NATIONAL INSTITUTE OF TECHNOLOGY DURGAPUR

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

Revised Curriculum and Syllabi

Program Name
Master of Technology in MICRO-ELECTRONICS & VLSI
Effective from the Academic Year: 2021-2022

Recommended by DAC	: 12.08.2021
Recommended in PGAC	: 16.08.2021
Approved by the Senate	: 22.08.2021

CONTENTS

Curriculum for M. Tech. in Microelectronics & VLSI

SEMESTER I

Sl. No	Code	Subject	L	T	S	C	H
1	EC1011	Semiconductor Device & Modeling	3	0	0	3	3
2	EC1012	Analog IC Design	3	1	0	4	4
3	EC1013	Digital IC Design	3	0	0	3	3
4	EC90XX	SPECIALIZATION ELECTIVE - I	3	1	0	4	4
5	EC90XX	SPECIALIZATION ELECTIVE - II	3	1	0	4	4
6	EC1061	Analog IC Design Lab	0	0	4	2	4
7	EC1062	Digital IC Design Lab	0	0	4	2	4
		TOTAL	**15**	**3**	**8**	**22**	**26**

SEMESTER II

Sl. No	Code	Subject	L	T	S	C	H
1	EC2011	VLSI Technology	3	0	0	3	3
2	EC2012	VLSI System Design	3	1	0	4	4
3	EC90XX	SPECIALIZATION ELECTIVE - III	3	1	0	4	4
4	EC90XX	SPECIALIZATION ELECTIVE - IV	3	1	0	4	4
5	EC90XX	SPECIALIZATION ELECTIVE - V	3	1	0	4	4
6	EC2061	VLSI System Design Lab	0	0	4	2	4
7	EC2062	Term Project/ Lab-Based Project	0	0	6	3	6
		TOTAL	**15**	**4**	**10**	**24**	**29**

SEMESTER III

Sl. No	Code	Subject	L	T	S	C	H
1	XX90XX	AUDIT LECTURES / WORKSHOPS	0	0	0	0	2
2	EC3061	Project - I	0	0	24	12	24
3	EC3062	SEMINAR - NON-PROJECT / EVALUATION OF SUMMER TRAINING	0	0	4	2	4
		TOTAL	0	0	28	14	30

SEMESTER IV

Sl. No	Code	Subject	L	T	S	C	H
1	EC4061	Project - II	0	0	24	12	24
1	EC4062	PROJECT SEMINAR	0	0	4	2	4
		TOTAL	0	0	28	14	28

Note: (i) Project I & II may be done independently or completed in continuation,

(ii) Project I and/or II may be done in collaboration with Industry/other academic/R&D Organization

1. List of Common Pool Electives:

Sl. No.	SUBJECT CODE	SUBJECT	L-T-S	CREDIT
1.	EC9001	Digital Signal Processing using MATLAB*	3-0-2	4
2.	EC9002	Statistical Signal Processing	3-1-0	4
3.	EC9003	Applications of Image Processing using Python*	3-0-2	4
4.	EC9004	Automated Speech Signal Processing	3-1-0	4
5.	EC9005	Probability & Random Process	3-1-0	4
6.	EC9006	Error Correction Coding	3-1-0	4
7.	EC9007	Detection & Estimation Theory	3-1-0	4
8.	EC9008	Optical Communication & Networks	3-1-0	4
9.	EC9009	Cooperative Communication Networks	3-1-0	4
10.	EC9010	Network Information Theory and Coding	3-1-0	4
11.	EC9011	Digital Microwave Communication	3-1-0	4
12.	EC9012	Microwave Photonics	3-1-0	4
13.	EC9013	Radiating Systems for Next Gen Communication	3-1-0	4
14.	EC9014	Microwave and Millimeter-wave Measurements	3-1-0	4
15.	EC9015	Microwave Solid state Devices	3-1-0	4
16.	EC9016	Digital Satellite and Navigational Systems	3-1-0	4
17.	EC9017	Bimolecular Communication	3-1-0	4
18.	EC9018	Queuing Theory for Telecommunication	3-1-0	4
19.	EC9019	Quantum Communication and Computing	3-1-0	4
20.	EC9020	Cloud Computing	3-0-0	3
21.	EC9021	Machine Learning and Deep Learning using Python	3-1-0	4
22.	EC9022	Big Data Computing	3-1-0	4
23.	EC9023	Internet of Things (IoT)	3-1-0	4
24.	EC9024	Virtual Reality and Augmented Reality	3-1-0	4
25.	EC9025	Network Function Virtualization & Software Defined Networks	3-1-0	4
26.	EC9026	Game Theory for Telecom Management	3-1-0	4
27.	EC9027	Multiphysics Analysis and Modeling using COMSOL/ANSYS	3-1-0	4
28.	EC9028	Mixed Signal IC Design	3-1-0	4
29.	EC9029	Architectural Design of ICs	3-1-0	4
30.	EC9030	RF IC Design	3-1-0	4
31.	EC9031	SoC Design	3-1-0	4
32.	EC9032	FPGA based design*	3-0-2	4

Sl. No.	SUBJECT CODE	SUBJECT	L-T-S	CREDIT
33.	EC9033	Embedded Systems	3-1-0	4
34.	EC9034	MEMS & Microsystems Technology	3-1-0	4
35.	EC9035	Nanoelectronics	3-1-0	4
36.	EC9036	ASIC Design using Verilog/VHDL*	3-0-2	4
37.	EC9037	Low Power Circuits and Systems	3-1-0	4
38.	EC9038	Testing and Verification of VLSI Circuits	3-1-0	4
39.	EC9039	Advanced Computer Architecture	3-1-0	4
40.	EC9040	DSP Architectures in VLSI	3-1-0	4
41.	EC9041	Power Management IC Design	3-1-0	4
42.	EC9042	Cyber Physical Electronic System Design	3-1-0	4
43.	EC9043	Smart Material based Devices	3-1-0	4

Note: Other than the above-mentioned courses, maximum two courses (one from each semester) including core and elective offered by other PG programs of the Institute can be opted as an ELECTIVE subject with the necessary prior approval from the Department.

***The Lecture, Tutorial and Sessional distribution of EC9001, EC9003, EC9032, and EC9036 are 3, 0 and 2, respectively.**

2. Assessment:

The assessment method followed from the academic year 2019-2020 is briefly mentioned as follows.

A. Theory Courses (15 + 25 + 60)

In the subjects, total 100 marks consist of the following three components.

(i) Continuous Assessment 1 (CA1): (15 marks)

This is realized with class tests, quizzes, home assignments, surprise tests or a combination of these components. If more than two class tests are conducted, average marks are considered.

(ii) Continuous Assessment 2 (CA2): (25 marks, 2 hours)

Mid-term assessment (CA2) covers half of the syllabus. The exam is conducted at the middle of the semester following the academic calendar. The evaluation is done within a fortnight and the answer scripts are shown to the students so that they can understand their shortcomings in learning the subject.

(iii) End-term Examination: (60 marks, 3 hours)

End-term examination covers the full syllabus. The exam is centrally conducted at the end of the semester. After the evaluation, the answer scripts are shown to the students. Model answers are also provided.

