response of First and Second Order systems for standard inputs.
Mathematical modelling of Electronic and Electro-mechanical systems - Block diagram reduction techniques - Signal flow graph - Mason's Rule - Analysis and design of feedback systems – Time domain performance parameters - Steady state error in unity feedback systems and types of systems- Response with addition of poles and zeros.
State Space representation - Relation between Laplace Transform and State Space Representation, Eigen values and poles - Time domain solution of state equations - Steady state error, Case studies using MATLAB.

Stability of systems: Concept of Stability – Open loop system Vs closed loop system. Routh-Hurwitz method – General and Special cases. Root locus method - Rules for plotting Root Locus - Pole sensitivity - Stability analysis. Bode plot method – Magnitude and phase plots - Gain margin and Phase margin, Stability analysis. Stability analysis in state space. Case studies using MATLAB

Controller design: Controller design using root locus – Design of Proportional (P), Proportional-Integral (PI), Proportional-Differential (PD), and PID controllers -Lag, lead, lag-lead compensators - Simple circuit realizations. Controller design using Bode plot, Controller design in state space using pole placement, controllability, Observability, Basic concepts of intelligent control systems- overview of techniques, Case studies using MATLAB

References:

1. Norman S.Nise, *Control Systems Engineering*, Eight Edition, John Wiley & Sons, 2019
2. Katsuhiko Ogata, *Modern Control, Engineering*, Fifth Edition, Prentice Hall, 2010
3. Farid Golnaraghi, Benjamin C. Kuo, *Automatic Control Systems*, Ninth Edition, Wiley, 2014
4. Pedro Ponce-Cruz, Fernando D. Ramírez-Figueroa, *Intelligent Control Systems with LabVIEW*, Springer, 2014

EC3002E DIGITAL SIGNAL PROCESSING

Pre-requisites: A first level course in Signals and Systems

L	T	P	O	C
3	0	2	7	4

Total Sessions: 39L + 26P

Course Outcomes:

CO1: Analyze the relations among time and Fourier domain representation of signals and systems and illustrate them using examples
CO2: Design and simulate fast algorithms for digital LTI system implementation
CO3: Design digital systems and evaluate them with reference to practical applications
CO4: Analyze and choose architectures to efficiently implement the DSP systems taking into consideration the practical aspects

Fourier analysis of discrete-time signals and systems: Basic elements of a DSP system, Review of Sampling and Quantization, Review of Discrete Fourier series, discrete time Fourier transform and discrete Fourier transform (DFT) – Properties of the transforms, Interpreting the DFT and approximation of Fourier transform through DFT. Fast algorithms for DFT computation: The Radix-2 DIT and DIF FFT algorithms and prime factor algorithms, Computation of inverse DFT using FFT algorithms - DSP system implementation using FFT algorithm - Overlap-save and overlap-add methods.

Digital filters: All pass and minimum phase systems - FIR Filters: Impulse response, transfer function, Linear phase properties - Design: window based design, frequency sampling design and minimax design. Introduction to IIR filters: Impulse response, Transfer function, Pole-zero representation- Structures for FIR and IIR filters - Direct form, cascade form and parallel structures - Lattice Structures.

Design of IIR filters and finite word length effects: Design from analog filters – analog Butterworth function for various frequency selective filters- analog to digital transformation - backward -difference and forward - difference approximations – impulse invariant transformation - bilinear transformation -prewarping - design examples. Introduction to Chebychev functions and design of low pass Chebychev filter. Finite word length effect in DSP: Fixed-point and floating-point DSP arithmetic, zero-input limit cycles in fixed point realizations of IIR digital filters-Limit cycles due to overflow.

Introduction to Multirate Signals and Systems: Multirate digital signal processing fundamentals: Decimation and interpolation - time and frequency domain analysis. Multirate structures and analysis.

Suggested List of Topics for Practical Sessions:

1. Generation of elementary signals (Unit impulse, Unit step, ramp, impulse train, pulse train etc.).
2. Plotting and visualising discrete representations of elementary signals. Study of sampling theorem and the effect of undersampling.
3. Study and implementation of convolution.
4. Study and implementation of block convolution using (a) Overlap Add method and (b) Overlap Save method
5. Spectral analysis of elementary signals by computing the Discrete Fourier Transform/ Fast Fourier Transform of signals
6. Study and implementation of FIR filter design using window method
7. Study and implementation of Infinite Impulse Response (IIR) filter
8. Study of finite word length effects in DSP systems
9. Study and implementation of a practical sampling rate converter
10. A Course project spanning 2 – 3 weeks based on the concepts learned in the laboratory to be implemented and demonstrated. The course faculty may give a list of feasible projects.

References:

1. John G. Proakis, Dimitris G. Manolakis, *Digital Signal Processing: Principles, Algorithms and Applications*, 4th Edition, Pearson India, 2007.
2. Oppenheim A. V., Schafer R. W, *Digital Signal Processing*, Pearson India, 2015.
3. Mitra S. K., *Digital Signal Processing: A Computer Based Approach*, McGraw-Hill Publishing Company, 2013.
4. Lonnie C. Ludeman, *Fundamentals of Digital Signal Processing*, Wiley India Pvt. Ltd., 2009.
5. Boaz Porat, A *Course in Digital Signal Processing*, Wiley India Pvt. Ltd., 2012.
6. Emmanuel C. Ifeacher, Barry W. Jervis, *Digital Signal Processing: A Practical Approach*, 2nd Edition, Pearson Education, 2004.

EC3003E COMMUNICATION ENGINEERING II

Pre-requisites: A first level course in Communication Engineering

L	T	P	O	C
3	1*	0	5	3

Total Lecture Sessions: 39

Course Outcomes

CO1: Analyze the fundamental limits on the error free representation of information signals
CO2: Analyze and design optimum digital communication receivers for additive white Gaussian noise channels
CO3: Develop a strong framework for the performance evaluation of baseband and passband digital communication systems under additive white Gaussian noise channels in terms of bit/symbol error probability and spectral efficiency
CO4: Analyze the fundamental limits on the transmission of information over a noisy communication channel.
CO5: Design channel encoders and decoders for a given error correction requirement.

Source coding: Block diagram of digital communication system, Information source, Discrete memoryless source, Entropy, Joint entropy, Conditional entropy, Relative entropy and Mutual information, Source coding, Fixed and variable length codes, Kraft inequality, Shannon’s source coding theorem, Huffman codes, Continuous source, Differential entropy.

Signal detection design and analysis: Signal Detection, AWGN channel, MAP/ML detection, optimal correlation receiver, probability of error, union bound and lower bound of probability of error, Power spectra of digitally modulated signal, Performance analysis of digital modulation schemes: error performance of coherent and noncoherent binary and Mary modulation schemes in AWGN channels, Channel capacity, Channel models, Symmetric Channels, Capacity, Shannon-Hartely theorem, Bandwidth-energy trade-off.

Channel coding: Shannon’s Channel Coding Theorem, Channel coding, Review of vector space, Generator matrix and parity check matrix, Linear block codes, Hamming code, Minimum distance decoding, Cyclic codes, Convolutional code, Viterbi decoding, Hard decision and soft decision decoding, Features of capacity achieving codes, Belief propagation decoding.

References:

1. Thomas M. Cover and Joy A. Thomas, *Elements of Information Theory*, Wiley India Pvt Ltd, 2nd Edition, 2013.
2. John G Proakis and M. Salehi, *Communication System Engineering*, Pearson Education, 2nd edition, 2001.
3. Upamanyu Madhow, *Fundamentals of Digital Communication*, Cambridge University Press, 1st edition, 2008.
4. Shu Lin and Daniel. J. Costello Jr., *Error Control Coding: Fundamentals and applications*, 2nd Edition, Pearson Education, 2010.
5. Ranjan Bose, *Information Theory, Coding and Cryptography*, 2nd Edition, McGraw Hill Education, 2008.
6. R. E. Blahut, *Theory and Practice of Error Control Codes*, Addison-Wesley, 1983.

EC3091E COMMUNICATION ENGINEERING LAB

Pre-requisites: A first level course in Communication Engineering

L	T	P	O	C
0	0	3	3	2

Course Outcomes:

CO1: Acquire the ability to design, implement, test and measure performance of modulation and demodulation for communication systems
CO2: Compare the theoretical and measured performance of communication systems
CO3: Acquire the capability to use new tools to effectively and creatively implement and evaluate communication systems
CO4: Develop the ability to work independently and also as a team member to achieve the targeted goals and objectives
CO5: Demonstrate skills for conducting oral presentations and writing good quality report on communication system design

Suggested Topics for Practical Sessions:

1. AM generation and envelope detection with simple and delayed AGC
2. Radio Frequency Amplifier/Mixer
3. FM modulation/demodulation using VCO/PLL
4. PAM generation and demodulation
5. Pulse code modulation
6. Time division multiplexing
7. Binary Frequency Shift Keying or Binary Frequency Shift Keying: Modulation and Demodulation
8. Quadrature PSK: Modulation and Demodulation
9. ISI and pulse shaping
10. Design and development of an L/S band power divider for a communication system
11. Design and development of a microstrp patch antenna for wireless communication
12. Bit/symbol error rate evaluation of digital modulation schemes such as BPSK, QPSK, BFSK
13. Linear block codes and Cyclic Codes: Encoder and decoder
14. Convolutional Encoder and Viterbi Decoder: Performance evaluation over AWGN channels

References:

1. L.W. Couch, *Digital and Analog Communication Systems*, 8/e, Pearson, 2013.
2. W. Tomasi, *Electronics Communication Systems: Fundamentals Through Advanced*, 5/e, Pearson, 2007
3. J. G. Proakis, M. Salehi, and G. Bauch, *Contemporary Communication Systems using MATLAB*, Cengage Learning, 3rd Edition, 2013.

EC3011E WIRELESS COMMUNICATION

Pre-requisites: First/Second level courses in Communication Engineering

L	T	P	O	C
2	0	2	5	3

Total Sessions: 26L + 26P

Course Outcomes:

CO1: Examine multiple access techniques and network dimensioning for wireless networks
CO2: Analyze effects of large-scale mobile radio propagation on wireless systems
CO3: Differentiate different types of wireless channels and their key parameters
CO4: Analyze effects of small-scale mobile radio propagation on wireless systems
CO5: Evaluate different diversity techniques for wireless communication with fading
CO6: Analyze wireless communication techniques for wideband channels, and explain their relevance in modern wireless systems

Cellular concept and wireless channel models: Cellular concept, TDMA, FDMA, CDMA, frequency reuse, co-channel interference, improving capacity in cellular systems, cell splitting, sectoring; Mobile radio propagation, free space propagation model, ground reflection model, large scale path loss, small scale fading and multipath propagation, impulse response model of a multipath channel; parameters of a mobile multipath channel, multipath delay spread, doppler spread, coherence bandwidth, coherence time, time dispersion and frequency selective fading, frequency dispersion and time selective fading.

Diversity techniques: Digital communication through fading multipath channels; frequency non-selective, slowly fading channels; frequency selective, slowly fading channels; calculation of error probabilities; tapped delay line model; the RAKE receiver performance; diversity techniques for mobile wireless radio systems concept of diversity branch and signal paths, combining methods, selective diversity combining, maximal ratio combining, beamforming, Alamouti scheme.

OFDM: Introduction to spread spectrum systems; Orthogonal frequency division multiplexing (OFDM), cyclic prefix, peak-to-average power ratio, OFDMA, single carrier FDMA, case study with LTE/LTE-advanced 4G/5G system.

Suggested Topics for Practical Sessions:

1. Simulate and study propagation models
2. Verification of theoretical performance of diversity
3. Implementation of OFDM generation and detection

References:

1. Rapport Thoedore S., *Wireless Communications, Principles and Practice*, 2nd Edition, Pearson, 2010.
2. David Tse and Pramod Viswanath, *Fundamentals of Wireless Communication*, Cambridge University Press, 2005.
3. Andrea Goldsmith, *Wireless Communications*, Cambridge University Press, 2005.
4. Haykin, S. and Moher M., *Modern Wireless Communications*, Prentice Hall, 2011.

EC3012E COMPUTER NETWORKS

Pre-requisites: A first level course in Programming

L	T	P	O	C
2	0	2	5	3

Total Sessions: 26L + 26P

Course Outcomes:

CO1: Describe the basic building blocks of a computer network and visualize the architecture of the global Internet
CO2: Analyze network protocols and algorithms to illustrate the basic principles on which they are designed
CO3: Evaluate performance of various network protocols, design and optimize protocols' parameters
CO4: Modify various existing network technologies for the design and development of more resource efficient network technologies in the future

Foundations and data link layer: Foundation: Building blocks- links, nodes - Layering and protocols - OSI architecture - Internet architecture - Multiplexing -Circuit switching vs packet switching - Datagram Networks - Implementing network software – socket programming Direct Link Networks: Framing - Error detection - Reliable transmission - Multiple access protocols – Ethernet (IEEE 802.3) - wireless LAN (IEEE 802.11) - LAN switches.

Network Layer and Transport Layer: Internetworking: IPv4- addressing, datagram forwarding – ARP - routing for mobile hosts - Global Internet- subnetting – CIDR. End to End protocols: Simple demultiplexer (UDP) - Reliable byte stream (TCP)- segment format, connection management, sliding window, flow control, adaptive retransmission, congestion control, TCP extension, performance.

QoS for Networking: Broadband services and QoS issues: Quality of Service issues in networks - Queuing Disciplines- Weighted Fair Queuing.

Suggested Topics for Practical Sessions:
1. Implementation of ping using socket programming
2. Implementation of web server using socket programming
3. Implementation of two user network chat program using socket programming
4. Implementation of web server with SSL security using socket programming

References:

1. Peterson L.L. & Davie B.S., *Computer Networks: A System Approach*, Elsevier, 6th edition, 2021.
2. James. F. Kurose and Keith. W. Ross, *Computer Networks, A top-down approach featuring the Internet*, Pearson Education, 8th edition, 2020.
3. D. Bertsekas and R. Gallager, *Data Networks*, PHI, 2nd edition, 2000.

EC3092E PROJECT

L	T	P	O	C
0	0	0	9	3

Course Outcomes:

CO1: Demonstrate sound technical knowledge in the domain of the selected project topic.
CO2: Develop the skills of independent and collaborative learning
CO3: Acquire the knowledge and awareness to carry out cost-effective and environmental friendly designs
CO4: Attain the expertise to use new tools for the design and development
CO5: Develop the ability to write good technical report and to make oral presentation of the work carried out

The major project represents the culmination of study towards the Bachelor of Technology (B. Tech.) degree. The major projects offer the opportunity to apply and extend knowledge acquired throughout the B. Tech. program. The major project can be analytical work, simulation, hardware design or a combination of these in the emerging areas of Electronics and Communication Engineering under the supervision of a faculty from the ECE Department. The specific project topic undertaken will reflect the common interests and expertise of the student(s) and supervisor. Students will be required to: 1) perform a literature search to review current knowledge and developments in the chosen technical area; 2) undertake detailed technical work in the chosen area using one or more of:

- analytical models
- computer simulations
- hardware implementation

The emphasis of major project shall be on facilitating student learning in technical, project management and presentation spheres. Project work can be carried out individually or by a group. The B. Tech. project evaluation committee of the department shall evaluate the project work in two phases. The first evaluation shall be conducted in the middle of the semester. This should be followed by the end-semester evaluation. Students are expected to complete the literature review, preliminary design, and learning of the analytical / software / hardware tools.

EC3093E TECHNICAL SEMINAR

L	T	P	O	C
0	0	3	3	2

Total Sessions: 39P

Course Outcomes:

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

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

EC4001E SUMMER INTERNSHIP

L	T	P	O	C
0	0	0	6	2

Course Outcomes:

CO1: Acquire the technical skills towards understanding requirements, defining scope and preparing deliverables for an industrial application..
CO2: Develop the soft skills towards effective communication, discussion and management of technical projects.
CO3: Analyse the work culture and processes of an organisation, and contribute to their improvement.
CO4: Prepare necessary documentation and presentation to describe the delivered work.

The aim of this course is to enable the students to integrate the theoretical concepts in the courses credited with the practice in the field. The objective of the course is to enable the students to develop work culture, attitudes, as well as, communication and interpersonal skills necessary for job success. The students are made proficient to make proper technical documentation on the work done. Moreover, the course would train the students to make effective technical presentations.

Detailed Syllabus

(Electives)

EC2021E OBJECT ORIENTED PROGRAMMING

Pre-requisites: A first level course in Programming

L	T	P	O	C
2	0	2	5	3

Total Sessions: 26L + 26P

Course Outcomes:

CO1: Introduce object oriented programming using C++ language
CO2: Understand the principles of data abstraction, inheritance and polymorphism
CO3: Apply the principles of virtual functions and polymorphism
CO4: Apply standard template library to efficiently and flexibly handle data in real world applications

Basics of C++ programming
C++ Program Structure, Character Set and Tokens, Data Type, Type Conversion, Preprocessor Directives, Namespace, Input/Output Streams and Manipulators, Dynamic Memory Allocation with new and delete, Control Statements.
Functions: Function Overloading, Inline Functions, Default Argument, Pass by Reference, Return by Reference, Scope and Storage Class.
Pointers: Pointer variables declaration & initialization, Operators in pointers, Pointers and Arrays, Pointer and Function.

Classes & Objects
Class and Objects: Accessing members of class, Initialization of class objects: (Constructor, Destructor), Default Constructor, Parameterized Constructor, Copy Constructor, The Default Copy Constructor, Objects as Function Arguments, Returning Objects from Functions, Structures and Classes, Memory allocation for Objects, Static members, Member functions defined outside the class.

Operator Overloading
Fundamental of operator overloading, Restriction on operator overloading, Operator functions as a class member, Overloading unary and binary operator, Data Conversion (basic to basic, basic to user-defined, user-defined to basic, user-defined to user-defined)

Inheritance
Introduction to inheritance, Derived Class and Base Class, Access Specifiers (private, protected, and public), Types of inheritance, Public and Private Inheritance, Constructor and Destructor in derived classes, Aggregation

Virtual Function, Polymorphism
Concept of Virtual functions, Late Binding, Abstract class and pure virtual functions, Virtual Destructors, Virtual base class, Friend function and Static function, Assignment and copy initialization, Copy constructor, This pointer, Concrete classes, Polymorphism and its roles.

Templates
Template: template classes, template functions.
Standard Template Library: Fundamental idea about string, iterators, hashes, iostreams and other types

References:
1. Robert Lafore, *Object-Oriented Programming with C++*, 3rd Edition, SAMS, 2002.
2. E Balagurusamy, *Object-Oriented Programming with C++*, 8th Edition, McGraw Hill Education, 2020.
3. Herbert Schildt, *C++: The Complete Reference*, 4thEdition, Tata McGraw Hill, 2002..

EC2022E DATA STRUCTURES

Pre-requisites: A first level course in Object Oriented Programming

L	T	P	O	C
2	0	2	5	3

Total Lecture Sessions: 26L + 26P

Course Outcomes:

CO1: Analyze the complexity of recursive algorithms by solving recurrence equations.
CO2: Develop solutions to problems modeled as trees and graphs
CO3: Implement fundamental data structures and algorithms using a high level programming language

Complexity analysis, asymptotic notation, Recursion Sorting algorithms, Insertion Sort, Selection Sort, Quick sort, Merge Sort, Searching Linear and Binary search implementation. Abstract data types -Linked lists, Stack and Queue. Implementation of sorting, searching, linked lists, stack and queues using C++

Binary tree - in-order, pre-order and post-order traversals – representation and evaluation of arithmetic expressions using binary tree, Binary Search trees - insertion, deletion and search- Prefix, Infix and Postfix representation and conversions -Heaps and heap sort, Priority Queues, Disjoint set data structures, Implementation of tree algorithms using C++

Graph Representation-Adjacency matrix, Adjacency lists- Depth First Search (DFS)-Breadth First Search (BFS), Minimum spanning tree problem – Kruskal's algorithm- Prim's algorithm Shortest path problem – Dijkstra's algorithm, Bellman Ford algorithm, Floyd Warshall algorithm. Implementation of graph algorithms using C++ and the Standard Template library. Hashing -chaining –linear probing –double hashin**g**

Suggested List of Topics for Practical Sessions:

1. Linear and Binary search implementations
2. Insertion sort, Selection sort, Quick sort and Merge Sort implementations
3. Stack and Queue implementation using arrays and linked list
4. Binary tree representation and tree traversal
5. Heap sort and priority queue implementation
6. Binary search tree - insert, delete and search.
7. Implementation of Graph algorithms

References:

1. D. Ravichandran, *Programming with C++*, Third Edition, McGraw Hill Education, 2017.
2. Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest, Clifford Stein, *Introduction to Algorithms*, Third Edition, MIT, 2009.
3. Yedidyah Langsam, Moshe J. Augenstein, Aaron M. Tanenbaum, *Data Structures using C++*, Pearson Education, 2016
4. Larry Nyhoff, ADTs, *Data Structures and Problem Solving with C++*, Second Edition, Pearson Education, 2012
5. Ellis Horowitz, Sartaj Sahni, Dinesh Mehta, *Fundamentals of Data Structures, in C++*, Second Edition, Universities Press, 2008.

EC2023E FOUNDATIONS OF DATA SCIENCE

L	T	P	O	C
2	0	2	5	3

Total Sessions: 26 L + 26 P

Course Outcomes:
CO1: Demonstrate ability to identify and integrate data of various types from a variety of sources, and make informed judgements about their use in data science research.
CO2: Critically evaluate the methodologies applied in data gathering, data processing and data exploration to disseminate findings using data visualization tools.
CO3: Apply different data science tools to create appropriate visualization of high dimensionality data, aligned to the student's area of interest.

Database for Data Science
Introduction to Data Science: Data, knowledge and information. Structured, semi-structured, and unstructured data – Database theory for data science – Relational database, primary key, secondary key– Database normal form: First normal form, second normal form, and third normal form–SQL database for structured data: adding/deleting/modifying tables, adding/deleting/modifying rows, searching and other essential operations–Semi-structured data: XML for semi-structured data, XML syntax and parsing XML using python–Big data: Characteristics of big data, Big data models: key value model, column model, document model, graph model. High level architecture of NoSQL systems.

Data Pre-processing
Data pre-processing: Introduction to Pandas in Python, Data cleaning and preparation: Duplicates, Missing data, transformation using a function/mapping, discretisation of data, errors and outliers – Data wrangling: Hierarchical indexing, combining and merging data, reshaping and pivoting – Data munging, Data cleaning – Quality of data, meta-data, Canonicalization, legal and ethical aspects.

Data Visualization
Introduction to data visualization – Visualization plots: Bar graph and pie charts, box plots, scatter plots and bubble charts, KDE plots – Introduction to data visualization libraries in Python: matplotlib, pandas and seaborn – Data transformation: Indexing, slicing, splitting, iterating, filtering, sorting, combining and reshaping – Introduction to data transformation libraries in Python: numpy and pandas – Exploratory data analytics: Univariate analytics, bivariate analytics and multi-variate analytics – Measures of central tendency and dispersion – Data aggregation, pivot tables and correlation – Scraping online/website data, Interactive visualization plots.