** It is to be mentioned here that in the previous two academic years - 2017-2018 and 2018-2019, the assessment methods and distributions of the three components corresponding to the total 100 marks are as given below.

a) Continuous Assessment (CA): 20 marks – This is based on quizzes, home assignments, class test and surprise tests.
b) Mid-Semester Assessment (MA): 30 marks – A mid-semester examination is conducted tentatively within 7-8 weeks after beginning of teaching in each semester.
c) End-Semester Examination: 50 marks – The examination is conducted at the end of teaching session of the semester.

Based on the feedback taken from the concerned stakeholders of the Institute as well as academic, industry and R&D personnel, PG curriculum has been revised in the academic year 2019-2020.

B. Laboratory Courses (40 + 40 + 20)

For the evaluation of Laboratory Courses, total 100 marks has following three components

(i) **Continuous Assessment (CA): 40 marks** – The students are evaluated based on their performance on day to day basis in conducting the experiments and obtaining the experimental results in the Laboratory. Attendance, general attentiveness/ sincerity /behavior of student and occasional instant quizzes are considered in this component.

(ii) **End-Semester Assessment (EA): 40 marks** – The end-semester evaluation consists of two subcomponents. 20 marks for the performance of the students in conducting the experiment or program assigned during the end-semester examination and 20marks for viva-voce examination.

(iii) **Laboratory Reports: 20 marks**– 20 marks is awarded based on the representation of the experimental results, writing ability of the associated theory, analysis of the obtained results and observation/concluding remarks drawn corresponding to each experiment performed in the laboratory throughout the semester including the end-semester examination.

3. Program Outcomes (POs) and Program Specific Outcomes (PSOs)

A. Program Outcomes (Pos):

NBA has defined the following three POs for the PG programs:

PO 1: An ability to independently carry out research /investigation and development work to solve practical problems.

PO 2: An ability to write and present a substantial technical report/document.

PO 3: Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program

B. Program Specific Outcomes (PSOs):

In addition to the three POs, three program specific outcomes (PSOs) have been defined by the Department as follows -

PSO 1 (PO 4): Identify, formulate and solve engineering problems in the field of Microelectronics and VLSI

PSO 2 (PO 5): Apply knowledge, proper methodology and modern tools to analyze and solve the problems in the domain of Microelectronics and VLSI.

PSO 3 (PO 6): Acquire professional and intellectual integrity and ethics of research and recognize the need to engage in learning with a high level of enthusiasm and commitment to contribute to the community for sustainable development of society

Course Articulation Matrices: Connection between the courses and the POs and PSOs

The correlation levels are 1, 2 or 3, denoting:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High).

4. Detailed Syllabus:

A. Core Subjects

Department of Electronics & Communication Engineering								
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total contact hours : 42				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
EC1011	**Semiconductor Device & Modeling**	PCR	3	0	0	3	3
Pre-requisites/Co-requisites: [PHC331, ECC302]			Course Assessment methods: (Continuous Assessment (CA:15%), Mid-Term Assessment (MA:25%) and End-Term Assessment (EA:60%)):				
			Continuous Assessment (CA): Quizzes/Class tests/Assignments/Attendance				

Course Outcomes

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

- **CO 1:** To introduce the physics of semiconductor materials for understanding the device modeling of semiconductor devices.
- **CO 2:** To understand the transport of charge carriers for the operation of semiconductor devices.
- **CO 3:** To apply suitable approximations and techniques to derive the physical model of semiconductor devices such as P-N junctions.
- **CO 4:** To analyze electrostatic variables and current-voltage characteristics of MOS devices under a variety of conditions.
- **CO 5:** To evaluate qualitative understanding of the physics of emerging MOS devices and conversion of this understanding into modeling.
- **CO 6:** To develop the fundamental understanding of device modeling and numerical simulation

Topics Covered

Module I. Semiconductor Electronics [L – 6; T - 0]
Semiconductor Materials, Band Model of Solids Thermal-Equilibrium Statistics, Carriers in Semiconductors, Drift Velocity, Mobility and Scattering, Drift & Diffusion Current, Device: Hall-Effect.

Module II. Metal-Semiconductor Contacts And P-N Junctions [L – 8; T - 0]
Metal-Semiconductor junctions, Current-Voltage Characteristics, Surface Effects. The pn junction, Step Junction, Linearly Graded Junction, Heterojunctions, Reverse-Biased p-n junctions and break down mechanism. Generation and Recombination.

Module III. Field-Effect Transistors (MOSFETs) and Its 1st order I-V Model [L – 9; T - 0]
MOS Capacitor, Flat Band Voltage, Oxide and Interface Charge, High and Low Frequency C-V Characteristics, Basic MOSFET behavior, Threshold Voltage Model, 1st Order I-V Model.

Module IV. Short Channel Effects and 2nd Order I-V Model [L – 10; T - 0]
Moore’s law, Technology nodes and ITRS, Physical & Technological Challenges to scaling short-channel effects: velocity saturation, device degradation, channel length modulation, body bias effect, threshold adjustment, mobility degradation, subthreshold current, hot carrier effects, velocity overshoot, high field effects in scaled MOSFETs, substrate current and effects in scaled MOSFETS.

Module V. Nonconventional MOSFETs [L – 5; T - 0]
High-k/metal gate, high mobility MOSFETS, SOI, Multi-gate MOSFETs, FinFET, GAA MOSFETs.

Module VI. Introduction to BSIM Modeling [L – 4; T - 0]
History of BSIM models, BSIM family of Compact device models, BSIM6 model, EKV Model, Introduction to the TCAD Simulation Tool, Examples of TCAD Simulations.

	Total Contact Hours: (L=42, T=0)= 42
Text Books, and/or Reference Material	**Text Books:** 1. Yuan Taur and Tak H. Ning, *"Fundamentals of Modern VLSI Devices"* 2nd Edition, Cambridge University Press, 2013. 2. Theodore I. Kamins Richard S. Muller, *"Device Electronics for Integrated circuits"*, 3rd Edition Wiley, 2007. 3. Dragica Vasileska, Stephen M. Goodnick, and Gerhard Klimeck, "*Computational Electronics: Semiclassical and Quantum Device Modeling and Simulation*", CRC Press, 2010. 4. A B. Bhattacharyya, "*Compact MOSFET Models for VLSI Design*", Wiley-IEEE, 2009. **Reference Books:** 1. S. M. Sze and Kwok K. Ng., "*Physics of Semiconductor Devices*", 3rd Edition, John Wiley & Sons, 2002. 2. Robert F. Pierret, "*Semiconductor Device Fundamentals*", Pearson Education, 2006. 3. Donald A. Neamen, "*Semiconductor Physics and Devices*", 3rd Edition, Mc-Graw Hill, 2003. 4. Jasprit Singh, "*Semiconductor Devices- Basic Principles*", John Wiley and Sons Inc., 2001.