Suggested List of Topics for Practical Sessions:
1. Python Programming Basics
2. Normalizing a database to normal form
3. Creating, Querying and searching in SQL
4. Parsing XML in Python
5. Pandas: Data cleaning and wrangling
6. Matplotlib: Basic data visualization
7. Advanced data visualization using ggplot2 (plotnine)

References:
1. Meysman, A., Cielen, D. and Ali, M, *Introducing Data Science: Big data, machine learning, and more, using Python tools*, Manning Publishers, 2016.
2. C J Date, *Database Design and Relational Theory: Normal Forms and All That Jazz*, O′Reilly, 2012
3. Cathy Tanimura. *SQL for Data Analysis: Advanced Techniques for Transforming Data into Insights*, O′Reilly, 2021.
4. Deborah Nolan, *Duncan Temple Lang*, *XML and Web Technologies for Data Sciences with R*, Springer, 2014.

5. Andreas Meier, Michael Kaufmann. *SQL & NoSQL Databases: Models, Languages, Consistency Options and Architectures for Big Data Management*, Springer, 2019.
6. Andy Kirk, *Data Visualisation: A Handbook for Data Driven Design*, 2nd Edn., SAGE Publications Ltd, 2016.
7. Kyran Dale., *Data Visualization with Python and JavaScript: Scrape, Clean, Explore & Transform Your Data*, O′Reilly, 2016.
8. Abha Belorkar, Sharath Chandra Guntuku., *Interactive Data Visualization with Python: Present your data as an effective and compelling story*, 2nd Edn, Packt Publishing Limited, 2020.

EC2024E HARDWARE MODELLING USING HDL

Pre-requisites: A first level course in Digital Circuits and Systems

L	T	P	O	C
2	0	2	5	3

Total Sessions: 26L + 26P

Course Outcomes:

CO1: Understand the constructs of Hardware Description Language.
CO2: Design and describe digital systems at different levels of abstraction.
CO3: Develop reusable and synthesizable RTL code.

Introduction to Hardware Description Languages (HDL), VLSI design flow - Verilog/System Verilog constructs, datatypes, operators - Modules, ports, vectors - Structural and data flow modelling, hierarchical structure, testbenches, examples - Delay modeling - Behavioral modeling, procedural statements, timing control - Blocking and Non-blocking assignments - Combinational and sequential circuit modeling - Parameter and generate - task and function - File I/O.

Design of finite state machines, examples - Modeling FSM, memory - pipeline modeling - IP reuse and parameterized models - Clock generators - Introduction to synthesis - Logic synthesis - RTL synthesis - High-Level-Synthesis, Synthesis of combinational Logic - Synthesis of priority structures - Exploiting logical don't-care conditions, Synthesis of sequential logic with latches and flip-flops - Code optimizations and design examples - Programmable LSI techniques - PLA/PAL/PLDs - CPLD and FPGAs - Xilinx/Altera series FPGAs.

References:

1. Michel D. Ciletti, *Advanced digital design with the Verilog HDL*, Second Edition, Pearson, 2010.
2. Palnitkar S., *Verilog HDL: A guide to digital design and synthesis*, Prentice Hall; 2003.
3. Charles Roth, Lizy Kurian John, Byeong Kil Lee, *Digital systems design using Verilog*, First Edition, Cengage Learning, 2014.
4. Stuart Sutherland, Simon Davidmann, Peter Flake, *SystemVerilog for Design: A Guide to Using SystemVerilog for Hardware Design and Modeling*, Second Edition, Springer Science & Business Media, 2006.

EC2025E INTRODUCTION TO C PROGRAMMING

L	T	P	O	C
2	0	2	5	3

Total Sessions: 26L + 26P

Course Outcomes:
CO1: Demonstrate proficiency in solving real-world problems using procedural programming concepts in C.
CO2: Design and implement computer programs in C to address algorithmic challenges.
CO3: Apply principles of procedural programming for efficient code organization and modularity in C.
CO4: Evaluate and optimize the performance of C programs

Introduction to C Programming: Overview of C Programming, History and Significance, Comparison with Python, Setting Up the Environment, Installing a C compiler (e.g., GCC), Writing and compiling a simple "Hello, World!" program, Basic Syntax and Data Types, Variables and data types (int, float, char), Constants and literals, Arrays, Input and output using `printf` and `scanf, Control Flow, Conditional statements (if, else, switch), Looping constructs (for, while, do-while), break and continue.

Functions, Pointers, and File Handling: Functions in C, Function declaration and definition, Parameters and return values, Recursion, Pointers and Memory Management, Understanding pointers, Dynamic memory allocation (malloc, free), Pointer arithmetic- File Handling - Reading from and writing to files - File operations using `fopen`, `fclose`, `fread`, and `fwrite`- Structures and Unions - Defining and using structures - Unions and their applications

Advanced Concepts and Applications: Advanced Control Flow - Advanced looping constructs - Error handling with `try-catch` - Advanced Input/Output - File streaming and handling - Formatted input/output with `fprintf` and `fscanf`- Dynamic Memory Allocation - Memory allocation strategies - Multi-File Programming - Modular programming with multiple source files - Header files and compilation units.

References:

1. Kernighan, B. W., Ritchie, D. M. *The C Programming Language* 2nd Edn. Prentice Hall. 2015.
2. 2. Prata, S, *C Primer Plus* 6th Edn., Addison-Wesley, 2013.
3. 3. Perry, G., Miller, P, *C Programming for the Absolute Beginner*,3rd Edn., Que Publishing, 2013.

IE2001E INNOVATION AND ENTREPRENEURSHIP

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Taking up innovative projects and identifying novelty
CO2:Starting innovative practices in their entrepreneurial activities.
CO3:Involve themselves in the business activities like startups scientifically.
CO4:Understanding linking procedure and methods with other Institutions

Introduction to innovation and idea development: Introduction to Innovation, managing innovation, types of innovation, creativity, concept of design thinking, measuring innovation, Novelty -definition, identification- Protection of innovation - Introduction to Intellectual Property Rights – IPR, Patents, Trademarks, Copyrights, grassroots innovation, Issues and Challenges in Commercialization of Technology Innovations.

Entrepreneurship basics: scope of entrepreneurship, characteristics of an entrepreneur, building a business, business plan, concept of lean canvas model, Entrepreneurship and Innovations, Converting Innovation to Economic Value - Growth Strategies, value proposition, Market Segments, Revenue Model, Social Entrepreneurship, Intrapreneurship. Case studies- based on the area of specialization

Technology product development: Technology Life Cycle, how to implement and manage a technological innovation, new product development, managing the resources, technology business incubation, Sources of Information and schemes to support technology entrepreneurship.
Demonstration - based on the area of specialization

Functional areas of entrepreneurship: marketing management, operations management, personnel management, financial management, procedure and formalities in setting up an Industrial unit, Problems for Small Scale Enterprises and Industrial Sickness. Site visits to understand the Entrepreneurship activities of start ups

References:

1. Hisrich R D, Peters M P, "*Entrepreneurship*" 8th Edition, Tata McGraw-Hill, 2013
2. Holt David H., *Entrepreneurship: New Venture Creation*, Pearson Education, 2016
3. Debasish Biswas, Chanchal Dey, *Entrepreneurship Development in India*, 2021, Taylor & Francis
4. Tarek Khalil, *Management of Technology*, Tata McGraw-Hill
5. Barringer, B. R. *Entrepreneurship: Successfully launching new ventures*, Pearson Education India, 2015
6. Desai, Vasant, *Small-Scale Industries and Entrepreneurship*. Himalaya Publishing House, Delhi. 2008
7. Donald F. Kuratko, *Entrepreneurship: Theory, Process, Practice*. Cengage Learning India, Delhi, 2017
8. Cynthia, L. Greene. *Entrepreneurship Ideas in Action*. Thomson Asia Pvt. Ltd., Singapore. 2004

EC3021E ANALOG MOS INTEGRATED CIRCUITS

Pre-requisites: A first level course in Analog Circuits/equivalent

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Generate bias voltages and currents for various analog building blocks
CO2: Apply suitable device models to obtain circuit design parameters
CO3: Analyse and design single and multi-stage amplifiers
CO4: Make use of analog building blocks to realize dynamic, discrete-time and filter circuits

Components in CMOS process, Review of MOSFET operation, small signal and large signal models, Current sources and sinks, current mirrors, cascode connection, low voltage cascode current mirrors, biasing current mirrors, constant-Gm biasing, start-up circuits, self-biasing techniques (CTAT and PTAT), bandgap references - Review of single stage amplifiers - Design and simulation of single stage amplifiers

MOSFET noise sources, representation of noise in circuits, noise bandwidth, noise estimation in single stage amplifiers and cascaded stages - Single stage op amps, realizing buffer, folded cascode input stage, multi-stage amplifiers, systematic design of two-stage op amp, noise in multi-stage amplifiers – Output amplifiers, efficiency and distortion, push-pull configuration, low impedance output stages, buffered op amps, Operational transconductance amplifiers, unity gain frequency, Gm-C filters

MOSFET switch, charge injection and clock feedthrough, kT/C noise - Introduction to switched capacitor circuits, resistor emulation using switch, switched capacitor integrator, switched capacitor equivalents of continuous-time filters - Latched comparators, time constant, offset, CMOS transconductors using triode and active transistors, Random and systematic mismatch in CMOS process, circuit and layout techniques to reduce mismatch

References:

1. B. Razavi, *Design of Analog CMOS Integrated Circuit*, 2nd Edition McGraw Hill India, 2017
2. P. Allen and D. Holberg, *CMOS Analog Circuit Design*, 3rd Edition, Oxford University Press, 2013.
3. R. J. Baker, *CMOS Circuit Design, Layout and Simulation*, 3rd Edition, Wiley-Blackwell , 2010
4. T. C. Carusone, D. Johns and K. Martin, Analog Integrated Circuit Design, Second Edition, Wiley India 2014.

EC3022E ARCHITECTURE OF ADVANCED PROCESSORS

Pre-requisites: A first level course in Computer Architecture.

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39L

Course Outcomes:

CO1: Compare performance of various computer architectures using measurement parameters
CO2: propose methods to improve the performance of a processor while designing
CO3: Summarize the characteristics of RISC-V based processor design
CO4: Differentiate between uniprocessors and multiprocessors.

Review of computer architecture: Performance measure – Definition, Measurement, Parameters, Optimisation between power, speed and performance, Uniprocessor vs multiprocessor designs. From high level language to computer hardware, Parallelism, Pipe lining, Pipelined Datapath and Control, Control and Data Hazards, Forwarding and Stalling, Parallelism and Instructions, Parallelism and Memory Hierarchy, Memory technologies, Measuring and improving memory performance, Virtual machines, Virtual memory.

Introduction to RISC-V: History and motivation, RISC-V instruction set architecture (ISA), execution model and basic concepts, Assembly Language Programming, assembly language syntax and conventions, Basic instructions and addressing modes, Control flow instructions, Data transfer and manipulation instructions. RISC-V Pipeline Architecture. RISC-V Memory Hierarchy. RISC-V System Architecture - Interrupts and exceptions handling in RISC-V, Privilege levels and protection mechanisms, System calls and operating system interface interrupt controllers and device drivers. RISC-V Design and Implementation - design principles and methodologies for RISC-V processors, RISC-V Tools and Ecosystem - assemblers, compilers, and linkers, simulation and debugging tools, development boards and platforms, software development and debugging.

Parallel processors from client to cloud: Creating parallel processing programs, SISD, MIMD, SIMD, SPMD and vector, Hardware multithreading, Multicore and Other Shared Memory Multiprocessors, Graphics Processing Units, Clusters, Warehouse Scale Computers, and Other Message-Passing Multiprocessors, Multiprocessor Network Topologies, communicating to the Outside World: Cluster Networking, Multiprocessor Benchmarks and Performance Models.

References:

1. David A. Patterson, John L. Hennessy. *Computer Organization and Design RISC-V Edition: The Hardware Software Interface,* Morgan Kaufmann; first edition, 2018
2. Jim Ledin, *Modern Computer Architecture and Organization: Learn x86, ARM, and RISC-V architectures and the design of smartphones, PCs, and cloud servers*, Packt Publishing; first edition, 2020
3. RISC-V international, https://riscv.org/

EC3023E COMPUTER ORGANIZATION

Pre-requisites: A first level course in Digital Circuits and Systems

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Evaluate the performance of different designs of computer
CO2: Understand the abstractions and interfaces that are the building blocks of modern computer systems
CO3: Design the data path that satisfy requirements
CO4: Apply the concept of memory hierarchy for efficient memory organization

Basic functional blocks of a computer: Overview and history of computer, Basic functional block of computer-CPU, memory, input-output subsystems, control unit, Performance evaluation of computers.

Data Representation- signed number representation, fixed and floating point representations, character representation. Computer arithmetic - integer addition and subtraction, ripple carry adder, carry look-ahead adder, etc. multiplication - shift-and-add, Booth multiplier, carry save multiplier, etc. Division - non-restoring and restoring techniques, floating point arithmetic.

Instruction set architecture of a CPU - registers, instruction execution cycle, RTL interpretation of instructions, addressing modes, instruction set. Case study - instruction sets of some common CPUs.

Data Path and Control Design design: Hardwired and Microprogrammed design approaches, Processor Single Cycle, multi-cycle and pipelined architecture, Case study - design of a simple hypothetical CPU. Hazards- structural, data and control hazards etc., Performance Evaluation.

Memory system and Organization: semiconductor memory technologies, memory organization, Memory interleaving, concept of hierarchical memory organization, cache memory, cache size vs block size, mapping functions, replacement algorithms, write policy, performance evaluation of memory hierarchy

References:

1. John L. Hennessy David A. Patterson, *Computer organization & Design, Hardware software interface* ,5th Edition, Morgan Kaufmann Publisher
2. Behrooz Parhami, *Computer Architecture, form Microprocessor to Supercomputer,* Orford University Press
3. Jean-Loup Baer, *Microprocessor Architecture: From Simple Pipelines to Chip Multiprocessors,* Cambridge University Press

EC3024E DESIGN FOR ELECTROMAGNETIC COMPATIBILITY

Pre-requisites: A first level course in Electronic Circuits

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Summarize the importance of electromagnetic compatibility in electronic product design.
CO2: Analyse electronic circuits and identify different mechanisms of noise coupling in it
CO3:Examine different parts of an electronic product for probable EMC failures and propose methods to solve them
CO4: Choose suitable design techniques to develop EM compatible electronic products.

Need for Electromagnetic Compatibility, Emission Susceptibility, Radiation and Conduction aspects of EMC, EMC regulations, Noise and Interference, Typical Noise path, Methods of noise coupling ,Capacitive and Inductive Coupling, Shielding to prevent coupling,

Safety grounds, signal grounds, single point, multi-point and hybrid grounds, Chassis Grounds, Common Impedance Coupling, Grounding of cable shields, Ground loops and it's breaking

Digital circuit grounding, Digital circuit ground noise, minimizing ground impedance and loop area, ground grid, ground plane, Ground plane current distribution, ground plane impedance. Current flow in micro-strip and strip-line routing

Digital circuit power distribution- Transient power supply currents, decoupling capacitor design, effective decoupling strategies, decoupling capacitor selection and mounting

Radiated emission - Differential mode and common mode radiation – Reasons and controlling methods - Conducted emission – Power line impedance, Line impedance stabilization network, Common mode and differential mode noise sources in SMPS. Power line filters

PCB layout and stack up - General PCB layout Considerations, PCB to chassis ground connections, return path discontinuity, PCB layer stack up, General PCB design procedure, mixed signal PCB layout, Split planes, Ground connection and power distribution, vertical isolation - Electrostatic Discharge (ESD) -Static generation, human body model, static discharge, ESD protection in equipment design

References:

1. Henry W.Ott, *Electromagnetic Compatibility Engineering*, John Wiley & Sons, 2009.
2. Henry W.Ott, *Noise Reduction Techniques in Electronic Systems*, Second Edition, Wiley Interscience Publication, 1988.
3. Clayton R.Paul, *Introduction to Electromagnetic Compatibility*, Second Edition , Wiley Interscience Publication, 2006.
4. V. Prasad Kodali, *Engineering Electromagnetic Compatibility: Principles, Measurements, Technologies, and Computer Models,* Second Edition, IEEE Press, 2001.
5. Ralph Morrison, *Grounding and Shielding circuits and interference*, Fifth Edition, Wiley, 2007.

.

EC3025E ELECTRONIC INSTRUMENTATION

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Explain the basic measurement theory
CO2: Analyse the working of transducers, measurement circuits and signal conditioning circuits
CO3: Analyse the working of electronic instrumentation systems

Basics of measurement, Static characteristics, Dynamic characteristics, Error and error propagation, Calibration of instruments, Sensors and Transducers, Measurement of Strain, Vibration, Force, Pressure, Temperature, Light, Position, Velocity, Acceleration, Sensors with operational amplifier circuits

Bridge circuits for measurement of resistance, inductance, capacitance, Amplifiers, Operational amplifier based circuits, Chopper amplifier, Carrier amplifier, Lock-in amplifier, Filters, Wave shaping circuits, Oscillators, Data converters, DAC, ADC, Voltage to Frequency converter

Analog V/s Digital instruments, Electronic Voltmeters, Ammeters and Multimeters, Oscilloscopes, Signal Generators, Data Acquisition System, Basics of Electro-magnetic interference (EMI), Grounding and shielding, Probes, Connectors, IEEE-488 GPIB instruments

References:

1. Joseph J Carr, *Elements of Electronic Instrumentation and Measurement*, Third Edition, Pearson Education, 2011.
2. C S Rangan, G R Sharma, V S V Mani, *Instrumentation: Devices & Systems*, Second Edition, Tata McGraw-Hill, 2002.
3. Albert D Helfrick, William D Cooper, *Modern Electronic Instrumentation and Measurement Techniques*, First Edition, Pearson Education India, 2015.
4. Klaas B Klaassen, *Electronic Measurement and Instrumentation*, Cambridge University Press, 1996.

EC3026E EMBEDDED SYSTEMS

Pre-requisites: A first level course in Computer Architecture and Processors

L	T	P	O	C
2	0	2	5	3

Total Sessions: 26L + 26P

Course Outcomes:

CO1: Model embedded systems with appropriate hardware and software components
CO2: Analyze, program and use a typical ARM processor and its peripherals
CO3: Design and implement embedded systems using ARM Cortex based processors

Introduction to Embedded Systems: Application domain, General Structure, Modular approach of design, Figures of merit, Classification, Desirable features and History. CISC, RISC, Harvard, Von-Neumann Architectures. General aspects of embedded system hardware, Basics of embedded system design using microcontrollers, Clock, Reset types, Timers, Stacks, Interrupts, DMA, Communication protocols etc. Memory: SRAM, DRAM and Flash. Pullup, Pulldown and High Z connections, Introduction to sensors and actuators, Fundamentals of physical interfacing, Interfacing sensors and actuators with micro-controllers, Analog to Digital Converters, Digital to Analog Converters, Design examples of simple embedded systems, Software Development Tools: IDE, Compilers, Simulators.

Buses and protocols: Bus Arbitration, On Board Buses- I2C and SPI, Off Board buses –USB, CAN, AMBA, Ethernet, Wi-Fi, Zigbee and Bluetooth. Basics of power supplies: Linear regulators, switching regulators, Battery operated devices, Design consideration of power supply for embedded systems.

Microprocessors: The ARM Processor: History and architecture, ARM Assembly language-ARM Cortex processor – Register architecture, Instruction set, Clock sources and distribution, GPIO, Timer/counter, Watchdog timer, Stack, Interrupts, DMA and other peripherals. Programming and Design examples of embedded system using ARM Cortex based processors.

Introduction to applications of Embedded Systems in the modern era – IoT, Edge computing, Electric vehicles, Health care, Cyber physical systems etc.

Practical Sessions: Design and implementation of Embedded systems using ARM Cortex based processors – Interfacing of input devices like switch, LDR, IR sensor, Ultrasound sensors and output devices like LED, Relay, Motor etc. ADC interfacing, Waveform generation, Timer programming, Interrupts.

References:

1. Lyla B.Das., *Embedded Systems-an integrated approach*, Pearson Education, 2013.
2. John Catsoulis, *Designing Embedded Hardware*, 2nd Edn, Shroff Publishers and Distributors, 2006.
3. Wayne Wolfe, *Computers as Components*, 2nd Edn, Morgan Kaufmann, 2011.
4. Ganssle J, Noergaard T, Eady F, Edwards L, Katz DJ, Gentile R, Arnold K, Hyder K, Perrin B., *Embedded Hardware: Know It All*, 1st Edn, Newnes, Elsevier Publications, 2007.
5. Jonathan W Valvano, *Embedded Systems: Introduction to ARM Cortex-M Microcontrollers*, 5th Edn, 6th printing- January 2019.

EC3027E HIGH SPEED DIGITAL CIRCUITS

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Recognize various parameters which decides the high-speed behavior of electronic systems
CO2: Evaluate transmission line behavior of interconnects in high-speed circuits
CO3: Identify noise sources in a digital system and design low noise systems
CO4: Design Power and Clock distribution lines for high-speed applications.

Frequency, Time and Distance, Lumped and Distributed Systems, 3-dB and RMS frequencies, Capacitance, Inductance, Mutual Capacitance, Mutual Inductance. Measurement of high-speed signals, Power, Speed and Performance.

Transmission Lines, Interconnect Modelling, Effects of source and load impedances, Line impedance and propagation delay, Terminations. Cross talk, signal integrity, General aspects of PCB design for high-speed circuits. Using connectors in high-speed applications. Cables.

Power supply Distribution – Providing stable voltage reference, distributing uniform voltages, IR drop, bypass capacitors, regulators, power supply isolation
Noise sources in digital system – Noise budgeting and SNR

Timing properties of clocked systems, clock distribution, Timing margin, clock skew, jitter, clock Terminations, impedances of clock driver and distribution line, Synchronisation failure and metastability, probability of synchronization failure.

References:

1. H W Johnson, Martin Graham, *High Speed Digital Design – A handbook of black magic*, Pearson India, 2003
2. William J Dally, John W Poulton, *Digital Systems Engineering*, Cambridge University Press, 2008
3. Stephen H. Hall, Garrett W. Hall, James A. McCall, *High-Speed Digital System Design - A Handbook of Interconnect Theory and Design Practices*, John Wiley & Sons, 2014
4. Stephen H. Hall, Howard L. Heck, *Advanced Signal Integrity for High-Speed Digital Designs*, John Wiley and Sons, 2009

EC3028E INTERNET OF THINGS

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Develop market perspective view of internet-of-things (IoT) systems and understand its architectural features.
CO2: Explore and apply the techniques on sensing, actuation, embedded system, networking, and data analysis pertaining to IoT systems.
CO3: Capable to analyse typical IoT based systems for Smart City, Smart Transportation, Smart Manufacturing, and Smart Healthcare.
CO4: Apply acquired skills to design and implement prototype IoT systems based on given requirements.

Design Principles of Internet-of-Things:
Introduction to internet-of-things (IoT), What is IoT, impact of IoT, IoT challenges, Market perspective of IoT based systems, Introduction, machine-to-machine (M2M) value chains, IoT value chains, an emerging industrial structure for IoT, An Architectural overview IoT systems, Building an architecture, main design principles, an IoT architecture outline, standards considerations, Basics of networking, data management, business processes in IoT, everything as a service(XaaS), M2M and IoT Analytics, knowledge management.

Components of Internet-of-Things:
IoT system design, Components of an IoT system, Sensors, actuators, smart objects, sensor networks and communicating with smart objects, communication criteria, basics of IoT access technologies, Wireless Hart, mZ-Wave, Bluetooth Low Energy, Zigbee Smart Energy, NB-IoT, basics of network layer and transport layer design aspects, Security in IoT protocols, Application Layer, Data and Analytics for IoT, IoT Middleware, Data analytics for IoT, Big Data analytics tools and technology.

Internet-of-Things for Practical Applications:
Some example IoT hardware platforms, Basic architecture, interfacing sensors and actuators, programming aspects, interfacing to external devices, design of simple IoT systems, Introduction to software defined networking (SDN), SDN for IoT, Basics of cloud computing, Sensor cloud, Fog computing, IoT application case study, Smart City, Smart Transportation, Smart Manufacturing, and Smart Healthcare.

References:

1. M. Jan Holler, et al., *From Machine-to-Machine to the Internet of Things: Introduction to a New Age of Intelligence*, 1st Edition, Academic Press, 2014.
2. A. Bagha, V. Madisetti, *Internet of Things ,A hands on approach*, Universities Press 2015
3. D. Hanes, G. Salgueiro, P. Grossetete, R. Barton, J. Henry; *IoT Fundamentals: Networking Technologies, Protocols, and Use Cases for the Internet of Things*, 1st Edition, Pearson India Pvt. Ltd., 2018.
4. P. Raj, A. C. Raman, The Internet of Things: Enabling Technologies, Platforms, and Use Cases, CRC press, 2017
5. Y. Kanetkar, S. Korde*; 21 Internet of Things (IOT) Experiments: Learn IoT, the programmer's way*, 1st Edition, BPB Publications, 2018.
6. Relevant research articles

EC3029E MICRO-NANO FABRICATION

Pre-requisites: A first level course in Semiconductor Devices

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Explain various semiconductor materials used in device fabrication.
CO2: Identify and analyse various unit processes involved in IC fabrication
CO3: Evaluate fabricated devices effectively in terms of various performance parameters.
CO4: Build an idea on process integration – NMOS, CMOS and Bipolar process.

Unit Processes I:

Brief history of Semiconductor technology, Moore's Law, Scaling trends and Scaling methodologies, Scaling challenges, ITRS Roadmap. Crystal growth techniques, Epitaxy, Clean room and Safety requirements. Oxidation: Kinetics of Silicon dioxide growth both for thick, thin and ultra-thin films, Deal-Grove model. Diffusion process, Ion implantation, modeling of Ion implantation, statistics of ion implantation, Annealing.

Unit Processes II:

Deposition & Growth: Various Deposition techniques: Physical Vapor Deposition and Chemical Vapor Deposition, Evaporation, Sputtering, Spin coating, Different kinds of CVD techniques: APCVD, LPCVD, Metal-organic CVD, Plasma Enhanced CVD etc. Etching Techniques: Anisotropy, Selectivity, Wet Etching, Plasma Etching, Reactive Ion Etching, Photolithography: Light sources, Wafer exposure systems, Photoresists, Mask design. Advanced Lithography: E-beam Lithography, X-ray Lithography, Ion Beam Lithography, Immersion lithography.

Process Integration:

Planarization Techniques: Need for planarization, Chemical Mechanical Polishing, Interconnections and contacts, Copper damascene process, Multi-level metallization schemes, Process integration-NMOS and CMOS, Overview of advanced technologies (SOI MOSFETs, Strained Si, Silicon-Germanium MOS, High K, Double gate MOSFETs, FinFETs, Gate All Around (GAA) etc.).

References:

1. James Plummer, M. Deal and P.Griffin, *Silicon VLSI Technology*, Prentice Hall Electronics, 2010
2. S.M. Sze, *Stephen Campbell, The Science and Engineering of Microelectronics*, Oxford University Press, 2001.
3. S.K. Ghandhi, *VLSI Fabrication Principles*, John Wiley Inc, New York, 2008
4. Peer reviewed international journals from IEEE Electronic Device Letters, IEEE Transactions on Electron Devices, IEEE Transactions on Nanotechnology etc.

EC3030E VLSI TESTING

Pre-requisites: A first level course in Digital Circuits and Systems

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Apply different methods to find test patterns to identify the faults in a circuit.
CO2: Develop testable designs using DFT techniques.
CO3: Design BIST circuits for logic and memory testing.

Introduction to digital VLSI testing, challenges - Faults in digital circuits - Fault models, stuck-at-faults - Fault collapsing, fault equivalence, fault dominance, logic and fault simulation - Test pattern generation, fault coverage - Testability measures.

Design For Testability (DFT), Testability analysis, Scan design rules, tests, architectures - Scan chain, partial scan, full scan, - Boundary scan standard, scan cell - Test access port, controller, instructions - Board level testing using boundary scan.

Built In Self Test (BIST), design rules - Exhaustive testing, Pseudo-random testing, Pseudo-exhaustive testing - LFSR design for testing circuits, SISR, MISR - Memory BIST – Type of memory faults, Fault modeling, Fault detection by MARCH tests.

References:

1. Bushnell M, Agrawal V., *Essentials of electronic testing for digital, memory and mixed-signal VLSI circuits*, Springer Science & Business Media, 2013.
2. Wang Laung-Terng, Cheng-Wen Wu, and Xiaoqing Wen, *VLSI test principles and architectures: design for testability,* Academic Press, 2006.
3. N. Jha & S.D. Gupta, *Testing of Digital Systems*, Cambridge, 2003.
4. Abramovici Miron, M. A. Breuer and A. D. Friedman, *Digital Systems testing and testable design*, Computer Science Press, 1990.

EC3031E NANOELECTRONICS

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Illustrate the challenges faced by present CMOS VLSI device design
CO2: Analyse the transport phenomenon in nanotransistors
CO3: Examine various novel transistor structures

Scaling laws, Short channel effects, Tunneling in Oxide layer, Issues with gate layer, Fundamental limits for MOS operation, Remedial measures in current MOSFET fabrication technology

Review of basic semiconductor physics, Energy band diagram and electrostatics of bulk transistors, Velocity saturated transistors, Ballistic transport, Landauer model, Virtual source model, Transmission model

Strained silicon transistor, Silicon on Insulator (SOI) transistor, FinFET, Heterostructure transistor, Nanoparticles, Nanowires and Nanotubes, Resonant tunneling devices, Single electron transistors, Simulation of semiconductor devices

References:

1. Jan M Rabaey, *Digital Integrated Circuits - A Design Perspective*, Prentice Hall, 2nd Edition, 2005.
2. Robert F Pierret, *Semiconductor Device Fundamentals*, 1st edition, Pearson, 2006.
3. Mark Lundstrom, *Fundamentals of Nanotransistors: Lessons from Nanoscience* - Lecture note series Vol 6, First edition, World Scientific Press, 2017.
4. Mark Lundstrom, *Fundamentals of carrier transport*, Second edition, Cambridge University Press, 2009.
5. George W Hanson, *Fundamentals of Nanoelectronics*, First edition, Pearson Education India, 2009.
6. Vladimir V Mitin, Viatcheslav A Kochelap, Micheal A Stroscio, *Introduction to Nanoelectronics: Science, Nanotechnology, Engineering and Application*, First Edition, Cambridge University Press, 2007.
7. Mircea Dragoman, Daniela Dragoman, *Nanoelectronics: Principles and Devices*, Second Edition, Artech House Publishers, 2008.

EC3032E RF INTEGRATED CIRCUITS

Pre-requisites: A first level course in Analog Circuits

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Estimate the circuit/system-level performance parameters of an RF transceiver system
CO2: Analyse and compare the circuit/architectural design choices of RF systems
CO3: Design and simulate RF sub circuits

Review of communication systems and modulation schemes, Transceiver architectures, filters in transceivers-System-level design parameters: nonlinearity and distortion, noise figure, representation of noise in circuits, sensitivity, dynamic range, impedance transformation and impedance matching-Scattering parameters, RF components in CMOS technology, High frequency MOSFET models, bandwidth estimation and enhancement techniques

Low noise amplifiers: narrow band and wide band LNA configurations, LNA circuits in short channel regime, differential LNAs, Noise and reactance cancelling LNAs, Gain and band switching, SPICE simulation of LNA circuits, Up conversion and down conversion mixers, Performance parameters: conversion gain, noise figure and linearity

Review of oscillator fundamentals, ring and LC oscillators, voltage controlled oscillators, tuning in oscillators, noise in oscillators, VCO phase noise, Frequency synthesizers, Power amplifiers: classifications, efficiency, modulation of power amplifiers, linearization techniques-Layout techniques for RF circuits, Design and simulation of oscillator circuits

References:

1. Behzad Razavi, *RF Microelectronics*, 2nd Edition, Prentice Hall, 2012.
2. Thomas H Lee, *The Design of CMOS Radio-Frequency Integrated Circuits*, 2nd Edition, Cambridge University Press, 2004
3. Bosco Leung and Charles G. Sodhini, *VLSI for Wireless Communication*, Pearson Education 2009.
4. Hooman Darabi, *Radio Frequency Integrated Circuits & Systems*, Cambridge University Press, 2015.

EC3033E SEMICONDUCTOR DEVICE MODELLING

Pre-requisites: First level course on Semiconductor Devices

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Analyze the basic equations governing the physics of semiconductor devices.
CO2: Modeling of the MOS Capacitor and MOSFETs
CO3: Analyze and model small dimension effects in modern MOSFETs
CO4: Apply modeling skills to improve MOS device performance

Foundations of Semiconductor Modeling: Introduction to modelling, Different approaches of modelling, Equilibrium carrier concentration, Band gap narrowing, Incomplete ionization of impurities, Excess carriers and carrier transport, Traps and defects, Generation-recombination models, Schottky Contacts, tunneling models

MOS Capacitor Modeling: MOS Capacitor, Contact potentials, Insulator charges, Flat band voltage, Potential Balance and charge Balance, Effect of gate body voltage on MOS surface conditions, Small signal capacitance, Body effect

MOSFET Modeling: MOSFET, Regions of operation, Complete all region model, Strong inversion, weak inversion and moderate inversion, Effective mobility, Temperature effects, Modeling of Advanced MOSFETs

Small Dimension Effects: Small channel and thin oxide effects, Carrier velocity saturation, Channel length modulation, Charge sharing, Drain induced barrier lowering, Punch through, Hot carrier effects, Polysilicon depletion, Quantum mechanical effects, Junction leakages, Scaling

References:
5. Y. Tsividis and Colin McAndrew, *The MOS Transistor*, 3rd Edition, Oxford University Press, 2013.
6. Narain Arora, *MOSFET modeling for VLSI simulation: Theory and Practice*, World Scientific, 2007.
7. Yuan Taur and Tak H Ning, *Fundamentals of Modern VLSI Devices*, Cambridge University Press, 2013.
8. C. C. Hu, *Modern Semiconductor Devices for Integrated Circuits*, Pearson, 2010
9. A. B. Bhattacharya, *Compact MOSFET Models for VLSI Design*, John Wiley, 2009
10. Research articles and technical reports in the area of semiconductor device fabrication and modeling
11. Silvaco, *ATLAS User's Manual-Device simulation software*, Santa Clara, 2022.
12. Synopsys Sentaurus Device User Guide, Version S-2021.06, June 2021

EC3034E SENSORS: DESIGN AND FABRICATION

Pre-requisites: A first level course in Micro-Nano Fabrication

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Gain knowledge of basic approaches for various MEMS sensors and actuators design. (Cognitive understanding)
CO2: Capability to critically analyze microsystems technology for technical feasibility as well as practicality. (Affective- Evaluate)
CO3: Develop efficient MEMS design for improving device performance in terms of speed, sensitivity, Selectivity and accuracy. (Skills- Create)
CO4: Design and analysis of efficient MEMS sensors and actuators . (Skills- Analyze)

MEMS Materials and Micromachining Technology: The History of MEMS Development, Nano and Microelectromechanical Systems and Applications. Materials for MEMS and NEMS devices. Review of Electrical and Engineering Mechanics for Micro/Nanosystems Design - Stress and strain analysis, beam bending theory, types of beams, cantilevers, membranes, and plates. Overview of fabrication process for VLSI devices, MEMS fabrication micromachining technologies, Assembly of 3D MEMS – Foundry process.

Piezoresistive sensors : Piezoresistive sensor materials, Stress analysis of mechanical elements, Design of cantilevers and Membranes Piezoresistive sensor, Applications to Inertia, Accelerometers, Tactile and Flow sensors. Electrostatic Sensing and Actuation- Design parallel plate Capacitive and Comb drive actuators, Pull-in Effect, Applications to Inertia, Pressure, Tactile and Flow sensors, MEMS RF switches.Thermal actuators- Fundamentals of thermal transfer, Thermal bimorph principle, Thermal Couples, and resistors & their applications.

Piezoelectric sensors and actuators: piezoelectric effects – piezoelectric materials – Applications to Inertia, Acoustic, Tactile and Flow sensors, Microphone, Micro speaker, Nanogenerator, RF resonator, Acoustic wave sensors, SAW filter. Magnetic Actuation- Fabrication of Micro Magnetic Components, Case Studies of MEMS Magnetic Actuators. Bio-MEMS- Chemoresistors, Chemocapacitors, Chemotransistors, Electronic nose (E-nose). Basic Fluid Mechanics Concepts, Microfluidics Applications. Case Studies- Gyros.

MEMS device Calibration and packaging techniques: Device Design Considerations, Packaging and yield -Types of packaging, Hermetic or Nonhermetic Packaging, Wafer Dicing, Wafer Bonding, Reliability Market Uncertainties, Investment, and Competition. MEMS software- COMSOL & Intellisuite. AI Applications in the MEMS Manufacturing and Design Process.

References

1. Chang Liu, *Foundations of MEMS*, Prentice Hall (2006)
2. Tai Ran Hsu , *MEMS and Microsystems Design and Manufacture*,Tata McGraw Hill, (2002).
3. Albert Folch, *Introduction to BioMEMS* CRC (2012)
4. Edward Lyshevski, *MEMS and NEMS: Systems, Devices, and Structures*, CRC Press, (2002)

EC3035E DESIGN WITH OP-AMPS AND ANALOG ICS

Pre-requisites: A first level course in Analog Circuits

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Analyse op-amp based analog and mixed signal circuits.
CO2: Design analog filters and realize them using operational amplifier based simple filter circuits.
CO3: Design circuits and systems using operational amplifiers and analog integrated circuits.

Op-Amp Circuits

Various stages of an operational amplifier - typical op-amp parameters: slew rate, CMRR, PSRR, open loop gain, unity gain bandwidth, offset current & offset voltage, Effect of practical op-amp parameters on the performance of op-amp linear circuits - voltage to current converter, current to voltage converter - nonlinear op-amp circuits: rectifiers, clippers, clampers, comparators, astable and mono-stable circuits, triangular waveform generator, linear sweep circuits, oscillators, log and antilog amplifiers, multipliers and dividers

Analog Filter Design

Approximations to ideal low pass filter characteristics - normalized pole locations of Butterworth approximation, filter specifications, estimation of filter order from specifications, normalized filter transfer functions for cascaded realization, de-normalization, design of cascaded section -frequency transformations to obtain HPF, BPF and BEF from normalized prototype LPF

Active Filters

Review of filter characteristics, shortcomings of RC filters for higher order filters, active filter design, design of first order filter from the locations of pole and zero, second order Sallen key LPF and HPF, BPF and BEF realizations, universal active filter - all pass filter (first & second orders) realizations - inductance simulation using Antoniou's gyrator – Switched capacitor filter

DACs and ADCs

Digital to analog converters - binary weighted - R-2R ladder - current steering - charge scaling, - accuracy - resolution - conversion speed - offset and gain error-Analog to digital converters –flash, staircase, successive approximation and dual slope ADCs

Voltage Regulators

Linear voltage regulators, series and shunt configurations, Low dropout regulators (LDOs), DC-DC converters, Buck, Boost converters, Selection of components in the power stage and control stage, Voltage Regulator ICs

References:

1. Sergio Franco, *Design with Operational Amplifiers and Analog Integrated Circuits*, McGraw Hill Education; 3rd edition, 2017
2. S. Sedra, K C Smith, *Microelectronic Circuits*, 7th Edn., Oxford University Press. 2017.
3. D. A. Neamen, *Electronic Circuit Analysis and Design*, 3rd Edn., McGraw-Hill India, 2006.
4. Schaumann, Rolf, Haiqiao Xiao, and Van Valkenburg Mac. *Design of analog filters* Indian Edition 2/e. Oxford University Press., 2013.
5. R. J. Baker, CMOS *Circuit Design, Layout and Simulation*, Wiley India Pvt Ltd, 2009

EC3036E COMPOUND SEMICONDUCTOR DEVICES

Pre-requisites: A first level course in Semiconductor Devices

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Interpret important parameters governing the high speed performance of devices and circuits
CO2: Model the properties of Hetero junctions from the energy band diagram point of view
CO3: Model the Physics and operation and modeling of MESFETs
CO4: Interpret the operation and performance parameters of HEMT, HBTs and Optoelectronics Devices

Basic Properties of Compound Semiconductor
Important parameters governing the high speed performance of devices and circuits: Transit time of charge carriers, junction capacitances, ON-resistances and their dependence on the device geometry and size, carrier mobility, doping concentration and temperature. Materials properties of III –V binary and ternary compound semiconductors (GaAs, InP, InGaAs, AlGaAs, SiC, GaN etc.), different SiC structures, and silicon carbide for high speed devices. Energy Band diagrams for homo and hetero junctions.

Metal Semiconductor related parameters and device
Metal semiconductor contacts and Metal Insulator Semiconductor and MOS devices: Native oxides of Compound semiconductors for MOS devices and the interface state density related issues. Metal semiconductor Field Effect Transistors (MESFETs): Basic features, Pinch off voltage and threshold voltage.

HEMT, HBTs and Optoelectronics Devices
High Electron Mobility Transistors (HEMT): Principle of operation and the unique features of HEMT. Hetero junction Bipolar transistors (HBTs): Principle of operation and the benefits of hetero junction BJT for high speed applications. Optoelectronic Devices: Basic working principles and performance parameters of LED, Photodetectors and Solar Cell.

References:

1. Robert F. Pierret, *Semiconductor Device Fundamentals*, Addison-Wesley 1996.
2. S. M. Sze, *High-Speed Semiconductor Devices*, Wiley, 1990.
3. B. J. Baliga, *Gallium Nitride and Silicon Carbide Power Devices*, World Scientific, 2017.
4. Sandip Tiwari, *Compound Semiconductor Device Physics*, Academic Press, 1992.
5. Avishay Katz, *Indium Phosphide and Related materials: Processing, Technology and Devices*, Artech House, 1992.

EC3037E POWER SEMICONDUCTOR DEVICES

Pre-requisites: A first level course in Semiconductor Devices

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Analyze and model the physics of Silicon power semiconductor devicesCO2: Design edge termination structures to improve the breakdown voltage.
CO3: Analyze the trade-offs in the design of power semiconductor devices.
CO4: Interpret the physics of wide band gap material devices and their use in high power semiconductor applications.

Avalanche breakdown voltage of planar pn junctions, Dependence of breakdown voltage on drift layer doping and thickness, On resistance, Edge termination techniques to Improve breakdown voltage, floating field rings, junction termination extension, field plates, design trade offs

Power MOSFETs, V Groove (V) MOSFET, U Groove (U)MOSFET and Vertical double diffused (VD) MOSFET, VD MOSFET process, cellular design, IV characteristics, On resistance components, break down voltage ,design considerations ,safe operating area, edge termination of VDMOSFETs , Lateral double diffused (LD) MOSFET , Power BJT, Blocking characteristics , IGBT, device operation ,equivalent circuit ,characteristics.

Gallium Nitride (GaN) and Silicon Carbide (SiC) Power devices, Advantage of wide band gap materials, Wide band gap material physics, Various GaN/SiC devices, Polytypes of SiC, SiC Double implanted (D) MOSFET , on resistance components, break down voltage , GaN/SiC device manufacturing technology

References:

1. B. J. Baliga, *Gallium Nitride and Silicon Carbide Power Devices*, World Scientific, 2017.
2. Hongyu Yu , Tianli Duan, *Gallium Nitride Power Devices*, Pan Stanford 1e, 2017.
3. B. J. Baliga, *Power Semiconductor Devices*, PWS Publishing Co., Boston, 1996.
4. Benda, Vitezslav, John Gowar, and Duncan A. Grant, Chichester, *Power semiconductor devices: theory and applications*, New York Wiley, 1999.
6. Research articles and technical reports in the area of power semiconductor device fabrication and modeling

EC3038E FLEXIBLE ELECTRONICS

Pre-requisites: A first level course in Semiconductor Devices

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Understand the electronic transport in non-crystalline semiconductors
CO2: Analyze the device physics of thin film transistors and assess its performance in comparison to CMOS technology
CO3: Analyze and design various circuit building block using TFTs

Non-crystalline semiconductors : Review of semiconductor device physics, MOSFET theory. Introduction to flexible and large area electronics, Various types of free form electronics: Bendable, Stretchable, Printed, Hybrid electronics. Stretchable interconnects. Introduction to non-crystalline semiconductors: Crystal structure, Band structure and electronic transport, Comparison with c-Si. Different material technologies: AOS, 2D materials. Mechanical behaviour of thin films under bending.

Thin film transistors and circuits : Introduction to thin film transistors (TFTs): Different TFT configurations, Density of States, Device physics, Current conduction mechanisms, Mobility model, Threshold voltage shift, Issues in TFTs and methods to address the limitations. TFT circuits: TFT as a switch, diode connected transistor, single stage amplifiers, current mirrors, Digital inverters, Logic gates. Compensation circuits for threshold voltage shift. Verilog-A modeling of TFT characteristics, Spice Simulation of TFT circuits.