EC1011: Semiconductor Device & Modeling
[Mapping between course outcomes (COs) and Program Outcomes (POs)]

CO	Statement	Program Outcomes					
		PO1	PO2	PO3	PSO1	PSO2	PSO3
CO1	To introduce the physics of semiconductor materials for understanding the device modeling of semiconductor devices.	1	1	3	2	1	1
CO2	To understand the transport of charge carriers for the operation of semiconductor devices.	2	1	3	2	1	1
CO3	To apply suitable approximations and techniques to derive the physical model of semiconductor devices such as P-N junctions.	2	2	3	2	3	1
CO4	To analyse electrostatic variables and current-voltage characteristics of MOS devices under a variety of conditions.	2	2	3	3	2	1
CO5	To evaluate qualitative understanding of the physics of emerging MOS devices and conversion of this understanding into modeling.	2	2	3	3	3	2
CO6	To develop the fundamental understanding of device modeling and numerical simulation	3	3	3	3	3	2
Average		2.00	1.83	3.00	2.50	2.17	1.33

Department of Electronics & Communication Engineering

Course Code	Title of the course	Program Core (PCR) / Elective (PEL)	Total contact hours : 56				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
EC1012	**Analog IC Design**	PCR	3	1	0	4	4

Pre-requisites/Co-requisites: [ECC301, ECC302, ECC602/EC1011]	Course Assessment methods: (Continuous Assessment (CA:15%), Mid-Term Assessment (MA:25%) and End-Term Assessment (EA:60%)) Continuous Assessment (CA): Quizzes/Class tests/Assignments/Attendance

Course Outcomes

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

- **CO 1:** Define various parameters/terms associated with MOS transistors and Analog IC design.
- **CO 2:** Describe the operation of a MOS transistor /Amplifier/other fundamental blocks.
- **CO 3:** Solve any given circuit using appropriate Large/Small Signal model equations.
- **CO 4:** Evaluate various performance metrics such as gain/BW/Power dissipation/Input & output range.
- **CO 5:** Analyze feedback circuit and determine its poles, zeros, gain margin & phase margin.
- **CO 6:** Design a Single stage Amplifier/Differential Amplifier to meet the given specifications.

Topics Covered

Module I. MOS Device Physics [L – 4; T - 2]
General Considerations, Overview of CMOS technology, MOS I/V Characteristics, Short Channel Effects, Noise, Large Signal MOS Device models.

Module II. MOS Models [L – 2; T - 1]
MOS Device Capacitance, Small Signal Device Models. Different trans-conductance (front gate: g_m, output: g_ds, back-gate: g_mb). Unity gain frequency calculation.

Module III. Single Stage Amplifiers [L – 8; T - 2]
Basic Concepts, Common Source Stage, Source Follower, Common Gate Stage, Cascode Stage, Calculation of Amplifier parameters.

Module IV. Current Mirror [L – 3; T - 2]
Simple, Cascode, Wilson and Large Swing current mirrors; Constant g_m, Band gap references.

Module V. Differential Amplifiers [L – 7; T - 2]
Single Ended and double ended. Differential Operation, Basic Differential Pair, Common- Mode Response, Differential Pair with MOS loads, current mirror load.

Module VI. Frequency Response of Amplifiers [L – 6; T - 1]
General Considerations, Common Source Stage, Source Follower, Common Gate Stage, Cascode Stage, Differential Pair.

Module VII. Operational Amplifiers [L – 7; T - 2]
General Considerations, One Stage Op Amps, Two Stage Op Amps, Common – Mode Feedback(CMFB), Power Supply Rejection Ratio (PSRR) Input Range limitations(ICMR), Slew Rate, Noise and Offset in Op Amps.

Module VIII. Feedback [L – 5; T - 2]
Feedback-Types, Nyquist plot, Stability- Frequency compensation techniques, Miller compensation, pole splitting, Gain Margin, Phase Margin.

Total Contact Hours: (L=42, T=14)= 56

Text Books, and/or Reference Material	**Text Books:** 1. Behzad Razavi, "*Design of Analog CMOS Integrated Circuits*", McGraw-Hill, 2nd Edition 2017. 2. Adel Sedra, Kenneth C. Smith, Tony Chan Carusone, Vincent Gaudet, "*Microelectronic Circuits*", Oxford, 8th Ed. 2020 3. Franco Maloberti, "*Understanding Microelectronics: A Top-Down Approach*", Wiley 2011. **Reference Books:** 1. Paul R. Gray, Paul J. Hurst, Stephen H. Lewis, and Robert G. Meyer, "*Analysis and Design of Analog Integrated Circuits*", John Wiley & Sons, Inc., 5th Edition 2015. 2. Roubik Gregorian, Gabor C. Temes, "*Analog MOS Integrated Circuits for Signal Processing*", Wiley 1986.

EC1012: Analog IC Design

[Mapping between Course Outcomes (COs) and Program Outcomes (POs)]

CO	Statement	Program Outcomes					
		PO1	PO2	PO3	PSO1	PSO2	PSO3
CO1	Define various parameters/terms associated with MOS transistors and Analog IC design.	2	1	2	3	1	1
CO2	Describe the operation of a MOS transistor /Amplifier/other fundamental blocks.	2	3	1	3	2	2
CO3	Solve any given circuit using appropriate Large/Small Signal model equations.	3	2	1	2	2	1
CO4	Evaluate various performance metrics such as gain/BW/Power dissipation/Input & output range etc.	3	1	1	3	2	1
CO5	Analyze feedback circuit and determine its poles, zeros, gain margin & phase margin.	3	1	1	2	1	2
CO6	Design a Single stage Amplifier/Differential Amplifier to meet the given specifications.	2	1	3	3	1	1
Average		**2.50**	**1.50**	**1.50**	**2.67**	**1.50**	**1.33**

Department of Electronics & Communication Engineering								
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total contact hours : 42				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
EC1013	**Digital IC Design**	PCR	3	0	0	3	3

Pre-requisites/Co-requisites: Digital Circuits and Systems[ECC401/EC1011]	Course Assessment methods: (Continuous Assessment (CA:15%), Mid-Term Assessment (MA:25%) and End-Term Assessment (EA:60%))
	Continuous Assessment (CA): Quizzes/Class tests/Assignments/Attendance

Course Outcomes

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

- **CO 1:** Acquire idea about the digital IC design techniques.
- **CO 2:** Understand the characteristics of CMOS inverter.
- **CO 3:** Identify the basic steps of ASIC Design Flow and fabrication process.
- **CO 4:** Analyze the static and dynamic characteristics of CMOS circuits.
- **CO 5:** Design and implementation of combinational and sequential circuits.
- **CO 6:** Evaluate the performance of CMOS circuits.

Topics Covered

Module I. Overview of VLSI Design [L – 2; T - 0]
Overview of VLSI design methodologies, design hierarchy, concepts of regularity, modularity, and locality, VLSI design styles, design quality, packaging technology, Recent Trends in VLSI Design & its research issues in industry, MOS Transistor.

Module II. MOS Inverter- Static & Switching Characteristics [L – 8; T - 0]
CMOS inverter, Delay-time definitions, calculation of delay times, logical efforts, inverter design with delay constraints, estimation of interconnect parasitics, calculation of interconnect delay, Bus vs. Network-on-Chip (NoC), switching power dissipation of CMOS inverters.

Module III. Combinational and Sequential CMOS Logic Circuits [L – 8; T - 0]
MOS logic circuits with depletion nMOS loads, CMOS logic circuits, complex logic circuits, CMOS transmission gates (pass gates), ratioed, dynamic, and pass transistor logic circuits, and domino circuits.
Behavior of bi-stable elements, SR latch circuits, clocked latch and flip-flop circuits, CMOS D-latch, and edge-triggered flip-flop.