Applications of TFTs : Large area electronic systems: displays, sensors – Design considerations. Applications of TFTs in neural networks: Basics of Neuromorphic computing, Artificial synapse: definition, basic synaptic properties. Implementation of neural networks using TFTs as artificial synapses. Case studies based on applications in areas such as Consumer electronics, wearable sensors, prosthetics, medical implants, E-skin, defense and aerospace, soft robotics, energy management etc.

References:

1. Sanjiv Sambandan, *Circuit Design Techniques for Non-crystalline semiconductors*, CRC Press, 2013.
2. S. D. Brotherton, *Introduction to Thin Film Transistors: Physics and Technology of TFTs*, Springer, 2013.
3. Alberto Salleo, William S. Wong, *Flexible Electronics-Materials and Applications*, Springer, 2009.
4. Cherie R. Kagan, Paul Andry, *Thin-Film Transistors*, 1st ed, CRC Press, 2003.
5. Reza Chaji and Arokia Nathan, *Thin Film Transistor Circuits and Systems*, Cambridge University Press, 2013.
6. Vinod Kumar Khanna, *Flexible Electronics*, Volume1 – Mechanical background, materials and manufacturing, IOP Publishing, 2019.
7. Research articles in relevant peer reviewed international journals such as IEEE Transactions on Electron Devices, IEEE Electron Device Letters etc.

EC3039E RF COMPUTATIONAL LAB

L	T	P	O	C
1	0	3	5	3

Total Sessions: 13L + 39P

Course Outcomes:

CO1: Develop the basic skills to design and simulate microwave passive circuits in the EM-simulation tool.
CO2: Develop the basic skills to analyse the characteristics of design using S-parameters.
CO3: Develop the skills to fabricate a prototype device and measure the devices using VNA and measurement.

Basic functionality of various RF microwave components – Waveguide (Rectangular and circular), Microstrip line and others transmission lines, Smith Chart, Familiarisation of Vector Network Analyser (VNA).

Filters: lumped element filter (Low-pass Filter, High-pass Filter, bandpass Filter, bandstop Filter), Kruda's identities, stepped low-pass filter and all open stub low-pass filters, microstrip bandpass filter and band stop filter

Couplers: Branch line coupler, rate-race coupler, Power combiner and splitter: Equal and unequal; power combiner and splitter, Wilkinson power divider.

Antenna: Micro-strip patch antenna and antenna's applications as a sensor.

Fabrication of the prototype of the device.

Suggested Topics for Practical Sessions:

1. Familiarisation of Vector Network Analyser (VNA) and calibrations of VNA.
2. Design and simulation of different transmission lines (waveguides (rectangular, circular), 50Ω-microstrip line)
3. Design and simulation of 5^{th} order low-pass filter in stepped impedance and all open stub configuration.
4. Design and simulation of branch line coupler.
5. Design and simulation of Wilkinson equal power divider.
6. Design and simulation of rate-race coupler.
7. Design and simulation of microstrip rectangular, and circular patch antenna with different feeding.
8. Design a matching network to match arbitrary load impedance to 50Ω impedance.
9. Project.

References:

1. Pozar, D.M., "*Microwave Engineering*", 4th Ed., John Wiley & Sons. 2012.
2. Ludwig, R. and Bogdanov, G., "*RF Circuit Design: Theory and Applications*", 2nd Ed, Pearson Education, 2011.
3. Constantine A. Balanis, *Antenna Theory-Analysis and Design*, Wiley-India, 3rd Edn., 2010.

E3040E COMPACT MODELING FOR IC DESIGN

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO-1: Learning about compact Models and Hardware Descriptive Languages (Verilog-A)
CO2: Development of compact model and understanding of compact modeling techniques
CO3: Implementation of compact model in Verilog-A for circuit simulation.

Introduction to SPICE simulator; basic principles of physical device simulation (TCAD) and compact models; application of compact model; existing industry-standard compact models; implementation of compact models using hardware descriptive languages (Verilog-A), Verilog-A details and coding practices, mathematics for compact Modeling.

Compact modeling of two and three terminal devices: Integrated resistor and Inductor and MOSCAP; MOSFET modeling approaches – threshold voltage (BSIM3 and BSIM4), charge based (EKV, BSIM6), surface-potential based (PSP; BSIMCMG, ASM-HEMT); MOSFET Modeling – Core model, terminal current, terminal charges, terminal capacitances; short-channel effects, self-heating effect.

Advanced concepts: MOSFET model for RF application- Noise models, NQS effects, Parasitic elements; Modeling of Process Variability, Concept of binning, Benchmark Test of MOSFET compact Models; Advanced Devices Compact Model – Multigate FETs, FDSOI, Nanosheets, Tunnel FETs, GaN HEMT, NC-FETs, Magnetic Devices; Case Study on development of Industry Standard Compact Models – BSIM4, BSIM6, PSP, HiSIM, ASM-HEMT, MVSG; Parameter extraction procedure, Device Characterization and its importance in compact Model development.

References:
1. G. Gildenblat, *Compact Modeling: Principles, Techniques and Applications*, Springer, 2010
2. W. Liu, *MOSFET Models for SPICE Simulation: Including BSIM3v3 and BSIM4*, Wiley, 2001.
3. Y. S. Chauhan et.al., *FinFET Modeling for IC Simulation and Design: Using the BSIM-CMG standard*, Academic Press, 2015.
4. S. K. Saha *Compact Models for Integrated Circuit Design: Conventional Transistors and Beyond*, CRC Press is an imprint of Taylor & Francis Group, 2016.
5. Y. Tsividis, *Operation and Modeling of the MOS Transistor*, McGraw Hill, Boston, 1999
6. N. Arora, *MOSFET Modeling for VLSI Simulation: Theory and Practice*, World Scientific, 2007
7. C. C. Enz and E. A. Vittoz, *Charge Based MOS Transistor Modeling: The EKV Model for Low power and RF IC Design*, John Wiley & Sons, Ltd., 2006.
8. G. Massobrio and P. Antognetti, *Semiconductor Device Modeling with SPICE*, McGraw Hill Book Co., Singapore, 1988.

EC3041E THZ ELECTRONICS

Pre-requisites: A first level course in Semiconductor Devices, Electromagnetism and Analog Circuits

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Understanding the specifications of THz electronics system and Applications of THz Electronics
CO2: Distinguish between different THz sources and detection methods.
CO3: Application of Integrated Active, Passive components and measurement techniques at THz to design on-chip THz electronics.

Introduction to THz science and Technologies: THz Gap; Terahertz interaction in molecular- and atomic-scale; Terahertz systems specifications: active vs passive, broadband vs narrowband, time domain vs frequency domain, coherent vs incoherent, far-field vs near-field, power vs field; THz Applications – THz communication, THz Imaging, THz spectroscopy.

CMOS Passives at THz: Metal stacks, Capacitors, Inductors Transmission lines, On-chip Antennas; Transistors at THz - Transistor power gain, fT and fmax, Gate resistance, Technology comparison; THz in CMOS/BiCMOS above fmax; Calibration/de-embedding methodologies, on-chip and off-chip, Thru-Reflect-Line, Short-Open-Load-Thru, Line-Reflect-Match and Line-Reflect-Reflect-Match, De-embedding Techniques.

THz Sources: Traditional THz sources- Vacuum Device Sources, Diode Sources - Gunn Diodes, IMPATT Diodes, Resonant Tunneling Diodes (RTDs); Transistor based THz sources - Harmonic generators, Oscillators; Optical THz Sources - THz photomixing.

THz Detectors: Detector figures of merits; Thermal Detectors – Bolometers, Golay cells, pyroelectric; Diode Detectors - Schottky Barrier Diodes (SBDs), SIS Mixers, Superconducting Hot Electron Bolometers (HEBs); Transistor and transistor Circuit Detectors; Direct Detection, Heterodyne Detection.

References:

1. G. Carpintero, L.E. Garcia Munoz, S. Preu, H. Hartnagel, and A.V. Räisänen, *Semiconductor THz Technology: From Components to Systems*, John Wiley & Sons, 2015
2. H. Wang and K. Sengupta, *RF and mm-Wave Power Generation in Silicon,* Academic Press, 2015
3. J.-S. Rieh, *Introduction to Terahertz Electronics,* Cham: Springer Nature, 2021
4. J.-H. Son, *Terahertz biomedical science and technology*, CRC Press, 2014.
5. X.-C. Zhang and J. Xu *Introduction to THz Wave Photonics,* Springer, 2010
6. J. H. Choi, *High-Speed Devices and Circuits with THz Applications,* CRC Press, 2017.

EC3042E SEMICONDUCTOR MEMORY TECHNOLOGIES

Pre-requisites: A first level course in Semiconductor Devices

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Fundamentals about Memory Technologies
CO2: Design and Fabrication of Non-volatile Memories
CO3: Design of emerging memories for low power and high speed applications

Module 1 (10 Hours)
Introduction to memory devices: Evolution and history; archival data storage; different types of memories, advances in optical memories. Volatile memory devices: Random access memories, classification and operation; SRAMs; DRAMs; history and challenges.

Module 2 (18 Hours)
Non-volatile memory devices: Magnetic memories, HDDs; Silicon based thin film transistor non-volatile memories; Flash memories, classification and operation; device design considerations, device scaling, device fabrication, memory array architecture, and addressing and readout circuits; Case study on NVMs.

Module 3 (11 Hours)
Emerging memory technologies: Phase Change Memory (PCM); Magneto-resistive Random Access Memory (MRAM); Ferroelectric Random Access Memory (FeRAM), Resistive Random Access Memory (RRAM); Application in Neuromorphic computing using emerging memories.

References:

1. Ashok K Sharma, "*Advanced Semiconductor Memories: Architectures, Designs and Applications*" , Wiley, 2003
2. Simone Raoux and Mathias Wuttig, *"Phase change materials and Applications"*, Springer, 2012
3. Kiyoo Itoh, "*VLSI memory chip design*" , Springer International Edition, 2010

EC3043E SPINTRONIC DEVICES

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Develop knowledge about spin related phenomena
CO2: Understand the operation of spin based devices
CO3: Model spin based devices
CO4: Design spintronic devices for building memory devices and for RF applications

Ground for Spin related phenomena:
Introduction: The early history of spin, Quantum Mechanics of spin, Spin-orbit interaction, exchange interaction, Spin relaxation mechanism, Normal and ferromagnetic metals, Basic electron transport, Spin-Orbit Interaction, Spin relaxation, Spin dependent Scattering and Transport, Spin dependent Tunneling and Transport, Spin relaxation in metals and semiconductors, Spin Galvanic effect

Spin Torque:
Giant magneto resistance, Spin Phenomena, Spin dependent transport in magnetic metals - Anisotropic Magnetoresistance, Giant Magnetoresistance, Spin dependent tunneling, Tunneling magnetoresistance, Hall effects – Spin Hall Effect and Inverse Spin Hall Effect; Spin injection phenomena and applications - Spin Transfer Torque, Spin injection magnetization reversal; Spin Transfer Torque applications, High frequency phenomena - Spin transfer oscillation

Spintronic Devices:
Materials for spintronics, Ferromagnetic semiconductors, Spin transport in semiconductors, multiferroics, Diluted magnetic semiconductors, Spin diode and transistors, Spin-Valve, spin-tunnel devices in data storage, Magnetic RAM, spin based bio-sensors, Spin LEDs, Spin photoelectronic devices, Spin filtering, Qubits and introduction to quantum computing, Spintronics-Based Neuromorphic Computing, Spintronic based RF components

References:

1. Johnson, Mark. "*Introduction to magnetoelectronics*." *Magnetoelectronics*. Elsevier, 2004.
2. Shinjo, Teruya, ed. *Nanomagnetism and spintronics*. Elsevier, 2013.
3. Bandyopadhyay, Supriyo, and Marc Cahay. *Introduction to spintronics*. CRC press, 2015.
4. Prabhakar, Anil, and Daniel D. Stancil. *Spin waves: Theory and applications*. Vol. 5. Springer US, 2009.
5. Ziese, Michael, and Martin J. Thornton, eds. *Spin electronics*. Vol. 569. Springer, 2007.
6. Coey, John MD. *Magnetism and magnetic materials*. Cambridge university press, 2010.
7. Griffiths, David J., and Darrell F. Schroeter. *Introduction to quantum mechanics*. Cambridge university press, 2018.

EC3044E IC HARDWARE SECURITY

Pre-requisites: A first level course in digital & Analog Circuits

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Fundamentals about Hardware Security
CO2: Design of circuits for hardware security
CO3: Analysis of Analog-mixed signal /RF Hardware Security and countermeasure.

Foundation of Hardware Security: Semiconductor Supply chain, IC design flow/lifecycle, trust issues at each stage of the IC lifecycle, Hardware trojan, Side Channel Attacks, Fault Injection Attacks, Reverse Engineering, Counterfeiting, IP and IC piracy, Need for security and Trust.

Design for Security: Physically Unclonable Functions (PUFs), PUF characteristics, unclonable, uniqueness, randomness, reliability/repeatability, PUF performance metrics, instability & bit error rate, robustness, hamming distance & autocorrelation, spatial distribution, power consumption, design of PUF using CMOS and emerging non-volatile memories (eNVM); True random number generator (TRNGs), TRNGs characteristics, pseudo vs true TRNG, TRNG implementations: CMOS and emerging non-volatile memories (eNVM).

Analog-mixed signal (AMS) and RF hardware security- hardware trojans in AMS/RF ICs, analog/RF trojans, Analog triggers-hardware trojan defenses, Pre-Silicon Methods, Post-Silicon Methods, Design-for-trust methods, Piracy countermeasures for Analog ICs, Analog locking, Obfuscation, Split manufacturing, IC Recycling protection, Mixlock, Analog sizing camouflaging, Case study on AMS/RF hardware security.

References:

1. M. M. Tehranipoor, U. Guin, and D. Forte, *Counterfeit Integrated Circuits: Detection and Avoidance*, Springer International Publishing, 2015, ISBN: 978-3-319-11823-9
2. M. Tehranipoor, C. Wang, *Introduction to Hardware Security and Trust,* Springer-Verlag New York, 2012, ISBN 978-1-4419-8079-3
3. M. Tehranipoor, Mark, ed. *Emerging Topics in Hardware Security*. Springer, 2021.
4. Debdeep Mukhopadhyay and Rajat Subhra Chakraborty, "*Hardware Security: Design, Threats and Safeguards", CRC Press*
5. S. Bhunia and M. Tehranipoor (Editors), *The Hardware Trojan War: Attacks, Myths, and Defenses,* Springer, 2017

EC3045E FUNDAMENTALS OF PHOTOVOLTAIC DEVICES

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Analyse the requirements for the effective design and processing of photovoltaic devices.
CO2: Understand the Photovoltaic devices fabrication and characterization techniques
CO3: Design the Photovoltaic Devices and Modules

Basics of Solar Cell
Solar Resource, Air Mass, Need of Solar PV, Prospects of PV technology, Light Absorption, Charge Excitation, Charge Drift/Diffusion, Charge Separation, Charge Collection. PN junction diodes: Dark IV, Illuminated IV. Device Performance parameters, Series/ Shunt Resistance, Factors affecting the performance parameters, Losses and Conversion Efficiency Limit, Generations of solar cell.

Fabrication and Characterization of Solar Cells
Fabrication: Chemical Vapor Deposition (CVD), Physical Vapor Deposition (PVD: Sputtering, Electron Beam Evaporation, Pulsed Laser Deposition, Atomic Layer Deposition), Electrodeposition, Spin Coating. Characterization: Solar Simulator, Quantum Efficiency Measurement, XPS/UPS, FESEM, Energy Dispersive X-Ray Spectroscopy, Photo-Luminescence.

Cutting Edge Themes, PV modules and PV Device Modelling
Light manipulation in PV Devices: Plasmonic Integration, Surface Texturing, Spectrum Splitting Techniques. Advance PV Technologies: Multijunction, Quantum Well, Concentrator, Hot Electron Solar Cell. PV modules: Series and parallel connection, parameters, fabrication and lifetime testing. PV Device Modeling: Hands-on with an Open Source Tool.

References:

1. Smets Arno et al., "*Solar Energy Fundamentals, Technology, and Systems*", UIT Cambridge. 2013
2. Martin A. Green, "*Solar Cells: Operating Principles, Technology and System Applications*", Prentice Hall, 1986.
3. Jenny Nelson, "*The Physics of Solar cells*", World Scientific, 2003.
4. D. K. Schroder, "*Semiconductor Material and Device Characterization*", Wiley Interscience, 2006
5. Konrad Mertens, "*Photovoltaics Fundamentals, Technology, and Practice*", Wiley, 2018,
6. J. Poortmans and V. Arkhipov, "*Thin Film Solar Cells: Fabrication, Characterization and Applications*", Willey, 2006.

EC3046E DATA CONVERSION SYSTEMS

Pre-requisites: A first level course in Signals and Systems & Analog Circuits

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Appreciate the use of signal processing in data conversion systems.
CO2: Assess the impact of individual building blocks on the overall performance of a data converter
CO3: Derive design parameters from the specifications of data converters.
CO4: Recommend architectural/algorithmic level solutions to achieve the data converter specifications

Introduction to data conversion systems, Ideal ADCs and DACs, - Review of signal processing fundamentals for sampled systems - Sampling in time and frequency domains, quantization error, noise spectral density, reconstruction of continuous-time signals from samples, aliasing, thermal noise limitation, anti-aliasing filter - Oversampling, noise-shaping and time-interleaved sampling - Static and dynamic specifications of data converters, understanding specifications from a data sheet

ADC architectures, flash and its variants, SAR, integrating type and oversampling ADCs, speed, power, resolution – Building blocks of different ADC architectures, comparators, op-amps, DACs, digital filters etc., performance of building blocks on the specifications of ADCs, deciding the specifications of the building blocks - Choosing an ADC topology for an application from specifications, error correction and calibration

DAC architectures, digital representation, building blocks of voltage, current and charge-mode DACs, selection of resistors, capacitors and current cells, segmentation – Technology limitations in the design of data converters, deterministic and random errors, methods to improve accuracy – Mixed signal design approaches, power and signal integrity issues – Testing of data converters, test setup and measurement methods

References:

1. R. J. Baker, *CMOS Circuit Design, Layout and Simulation*, Wiley India Pvt Ltd, 2009
2. Marcel J. M. Pelgrom, *Analog-to-Digital Conversion*, Springer, 2010.
3. W. Kester, *The data conversion handbook*, Newnes, 2005

EC3047E VLSI ARCHITECTURES FOR DSP

Pre-requisites: A first level course in Digital Signal Processing

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Apply suitable transformation techniques on the architectures.
CO2: Design high performance architectures using systolic arrays.
CO3: Design high performance arithmetic unit architectures.

DSP Algorithm representations, data flow, control flow, signal flow graphs, block diagrams - Loop bound, iteration bound, critical path - Pipelining, parallel processing, low power architectures - Retiming, folding and unfolding techniques, applications.

Systolic Architecture design – Systolic array design methodology, FIR systolic arrays - Fast convolution algorithms, Cook-Toom, Winograd, Iterated and Cyclic Convolution algorithms.

High performance arithmetic unit architectures (adders, multipliers, dividers), bit-parallel, bit-serial, digit-serial, carry-save architectures, distributed arithmetic, canonic signed digit arithmetic - Introduction to redundant number system and examples – Scaling and round off noise - Numerical strength reduction.

References:

1. Keshab K. Parhi, *VLSI Signal Processing Systems, Design and Implementation*, John Wiley & Sons,1999.
2. Lars Wanhammar, *DSP Integrated Circuits,* Academic Press, 1999.
3. Shoab Ahmad Khan, *Digital Design of Signal Processing Systems - A Practical Approach*, John Wiley, 2011.
4. Sen M.Kuo, Woon-Seng S. Gan, *Digital Signal Processors: Architectures, Implementations, and Applications*, Prentice Hall, 2004.

EC3050E ARRAY SIGNAL PROCESSING

Pre-requisites: A first level course in Linear Algebra

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Obtain a basic understanding of spatial signals and their analysis.
CO2: Familiarize with the basic knowledge of the sensor arrays.
CO3: Perform the spatial frequency analysis of array signals.
CO4: Implement various methods of beamforming, direction of arrival estimation, and target tracking.

Spatial Signals and Sensor Arrays
Spatial Signals, Signals in space and time, Spatial frequency, Direction vs. frequency, Wave fields, Far field and near field signals, Sensor arrays, Spatial sampling, Uniform linear arrays, Planar arrays, Random arrays, Array steering vector, Virtual array of MIMO configuration, Broadband arrays.

Spatial Frequency and Beamforming
Aliasing in spatial frequency domain, Spatial frequency transform and spatial spectrum, Spatial domain filtering, Data-independent beamforming, Statistically optimum beamforming, Adaptive beamforming, Spatially white signal.

Direction of Arrival Estimation and Target Tracking
Non parametric methods, Beamforming-based method, Capon methods, Resolution of beamforming method, Signal subspace methods, Subspace fitting, ESPRIT, Toeplitz approximation, Noise subspace methods, Pisarenko's method, MUSIC method, Minimum norm method, Spatial smoothing, Target tracking, Interacting multiple model filter.

References:

1. Harry L. Van Trees, *Optimum Array Processing: Part IV of Detection, Estimation, and Modulation Theory*, Wiley, 2002.
2. Don H. Johnson and Dan E. Dudgeon, *Array Signal Processing: Concepts and Techniques*, Prentice-Hall, 1993.
3. Prabhakar S. Naidu., *Sensor Array Signal Processing*, CRC Press, 2001.
4. Vijay K. Madisetti, *The Digital Signal Processing Handbook: Wireless, Networking, Radar, Sensor Array Processing, and Nonlinear Signal Processing*, CRC Press, 2nd Edition, 2010.

EC3051E ARTIFICIAL INTELLIGENCE

Pre-requisites: A first level course in Programming

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Discuss the key developments and milestones in the evolution of Artificial Intelligence (AI).
CO2: Implement uninformed and informed search algorithms and knowledge representation.
CO3: Develop proficiency in expert systems and learning.
CO4: Investigate the practical applications of AI across various domains and envisage future developments.

Introduction to Artificial Intelligence
Basics of Artificial Intelligence (AI): History and evolution of AI, Types: Narrow AI and General AI, Different branches of AI, Predictive AI and Generative AI. AI ethics and societal implications.

Intelligent Agents (14 Lecture Sessions)
Intelligent Agents, Problem Solving Agents, Searching for solutions, Search strategies: uninformed — BFS, DFS, Dijkstra and informed — A* search, heuristic functions, hill-climbing. Local search algorithms and optimization problems, Adversarial search — Games, Optimal Decision in Games, The minimax algorithm, Alpha-Beta pruning.
Logical Agents, Agents based on propositional logic; First order logic: syntax, semantics, Inference in First order logic. Classical planning and multiagent planning, foundations of Ontology.

Expert systems and Learning
Expert systems: Rule-Based Expert Systems, Uncertainty Handling — Bayesian Networks.
Learning: Learning From Examples, Knowledge in Learning, Learning probabilistic Models, Reinforcement Learning (RL): Passive RL, Active RL, Generalization in RL, Policy Search.