Module IV. RTL-to GDS II [L – 20; T - 0]
Basics of IC; an overview of VLSI design flow, and layout design rules, stick diagram; idea to RTL; functional verification: simulation and formal verification; pre-synthesis: linting, CDC, RDC, and X-propagation; Synthesis: technology mapping, logic optimization, post-synthesis: LEC, GLS; static timing analysis; constraints, timing path, setup time and hold time static, slack, clock skew and jitter, clock, reset and power distributions; testing: insertion, ATPG, BIST; chip planning and physical verification; physical design; partitioning, floor planning, power planning, placement, CTS, routing, post route LEC, post routing GLS, DFM, ECO, DRC, physical and timing sign-off, sealring, dummy filling, SPICE simulation, DRC and antenna clean, GDS II extraction.

Module V. Semiconductor Memories [L – 4; T - 0]
Memory hierarchy and types, SRAM, DRAM structure, and implementations.

	Total Contact Hours: (L=42, T=0)= 42
Text Books, and/or Reference Material	**Text Books:** 1. N. H. E. Weste and C. Harris, "*Principles of CMOS VLSI Design: A System Perspective"*, 3rd Edition, Pearson Education 2007. 2. Sung-Mo Kang, Yusuf Leblebici, Chulwoo Kim, "*CMOS Digital Integrated Circuits*", 4th edition, McGraw-Hill, 2018. 3. Luciano Lavagno, Igor L. Markov, Grant E. Martin, Louis K. Scheffer, "Electronic Design Automation for Integrated Circuits", Handbook, Second Edition, - 2016, - CRC Press. 4. Michael Smith, Addison-Wesley, "Application-Specific Integrated Circuits," Professional; 1 edition, June 20, 1997. **Reference Books:** 1. Jan M. Rabaey, Anantha Chandrakasan, Borivoje Nikolic, "Digital Integrated Circuits: A Design Perspective," 2nd Edition, Pearson Education, 2009. 2. J. Bhaskar, "Verilog HDL synthesis: a practical primer," August 1998. 3. Giovanni De Micheli, "Synthesis and Optimization of Digital Circuits," McGraw-Hill, 1994. 4. J. Bhasker, Rakes Chadha, "Static Timing Analysis For Nanometer Designs: A Practical Approach," Springer, 2009. 5. J. D. Plummer, M. Deal, and P. B. Griffin, "Silicon VLSI Technology: Fundamentals, Practice, and Modeling," Pearson, Springer; 2009.

EC1013: Digital IC Design

[Mapping between Course Outcomes (COs) and Program Outcomes (POs)]

CO	Statement	Program Outcomes					
		PO1	PO2	PO3	PSO1	PSO2	PSO3
CO1	Acquire idea about the digital IC design techniques.	1	1	2	2	3	2
CO2	Understand the characteristics of CMOS inverter	1	1	2	2	3	1
CO3	Identify the basic steps of ASIC Design Flow and fabrication process.	1	1	2	3	3	3
CO4	Analyze the static and dynamic characteristics of CMOS circuits	2	1	2	3	3	1
CO5	Design and implementation of combinational and sequential circuits	1	1	2	3	3	2
CO6	Evaluate the performance of CMOS circuits	1	1	2	3	3	1
Average		**1.17**	**1**	**2**	**2.67**	**3**	**1.67**

<table>
<tr><th colspan="9">Department of Electronics & Communication Engineering</th></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total contact hours : 42</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>EC2011</td><td>VLSI Technology</td><td>PCR</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="3" rowspan="2">Pre-requisites/Co-requisites:
Semiconductor Device and Modeling [EC1011]</td><td colspan="5">Course Assessment methods: (Continuous Assessment (CA:15%), Mid-Term Assessment (MA:25%) and End-Term Assessment (EA:60%))</td></tr>
<tr><td colspan="5">Continuous Assessment (CA): Quizzes/Class tests/Assignments/Attendance</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">After the completion of the course, the student will be able to
• CO 1: Outline the basics of semiconductor crystal properties and growth process of Silicon wafer
• CO 2: Identify the fundamentals of IC fabrication
• CO 3: Illustrate the different methods involved in VLSI fabrication process
• CO 4: Appreciate the advanced methods involved in IC fabrication
• CO 5: Build the knowledge of process integration-NMOS, CMOS</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Module I. Introduction [L – 2; T - 0]
History of IC's; Operation & Models for Devices of Interest: CMOS and MEMS, Front End of Line (FEOL), Back End of Line (BEOL)

Module II. Electronic Materials and Clean Room Environment [L – 3; T - 0]
Crystal Structures, Defects in Crystals, Si, Poly Si, Si Crystal Growth, Definition of clean room, Need of Clean Room, RCA cleaning of Si.

Module III. Oxidation [L – 5; T - 0]
Dry and Wet Oxidation, Kinetics of Oxidation, Oxidation Rate Constants, Dopant Redistribution, Oxide Charges, Device Isolation, LOCOS, STI, Oxidation System.

Module IV. Lithography [L – 5; T - 0]
Overview of Lithography, Radiation Sources, Masks, Photoresist, Components of Photoresist Optical Aligners, Resolution, Depth of Focus, Advanced Lithography: E-beam Lithography, X-ray Lithography, Ion Beam Lithography.

Module V. Diffusion and Ion Implantation [L – 7; T - 0]
Pre-Deposition and Drive-in Diffusion Modeling, Dose, 2-Step Diffusions, Successive Diffusion, Lateral Diffusion, Series Resistance, Junction Depth, Irvin's Curves, Diffusion System. Problems in Thermal Diffusion, Advantages of Ion Implantation, Applications in ICs, Ion Implantation System, Mask, Energy Loss Mechanisms, Depth Profile, Range & Straggle, Lateral Straggle, Dose, Junction Depth, Ion Implantation Damage, Post Implantation Annealing, Ion Channeling, Multi Energy Implantation.

Module VI. Thin Film Deposition [L – 6; T - 0]
Physical Vapor Deposition: Thermal evaporation, Resistive Evaporation, Electron beam evaporation, Laser ablation, Sputtering. Chemical Vapor Deposition: Advantages and disadvantages of Chemical Vapor deposition (CVD) techniques over PVD techniques, reaction types, Boundaries and Flow, Different kinds of CVD techniques: APCVD, LPCVD, Metallorganic CVD (MOCVD), Plasma Enhanced CVD etc.

Module VII. Etching [L – 2; T - 0]
Anisotropy, Selectivity, Wet Etching, Plasma Etching, Reactive Ion Etching.</td></tr>
</table>

	Module VIII. Metallization/Interconnects [L – 5; T - 0] Overview of Interconnects, Contacts, Metal gate/Poly Gate, Metallization, Problems in Aluminum Metal contacts, Al spike, Electromigration, MetalSilicides, Cu metal lines, Multi-Level Metallization, Planarization, Inter Metal Dielectric. **Module IX. Process Integration [L – 7; T - 0]** NMOS, CMOS process, SOI process, 3D IC Process, Packaging. **Total Contact Hours: (L=42, T=0)= 42**
Text Books, and/or Reference Material	**Text Books:** 1. S. M. Sze, "*VLSI Technology*", 2nd Edition, McGraw Hill, 2003. 2. S. K. Gandhi, "*Silicon Process Technology*", 2nd Edition, Wiley India, 2009. **Reference Books:** 1. J. Plummer, M. Deal and P. Griffin, "*Silicon VLSI Technology*", 1st Edition, Pearson Education, 2009. 2. S. M. Sze and May, "*Fundamentals of Semiconductor Fabrication*", 2nd Edition, Wiley, 2004.

EC2011: VLSI Technology

[Mapping between Course Outcomes (COs) and Program Outcomes (POs)]

CO	Statement	Program Outcomes					
		PO1	PO2	PO3	PSO1	PSO2	PSO3
CO1	Outline the basics of semiconductor crystal properties and growth process of Si wafer.	1	1	3	2	1	1
CO2	Identify the fundamentals of IC fabrication.	1	1	3	3	2	1
CO3	Illustrate the different methods involved in VLSI fabrication process	2	2	3	2	3	1
CO4	Appreciate the advanced methods involved in IC fabrication.	2	2	3	3	3	1
CO5	Build the knowledge of process integration-NMOS, CMOS.	3	3	3	3	3	1
Average		1.8	1.8	3	2.6	2.4	1

Department of Electronics & Communication Engineering								
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	**Total contact hours : 56**				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
EC2012	**VLSI System Design**	PCR	3	1	0	4	4

Pre-requisites/Co-requisites: Digital IC Design[EC1013] Analog IC Design [EC1012]	Course Assessment methods: (Continuous Assessment (CA:15%), Mid-Term Assessment (MA:25%) and End-Term Assessment (EA:60%)) Continuous Assessment (CA): Quizzes/Class tests/Assignments/Attendance

Course Outcomes

After the completion of the course, the student will be able to

- **CO 1:** Understand the full custom and semicustom design flow.
- **CO 2:** Learn about static timing analysis and design constraints.
- **CO 3:** Understand the design for testability flows.
- **CO 4:** Identify and interpret the design towards realizing VLSI design.
- **CO 5:** Design and analyse the performance (speed, power) of VLSI circuits and design for different specifications.
- **CO 6:** Evaluate and design of memory cell.

Topics Covered

Module I. Overview of VLSI System Design [L – 2; T - 0]
VLSI System design methodologies, VLSI design flow, Recent Trends in VLSI Design & its research issues in industry: System case studies. Design automation of VLSI Systems: basic concepts. Deep Sub-micron Technologies: Some Design Issues.

Module II. Full Custom Flow [L – 6; T - 1]
Block specification, schematic design entry, netlist generation and simulation, simulation for process and operating corners, layout with DRC/ LVS clean, parasitic extraction for R & C, back annotation & simulation, simulation redone with parasitic information, Concepts of PCELL.

Module III. Constraints and Static Timing Analysis [L – 8; T - 3]
Basic tenets of synchronous static timing: setup & hold timing, multipath & false paths, clock skew & latency, Asynchronous and synchronous clocks, crossing clock domains & clock gating; Design a constraints for a design in SDC format: design objects, timing constraints, environmental constraints, case analysis; timing report, synchronous static timing.

Module IV. Semiconductor Memories [L – 8; T - 2]
Memory hierarchy and types; SRAM Cell optimization and design metrics, memory read and write path; DRAM array design and related constraints, DRAM interface- address decoding, pipelining, data interface, charge pumps; non-volatile memory cell-basic principle and operation, reliability considerations of NVM; Case study- high speed memory, low voltage memory.

Module V. Design for Testability [L – 8; T - 2]
Introduction to DFT, DFT directory structure, DFT rule checker, debugging and fixing DFT violations, scan Mapping, Scan mapping, scan chain connection, using pre-compiled cores, adding testability logic, ATPG, DFT flows.

Module VI. Flow for Designing Full SoC [L – 5; T - 3]
Block specification, schematic design entry, netlist generation and simulation, simulation for process and operating corners, layout with DRC/ LVS clean, parasitic extraction for R & C, back annotation & simulation, simulation redone with parasitic information, concepts of PCELL.

Module VII. Physical Design [L – 5; T - 3]
Floorplanning and placement, clock tree insertion & DFT insertion, routing, post PnR function

	& timing checks, interconnection architectures. **Total Contact Hours: (L=42, T=14)= 56**
Text Books, and/or Reference Material	**Text Books:** 1. N. H. E. Weste and C. Harris, "*Principles of CMOS VLSI Design: A System Perspective*", 3rd Edition, Pearson Education 2007. 2. Jan M. Rabaey, Anantha Chandrakasan, Borivoje Nikolic, "*Digital Integrated Circuits: A Design Perspective*", Second Edition, Pearson Education, 2016. **Reference Books:** 1. Michael L. Bushnell, Vishwani D. Agrawal, "*Essentials of Electronic Testing for Digital, Memory and Mixed-Signal VLSI Circuits*", Kluwer Academic Publishers 2002. 2. Sung-Mo Kang, Yusuf Leblebici, "*CMOS Digital Integrated Circuits*", 3rd edition, Tata McGraw-Hill, 2003.

EC2012: VLSI System Design

[Mapping between Course Outcomes (COs) and Program Outcomes (POs)]

CO	Statement	Program Outcomes					
		PO1	PO2	PO3	PSO1	PSO2	PSO3
CO1	Understand the full custom and semicustom design flow.	1	1	2	2	3	2
CO2	Learn about static timing analysis and design constraints.	1	1	2	2	3	1
CO3	Understand the design for testability flows.	1	1	2	3	3	3
CO4	Identify and interpret the design towards realizing VLSI design.	2	1	2	3	3	1
CO5	Design and analyse the performance (speed, power) of VLSI circuits and design for different specifications.	1	2	2	3	3	3
CO6	Evaluate and design of memory cell.	2	1	2	3	3	3
Average		**1.33**	**1.17**	**2**	**2.67**	**3**	**2.67**

B. Core Laboratories

<table>
<tr><th colspan="9">Department of Electronics and Communication Engineering</th></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>EC1061</td><td>Analog IC Design Lab</td><td>Core (Lab)</td><td>0</td><td>0</td><td>4</td><td>4</td><td>2</td></tr>
<tr><td colspan="2" rowspan="2">Pre-requisites/Co-requisites: Basic knowledge of Linux and Devices / Circuits [ECS352]</td><td colspan="6">Course Assessment methods: (Continuous Assessment (CA), Mid-semester assessment (MA) and end assessment (EA)):</td></tr>
<tr><td colspan="6">Assignments, Quiz/ test, and End Semester Examination</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">After going through the course, student will be able to
• CO1: Operate CAD tools (Cadence/Mentor) to simulate Analog blocks in Modern CMOS process.
• CO2: Determine the characteristics of active/ & passive devices for modeling and analysis.
• CO3: Design an inverter (and other basic gates) based on the given specifications.
• CO4: Optimize a differential amplifier to meet the target specification
• CO5: Appreciate various performance metrics like CMRR, ICMR, PSRR, SR, Power Dissipation, Delay, and Noise Margin with respect to design variables.
• CO6: Examine the effect of process variation using Monte Carlo simulation</td></tr>
<tr><td>Topics Covered/ Syllabus</td><td colspan="7">List of experiments:
1. Determination of NMOS and PMOS characteristics
2. Determination of NMOS and PMOS device parameter (V_{T0}, k', λ, γ, SS)
3. Simulation of NMOS and PMOS Resistive Load Inverter.
4. Simulation of CMOS Inverter and measure its delay, Noise margin, power
5. Design of a voltage reference and simple, Cascode current mirror
6. Design & simulation of Common Source Amplifier
7. Simulation of Ring Oscillator.
8. Monte Carlo Simulation and process variation</td></tr>
<tr><td>Text/ Reference Materials</td><td colspan="7">1. Behzad Razavi , “Design of Analog CMOS Integrated Circuits”, McGraw-Hill
2. Cadence Tutorials : https://nano.wiki.ifi.uio.no/Cadence-Tutorial-English-cadence_6.1.6</td></tr>
</table>