Applications of Artificial Intelligence
AI Applications in Healthcare, E-commerce, Education, Communication, Agriculture and Smart cities. Voice assistants and chatbots. Robotic applications — Visual Perception, Locomotion and Navigation, Automation systems.

References:

1. Stuart Jonathan Russell, Peter Norvig, *Artificial intelligence a modern approach*, 4th Edn, Pearson Education, Inc,2016.
2. Elaine Rich Kevin Knight, Shivashankar Nair, *Artificial Intelligence,* 3rd Edn, McGraw Hill Education, 2017.
3. R. Sutton and A. Barto, *Reinforcement Learning: An Introduction*, 2nd Edn., MIT Press, 2018.
4. Lyla B. Das, Sudhish N. George, Anup Aprem, *Artificial Intelligence and Machine Learning: Theory and Practice*, IK International Publishing House, 2022.
5. Joseph C. Giarratano, Gary D. Riley, *Expert Systems: Principles and Programming,* 4th Edn, Course Technology Inc 2004.

EC3052E INTRODUCTION TO AUTONOMOUS INTELLIGENT SYSTEMS

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Describe essential subsystems for autonomous intelligent systems.
CO2: Model autonomous decision-making tasks using the estimation, planning and control architecture.
CO3: Apply reinforcement learning approaches for autonomous decision making for complex environments.

Introduction to Autonomous Systems
Introduction to autonomous systems, Levels of autonomy. Example of autonomous systems: Self driving cars, autonomous drones – Architecture of autonomous systems: Sensorimotor architecture, Stateful architectures, Logical and physical architectures – Modelling and control for autonomous systems: Representations and models, PID control.

Vision for Autonomous Systems
Vision: Introduction to projective geometry, Camera modeling and calibration, Image processing techniques for object detection, Machine learning techniques for object detection: Introduction to neural networks, Convolutional neural networks, One and two-stage object detection.

State Estimation, Localization, and Planning
State estimation and localization: Bayes filtering framework, Parameterized methods (Kalman filter), Sampling-based methods (particle and histogram filter).
Planning: Formalization of the planning problem, Graphs, Graph search algorithms.

Reinforcement Learning
Reinforcement Learning: Markov decision processes, Value functions, Q-learning, Exploration and Exploitation techniques.

References:

1. Ulrich Nehmzow, *Mobile robotics: a practical introduction*, 2nd Edn, Springer Science & Business Media, 2012.
2. Roland Siegwart, Illah Reza Nourbakhsh, Davide Scaramuzza, *Introduction to Autonomous Mobile Robots*, 2nd Edn, MIT Press, 2011
3. Luc Jaulin, *Mobile robotics*. John Wiley & Sons, 2019.
4. R. Sutton and A. Barto, *Reinforcement Learning: An Introduction*, 2nd Edn., MIT Press, 2018.
5. Stuart Jonathan Russell, Peter Norvig, *Artificial intelligence a modern approach*, 4th Edn, Pearson Education Inc, 2016.

EC3053E BASES AND FRAMES FOR SIGNAL PROCESSING

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Understand the foundational concepts of signal spaces.
CO2: Understand the construction of bases and frames.
CO3: Analyze frames and frame operators.
CO4: Apply bases and frames for the synthesis of signals.
CO5: Develop ability to think clearly with sound logical reasoning and Mathematical precision.

Review of finite dimensional vector spaces: Bases, Linear operators, inner products and orthonormal bases, orthogonal and nonorthogonal direct sums; Finite dimensional operator theory: Linear functionals and the dual space, Riesz representation theorem, Adjoint operators, orthogonal and oblique projections, generalized inverses, eigenvalues for operators, square-root of positive operators. Traces of operators, operator norm, the spectral decomposition theorem, singular-value decomposition.

Infinite dimensional spaces and sequences: normed linear spaces and sequences, Hilbert spaces, separable spaces, operators on Hilbert spaces; Bases: Bessel sequences in Hilbert spaces, Schauder basis, orthonormal basis, Riesz basis, the Gram matrix, Limitations of bases, wavelet bases.

Finite Frames: $\boldsymbol{R}^n$-frames, Basic frame theory, Parseval frames, general frames and canonical reconstruction formula, Frames and matrices, similarity and unitary equivalence of frames, frame potential, synthesis of a signal from frame coefficients, Frames in $\boldsymbol{R}^2$: Diagram vectors, unit tight frames with four and *k* vectors, frame surgery (removals and replacements); Dilation property of frames, orthogonal compression of frames, frames and oblique projections, dual and orthogonal frames.

References:

1. Ole Christensen, "*Frames and Bases: An Introductory Course*", Birkhauser, Boston 2008.
2. Deguang Han, Keri Kornelson, David Larson, and Eric Weber, "*Frames for Undergraduates*", American Mathematical Society, Rhode Island, 2007.
3. Yonina C Eldar, "*Sampling Theory: Beyond Band-limited Systems*", Cambridge University Press, UK, 2015.
4. Peter G Casazza, Gitta Kutyniok (Editors), "*Finite Frames: Theory and Applications*," Birkhauser, NY, 2010.

EC3054E COMPRESSED SAMPLING: PRINCIPLES AND ALGORITHMS

Pre-requisites: A first level course in Signals, Systems and Signal Processing

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1 Develop a mathematical framework for the representation of signals.
CO2 Apply compressed sampling for energy-efficient designs.
CO3 Apply mathematical principles for cost-effective practical designs.
CO4 Develop ability to think clearly with sound logical reasoning to unfold new theory and design methods.

Fundamentals of Sampling Analog Signals, and Mathematical Preliminaries: Classical sampling theorem for band-limited signals; Bandpass sampling theorem; Sample-rate reduction and multichannel sampling; Sampling of random signals; Sampling as a signal representation problem; Sampling of duration-limited signals and motivation for compressed sampling.

Signal Spaces: normed linear spaces - topology, Convergence, completeness and stable signal synthesis; Hamel basis, Schauder basis and Riesz basis; Linear transformations and change of basis on finite dimensional signal spaces; Separable signal spaces and Decomposition of signals; Orthogonality and bi-orthogonality; Riesz representation theorem; Frames; Under-determined system of equations - methods of solution, sparse solution.

Compressed Sampling: Sparse representation of signals; Sparsity and compressibility; Construction of sparsifying basis and the measurement (Sensing) matrix; Null-space conditions and the spark; The Restricted Isometry Property (RIP); RIP and the null-space property; Measurement bounds and condition for stable recovery; Coherence of the measurement matrix; mutual coherence between the sensing matrix and the matrix of representation bases.

Sparse Signal Recovery: The l_0 and l_p for $p \in (0, 1)$, and the l_p-norm for $p \geq 1$; Recovery through l_1-norm minimization; Recovery under noiseless and noisy conditions; Algorithms for sparse recovery - Design requirements; Convex optimization based methods: linear programming; Greedy algorithms: Matching pursuit, Orthogonal matching pursuit, Regularized orthogonal matching pursuit; Compressive sampling matching pursuit; Relaxation on the l_0: The l_p for $p \in (0, 1)$ as a weighted l_2-norm; Iterative re-weighted least squares algorithm; Performance analysis of the recovery algorithms.

References:

1. S. G. Mallat, "*A Wavelet Tour of Signal Processing: The Sparse Way*," Academic Press/Elsevier, 2009.
2. Richard G. Baraniuk, Mark A. Davenport, Marco F. Duarte, Chinmay Hegde (Collection Editors), "*An Introduction to Compressive Sensing*," CONNEXIONS (Publishing) Rice University, Houston, Texas, 2012.
3. Michael Elad, "*Sparse and Redundant Representations*," Springer, New York, 2010.
4. Yonina C. Eldar and Gitta Kutyniok, "*Compressed Sensing: Theory and Applications*," Cambridge University Press, 2012.
5. Simon Foucart, Holger Rauhut, "*A Mathematical Introduction to Compressive Sensing*," Springer/Birkhauser, New York, 2013.

EC3055E COMPUTER VISION: ALGORITHMS AND APPLICATIONS

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Apply knowledge of linear systems, probability theory, statistics and optimization theory for computer vision applications.
CO2: Design computer vision algorithms on real world data.
CO3: Evaluate computer vision systems to make sound decisions on real world problems.
CO4: Develop skill to conduct independent research in the area of computer vision.

Digital Image Formation and low-level processing: Overview and State-of-the-art, Fundamentals of Image Formation, Transformation: Orthogonal, Euclidean, Affine, Projective, etc, Fourier Transform, Convolution and Filtering, Image Enhancement, Restoration, Histogram Processing, Depth estimation and Multi-camera views: Perspective, Binocular Stereopsis: Camera and Epipolar Geometry, Homography, Rectification, DLT, RANSAC, 3-D reconstruction framework; Auto-calibration. apparel.

Feature Extraction: Edges - Canny, LOG, DOG, Line detectors (Hough Transform), Corners, Harris and Hessian Affine, Orientation Histogram, SIFT, SURF, HOG, GLOH, Scale-Space Analysis- Image Pyramids and Gaussian derivative filters, Gabor Filters and DWT. Image Segmentation: Region Growing, Edge Based approaches to segmentation, Graph-Cut, MeanShift, MRFs, Texture Segmentation, Object detection.

Motion Analysis: Background Subtraction and Modeling, Optical Flow, KLT, Spatio-Temporal Analysis, Dynamic Stereo, Motion parameter estimation, Object Recognition: Hough transforms and other simple object recognition methods, Shape correspondence and shape matching, Shape priors for recognition. Deep Neural Networks in Computer Vision.

References:

1. Richard Szeliski, *Computer Vision: Algorithms and Applications*, 2nd Edn., Springer-Verlag London Ltd., 2022.
2. Richard Hartley and Andrew Zisserman, *Multiple View Geometry in Computer Vision*, 2nd Edn., Cambridge University Press, 2004.
3. K. Fukunaga, *Introduction to Statistical Pattern Recognition*, 2nd Edn., Academic Press, Morgan Kaufmann, 2014.
4. R.C. Gonzalez and R.E. Woods, *Digital Image Processing*, 3rd Edn., Prentice Hall, 2007.

EC3056E NATURAL LANGUAGE PROCESSING

Pre-requisites: A first level course in Programming and Fundamentals of Machine Learning

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Discuss the fundamentals of Natural Language Processing (NLP) and the steps involved in the NLP process.
CO2: Illustrate the use of NLP tools for the development of real world applications
CO3: Assess the performance and limitations of available NLP techniques towards an application
CO4: Develop the skills to independently analyze NLP problems and techniques, fostering a commitment to lifelong learning.

Introduction to NLP and Text Pre-processing
History and evolution of NLP, syntax, semantics, and pragmatics. Steps in the NLP process: Vocabulary, Tokenization, Stop words removal, Stemming and Lemmatization, Text cleaning and normalization.

Language Modeling and Text classification
Simple N-gram models. Estimating parameters and smoothing. Evaluating language models. Lexical syntax. Hidden Markov Models, Forward and Viterbi algorithms and EM training.
Part-of-Speech (POS) Tagging, Techniques for POS tagging, Practical applications of POS tagging.
Feature extraction and representation: One hot vector representation, Bag of Words, TF-IDF, Text classification using machine learning.

Sequence labeling, Syntax Parsing and Word embedding
Grammar formalisms and treebanks. Efficient parsing for context-free grammars (CFGs). Statistical parsing and probabilistic CFGs (PCFGs). Lexicalized PCFGs. Neural shift-reduce dependency parsing. Dependency parsing and constituency parsing, Parsing algorithms, Practical parsing applications.
Word2Vec and GloVe, Training word embeddings, Word embedding applications. CBOW vs Skipgram.

Deep Learning for NLP
CNNs, RNNs: LSTM & GRU, Encoder–Decoder Network, Seq2Seq models, Attention mechanisms, Transformer Models: BERT, GPT, Large Language Models (LLMs), History and development of LLMs.
Deep learning models for NLP applications such as Sentiment Analysis, Machine Translation, Image captioning, Text to image synthesis, GPT models for Text Generation, speech to text processing.
Voice assistants and chatbots: Types of chatbots (rule-based, ML-based, hybrid), chatbot development framework (e.g., Rasa, Dialogflow).

References:

1. Jurafsky, Daniel and Martin, James, *Speech and Language Processing:An Introduction to Natural Language Processing, Computational Linguistics and Speech Recognition*, Second Edition, Prentice Hall, 2008.
2. Allen, James, *Natural Language Understanding*, Second Edition, Benjamin/Cumming, 1995.
3. Lyla B. Das, Sudhish N. George, Anup Aprem, *Artificial Intelligence and Machine Learning: Theory and Practice*, IK International Publishing House, 2022.
4. Charniack, Eugene, *Statistical Language Learning*, MIT Press, 1993.
5. Manning, Christopher and Heinrich, Schutze, *Foundations of Statistical Natural Language Processing*, MIT Press, 1999.
6. Tanveer Siddiqui, U.S. Tiwary, *Natural Language Processing and Information Retrieval*, Oxford University Press, 2008.
7. Andrew Radford, Martin Atkinson, David Britain, Harald Clahsen, Andrew Spencer , *Linguistics: An Introduction*, Cambridge University Press, 1999.

EC3057E DEEP LEARNING FOR COMPUTER VISION

Pre-requisites: A first level course in Programming and Fundamentals of Machine Learning

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Apply knowledge of linear systems, probability theory, statistics and optimization theory for deep learning applications.
CO2: Design computer vision algorithms on real world data
CO3: Evaluate computer vision systems to make sound decisions on real world problems.
CO4: Develop skill to conduct independent research in the area of computer vision

Computer Vision Overview: Historical context, Applications. Image Classification with Linear Classifiers, Data-driven Approach, k-Nearest Neighbour, Linear Classifiers, Algebraic/Visual/Geometric viewpoints, SVM, Softmax loss, Regularization and Optimization: Regularization, Stochastic Gradient Descent, Momentum, AdaGrad, ADAM, Learning Rate Schedules – Neural Networks: Multi-layer Perceptron, Backpropagation.

Image Classification with Convolutional Neural Networks (CNN): History, Higher-level Representations, Image Features, Convolution and Pooling, CNN Architectures: Batch Normalization, Transfer Learning, AlexNet, VGG, GoogLeNet, ResNet.

Training Neural Networks: Activation Functions, Data Processing, Weight Initialization, Hyperparameter tuning, Data augmentation. Visualizing and Understanding, Feature Visualization and Inversion, Adversarial Examples. DeepDream, Style Transfer, Object Detection and Image Segmentation, Single-stage Detectors, Two-stage Detectors, Semantic/Instance/Panoptic Segmentation, Recurrent Neural Networks: RNN, LSTM, GRU, Language Modeling, Image Captioning, Sequence-to-sequence Prediction, Encoder–Decoder Architecture, Attention and Transformers: Self-Attention, Transformers, Vision Transformers.

Generative Models - Supervised vs. Unsupervised Learning, Pixel RNN, Pixel CNN, Variational Autoencoders, Generative Adversarial Networks, Self-supervised Learning - Pretext tasks, Contrastive Learning, Multisensory Supervision, Low-Level Vision - Optical Flow, Depth Estimation, Stereo Vision.

References:

1. Bengio, Yoshua, Ian Goodfellow, Aaron Courville., *Deep learning*, Vol. 1. Cambridge, MA, USA: MI press, 2017.
2. Nielsen, Michael A., *Neural Networks and Deep Learning*, Vol. 25. San Francisco, CA, USA: Determination press, 2015.
3. Aggarwal, Charu C., *Neural Networks and Deep Learning*, Springer 10.978, 2020.
4. Szeliski R., *Computer Vision: Algorithms and Applications*, Springer Nature, 2022 Jan 3.
5. Lyla B. Das, Sudhish N. George, Anup Aprem, *Artificial Intelligence and Machine Learning: Theory and Practice*, IK International Publishing House, 2022.

EC3058E DIGITAL IMAGE PROCESSING

Pre-requisites: A first level course in Digital Signal Processing

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Demonstrate the methods of image acquisition, representation and manipulation to design and develop algorithms for solving image processing problems related to various applications like medicine, industry, communications, etc.

CO2: Acquire strong mathematical skills to model image as a 2-D signal and extend the use of 1-D signal processing tools to solve problems in image processing that meet the challenges of our age considering its social impacts.

CO3: Analyze various image processing algorithms for preprocessing, restoration, compression and segmentation using various spatial and frequency domain methods.

CO4: Identify and solve complex real world problems in image processing using modern signal processing tools, active cooperative learning and be able to demonstrate them effectively.

CO5: Perceive skills to conduct independent study and analysis of image processing problems and techniques that would also engage the scholar in lifelong learning

Image Acquisition, Representation and simple operations:

Digital image representation: Elements of visual perception, Imaging Geometry, Coordinate conventions, various types of images, Sampling and Quantization - Simple operations on images: Connectivity and relations between pixels, connectivity analysis, arithmetic, logical and geometric operations - Mathematical preliminaries: Introduction to 2D Signals and 2D LTI systems, 2D convolution, circulant and block circulant matrices, 2D Correlation, 2D random sequence.

Image Enhancement and Restoration:

Image Enhancement: Spatial domain processing - Simple intensity transformations, Histogram, Histogram based intensity transformations, Smoothing and sharpening filters, Nonlinear filtering; Frequency domain processing - Introduction to 2D Discrete Fourier Transform, Spectral domain representation of images, Filtering in frequency domain – low pass and high pass filters.

Image Restoration: Image observation and degradation model, Estimation of degradation function Inverse filtering, Minimum Mean squared Error (Wiener) filtering, Constrained Least Squares Filtering.

Morphological Processing and Image Segmentation

Morphological Image Processing: The structuring element, Basic operations on sets, Erosion, Dilation, Opening and Closing, Hit-or-Miss Transform, Basic Morphological Algorithms and applications. Image segmentation: Edge detection, line detection, curve detection, Edge linking and boundary extraction, boundary representation, region representation and segmentation - Thresholding, Otsu's Method, Variable and multi variable thresholding, Region Growing, Region Splitting and merging, Segmentation Using Morphological Watershed, Color image processing fundamentals

Image Transforms and Compression:

Image transforms: KL Transform, Discrete Cosine Transform (DCT). Image compression: Redundancy and compression models; Lossless Compression: Variable-length Coding - Huffman, Arithmetic coding, Compression of binary images – JBIG Standard, Bit-plane coding, Lossless predictive coding; Lossy Compression: Quantization – Scalar and Vector, Transform based coding, JPEG Compression standard, Introduction to Sub band coding.

References:

1. R. C. Gonzalez, R. E. Woods, *Digital Image Processing*, Pearson Education. III Ed.,2016
2. Jain A.K., *Fundamentals of Digital Image Processing*, Prentice-Hall, 2002.
3. Pratt W.K., *Digital Image Processing*, John Wiley, IV Edition, 2007.
4. K. R. Castleman, *Digital image processing*, Prentice Hall, 1996.
5. Jae S. Lim, *Two Dimensional Signal And Image Processing*, Prentice-Hall, Inc, 1990.
6. K R Rao, P Yip, Editors, *Transform and data compression handbook*, CRC Press.

EC3059E REINFORCEMENT LEARNING

Pre-requisites: Familiarity with Machine Learning and training Neural Networks with modern libraries and Background in Linear Algebra, Probability and Statistics, Computer Programming (Python)

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Model real-world sequential decision-making problems using Markov decision process and knowledge of associated solution methodologies.
CO2: Analyze classical model-free reinforcement learning algorithms and state-of-art deep reinforcement learning algorithms.
CO3: Solve sequential decision-making problems with hidden dynamics using exact and reinforcement learning techniques.
CO4: Demonstrate the potential of reinforcement learning in real-world problems through a course project.

Review of probability and statistics: Random variable, Expectation, Conditional Probability, Conditional Expectation, Markov Property, and Markov Chains. Markov Reward Process: Definition, Finite and Infinite horizon reward process, Value function and Bellman equation. Markov Decision Process (MDP): Definition, Finite and Infinite horizon MDP, Bellman dynamic programming equations for MDP. Numerical solution methods: Value iteration, Policy iteration (Generalized policy iteration), Linear programming.

Reinforcement learning: model free methods: Monte Carlo and Temporal Difference Learning methods: Estimation of value function using Monte Carlo: first-visit and every-visit – Q-learning and Q-learning with exploration – Temporal difference methods: TD (0) and TD (λ) – Policy iteration using TD learning – Double Learning – Deep reinforcement methodologies: Deep Q-learning (DQN), Double DQN, and Duelling DQN.

Policy Gradient reinforcement learning methods: Policy gradient, Policy gradient theorem (finite and infinite horizon), REINFORCE, REINFORCE with baseline – Actor-Critic algorithm. Advantage Actor-Critic (A2C) and Asynchronous A2C (A3C) – Exploration in policy gradient.

Recent advances in policy gradient reinforcement learning: Trust region policy gradient algorithms and its variants such as Natural Policy Gradient, Trust Region Policy Optimization, Proximal Policy Optimization, Deterministic Policy Gradient and Deep Deterministic Policy Gradient, Soft-Q learning and Soft actor-critic.

Partially Observed Markov Decision Process
Partially Observed Markov Decision Process (POMDP): Definition, Belief and Belief state formulation of POMDP, Belief computation using Hidden Markov Model (HMM) – Bellman dynamic programming for Finite and Infinite horizon POMDP – Exact algorithms for POMDP, Reinforcement learning in POMDP: Policy gradient and Deep Recurrent Q-learning networks (DQRN).

Other topics in reinforcement learning: Multi-agent learning, Meta-learning, Ethics in reinforcement learning, Application of reinforcement learning to real-world problems.

References:
1. Lyla B. Das, Sudhish N. George, Anup Aprem, *Artificial Intelligence and Machine Learning: Theory and Practice,* IK International Publishing House, 2022.
2. R. Sutton and A. Barto, *Reinforcement Learning: An Introduction*, 2nd Edn., MIT Press, 2018.
3. C. Szepesvari. Morgan and Claypool Publishers, *Algorithms for Reinforcement Learning*, 2010.
4. M. Wiering and M. van Otterlo, *Reinforcement Learning: State-of-the-Art,* Springer, 2012.

EC3060E MATHEMATICS FOR MACHINE LEARNING

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Illustrate the knowledge of linear systems, vector calculus and optimization theory to comprehend machine learning problems.
CO2: Design mathematical frameworks to formulate machine learning solutions for real-world problems.
CO3: Apply mathematical skills for analysis and independent research in the area of machine learning.

Review of Matrix Theory:, Eigenvalue and Eigenvectors, Eigenvalue Decomposition, Symmetric Positive Definite Matrices, Matrix Norms, Symmetric LU Decomposition. Numerical Algorithms for Finding Eigenvectors: QR Method via Schur Decomposition, Power Method for Finding Dominant Eigenvectors. Singular Value Decomposition (SVD): Principal Components and Low Rank Matrix, Truncated SVD, Curse of Dimensionality, Principal Component Analysis (PCA), Applications of SVD.

Linear Models: Regression and Classification Models, Training a Model, Logistic Regression, Activation Functions, Loss Functions, Minimum Problems, Perceptron. Curve Fitting: Polynomial Regression/Interpolation, Least Square Approximation. Convex Set, Convex Functions, Taylor Series, Hessian Matrix, Singular and Indefinite Hessian, Saddle-Point Problem, Useful Matrix Calculus Identities, Chain Rule of Calculus for Vectored Derivatives.

Optimization Basics: Univariate Optimization, Multivariate Optimization, Convex Optimization, Gradient Descent (GD) Algorithm, Stochastic Gradient Descent (SGD), Challenges in Gradient-based Optimization: Local Optima and Flat Regions, Differential Curvature, Vanishing and Exploding Gradients. Adjusting Derivatives for Descent: Momentum-Based Learning, AdaGrad, RMSProp, Adam. Constrained Optimization: Lagrangian Method, Kuhn-Tucker Optimality Conditions. Optimization Models for Binary Targets: Least-Squares Classification, Support Vector Machine (SVM), Logistic Regression.

Review of Probability: Bayes Theorem, Random Variable, Bayesian Classifier, Expectation and Variance, Discrete and Continuous Distribution Functions, Joint Probability and Covariance.

References:

1. Charu C. Aggarwal, *Linear Algebra and Optimization for Machine Learning*, Springer, 2020.
2. Gilbert Strang, *Linear Algebra and Learning from Data*, Cambridge: Wellesley-Cambridge Press, 2019.
3. Deisenroth, Marc Peter, A. Aldo Faisal, and Cheng Soon Ong. *Mathematics for Machine Learning*, Cambridge University Press, 2020.
4. Gareth Williams, *Linear Algebra with Application*s, Jones and Bartlett Publishers, 6th Edition, 2012.
5. Krishnan, Venkatarama. *Probability and Random Processes*. John Wiley & Sons, 2015.

EC3061E MULTI-RATE SYSTEMS

Pre-requisites: A first level course in Digital Signal Processing

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Analyze sampling rate alteration devices in time and frequency domains and develop efficient polyphase implementations of sampling rate converters.
CO2: Design uniform and non-uniform multi-rate filter banks which have perfect reconstruction and near perfect reconstruction and assess the computational efficiency of multi rate systems.
CO3: Analyze the quantization effects in filter banks.
CO4: Apply filter banks in Signal Processing and Communication applications.

Multirate System Fundamentals: Basic multirate operations: up sampling and downsampling - time domain and frequency domain analysis; Aliasing and imaging, Interpolator and decimator design, Identities of multi-rate operations, Fractional sampling Rate operation, Interconnection of multirate DSP blocks, Multiplexer and Demultiplexer functionality, poly-phase representation.

Multirate Filter Banks: Maximally decimated filter banks: Quadrature mirror filter (QMF) banks - uniform DFT filter bank, Poly-phase representation, Errors in the QMF bank-; Methods of cancelling aliasing error, Amplitude and phase distortions, Perfect reconstruction (PR) QMF bank, Near perfect reconstruction (NPR) filter banks

M-channel Perfect Reconstruction Filter Banks: Filter banks with equal pass bandwidths, filter banks with unequal pass bandwidths –Tree structured uniform and non-uniform filter bank: analysis, - Necessary and sufficient condition for perfect reconstruction, Modified DFT uniform and non-uniform filter banks, Design of PR and NPR systems. Interpolated FIR filter design.

Quantization effects - Types of quantization effects in filter banks – Reducing amplitude distortion using optimization techniques, hardware complexity, Implementation, Applications of filter banks in Signal Processing and Communication such as Software defined radio channelizer, Cognitive radio, hearing aids, Sparse beamforming.

References:

1. P. P. Vaidyanathan, *Multirate Systems and Filter Banks*, Pearson Education, 2006.
2. N.J. Fliege, *Multirate Digital Signal Processing*, John Wiley, 1999.
3. Sanjit K. Mitra, *Digital Signal Processing: A Computer based Approach*, Special Indian Edition, ,McGraw Hill, 2013.
4. Fredric J Harris, *Multirate Signal Processing for Communication Systems*, 1st Edition, Pearson Education , 2007.

EC3062E NEURAL NETWORKS AND DEEP LEARNING

Pre-requisites: A first level course in Programming and Fundamentals of Machine Learning

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Apply knowledge of linear systems, probability theory, statistics and optimization theory for deep learning applications.
CO2: Design deep learning algorithms on real world data.
CO3: Evaluate deep learning models to make sound decisions on real world problems.
CO4: Develop skill to conduct independent research in the area of neural networks and deep learning.

Review of Linear Models: Linear Regression, Linear Classifiers, Training a Linear Model, Perceptron Learning Rule, Activation Functions, Loss Functions. Optimization: Formulation of Objective Function, Convex Functions, Local Minima, Global Minima, Visualizing Gradient Descent, Stochastic Gradient Descent (SGD), Problems and Workarounds in SGD, Remedies, Adjusting Derivatives for Descent: Momentum-Based Learning, AdaGrad, RMSProp, Adam.

Multilayer Perceptron (MLP): Feedforward Neural Networks, Bias Vector, Weight Matrix, Activation Vector, Types of Activation Functions, Feature Learning, Deep and Shallow Networks. Back Propagation: Multivariate Chain Rule, Representation using Computational Graph, Backpropagation Algorithm, Backpropagation on Multilayer Network.

Convolutional Neural Networks (CNN): Foundations on 2D Convolution, Convolutional Layers - Sparse Connectivity and Weight Sharing, CNN Architecture, Applications of CNN: Classification, Object Recognition. Generalization of Trained Model, Reasoning about Generalization, Bias and Variance, Remedies for Overfitting. Transfer Learning.

Recurrent Neural Networks (RNN): Sequence to Sequence Prediction, Concept of RNN, Self-loops, Backpropagation through Time, Applications of RNN, Exploding/Vanishing Gradients: , Remedies, Adjusting Derivatives for Descent: Momentum-Based Learning, AdaGrad, RMSProp, Adam. LSTM Networks. Residual Networks: Residual Blocks, Deep Residual Networks (ResNets), Residual Learning, Examples.

Attention and Transformer Networks: RNN Encoder-Decoder Model, Learning to Align and Translate, Attention Networks, Transformers: Encoder-Decoder Stacks, Scaled Dot-product Attention, Self Attention, Multi-Head Attention, Transformer Architecture, Vision Transformer, Applications.

Generative Modeling: Generative Adversarial Networks (GAN), CycleGAN, Reversible Models: Reversible Blocks, Deep Reversible Architectures, Diffusion Neural Models.

References:

1. Bengio, Yoshua, Ian Goodfellow, Aaron Courville, *Deep learning*, Vol. 1. Cambridge, MA, USA: MI press, 2017.
2. Nielsen, Michael A., *Neural networks and Deep Learning*, Vol. 25. San Francisco, CA, USA: Determination press, 2015.
3. Aggarwal, Charu C., *Neural Networks and Deep Learning,* Springer 10.978 ,2020.
4. Lyla B. Das, Sudhish N. George, Anup Aprem *Artificial Intelligence and Machine Learning: Theory and Practice*, IK International Publishing House, 2022.

EC3063E BIG DATA ANALYTICS

L	T	P	O	C
2	0	2	5	3

Total Sessions: 26L + 26P

Course Outcomes:
CO1: Understand characteristics of big data and modern architectures to implement big data analytics
CO2: Demonstrate how to map data analytics techniques to the big data ecosystem, such as Spark, using high level programming languages.
CO3: Develop streaming and graph data analytics using a big data ecosystem such as Spark.

Introduction to Big Data: Data Storage and Analysis - Characteristics of Big Data – Big Data Analytics - Typical Analytical Architecture – Requirement for new analytical architecture – Challenges in Big Data Analytics – Need of big data frameworks

Hadoop: Hadoop – Requirement of Hadoop Framework - Design principle of Hadoop –Comparison with other system - Hadoop Components – Hadoop 1 vs Hadoop 2 – Hadoop Daemon's – HDFS Commands – Map Reduce Programming: I/O formats, Map side join, Reduce Side Join, Secondary sorting, Pipelining MapReduce jobs. Introduction to Hadoop ecosystem technologies: Serialization: AVRO, Coordination: Zookeeper, Databases: HBase, Hive, Scripting language: Pig, Streaming: Flink, Storm

Spark Framework: Spark Ecosystem, Spark components vs Hadoop. RDD Fundamentals: RDD Fundamentals, Transformations, Actions, and DAG, Key-Value Pair RDD. SparkSQL and DataFrames: Creating DataFrames, Querying with DataFrame API and SQL, Caching and Re-using DataFrames. Process Hive data in Spark. Spark Job Execution: Jobs, Stages, and Tasks, Partitions and Shuffles, Broadcast Variables and accumulators, Job Performance. Clustering Architecture: Cluster Managers for Spark, Understanding Spark on YARN

Spark Streaming and GraphX
Spark Streaming: Streaming Sources and Tasks, DStream APIs and Stateful Streams, Flink Introduction, Kafka architecture. Graph Representation in MapReduce: Graph Processing with Spark, Spark GraphX, GraphX features, Graph Examples, Graph algorithms-Shortest Path Algorithm. Spark MLlib-Introduction to Machine Learning with Spark.

List of Suggested Topics for Practical Sessions:
1. Installation of Hadoop, Introduction to HDFS
2. Wordcount using MapReduce
3. Running a Spark Application Word count in Hadoop and Spark
4. Manipulating RDDs
5. Implementation of Matrix algorithms in Spark SQL programming
6. Building Spark Streaming application

References:

1. Mike Frampton, "*Mastering Apache Spark*", Packt Publishing, 2015.
2. Tom White, "*Hadoop: The Definitive Guide*", O'Reilly,4th Edn,2 015.
3. Nick Pentreath, "*Machine Learning with Spark*", Packt Publishing,2015.
4. Mohammed Guller, *Big Data Analytics with Spark,* Apress, 2015
5. Donald Miner, Adam Shook, "*Map Reduce Design Pattern*", O'Reilly, 2012

EC3064E OPTIMIZATION TECHNIQUES

Pre-requisites: A first level course in Matrix Theory

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Analyze the optimality conditions for general non-linear programming problems.
CO2: Design algorithms for constrained and unconstrained optimization problems and analyze their convergence and rate of convergence.
CO3: Analyse convex functions, convex optimization problems and their applications.
CO4: Identify optimization problems in engineering and design efficient algorithms to solve them.

Review of sequences, continuous functions – Differentiation of multi-variable functions: Gradient and Hessian - Vector spaces, matrices, linear transformation, norms, and inner product spaces – Convexity: convex sets, separating and supporting hyperplanes of convex sets, convex functions: first order and second order conditions of differentiable convex functions, operations preserving convexity, conjugate functions – Non-linear optimization problem: First order and second order necessary and sufficient conditions for optimality – Convex optimization problem: optimality properties, Lagrange dual function and problem, Karush-Kuhn-Tucker conditions for optimality

Unconstrained optimization: Descent methods, Gradient descent method, Steepest descent method, Newton's method, convergence and rate of convergence analysis for convex optimization problems, global search algorithms for general non-convex problems: simulated annealing, particle swarm optimization, genetic algorithms – Constrained optimization: Newton's method for equality constrained minimization, Interior point methods: barrier method, primal-dual method, fractional programming, sequential quadratic programming, ADMM.

Linear Programming: formulation and applications, simplex method, basic solution and extreme points, degeneracy, primal simplex method, dual linear programs, dual simplex method, Dynamic Programming: introduction and examples, the basic Problem, the principle of optimality, the general DP algorithm, state augmentation, deterministic finite-state Problem, shortest path algorithm, Infinite horizon problems: Bellman's equation, value iteration, policy iteration.

References:

1. David G Luenberger, *Linear and Non-Linear Programming*, Addison-Wesley, 2nd Edn., 2001.
2. Chong, Edwin KP, Wu-Sheng Lu, and Stanislaw H. Żak, *An introduction to optimization*, John Wiley & Sons, 2023.
3. Boyd, Stephen P., and Lieven Vandenberghe, *Convex optimization*, Cambridge university press, 2004.
4. Bertsekas, Dimitri. *Dynamic programming and optimal control*: Volume I, Vol. 4, Athena scientific, 2012.

EC3065E PATTERN CLASSIFICATION

Pre-requisites: A first level course in Matrix Theory

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Apply knowledge of linear systems, probability theory, statistics and optimization theory for data representation
CO2: Analyze basic mathematical and statistical techniques in pattern recognition
CO3: Design pattern recognition algorithms to classify real world data
CO4: Evaluate pattern recognition systems to make sound decisions on real world problems.
CO5: Develop skill to conduct independent research in the area of pattern recognition

Introduction. Classification, training, and testing. Validation and overfitting, Linear classifiers. Decision functions and decision boundaries. The centroid method. Perceptrons. Gradient descent, stochastic gradient descent, and the perceptron learning algorithm. Feature space versus weight space. The maximum margin classifier, aka hard-margin support vector machine (SVM), Features and nonlinear decision boundaries. Decision theory: The Bayes decision rule and optimal risk. Generative and discriminative models.

Gaussian discriminant analysis, including quadratic discriminant analysis (QDA) and linear discriminant analysis (LDA). Maximum likelihood estimation (MLE) of the parameters of a statistical model. Fitting an isotropic Gaussian distribution to sample points.

Regression: fitting curves to data. The 3-choice menu of regression function + loss function + cost function. Least-squares linear regression as quadratic minimization. The design matrix, the normal equations, the pseudoinverse, and the hat matrix (projection matrix). Logistic regression. Ridge regression: penalized least-squares regression for reduced overfitting. Kernels. Kernel ridge regression. The polynomial kernel. Kernel perceptrons. Kernel logistic regression. The Gaussian kernel. Neural networks. Gradient descent and the backpropagation algorithm.

Unsupervised learning. Principal components analysis (PCA). The singular value decomposition (SVD) and its application to PCA. Clustering: *k*-means clustering aka Lloyd's algorithm; *k*-medoids clustering; hierarchical clustering; greedy agglomerative clustering, GMM- Expectation Maximization.

References:

1. C. Bishop, *Pattern Recognition and Machine Learning*, 1st Edition, Springer, 2006
2. Richard O. Duda, Hart P.E, and David G Stork, *Pattern classification,* 2nd Edition., John Wiley & Sons Inc., 2001.
3. S Theodoridis, K Koutroumbas, *Pattern Recognition*, 4th Edition, Academic Press, 2009.
4. Lyla B. Das, Sudhish N. George, Anup Aprem, *Artificial Intelligence and Machine Learning: Theory and Practice*, IK International Publishing House, 2022.

EC3066E SIGNAL COMPRESSION

Pre-requisites: A first level course in Information Theory & Signal Processing

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Understand the mathematical preliminaries of lossless and lossy compression techniques
CO2: Analyse and Assess the various compression techniques
CO3: Implement various lossless and lossy compression techniques
CO4: Criticize, Analyse and Evaluate the performance of various compression standards

Compression Techniques: Lossless and Lossy Compression, Modeling and Coding, Mathematical Preliminaries for Lossless Compression, Huffman Coding, Minimum Variance Huffman Codes, Extended Huffman Coding, Adaptive Huffman Coding, Arithmetic Coding, Application of Huffman and Arithmetic Coding, Golomb Codes, Run Length Coding, Tunstall Codes.

Dictionary Techniques: Static Dictionary, Adaptive Dictionary, LZ77, LZ78, LZW, Applications, Predictive Coding, Prediction with Partial Match, Burrows Wheeler Transform, Sequitur- Lossless Compression Standards (files, text, and images, faxes), Dynamic Markov Compression

Mathematical Preliminaries for Lossy Coding: Rate distortion theory: Motivation; The discrete rate distortion function R(D); Properties of R(D); Calculation of R(D); R(D) for the binary source, and the Gaussian source, Source coding theorem (Rate distortion theorem); Converse source coding theorem (Converse of the Rate distortion theorem), Design of Quantizers: Scalar Quantization, Uniform & Non-uniform, Adaptive Quantization: Vector Quantization, LindeBuzo Gray Algorithm, Tree Structured Vector Quantizers, Lattice Vector Quantizers, Differential Encoding Schemes.

Mathematical Preliminaries for Transforms: Subbands, and Wavelets, KarhunenLoeve Transform, Discrete Cosine Transform, Discrete Sine Transform, Discrete Walsh Hadamard Transform, Transform coding,Subband coding, Wavelet Based Compression, Analysis/Synthesis Schemes, Speech, Audio, Image and Video Compression Standards.

References:

1. Khalid Sayood, "*Introduction to Data Compression*", Morgan Kaufmann Publishers., 5th Edn., 2017.
2. David Salomon, "*Data Compression: The Complete Reference*", Springer Publications, 4th Edn., 2006.
3. Toby Berger, "*Rate Distortion Theory: A Mathematical Basis for Data Compression*", Prentice Hall, Inc., 1971.
4. K.R.Rao, P.C.Yip, "*The Transform and Data Compression Handbook*", CRC Press., 2001.
5. R.G.Gallager, "*Information Theory and Reliable Communication*", John Wiley & Sons, Inc., 1968.
6. Ali N. Akansu, Richard A. Haddad, "*Multiresolution Signal Decomposition: Transforms, Subbands and Wavelets*", Academic Press, 1992
7. Martin Vetterli, JelenaKovacevic, "*Wavelets and Subband Coding*", Prentice Hall Inc., 1995.

EC3067E WAVELET THEORY

Pre-requisites: A first level course in Signals, Systems and Signal Processing

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Understand Sampling Theory, Fourier Theory and representation of signals.
CO2: Design and Apply Continuous Wavelets and Continuous Wavelet Transforms and its inverse
CO3: Understand the principles of Multi-resolution Analysis and the discrete wavelet bases.
CO4: Design Discrete Wavelets and compute Discrete Wavelet Transforms.

Sampling Theory and Fourier Theory: Generalized Fourier theory, Fourier transform, Short-time (windowed) Fourier transform, Time-frequency analysis - uncertainty relation, Fundamental notions of the theory of sampling.

Continuous Wavelets: The basic functions, Specifications, Continuous Wavelet Transform (CWT), Construction of a wavelet from a scaling function, Resolution of Identity (ROI) Theorem for wavelet transforms, Inverse Continuous Wavelet Transform (ICWT), Admissibility conditions, Cross-wavelet transform, Vanishing moments and approximation power of a wavelet; Computation of CWT using Frequency- domain and Time-domain methods. Computation of ICWT.

The Multi-resolution Analysis (MRA) of L^2(R) and Discrete Wavelets: The MRA axioms, Construction of an MRA from scaling functions - The dilation equation and the wavelet equation, Compactly supported orthonormal wavelet bases – Necessary and sufficient conditions for orthonormality, Riesz basis formed out of discrete wavelets.

Construction of orthonormal wavelets: Regularity and selection of wavelets - Smoothness and approximation order – Criteria for wavelet selection with examples; Sub-band filtering, Construction of compactly supported orthonormal wavelet bases.

Discrete Wavelet Transform: Discrete wavelet transform (DWT): Wavelet decomposition and reconstruction of functions in L^2 (R), Fast wavelet transform algorithms, Relation to filter banks; Wavelet packets – Representation of functions, Selection of basis.

Construction of Bi-orthogonal wavelets: Bi-orthogonality and bi-orthogonal bases; Construction of bi-orthogonal system of wavelets: The Lifting scheme for constructing discrete wavelets and computing discrete wavelet transform.

References:

1. S. Mallat, "*A Wavelet Tour of Signal Processing: The Sparse Way*," Elsevier Inc, 2009.
2. M. Vetterli, J. Kovacevic, "*Wavelets and Sub-band Coding*," Prentice Hall Inc, 1995.
3. G. Strang, T. Q. Nguyen, "*Wavelets and Filter banks*," 2nd Ed., Wellesley-Cambridge Press, 1998.
4. R. M. Rao, A. S. Bopardikar, "*Wavelet Transforms: Introduction to Theory and Applications*," Pearson Education, 2000.
5. J. C. Goswami, A. K. Chan, "*Fundamentals of Wavelets: Theory, Algorithms and Applications*," 2nd Ed., John Wiley, 2011.

EC3068E SPEECH PROCESSING

Pre-requisites: A first level course in Signals, Systems and Signal Processing

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Obtain the basic knowledge of the mechanisms of human speech production and the articulation mode of different classes of speech sounds and acoustic characteristics.
CO2: Apply programming and mathematical tools to analyze speech and audio signals in time and frequency domains, and in terms of the parameters of a source-filter production model and harmonic models.
CO3: Analyze, compare and implement different methods of front end processing and pattern comparison in speech/speaker recognition.
CO4: Design and Implement methods and systems for speech and audio enhancement, speech and speaker recognition, music synthesizers, speech assisted applications etc.

Human speech production and speech sound units: Introduction, Review Of Signal Processing Theory, Speech production mechanism, Nature of Speech signal, Discrete time modelling of Speech production, Classification of Speech sounds, Phones, Phonemes, Phonetic and Phonemic alphabets, The stochastic parameters of human speech, Gaussian densities and statistical model training, voiced and unvoiced speech, voice-box modeling, pitch-perception models. Articulatory features, Psychoacoustics, Absolute Threshold of Hearing, Critical Bands-Simultaneous Masking, Masking-Asymmetry, and the Spread of Masking, Non simultaneous Masking, Perceptual Entropy, Basic measuring philosophy, Subjective versus objective perceptual testing, The perceptual audio quality measure (PAQM), Cognitive effects in judging audio quality

Front end processing and speech modelling: Linear Predictive Analysis of Speech, Formulation of Linear Prediction problem in Time Domain, Basic Principle, Auto correlation method, Covariance method, Solution of LPC equations, Cholesky method, Durbin's Recursive algorithm, lattice formation and solutions, Comparison of different methods, Application of LPC parameters, Pitch detection using LPC parameters, Formant analysis. Cepstral analysis of Speech, Formant and Pitch Estimation, Time frequency analysis of speech and audio, Sinusoidal Analysis of Speech and Audio

Speech processing applications: Statistical models for speech recognition, Vector quantization models for speech and speaker recognition, Gaussian mixture modeling for speaker, language and speech recognition, Hidden Markov modeling for isolated word and continuous speech recognition, Speech Recognition in practice.