<table>
<tr><th colspan="8">EC1061: Analog IC Design Lab
[Mapping between Course Outcomes (COs) and Program Outcomes (POs)]</th></tr>
<tr><th rowspan="2">CO</th><th rowspan="2">Statement</th><th colspan="6">Program Outcomes</th></tr>
<tr><th>PO1</th><th>PO2</th><th>PO3</th><th>PSO1</th><th>PSO2</th><th>PSO3</th></tr>
<tr><td>CO1</td><td>Operate CAD tools (Cadence/Mentor) to simulate Analog blocks in Modern CMOS process.</td><td>3</td><td>1</td><td>2</td><td>2</td><td>2</td><td>1</td></tr>
<tr><td>CO2</td><td>Determine the characteristics of active/ & passive devices for modeling and analysis.</td><td>1</td><td>1</td><td>3</td><td>3</td><td>3</td><td>1</td></tr>
<tr><td>CO3</td><td>Design an inverter (and other basic gates) based on the given specifications.</td><td>2</td><td>2</td><td>3</td><td>3</td><td>3</td><td>1</td></tr>
<tr><td>CO4</td><td>Optimize a Differential amplifier to meet the target specification</td><td>3</td><td>1</td><td>2</td><td>2</td><td>2</td><td>1</td></tr>
<tr><td>CO5</td><td>Appreciate various performance metrics like CMRR, ICMR, PSRR, SR, Power Dissipation, Delay, and Noise Margin with respect to design variables.</td><td>1</td><td>1</td><td>3</td><td>3</td><td>3</td><td>1</td></tr>
<tr><td>CO6</td><td>Examine the effect of process variation using Monte Carlo simulation</td><td>3</td><td>1</td><td>2</td><td>2</td><td>2</td><td>2</td></tr>
<tr><td colspan="2">Average</td><td>2</td><td>1.2</td><td>2.6</td><td>2.6</td><td>2.6</td><td>1</td></tr>
</table>

Department of Electronics and Communication Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)#	Total Hours	
EC1062	**Digital IC Design Lab**	**Core (Lab)**	0	0	4	4	2

Pre-requisites/Co-requisites: Basic Electronics (ECC01), Semiconductor Devices and Modeling (EC1011), Digital Circuits and Systems (ECC402), Digital IC Design (EC1012)	Course Assessment methods: (Continuous Assessment (CA:15%), Mid-Term Assessment (MA:25%) and End-Term Assessment (EA:60%)) Continuous Assessment (CA): Quizzes/Class tests/Assignments/Attendance
Course Outcomes	• **CO1:** Design a CMOS inverter to meet the given specifications. • **CO2:** Explain the CAD tool flow for Physical design of digital circuits. • **CO3:** Analyze the impact of device sizes in the implementation of CMOS circuits. • **CO4:** Design and implementation of combinational and sequential circuits • **CO5:** Evaluate the performance of CMOS digital circuits. • **CO6:** Draw the Layout of CMOS Circuits
Topics Covered	**List of experiments:** 1. Design and plot the static (VTC) characteristics of CMOS inverters. 2. Design and plot the dynamic characteristics of CMOS inverters. 3. Design and simulation of CMOS i) NAND, ii) NOR and ii) XOR gates. 4. Design and implementation of CMOS transmission gate and logic circuits using pass transistor logic (PTL). 5. Design a two-phase non-overlapping clock generator. 6. Design and implementation of dynamic and domino logic circuits. 7. Design and simulation of FFs (D, T, Master-slave) using pass transistors. 8. Design a 6T SRAM Cell and measure its characteristics. 9. Draw the Layout of CMOS i) Inverter ii) Transmission gate **Note: The simulations will be carried out using CMOS 180 nm and 65 nm process. For all the experiments, students need to measure and plot Static/dynamic power dissipation, Delay, Noise Margin, etc., for various loads. Results should also capture the impact of PVT variations.**
Text Books, and/or Reference Material	Suggested Text Books: 1. Eric Brunvand, "*Digital VLSI Chip Design with Cadence and Synopsys CAD Tools*", 2nd Edition, Pearson Education 2009. 2. Jan M. Rabaey, Anantha Chandrakasan, Borivoje Nikolic, "*Digital Integrated Circuits: A Design Perspective*", Pearson Education, 2nd Edition, 2016.

EC1062: Digital IC Design Lab
[Mapping between Course Outcomes (COs) and Program Outcomes (POs)]

CO	Statement	Program Outcomes					
		PO1	PO2	PO3	PSO1	PSO2	PSO3
CO1	Design a CMOS inverter to meet the given specifications.	3	1	2	2	2	1
CO2	Explain the CAD tool flow for Physical design of digital circuits.	1	1	3	3	3	1
CO3	Analyze the impact of device sizes in the implementation of CMOS circuits.	2	2	3	3	3	1
CO4	Design and implementation of combinational and sequential circuits	2	2	3	3	3	1
CO5	Evaluate the performance of CMOS digital circuits.	2	2	3	3	3	1
CO6	Draw the Layout of CMOS Circuits	2	2	3	3	3	1
Average		**2**	**1.6**	**2.8**	**2.8**	**2.8**	**1**

Department of Electronics and Communication Engineering								
Course Code	Title of the course	Program Core (PCR) / Elective (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
EC2061	**VLSI System Design Lab**	**Core (Lab)**	0	0	4	4	2
Pre-requisites/Co-requisites: EC1061, EC1062,			Course Assessment methods: (Continuous Assessment (CA:15%), Mid-Term Assessment (MA:25%) and End-Term Assessment (EA:60%))				
			Continuous Assessment (CA): Quizzes/Class tests/Assignments/Attendance				

Course Outcomes

- **CO1**: Employ CAD tools to carry out Mixed Signal Design using bottom up approach
- **CO2**: Illustrate gm/ID plots and its use in Analog Circuit Design
- **CO3**: Design Opamps to meet any given specification.
- **CO4**: Design and implementation of various components of a processor.
- **CO5**: Evaluate the performance of VLSI Designs.

Topics Covered/ Syllabus

List of experiments :

1. Generation of gm/ID plots for various Channel lengths.
2. Design and optimize a two stage Opamp.
3. Design of Band-gap reference Circuit.
4. Design of 8 bit Flash ADC and measure its DNL, INL etc.
5. Design and implementation of ALU and ALU Controller.
6. Design and implementation of Sequence Controller.
7. Design and implementation of Multiplexer and Program Counter.
8. Design and implementation of Concentration, Combinational and shift-by-2 modules.
9. Design and implementation of RAM and Register files.
10. Design and implementation of State Register and Sign-Extend Modules.

Reference Materials

1. B. Razavi, "*Design of Analog CMOS Integrated Circuits*", McGraw-Hill Education, 2002.
2. Allan Hastings, "*The Art of Analog Layout*", Prentice Hall, Second Edition, 2005.
3. N. H. E. Weste and C. Harris, "*Principles of CMOS VLSI Design: A System Perspective*", 3rd Edition, Pearson Education 2007.