References:

1. Ian McLaughlin, *Applied Speech and Audio processing*, Cambridge University Press, 2009.
2. Ben Gold, Nelson Morgan and Dan Ellis, *Speech and Audio Signal Processing: Processing and Perception of Speech and Music*, 2nd Edition, Wiley, 2011
3. John N. Holmes and Wendy J. Holmes, *Speech Synthesis and Recognition*, Taylor and Francis, 2nd Edition, 2003.
4. Lawrence R. Rabiner and Ronald W. Schafer, *Theory and Applications of Digital Speech Processing*, Pearson, 2010

EC3069E BIOMEDICAL SIGNAL PROCESSING

Pre-requisites: A first level course in Signals and Systems

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Understand the origin, waveform characteristics of important biological signals
CO2: Understand the sources, types & characteristics of different noises and artifacts present in biomedical signals
CO3: Design time domain and frequency domain filters for noise and artifact removal from biomedical signals.
CO4: Develop techniques to detect events and waves of biomedical signals.

Physiological and mathematical models of bioelectricity: cell membrane, resting and action potentials, Nernst equation, Origin and waveform characteristics of basic biomedical signals: Electrocardiogram (ECG), Electroencephalogram (EEG), Electromyogram (EMG), Phonocardiogram (PCG), Photoplethysmogram (PPG), Electroneurogram (ENG), Event-Related Potentials (ERPS), Electrogastrogram (EGG), speech signal, Vibromyogram (VMG), Vibroarthrogram (VAG), Otoacoustic emission (OAE) signals, Objectives of biomedical signal analysis, Difficulties in biomedical signal analysis.

Filtering for removal of artifacts: random and structured noise, physiological interference, stationary and nonstationary processes, time domain filters: synchronized averaging, moving average filters, derivative based operators to remove low frequency, frequency domain filters: Butterworth low pass, high pass filters, notch and comb filters, optimal filtering: the Wiener filter, Adaptive filters: adaptive noise canceler, the least mean squares adaptive filter, the RLS adaptive filter, selecting an appropriate filter, applications.

Detection of Events and Waves: Derivative based methods and the Pan–Tompkins algorithm for QRS detection, detection of the P wave in the ECG, detection of the dicrotic notch, Correlation analysis of EEG rhythms: detection of EEG rhythms, template matching for EEG spike and wave detection, detection of EEG rhythms related to seizure, PPG feature extractions, Applications: ECG and PPG rhythm analysis, Identification of heart sounds, Waveform analysis: problem with case studies, morphological analysis of ECG, envelop extraction and analysis, analysis of activity: root mean square value, zero-crossing rate, turns count, form factor.

References:

1. Rangayyan R.M., *Biomedical Signal Analysis: A Case Study Approach*, Wiley – IEEE Press, 2001
2. Willis J. Tompkins "*Biomedical Digital Signal Processing*", EEE, PHI, 2004
3. D C Reddy "*Biomedical Signal Processing: Principles and Techniques*", Tata McGraw-Hill Publishing Co. Ltd, 2005
4. Eugene N. Bruce, *Biomedical Signal Processing and Modeling*, John Wiley and Sons, Inc., 2000
5. Elgendi M, *PPG signal analysis: An introduction using MATLAB*®. CRC press, 2020.

EC3070E INVERSE PROBLEMS IN IMAGING

Pre-requisites: A firstevel course in Digital Signal Processing

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Understand the signal generation and acquisition mechanisms of modern medical imaging modalities
CO2: Develop mathematical formulations for inverse problems with a given forward model
CO3: Apply regularization to solve inverse problems using closed-form or iterative schemes
CO4: Evaluate the quality of reconstructed or restored image along with the convergence of algorithms

Inverse Problems and Regularization
Introduction, Forward problem, Inverse problem, Examples and challenges, Modelling of image blurring as a forward problem, Point spread function (PSF), Image deconvolution as an inverse problem, Ill-Posed nature of inverse problems, Least-Squares and generalized solution, Apriori information, Tikhonov regularization, Parameter selection, Landweber iterations.

Tomography
X-Rays: properties, radiation, production, dosage and exposure, Radiography, Detectors, Absorption and conversion efficiency, Patient dose and exposure index, Computed Tomography (CT), Acquisition, CT reconstruction, Artifacts and image quality, Dosimetry.
Light in matter: dispersion, absorption and scattering, Coherence, interference and diffraction, Time domain Optical Coherence Tomography (OCT), Dispersion and resolution, OCT in ophthalmology.

Magnetic Resonance Imaging and Ultrasound Imaging
Origin of Magnetic Resonance Imaging (MRI), Proton spin with magnetic field, Precession, Resonance, Bloch equation, Signal detection, Free induction decay, Spin echo and T_2 measurement, Inversion recovery and T_1 measurement, Fourier imaging and slice excitation, MRI reconstruction and artifacts, Signal, noise and contrast.
Ultrasound: characteristics and interaction with matter, Transducers and beam properties, Data acquisition, Display, Doppler ultrasound, Artifacts and image quality.

References:

1. Mario Bertero, Patrizia Boccacci, and Christine De Mol, *Introduction to Inverse Problems in Imaging*, 2nd Edition, CRC Press, 2022.
2. Jerrold T. Bushberg, J. Anthony Seibert, Edwin M. Liedholdt Jr, and John M. Boone, *The Essential Physics of Medical Imaging*, 3rd Edition, Lippincott Williams & Wilkins, 2012.
3. Robert Cierniak, *X-ray Computed Tomography in Biomedical Engineering*, 1st Edition, Springer Science & Business Media, 2011.
4. Robert W. Brown, Y-C. Norman Cheng, E. Mark Haacke, Michael R. Thompson, and Ramesh Venkatesan. *Magnetic Resonance Imaging: Physical Principles and Sequence Design*, 2nd Edition, John Wiley & Sons, 2014.
5. Mark E Brezinski, *Optical Coherence Tomography: Principles and Applications*, 1st Edition, Elsevier, 2006.

EC3071E PREDICTIVE AI AND GENERATIVE AI

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Apply data processing, exploration, feature extraction, and training and testing of ML models and demonstrate the pivotal role of data in the future of computing.

CO2: Investigate the practical applications of AI in day-to-day businesses and envisage future developments.

CO3: Acquire the skill to use predictive AI models for making data-driven decisions and generative AI models for creative applications, and cultivate a commitment to lifelong learning.

Basics of AI & ML

Foundations of AI: AI history, branches of AI, Narrow AI and General AI, Predictive AI and Generative AI, Hardware requirements, Cloud platforms, AI tools. Python for AI and ML: Basics, loops, functions, packages, libraries. Data collection and sources, Data preprocessing, Machine learning workflow. Data-driven emerging technologies. Real world use cases. Data privacy, ethics and societal implications.

Predictive AI

Deep learning (DL) and predictive modeling, Image feature extraction with CNNs, CNN architectures. CNNs for image classification and image restoration. sequence to sequence models and applications. time series forecasting. DL for dimensionality reduction, segmentation and object detection. Recommendation systems.

Generative AI

Generative models: Autoencoders (AEs), latent space, variational AEs (VAEs), Generative Adversarial Networks (GANs), Conditional GANs, CycleGANs, Attention mechanisms, Multi head attention, Transformer Models: BERT, GPT, Large Language Models (LLMs), Evolution of LLMs.

Real world Use Cases

Machine translation, Text generation with RNNs and GANs, Music composition and generation, Text to speech conversion and voice cloning, Image generation with GANs, Image captioning, Style transfer, Deepfake, Ethics related to AI generated contents.

References

1. Ian Goodfellow, Yoshua Bengio, and Aaron Courville, *Deep Learning*, MIT Press, 2016.
2. Francois Chollet, *Deep Learning with Python,* Manning Publications, 2017
3. Christopher M. Bishop., *Pattern Recognition and Machine Learning*, 1st Edn, Springer, 2006.
4. Stuart Jonathan Russell, Peter Norvig, *Artificial intelligence a modern approach*, 4th Edn, Pearson Education, Inc, 2016.
5. David Foster, *Generative Deep Learning: Teaching Machines to Paint, Write, Compose, and Play*, O'Reilly Media, 2019.
6. Charu C. Aggarwal, *Machine Learning for Text,* 2nd Edn, Springer, 2022.

EC3072E AI FOR TEXT, IMAGE AND VIDEO PROCESSING

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Provide students with a comprehensive foundation in Text, Image, and Video Processing.
CO2: Explore the use of AI algorithms and models for text, image, and video analysis.
CO3: Analyze how the recent advancements in deep learning solve real world problems.

Data formats and Visualization
Text data formats: XML, CSV, JSON, Text preprocessing and feature extraction, Text data visualization, speech, audio and music data visualization, Image data representation and formats: JPEG, PNG, TIF formats, Image feature extraction, Image processing and visualization techniques, MPEG and MP4 video formats, Video visualization, AI libraries and frameworks (e.g., TensorFlow, PyTorch)

AI for Text Processing and NLP Basics
Natural Language Processing (NLP), Text feature extraction: Bag of words, Term frequency-inverse document frequency, Word embeddings: Word2Vec, GloVe, Text classification, Named Entity Recognition, Part of Speech Tagging, Text generation techniques, Text summarization, Text based recommendation systems. Deep learning for Text processing (e.g., RNNs, Transformers)

AI for Natural Image Processing
The role of AI in image recognition, Data augmentation for image datasets, Model training, validation and fine tuning, post processing and visualization, AI for image applications (e.g., classification, denoising, superresolution, image generation), Emerging trends in AI image processing: Explainable AI, Few shot and zero shot learning, Semi-supervised and self supervised learning, Continual learning, Quantum machine learning, and Deep learning.

AI for Speech, Audio and Video Processing
Automatic Speech Recognition, CNNs for Speech, Voice assistance (e.g. Alexa, Google Assistant), Speaker recognition and anti spoofing emotion aware AI systems, AI driven music composition and generation, Audio restoration using AI, Object detection techniques in videos, Tracking objects across video frames, Human action recognition using videos, AI for multimedia forensics.

References

1. Christopher M. Bishop., *Pattern Recognition and Machine Learning*, 1st Edn, Springer, 2006.
2. Charu C. Aggarwal, *Machine Learning for Text*, 2nd Edn, Springer, 2022.
3. Adrian Rosebrock, *Deep Learning for Computer Vision with Python*, 1st Edn, PyImageSearch, 2017.
4. David Foster, *Generative Deep Learning: Teaching Machines to Paint, Write, Compose, and Play*, O'Reilly Media, 2019.
5. Ben Gold, Nelson Morgan, and Dan Ellis, *Speech and Audio Signal Processing: Processing and Perception of Speech and Music*, 2nd Edn, Wiley, 2011.

EC3073E AI FOR NATIONAL URBAN GROWTH AND SMART CITIES

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Discuss the concept of smart city and role of urbanization in national development.

CO2: Investigate AI and ML systems for solving real world problems related to smart cities.

CO3: Develop the skill to conduct independent research and innovation in the areas of AI enabled smart cities, fostering a commitment to lifelong learning.

AI enabled Smart City concept

Role of urbanization in national development, Smart cities mission, Concept of smart cities, Characteristics, Sustainable cities. Data sources, Data collection and sensors, Data analytics and visualization, Data privacy and ethical considerations. Key concepts in AI and ML. AI for smart city infrastructure, urban planning, utility management and energy consumption. Importance of Explainable AI in urban environments.

AI for Smart Mobility and Transportation

Applications of AI in smart mobility and transportation: Intelligent public transport, Advanced traffic information systems, Efficient parking management, Smart emergency and traffic management, Smart pavement maintenance system.

AI for Public Safety in Smart Cities

Data sources for public safety: crime data, emergency calls, social media, etc., Predictive analytics for public safety, Video and image analysis in law enforcement, AI for disaster prediction, response and recovery, natural disaster prediction. Generative models, Generative AI applications in public safety. Disaster management with generative AI.

AI for Healthcare in Smart Cities

Data sources in healthcare: electronic health records, wearable devices, IoT sensors, etc., Data privacy and security in healthcare, Disease outbreak prediction, Generative models for medical image generation, AI-enhanced medical imaging diagnostics.

References

1. Aija Staffans, Christopher Pettit, Robert Goodspeed, S. C. M. Geertman, *Urban Informatics and Future Cities,* Springer 2021.
2. P P Anilkumar, *Introduction to Smart Cities*, Pearson, 2019.
3. Juan Du, Kangjuan Lyu, Min Hu, Vijayan Sugumaran, *AI-Based Services for Smart Cities and Urban Infrastructure*, IGI Global, 2020.
4. Hussein Dia, *Handbook on Artificial Intelligence and Transport*, United Kingdom, Edward Elgar Publishing, Inc., 2023.
5. Stuart Jonathan Russell, Peter Norvig, *Artificial intelligence a modern approach*, 4^{th} Edn, Pearson Education, Inc, 2016.
6. Lyla B. Das, Sudhish N. George, Anup Aprem, *Artificial Intelligence and Machine Learning: Theory and Practice,* IK International Publishing House, 2022.

EC3075E ANTENNA THEORY

Pre-requisites: A first level course in Electromagnetics

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: To develop a comprehensive understanding of electromagnetic wave radiation, reception, and fundamental parameters of the antenna.
CO2: Acquire the ability to wave equations for far field calculations
CO3: To enable students to evaluate and design the antenna and array
CO4: Develop the basic skills to design and simulate different types of antennas in simulation tool.

Fundamentals of Antenna
Radiation mechanism, Radiation parameters of antenna: half power beam width, directivity, antenna gain, beam solid angle, effective height, radiation efficiency. Potential functions, radiation from Hertz dipole: near filed, far field, radiated power, radiation resistance, radiation pattern, thin linear dipole antenna, receiving antenna, monopole antenna, half-wavelength dipole antenna, Fourier transform relationship between current and radiation pattern

Antenna arrays
Two element array; Uniform Linear Array: direction of maximum radiation, broadside and end-fire directions, directions of nulls, directions of side lobes, half power beam width, directivity of uniform array, grating lobe, array synthesis; Special Types of Arrays: binomial array, Chebyshev array.

Antenna measurement
Gain measurement using two and three antennas, Polarization measurement, Different types of antenna. Simulation of different antennas (dipole antenna, horn antenna, patch antenna, etc.) in Electromagnetics simulation tool.

References:

1. Constantine A. Balanis, *Antenna Theory-Analysis and Design*, Wiley-India, 3rd Edn., 2010.
2. R K Shevgaonkar, *Electromagnetics Waves*, McGraw Hill, 1st Edn.,2016.
3. Jordan and Balmain: *Electromagnetic waves and radiating systems*, Pearson India, 2nd Edn., 2015.
4. Ronald J Marhefka, A S Khan, John D Krauss, *Antennas & Wave Propagation*, SIE, 4th Edn., 2017.

EC3076E CRYPTOGRAPHY: THEORY AND PRACTICE

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Identify security challenges in modern communication systems and explore the role of cryptographic services such as confidentiality, data integrity verification and data authentication in fixing them
CO2: Develop expertise in mathematical fundamentals from abstract algebra and number theory for the design and analysis of various cryptographic primitives
CO3: Design cryptographic systems to meet the specifications in terms of security, circuit complexity and power consumption by effectively making use of various primitives
CO4: Investigate latest developments in cryptology and develop knowledge on ethical aspects of information security

Challenges in information security, Cryptographic services, Kerckhoffs' principle, Private key and public key cryptosystems, Mathematical fundamentals, Divisibility, Prime numbers, Euclidean algorithm, Diophantine equations, Congruence, Euler function, Fermat's little theorem, Euler theorem, Finite groups and finite fields, Field extension, Basic operations in finite groups and fields.

Classical cryptography, Shannon's notion of perfect secrecy, One time pad, Stream cipher, Keystream generators, Linear feedback shift registers and sequences, Attacks on LFSR based stream ciphers, Substitution and transposition cipher, Block cipher, Operation schemes, Standards, Data encryption standard, Linear and differential cryptanalysis, Advanced encryption standard, One way functions, Asymmetric cryptosystems, Message authentication requirements, Hash function, Features of MD5 and SHA algorithms, Security of Hash function, Message authentication codes.

Factorization problem, RSA algorithm, Design aspects of RSA, Discrete logarithm problem, Elgamal cryptosystem, Key management, Diffie Hellmann key exchange, Elliptic curves arithmetic, Cryptographic applications of elliptic curves, Digital Signatures, Homomorphic encryption, Latest developments and design of cryptographic systems

References:

1. Wade Trappe, Lawrence C. Washington, *Introduction to Cryptography with Coding Theory*, 2nd Edition, Prentice-Hall, Inc. 2005.
2. Douglas R. Stinson, *Cryptography: Theory and Practice*, 3rd Edition, Taylor and Francis Group, 2006.
3. William Stallings, *Cryptography and Network Security: Principles and Practice*, 8th Edition, Pearson, 2020.
4. Johannes Buchmann, *Introduction to Cryptography*, Springer, 2001.
5. Alfred Menezes, Paul van Oorschot, and Scott Vanstone, *Handbook of Applied Cryptography*, CRC Press, 2001.

EC3077E 5G-6G TECHNOLOGIES AND STANDARDS

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Analyze impact of frequency allocation, signal propagation, modulation, coding, multiplexing, multiple access, antennas, diversity etc on wireless communication
CO2: Compare cellular technologies and identify motivation and challenges related to their evolution.
CO3: Analyze 5G features and study related clauses in standards.
CO4: Configure key parameters of the 5G system to meet given requirements.
CO5: Explain 5G enhancements and potential 6G features.

Fundamentals of Wireless Communications
Spectrum; Signal Propagation: large scale and small scale models; Basics of Digital Modulation and Error Control Coding; Multiplexing and Multiple Access: Frequency/Time/Code, OFDM and OFDMA; Antennas; Diversity and MIMO Systems.

5G: Evolution and Overview
Cellular concept and architecture, channel re-use; 5G overview: Key features, evolution from 1G to 5G, Migration challenges of 5G; 5G use cases, requirements and performance metrics: IMT 2020, eMBB, URLLC, mMTC; Spectrum for 5G, frequency ranges and bands, spectrum sharing, NR-U.

5G Standards, Architecture and Protocol Stacks
5G standards overview, 3GPP; 5G architecture: 5G RAN architecture, 5GC architecture; NFV, Network slicing, QoS, Policy control, 5G security; Control plane protocol stack: NAS, RRC; User plane stack: SDAP, PDCP, RLC, MAC, PHY; Initial access; Paging; Mobility.

5G PHY
Numerology; symbol, slot and frame structure; OFDM waveform; Bandwidth and sampling rate; Downlink control aspects: control region, search space, DCI formats; Downlink data aspects: modulation and coding, resource allocation in time and frequency, HARQ operation, Reference Signals; Uplink control aspects: UCI types, PUCCH formats; Uplink data aspects: resource allocation, modulation and coding options, HARQ, Reference signals, Power control; Link budget calculations; Peak throughput calculations; MIMO; Beam management.

5G Features and towards 6G
Selected topics related to 5G Advanced, mmWave, massive MIMO, URLLC, MTC, D2D/V2X, NTN, Edge computing, and 5G power saving features; Selected topics on potential 6G features.

References:
1. Juan Montojo, Peter Gaal, Haris Zisimopoulos and Wanshi Chen, "*Fundamentals of 5G Communications: Connectivity for Enhanced Mobile Broadband and Beyond*", First edition, McGraw Hill, 2021.
2. "3GPP TS 38.300", Version 16.12.0, 3GPP, 2023.
3. Stefan Rommer, Peter Hedman, Magnus Olsson, Lars Frid, Shabnam Sultana and Catherine Mulligan, "*5G Core Networks: Powering Digitalization*", First edition, Academic Press, 2019.
4. Erik Dahlman, Stefan Parkvall and Johan Skold, "*5G NR: The Next Generation Wireless Access Technology*", Second edition, Academic Press, 2020.
5. Stefania Sesia, Issam Toufik, Matthew Baker, "*LTE – The UMTS Long Term Evolution: From Theory to Practice*", Second edition, Wiley, 2011.

EC3078E OPTO-ELECTRONIC COMMUNICATION SYSTEMS

Pre-requisites: A first level course in Electromagnetics

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Understand the basic concepts of optical fibers and its propagation as well as transmission properties
CO2: Design optical sources and detectors with respect to their application in optical communication systems
CO3: Analyse and design optical amplifiers to meet specific requirements of real world applications
CO4: Assess the different techniques to enhance the capacity and performance of optical communication systems

Optical Fibers and their properties: Overview of optical fiber communications and its advantages, Optical Fibers: Geometrical optics description, wave propagation, Dispersion in fibers: intermodal dispersion, material dispersion, waveguide dispersion, polarisation mode dispersion, Dispersion shifted fibers, Dispersion compensating fibers, Attenuation in fibers: absorption, scattering, and bending losses, nonlinear optical effects

Optical Transmitters and Receivers: Light emitting diodes & Laser diodes: principles of operation, concepts of line width, phase noise, switching and modulation characteristics, typical LED and LD structures, transmitter design, Photo detectors: PN detector, pin detector, avalanche photodiode, Principles of operation, concepts of responsivity, sensitivity and quantum efficiency, noise in detection, typical receiver configurations (high impedance and transimpedance receivers).

Optical Amplifiers: Semiconductor amplifiers, Raman amplifiers, Doped fiber amplifiers, principles of operation, amplifier noise, signal to noise ratio, gain, gain bandwidth, gain and noise dependencies, intermodulation effects, saturation induced crosstalk, wavelength range of operation.

Multichannel systems and Coherent Light wave Systems: Multichannel systems: WDM systems, TDM systems, OFDM systems, CDM systems, Coherent Light wave Systems: Homodyne and heterodyne detection, optical hybrids and balanced receivers, Modulation formats: ASK, FSK, PSK, QAM, Demodulation schemes, BER & receiver sensitivity, Next Generation Optical Communications: Multi-core MMF based SDM transmission, Optical wireless communications.

References:

1. G. P. Agrawal, *Fiber-Optic Communication Systems,* 4th Edition., John Wiley & Sons, 2010.
2. R. L. Freeman, *Fiber-Optic Systems for Telecommunications*, John Wiley & Sons, 2002.
3. Leonid Kazovsky, Sergio Benedetto and Alan Willner, *Optical Fiber Communication Systems*, Artech House, 1996.
4. John M. Senior, "*Optical Fiber Communications*", PEARSON, 3rd Edition, 2010.
5. R. P. Khare, *Fiber Optics and Optoelectronics*, Oxford University Press, 2004.
6. Z. Ghassemlooy, W.Popoola, S. Rajbhandari "*Optical Wireless Communications- Systems and channel modelling with MATLAB*" CRC press, Taylor & Francis, 2013.

EC3079E CAD OF HIGH FREQUENCY CIRCUITS

Pre-requisites: A first level course in Electromagnetics

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Analyze the two-port network with the help of different parameters
CO2: Analyze passive microwave components using S- parameters
CO3: Design Stepped-Impedance and all open stub microstrip line low pass filter.
CO4: Develop the basic skills to design and simulate microwave passive circuits in the electromagnetic simulation tool

Network Analysis, Matching Technique and Transmissions Lines
Network analysis: Z, ABCD, Y, T, S-parameters. Smith chart, Impedance matching technique using lumped elements, single stub and double stub. Different types of transmission lines, strip lines, microstrip lines, and others. Discontinuities and Bends: Introduction, open-circuit end correction, corners, symmetrical step, T-junction, series gaps, and Bends in microstrip line.

Passive Microwave Components
Passive microwave components – S matrix formalism, directional coupler, waveguide tees, magic-tee, isolator, circulator, phase shifter, and Power divider. Even and odd mode analysis, Simulations in electromagnetics (EM) simulation tool, Resonators: series and parallel resonators.

Filter Design
Planar microwave Filter design by the Insertion Loss method, Filter transformations, Filter implementation, Stepped-Impedance low pass filters, all open stub low pass filter, Design and simulation of microstrip line of different characteristics impedance, matching the load using micostrp line, and low pass in EM simulation tool.

References:

1. Pozar, D.M., "*Microwave Engineering*", 4th Ed., John Wiley & Sons. 2012.
2. Franco di Paolo, "*Networks and Devices using Planar Transmission Lines*," CRC Press, 2018.
3. Roberto Sorrentino and Giovanni Bianchi, "*Microwave and RF Engineering*" John Wiley & Sons, 2010.
4. Ludwig, R. and Bogdanov, G., "*RF Circuit Design: Theory and Applications*", 2nd Ed, Pearson Education, 2011.
5. Collin, R.E., "*Foundations for Microwave Engineering*", 2nd Ed., Wiley - India, 2007.

EC3080E SIGNAL ESTIMATION AND DETECTION

Pre-requisites: A first level course in Communication and Random Processes

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Acquire estimation and detection theory knowledge and apply it in real-life applications.
CO2: Describe and validate the estimation techniques using standard properties and bounds.
CO3: Derive, implement, and analyze various techniques for parameter estimation.
CO4: Formulate, describe, and analyze various decision techniques in noisy observations.

Fundamentals of Estimation Theory: Fundamentals of estimation theory, Role of estimation in signal processing and communication systems, Desirable properties of estimators, Minimum variance unbiased (MVU) estimators, Finding MVU estimators, Cramer-Rao lower bound, Linear modeling, Generic formulation and examples.

Parameter Estimation: Deterministic parameter estimation, Least squares estimation, Batch processing, Recursive least squares estimation, Matrix inversion lemma, Best linear unbiased estimator, Maximum likelihood estimation, Random parameter estimation, Philosophy of Bayesian estimators, Multivariate Gaussian random variables, Minimum mean square error estimator, Maximum a posteriori estimator, Linear MMSE estimator, Wiener filters.

Detection Theory: Fundamentals of detection theory, Hypothesis testing, General modeling of binary hypothesis testing problem, Bayes' detection, MAP detection, ML detection, Minimum probability of error criterion, Min-Max criterion, Neyman-Pearson criterion, Receiver operating characteristics curves, Basics of multiple hypothesis testing, Detection of signals in white Gaussian noise, Binary detection of known signals in white Gaussian noise, M-ary detection of known signals in white Gaussian noise, Matched filter approach.

References:

1. S. M. Kay, *Fundamentals of Statistical Signal Processing*, Vol. 1: Estimation Theory, Vol. 2: Detection Theory, Pearson Education, 1993.
2. S. M. Kay, *Fundamentals of Statistical Signal Processing*, Vol. 3: Practical Algorithm Development, Pearson Education, 2018.
3. Jerry M. Mendel, *Lessons in Estimation Theory for Signal Processing*, Communication and Control, Prentice Hall Inc., 1995.
4. Ralph D. Hippenstiel, *Detection Theory: Applications and Digital Signal Processing*, CRC Press, 2002.

EC3081E WIRELESS TECHNOLOGIES AND SYSTEMS

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Analyze impact of frequency allocation, signal propagation, modulation, coding, multiplexing, multiple access, antennas, diversity etc on wireless communication.
CO2: Identify wireless system requirements in real world problems.
CO3: Design wireless systems to meet given wireless system requirements.
CO4: Compare wireless technologies and assess their suitability to meet wireless system requirements.
CO5: Choose appropriate wireless modules available in the market to solve real world problems

Fundamentals of Wireless Communications: Spectrum; Antennas; Signal Propagation: large-scale and small-scale models; Basics of Digital Modulation and Error Control Coding; Multiplexing and Multiple Access: Frequency/Time/Code, OFDM and OFDMA, ALOHA; Diversity and MIMO Systems.

Wi-Fi: Overview of 802.11 Wi-Fi; ALOHA, CSMA/CD and CSMA/CA; Spectrum: unlicensed v/s licensed, frequency ranges and bands; Infrastructure and Adhoc Networks, WLAN Architectures; Physical layer and MAC layer; WLAN Standards: IEEE 802.11a/g/n, Wi-Fi 6; Dual-band Wi-Fi APs, Mesh deployments; Spectrum planning.

Non-cellular Wireless Technologies: Classifications; Vehicular Adhoc Networks; Wireless Sensor networks; Wireless Personal Area Networks; IEEE 802.15.1 Bluetooth; IEEE 802.15.4, Zigbee, 6LowPAN; LoRaWAN; IEEE 802.15.6 Wireless Body Area networks; IEEE 802.16; Implementation considerations.

Cellular Wireless Technologies: Cellular concept: Cellular architecture, channel re-use, roaming; Evolution to 5G; 4G and 5G overview; 5G use cases, requirements and performance metrics: IMT 2020, eMBB, URLLC, mMTC; Standards, 3GPP; Spectrum for 5G, frequency ranges and bands, spectrum sharing, NR-U; 5G Architecture;User plane and control plane protocol stacks; 5G NR: downlink aspects, uplink aspects, resource allocation; Selected topics related to 5G Advanced, mmWave, massive MIMO, URLLC, MTC, D2D/V2X, NTN, Edge computing, and 5G power saving features; Selected topics on potential 6G features.

References:

1. T. S. Rappaport, *Wireless Communications: Principles and Practice,* Second Edition, Pearson, 2010
2. E. Khorov, A. Kiryanov, A. Lyakhov and G. Bianchi, "*A Tutorial on IEEE 802.11ax High Efficiency WLANs*", in IEEE Communications Surveys & Tutorials, vol. 21, no. 1, pp. 197-216, 2019.
3. Stefania Sesia, Issam Toufik, Matthew Baker, "*LTE – The UMTS Long Term Evolution: From Theory to Practice*", Second edition, Wiley, 2011.
4. Juan Montojo, Peter Gaal, Haris Zisimopoulos and Wanshi Chen, "*Fundamentals of 5G Communications: Connectivity for Enhanced Mobile Broadband and Beyond*", First edition, McGraw Hill, 2021.

EC3082E CODING SCHEMES FOR MODERN COMMUNICATION SYSTEMS

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Evaluate the error probability performance of digital communication systems over AWGN channels and analyze the coding gain achieved through the use of channel codes.
CO2: Design and implement various basic and advanced channel codes.
CO3: Apply various decoding algorithms, including Maximum Likelihood decoding, Viterbi algorithm, belief propagation decoding, and iterative decoding, for error correction in different channel codes.
CO4: Investigate polar codes and their performance over binary erasure channels.

Design of Channel Codes
Error probability performance of digital communication systems over AWGN channels, Coding gain of channel codes, Basics of linear block codes and cyclic codes, Groups, Rings, Fields, Field extension, Galois Field arithmetic, Minimal polynomial and conjugates, Vector space, BCH codes, Design of BCH codes, Decoding, Encoder and decoder circuits, Reed Solomon codes, Design of RS codes, Decoding algorithms over AWGN channel

Convolutional Codes
Convolutional Codes, Generator matrix, State, tree and trellis diagram, Transfer function, Maximum Likelihood decoding, Hard versus Soft decision decoding, Soft output Viterbi algorithm, Sequential decoding, Recursive Systematic Convolutional Coders, Turbo codes, Extrinsic information, Maximum Aposteriori Probability decoding, Iterative decoding of Turbo codes

LDPC and Polar Codes in Communication Systems
Low density parity check codes, Regular and Irregular codes, Quasi-Cyclic LDPC codes, Encoding methods, Tanner graphs, Belief propagation decoding, Density evolution, Thresholds, Polar codes, Encoding for binary erasure channels, Decoding algorithms, Concatenated codes

References:

1. Shu Lin and Daniel. J. Costello Jr., *Error Control Coding: Fundamentals and applications*, Second Edition, Pearson Education, 2010
2. R.E. Blahut, *Theory and Practice of Error Control Coding*, Addison-Wesley; Reprint. 1983.
3. W.C. Huffman and Vera Pless, *Fundamentals of Error correcting codes*, Cambridge University Press, 2010.
4. Ron M. Roth, *Introduction to Coding Theory*, Cambridge University Press, 2006
5. Elwyn R. Berlekamp, *Algebraic Coding Theory* Revised edition, World Scientific, 2015
6. Robert McEliece, *The Theory of Information and Coding*, Cambridge University Press, 2002
7. T. Richardson and R. Urbanke, *Modern Coding Theory*, Cambridge Press, 2008
8. MacWilliams, F. J., and N. J. A. Sloane, *The Theory of Error Correcting Codes,* North-Holland, 1978.

EC3083E NETWORK INFORMATION THEORY AND CODING

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Analyze and apply information theory concepts such as entropy, mutual information, source coding theorem, channel capacity, and differential entropy to characterize and optimize communication systems.
CO2: Analyze the capacity of networks and multiuser channels.
CO3: Design cooperative communication systems with networking coding concepts and analyze the achievable performance of some of the popular techniques and configurations.

Foundations of Information Theory
Entropy, Mutual Information, Source coding theorem, Asymptotic Equipartition Property, Channel capacity and coding theorem for discrete and continuous channels, Differential entropy, Entropy maximization results, Waveform channels, Gaussian channels

Network Information Theory
Network information flow problem, Max flow, Min cut theorem, Multiple sources and destinations, Joint typicality, Slepian-Wolf theorem, Wiener-Ziv Coding, Gaussian multiple user channels, Multiple access channels, Broadcast channels, Interference channels, Relay Channels, Capacity bounds and achievability, Coding for achievability

Network Coding
Introduction to network Coding, Merits, Challenges, Multicast in lossless wireless network, Scalar linear network coding, Random linear network coding, Delay and throughput analysis, Multicast network code construction, Physical layer network coding, Index coding, Equivalence between Network coding and Index coding, Introduction to coded caching

References:

1. Abbas El Gamal, Young-Han Kim, *Network Information Theory*, Cambridge University Press 2011
2. Thomas M. Cover and Joy A. Thomas, *Elements of Information Theory*, Wiley India Pvt. Ltd., 2nd Edition 2013
3. Tracey Ho, Desmond S. Lun, *Network Coding: An introduction*, Cambridge University Press, 2008
4. Christina Fragouli and Emina Soljanin, *Network Coding Fundamentals*, Now Publishers Inc, 2007

EC3084E WIRELESS NETWORKS

Pre-requisites: A first level course in Communication Engineering

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Analyse and design resource allocation algorithms in OFDMA and NOMA.
CO2: Analyse the physical layer and MAC layer aspects of 802.11
CO3: Understand and analyse the 5G cellular architecture and its networking aspects.

Cellular Orthogonal Multiple Access (OFDMA)- Time Division Multiple Access (TDMA): The general model, Resource allocation over a single carrier: power control for optimal service rate, power control for optimal power constrained delay, Multicarrier resource allocation for downlink: single MS case, multiple MS case.

Non-Orthogonal Multiple Access (NOMA): Non-orthogonal transmission for downlink broadcast/multicast, standardization of downlink superposition transmission, general discussion of uplink non-orthogonal multiple access, uplink transmitter side solution and receiver algorithms, performance evaluation of uplink NOMA of contention-free based grant-free, system design and performance evaluation of contention-based grant-free transmissions.

WIFI: Evolution of Wi-Fi, Spectrum: unlicensed spectrum, Wi-Fi architectures, Random Access Protocols without carrier sensing: Aloha and Slotted Aloha, Carrier sensing protocols: CSMA/CA principles of collision avoidance, saturation throughput of a co-located IEEE 802.11-DCF Network, Service differentiation aspect of IEEE 802.11 DCF protocol: EDCA protocol, analytical modeling of service differentiation, MAC aspects of IEEE 802.11 ax: BSS coloring, OFDMA, multi-user operation, power saving features, frame aggregation, PHY aspects of IEEE 802.11ax: MU-MIMO, numerology, tone plan, physical layer packet formats.

Cellular Network: 5G and Beyond, Review of cellular concept, Evolution to 5G, Spectrum for 5G, frequency ranges and bands, spectrum sharing, NR-U, Key 5G features, 5G architecture: 5G RAN architecture, 5G core architecture, Network slicing, Control plane protocol stack: NAS, RRC, User plane stack: SDAP, PDCP, RLC, MAC, SDN and NFV in 5G, Link budget and maximum throughput calculations.

References:

1. Anurag Kumar, D. Manjunath, and Joy Kuri, *Communication Networking: An Analytical Approach* Elsevier, 2004.
2. Anurag Kumar, D. Manjunath, and Joy Kuri, Wireless Networking, 1st Edition - March 24, 2008, Elsevier.
3. Cory Beard, and William Stallings, *Wireless Communication Networks and Systems*, Pearson, 2015.
4. Best readings in Non-orthogonal Multiple access available: https://www.comsoc.org/publications/best-readings/non-orthogonal-multiple-access accessed on 11th November 2023.
5. Yifei Yuan, Zhifeng Yuan, 5G New Radio Non-Orthogonal Multiple Access, CRC Press, First Edn, 2023.
6. E. Khorov, A. Kiryanov, A. Lyakhov and G. Bianchi, "*A Tutorial on IEEE 802.11ax High Efficiency WLANs*," IEEE Communications Surveys & Tutorials, vol. 21, no. 1, pp. 197-216, 2019.
7. Juan Montojo, Peter Gaal, Haris Zisimopoulos and Wanshi Chen, "*Fundamentals of 5G Communications: Connectivity for Enhanced Mobile Broadband and Beyond*", First Edition, McGraw Hill, 2021.

EC3085E TOPICS IN MULTI-USER COMMUNICATIONS

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Analyze various multi-user communications scenarios and challenges to enable multi-user communications.
CO2: Identify technical solutions for engineering design that involves multi-user communication systems.
CO3: Choose appropriate wireless modules available in the market to solve multi-user communication challenges.
CO4: Design and develop resource efficient and eco-friendly multi-user communication systems.

Introduction to Multi-User Communications in Data Networks: Introduction to communication networks, Circuit switching and Packet switching, Space switch, time switch, and space-time architectures, Synchronization, Basics of queuing theory: arrival and service process, Poisson processes, memorylessness, discrete and continuous Markov chains, Introduction to data networks and broadband access networks: Multiple access schemes, duplex modes, power control, Broadband access: Dialup and asymmetric digital subscriber Line (ADSL), Telecom operator business.

Multi-User Communications in Non-Cellular Networks: Effect of various physical medium for multi-user communication, Aloha, Slotted Aloha, stability analysis, Stabilized slotted Aloha, Bayesian analysis, Binary back-off algorithm, Ethernet medium access control, multi-user connectivity in Passive optical network (PON), Carrier-sense multiple access (CSMA), collision detection (CD) and CSMA-collision avoidance (CA), hidden and exposed nodes, Multi-user connectivity in IEEE 802.11, IEEE 802.15.1 Bluetooth, IEEE 802.15.4, Zigbee, IEEE 802.15.6 Wireless Body Area networks.

Multi-User Communications in Cellular Networks: Concept of cellular systems: architecture, frequency reuse, hand-off, Information theoretic aspects of uplink and downlink cellular capacity: two user scenario, Orthogonal frequency division multiplexing (OFDM) architecture, Orthogonal frequency division multiple access (OFDMA) systems: concept, basic resource allocation techniques, Basics of multiple-input-multiple-output (MIMO), Multi-user MIMO, Multi-user connectivity in 4G & 5G cellular systems, non-orthogonal multiple access (NOMA): power domain and code domain, Trends in multi-user communications in 5G beyond and 6G.

References:

1. D. Bertsekas, and R. Gallager. *Data networks*. Athena Scientific, 2021.
2. A. B. Forouzan, *Data communications and networking*. McGraw-Hill Higher Education, 2007
3. Dahlman, S. Parkvall, J. Skold. 4G, *LTE-advanced Pro and the Road to 5G*. Academic Press, 2016
4. A. Goldsmith, *Wireless communications*. Cambridge university press, 2005.
5. Any appropriate application notes or research documents

EC3086E TELECOM NETWORK MANAGEMENT

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Compare standard techniques on top-down design, implementation, performance evaluation of telecommunication networks.
CO2: Identify various requirements pertaining to network management in telecommunication networks.
CO3: Analyze state-of-the-art network management techniques.
CO4: Design network management systems to meet given specifications.

Design Fundamentals of Telecommunication Networks: Network Architectures: Requirement based top-down network design, end-to-end services, service level agreements, performance evaluation techniques - Analytic modelling and topological design of communication networks: centralized polling networks, packet switched networks, T1 networks, concentrator location problems - Design and implementation of networks: performance metrics, link budget, analysis tools, quality of service.

Components and Architectures for Network Management: Planning and managing networking elements: hardware, software, protocols, applications - Information modelling for Network Management – Network information models – Management information bases (MIB) and management platforms – Generic network information mode and technology-specific information models – Network level view information model.

Telecommunication Management Networks and Case Studies: Telecommunication Management Networks: physical, security, and logical layered architectures, examples, case studies in Internet and Mobile Networks – Network management protocols - Simple network management protocol (SNMP) and common management information protocol (CMIP).

References:

1. M. Subramanian, *Network Management Principles and Practice*, 2nd Edition, Pearson, 2010
2. A. Leinwand, K. F. Conroy, *Network Management*: A Practical Perspective, Addison-Wesley, 1996
3. J. Laiho, A. Wacker and T. Novosad, *Radio Network Planning and Optimization for UMTS*, John Wiley & Sons, 2006
4. H. Hanrahan, *Network Convergence: Services, Applications, Transport, and Operations Support*. John Wiley & Sons, 2007
5. S., Aidarous, P. Thomas, *Telecommunications Network Management Technologies and Implementations*, Wiley-IEEE Press, 1998

EC3087E RADAR ENGINEERING

Pre-requisites: A first level course in Electromagnetics

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Analyze radar systems using radar equations and block diagrams.
CO2: Choose pulse repetition frequency and antenna parameters, and analyze range performance of radar.
CO3: Analyze CW radar, FM-CW radar, MTI radar and non-coherent MTI pulse Doppler radar.
CO4: Design radar transmitters and receivers.

Introduction to radar, Radar equation, Block diagram, Radar frequencies, Applications, Prediction of range performance, Pulse repetition frequency, Range ambiguities, CW Radar, Doppler effect, FMCW radar, Multiple frequency radar, MTI radar, Delay line cancellers, Staggered PRF, Range gating, Noncoherent MTI and pulse Doppler radar, Tacking Radar, Sequential lobing, Conical Scan, Monopulse, Acquisition.

Radar Transmitters, Modulators, Solid state transmitters, Radar Antennas, Parabolic, Scanning feed, Lens, Radomes, Electronically steered phased array antenna, Applications, Receivers, Displays, Duplexers.

Detection of radar signals in noise, Matched filter criterion, Detection criterion, Extraction of information and waveform design, Propagation of radar waves, Radar clutter, Special purpose radars, Synthetic aperture radar, HF and over the horizon radar, Air surveillance radar, Height finder and 3D radars, Bistatic radar, Radar Beacons, Radar jamming, Electronic counters.

References:

1. Merrill I. Skolnik, *Introduction to Radar Systems*, 3rd Edition, MacGraw Hill, 2017.
2. Merrill I. Skolnik, *Radar Handbook,* 3rd Edition, McGraw Hill Publishers, 2008.
3. J. C. Toomay and Paul Hannen, *Radar Principles for the Non-Specialist*, 3rd Edn, SciTech Publishers, 2004.
4. N. Levanon and E. Mozeson, *Radar Signals*, 1st Edition Edition, Wiley-IEEE Press, 2004.
5. B. R. Mahafza, *Radar Systems Analysis and Design Using MATLAB*, 4th Edn, CRC Press, 2022.

EC3088E MULTICARRIER AND MIMO TECHNIQUES

Pre-requisites: A first/second level courses in Communication Engineering

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Examine limitations in single carrier and SISO communication systems, and explore solutions using multicarrier and MIMO communication systems.
CO2: Design various OFDM systems, analyze their impairments, and quantify performance.
CO3: Analyze the fundamental information-theoretic limits of MIMO and multicarrier systems.
CO4: Analyze and select communication architectures to efficiently address a given communication problem.

Communication using multiple carriers, Modulation with overlapping sub-channels, Multicarrier and OFDM systems, Implementation of OFDM systems using DFT techniques, Cyclic prefix, Matrix representation of OFDM, Vector coding, Challenges in multicarrier systems, Synchronization in OFDM, Intercarrier interference, Timing and carrier frequency offset estimation, Channel estimation in OFDM, Pilot arrangements for channel estimation, clipping in OFDM systems, Nonlinearity of power amplifier, PAPR properties and PAPR reduction techniques, BER analysis of OFDM communication systems.

Multiple access techniques with OFDM, OFDM-TDMA, OFDMA, Carrier assignment strategies, Synchronization and channel estimation in OFDMA, Modified forms of multicarrier transmission techniques, Single carrier FDMA, Generalized frequency division multiplexing, Universal filtered multicarrier systems, Brief overview on cognitive radio, OFDM-based cognitive radio.
Review of SISO fading communication systems, Comparison with MIMO communication systems, MIMO channel models, Precoding designs in MIMO systems, Capacity of MIMO systems with and without channel state information at the transmitter, Spatially correlated channels and effect of correlation on capacity.

Diversity in MIMO systems, Achieving diversity in MIMO systems with and without channel state information at the transmitter, Alamouti space-time code, Receivers for MIMO systems operating in diversity mode, Matched filter bound, Matched filter receivers, Zero forcing receivers, MMSE receivers, Ordered SIC and BLAST receivers, Sphere decoding receivers, Generalized space time code design criteria, Space-time trellis codes, Multicarrier MIMO systems.

References:

1. Yong S. Cho, J. Kim, Won Y. Yang, Chung G. Kang, *MIMO-OFDM Wireless Communications with MATLAB*, Wiley-IEEE Press, 2011.
2. Ahmad R.S. Bahai, B.R. Saltzberg, M. Ergen, *Multi-carrier Digital Communications - Theory and Applications of OFDM*, Second Edition, Springer, 2011.
3. R. Prasad, *OFDM for Wireless Communication Systems*, Artech House, 2004.
4. David Tse, Pramod Viswanath, *Fundamentals of Wireless Communication*, Cambridge University Press, 2005.
5. Andrea Goldsmith, *Wireless Communications*, Cambridge University Press, 2012.