EC2061: VLSI System Design Lab

[Mapping between Course Outcomes (COs) and Program Outcomes (POs)]

CO	Statement	Program Outcomes					
		PO1	PO2	PO3	PSO1	PSO2	PSO3
CO1	Employ CAD tools to carry out Mixed Signal Design using bottom up approach	1	1	2	3	3	1
CO2	Illustrate gm/ID plots and its use in Analog Circuit Design	2	2	2	3	3	1
CO3	Design Opamps to meet any given specification	2	2	2	3	3	1
CO4	Design and implementation of various components of a processor	3	2	3	3	3	1
CO5	Evaluate the performance of VLSI Designs.	3	3	3	3	3	2
Average		**2.2**	**2**	**2.4**	**3**	**3**	**1.2**

C. Common Pool Electives

<table>
<tr><th colspan="9">Department of Electronics and Communication Engineering</th></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total contact hours: 70 (L-42 + P-28)</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>EC9001*</td><td>Digital Signal Processing using MATLAB*</td><td>Electives (PEL)</td><td>3</td><td>0</td><td>2</td><td>5</td><td>4</td></tr>
<tr><td colspan="2" rowspan="2">Pre-requisites:
Signals and Systems (ECC303)
Mathematics – II (MAC02)</td><td colspan="6">Course Assessment methods: (Continuous Assessment (CA), Mid-semester assessment (MA) and end assessment (EA)):</td></tr>
<tr><td colspan="6">Assignments, Quiz/class test, Mid-semester Examination and End Semester Examination</td></tr>
<tr><td>Course Objective</td><td colspan="8">The course teaches Introduction to DSP; Digital Systems – Characterization, Description and Testing; FIR and IIR: Recursive and Non Recursive; Discrete Fourier Transform; Z Transform; Discrete Time Systems in Frequency Domain; Simple Digital Filters; Digital Processing of Continuous Time Signals; Analog Filter Design; Digital Filter Structure, Synthesis and Design of Adaptive Filters.</td></tr>
<tr><td>Course Outcomes</td><td colspan="8">On successful completion of this course, students should have the skills and knowledge to:

CO1# Analyse a given signal or system using tools such as Fourier transform and z-transform to know the property of a signal or system.

CO2# Process signals to make them more useful; and how to design a signal processor for a given problem, construct simple IIR and FIR filter.

CO3# Design and Analysis of various types of Analog Butterworth and Chebyshev Filters

CO4# Design methods to convert analog filters into digital filters.

CO5# Perform Frequency transformations in Analog and Digital domains. Realization of Digital FIR and IIR Filter Structure.

CO6# Describe the operation of adaptive systems</td></tr>
<tr><td>Topics Covered/ Syllabus</td><td colspan="8">Module I. (L – 1)
Introduction: reasons behind digital processing of signals, brief historical development, organization of the course. [CO#1]

Module II. (L – 2)
Theory of discrete time linear system sequences, linear time invariant systems, causality, stability, difference equations, frequency response, discrete Fourier series, relation between continuous and discrete systems, Inverse Systems, Stability. [CO#1]

Module III. (L – 2; P - 1)
Z –transform: definition, properties of Z transform, system function, digital filter implementation from the system function, region of convergence in the Z plane, determining filter coefficients from the singularity locations, geometric evolution of Z transform in the Z plane, relationship between Fourier transform and Z transform, inverse Z transform. [CO#1]

Module IV. (L – 3; P - 1)
Transform technique: Fourier transform, its properties, inverse Fourier transform, discrete Fourier transform, properties of DFT, circular convolution, computations for evaluating the DFT, decimation in time and decimation in frequency, discrete Hilbert transform.</td></tr>
</table>

	Module V. (L – 5; P - 2) Digital filter structures: system describing equations, filter categories, All Pass Filters, Comb Filters, direct form I and II structures, cascade and parallel communication of second order systems, Polyphase representation of filters, linear phase FIR filter structures, Compensatory Transfer Functions, frequency sampling structure for the FIR filter. Test for Stability using All Pass Functions. **[CO#1, 2]** **Module VI. (L – 5; P - 2)** IIR filter design techniques: Analog Filter Design, Analog Butterworth lowpass filter design techniques, Analog Chebyshev LPF, Design methods to convert analog filters into digital filters, frequency transformation for converting lowpass filters into other types, all-pass filters for phase response compensation. **[CO#2, 3]** **Module VII. (L – 5; P - 2)** Digital Filter Structures: IIR Realizations, All Pass Realizations, FIR and IIR Lattice Synthesis, IIR Design by Bilinear Transformation, Digital to Digital Frequency Transformation. **[CO#2, 3,4]** **Module VIII. (L – 5; P - 1)** FIR filter design techniques: Windowing method for designing FIR filters, DFT method for approximating the desired unit sample response, combining DFT and window method for designing FIR filter, frequency sampling method for designing FIR filter **[CO#2, 3]** **Module IX. (L – 5; P - 2)** FFT- Derivation of the Radix-2 FFT: Describe the purpose of the Fast Fourier Transform (FFT) and explain its relationship with DFT, Outline the Fast Fourier Transform (FFT) in mathematical form using twiddle factors, Explain the properties of twiddle factors, Describe how the N-point sequence can be decomposed into N/2-point sequences and how the Discrete Fourier Transform (DFT) can be calculated, Explain the relationship between N-point DFT with N/2-point DFT of even and odd values of the signal, Outline the benefits of the radix method for FFT and its computational savings. **[CO#1,2]** **Module X. (L – 3; P - 1)** Adaptive Filters - Prediction and System Identification: Describe the characteristics of adaptive systems, Explain the functionality and operation of a closed-loop configuration involving adaptive filters, Explain the functionality and operation of a prediction configuration and system identification configuration involving adaptive filters, Outline applications for the system identification configuration with adaptive filters. **[CO#5]** **Module XI. (L – 3; P - 1)** Adaptive Filters - Equalization and Noise Cancellation: Explain the operation of the equalization configuration and the noise cancellation configuration involving adaptive filters, Outline applications for the equalization and noise cancellation configurations with adaptive filters, Explain how noise cancellation works through adaptive filters. **[CO#4,5]** **Module XII. (L – 3; P - 1)** Adaptive Filters - Adaptive FIR filter and the LMS algorithm: Outline the operations of a basic adaptive Finite Impulse Filter (FIR) filter system in mathematical form, Explain the cost function of an adaptive Finite Impulse Filter (FIR) filter system, Outline the concept and purpose of the Steepest Descent and the Least Means Squares (LMS) algorithm, Discuss the pros and cons of using the LMS algorithm for adaptive FIR filtering. **[CO#2, 3, 4, 5]** **Total Contact Hours: (L-42 + P-28)= 70**
Text Books, and/or Reference material	**<u>Text Books</u>:** [1] Alan V. Oppenheim, Ronald W. Schafer, and John R. Buck, "*Discrete-Time Signal Processing*", Second Edition, Pearson Education India. [2] John G. Proakis, Dimitris G. Manolakis, and D Sharma, "*Digital Signal Processing: Principles*", Algorithms and Applications, 3rd Edition, Pearson Education India.

	[3] Richard G. Lyons, "*Understanding Digital Signal Processing*", Prentice Hall, 1996. ISBN: 0201634678. [4] Sanjit K. Mitra, "*Digital Signal Processing: A Computer - Based Approach*", McGraw-Hill Higher Education [5] **Tarun Kumar Rawat, "*Digital Signal Processing*", Oxford University Press, ISBN: 9780198081937** [6] **Donald S. Reay, "*Digital Signal Processing Using the ARM Cortex M4 Paperback*".**
	<u>Reference Books/materials</u>: [1] S. W. Smith, "*The Scientist and Engineer's and Guide to Digital Signal Processing*", California Technical Publishing, 1997. ISBN: 0-9660176-3. [2] Vinay K. Ingle, John G. Proakis, "*Digital Signal Processing using MATLAB*," Brooks/Cole-Thomson Learning [3] https://nptel.ac.in/courses/117/102/117102060/ [4] Digital Signal Processing using Arm Cortex-M based Microcontrollers: Theory and Practice https://www.arm.com/resources/education/textbooks/dsptextbook

EC9001: *Digital Signal Processing using MATLAB (Elective)
[Mapping between course outcomes (Cos) and program outcomes (POs)]

CO	Statement	Program Outcomes					
		PO 1	PO 2	PO3	PSO 1	PSO 2	PSO 3
CO 1	Analyse a given signal or system using tools such as Fourier transform and z-transform to know the property of a signal or system.	3	2	1	3	2	1
CO 2	Process signals to make them more useful; and how to design a signal processor for a given problem, construct simple IIR and FIR filter.	1	2	1	1	1	1
CO 3	Design and Analysis of various types of Analog Butterworth and Chebyshev filters.	3	3	3	3	2	2
CO 4	Design methods to convert analog filters into digital filters.	3	3	3	2	2	2
CO 5	Perform Frequency transformations in Analog and Digital domains. Realization of Digital FIR and IIR Filter Structure.	3	3	2	3	3	3
Average		**2.6**	**2.6**	**2**	**2.4**	**2**	**1.8**

Department of Electronics and Communication Engineering								
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	**Total Number of contact hours: 56**				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
EC9002	**Statistical Signal Processing**	PEL	3	1	0	4	4
Pre-requisites: EC1001		Course Assessment methods: (Continuous Assessment (CA), Mid-semester assessment (MA) and end assessment (EA)):					
		Assignments, Quiz/class test, Mid-semester Examination and End Semester Examination					
Course Outcomes	**CO1:** Understanding **statistical** models in the **analysis** of **signals** using Stochastic processes **CO2:** To familiarize students with application of hypothesis testing to signal and event detection problems. **CO3:** Design and development of optimum filters using classical and adaptive algorithms.						
Topics Covered	**Module 1. Background and Preview (L – 4, T – 1)** The filtering problem, Linear Optimum Filters, Adaptive Filters, Linear Filter Structures, Approaches to develop linear adaptive filters, Adaptive Beamforming (4L) **Module 2. Stochastic Processes and Models (L – 6, T – 2)** Partial characterization of a discrete-time stochastic process, Mean Ergodic Theorem, Correlation Matrix, Stochastic models, Wold decomposition, Asymptotic stationarity of an autoregressive process, Yule-Walker eqns., complex Gaussian Process, Power Spectral Density and its properties, transmission of stationary process through a linear filter, Power spectrum estimation. **Module 3. Weiner Filters: (L – 3, T – 1)** The statement of Linear Optimum Filtering, Principle of Orthogonality, minimum mean-square error, Wiener-Hopf equations (3L) **Module 4. Linear Prediction: (L – 5, T – 2)** Forward Linear Prediction, Backward Linear Prediction (3L), Levinson-Durbin Algorithm, Properties of prediction-error filters, Autoregressive modelling of a stationary random process, Cholesky Factorization, Lattice Predictors, All-pole, All-pass Lattice Filter **Module 5. Method of Steepest Descent: (L – 3, T – 1)** Basic idea of steepest descent algorithm, Steepest descent applied to Wiener filter, stability, Examples **Module 6. Least-Mean-Square (LMS) Adaptive Filters: (L – 5, T – 2)** Structure and operation of LMS algorithm, LMS Adaptation algorithm, Statistical LMS theory, comparison between LMS algorithm and steepest descent algorithm, directionality of convergence of the LMS algorithm for non-white inputs, Robustness of the LMS Filter, bounds on step size, transfer function approach for deterministic inputs, Normalized LMS Adaptive filters **Module 7. Method of Least Squares: (L – 5, T – 2)** Statement of Least Squares Estimation problem. Data windowing, Minimum sum of error squares, Normal Equations and Linear Least Squares Filters, Time-Averaged correlation matrix, Properties of Least Squares estimates, Singular Value Decomposition (SVD), Pseudo-inverse, Interpretation of singular values and singular vectors, Minimum-Norm solution to the Linear Least Squares problem **Module 8. Recursive Least Squares (RLS) Adaptive Filters: (L – 5, T – 2)**							

	Matrix Inversion Lemma, Exponentially weighted RLS algorithm, selection of the regularizing parameter, Update recursion for the Sum of Weighted Error Squares, Example of a single weight adaptive noise canceller, convergence analysis of the RLS algorithm, Robustness of RLS Filters **Module 9. Kalman Filters: (L – 5, T – 2)** Recursive MMSE for scalar random variables, Statement of the Kalman Filtering problem, The Innovations process, Estimation of the state using Innovations process, Filtering, Initial Conditions, Kalman Filter as the unifying basis for RLS Filters, Kalman Filter variants, the Extended Kalman Filter **Total Contact Hours: (L=41, T=15)= 56**
Text Books, and/or reference material	**Text Books:** 1.Fundamentals of Statistical Signal Processing: Estimation Theory - Steven M. Kay 2. Adaptive Filter Theory - Simon Haykin (Fourth Edition) **Reference Books:** 3. Statistical Digital Signal Processing and Modeling - Monson H. Hayes 4. Probability, Random Variables and Stochastic Processes - Athanasios Papoulis and S. Unnikrishna Pillai 5. An Introduction to Statistical Signal processing, Gray and Davisson, Cambridge University Press

EC9002: Statistical Signal Processing
[Mapping between course outcomes (COs) and program outcomes (POs)]

CO	Statement	Program Outcomes					
		PO 1	PO 2	PO 3	PSO 1	PSO 2	PSO 3
CO 1	Understanding **statistical** models in the **analysis** of **signals** using Stochastic processes	3	2	3	3	1	2
CO 2	To familiarize students with application of hypothesis testing to signal and event detection problems.	3	2	3	3	1	2
CO 3	Design and development of optimum filters using classical and adaptive algorithms.	3	2	3	3	1	3
Average		3	2	3	3	1	2.33

<table>
<tr><th colspan="8">Department of Electronics and Communication Engineering</th></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours: 70 (L-42 + P-28)</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>EC9003</td><td>Applications of Image Processing using Python</td><td>PEL</td><td>3</td><td>0</td><td>2</td><td>5</td><td>4</td></tr>
<tr><td colspan="2" rowspan="2">Pre-requisites:

Signals and Systems (ECC303), Digital Signal Processing (ECC603)</td><td colspan="6">Course Assessment methods: (Continuous Assessment (CA), Mid-semester assessment (MA) and end assessment (EA)):</td></tr>
<tr><td colspan="6">Assignments, Quiz/class test, Mid-semester Examination and End Semester Examination</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">• CO1: Understand image enhancement and restoration techniques.
• CO2: Analyze digital images through multiresolution techniques.
• CO3: Understand the application of morphological processing and segmentation in images.
• CO4: Ability to interpret digital image recognition techniques.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Module I: Digital Image Fundamentals, Image Enhancement and Restoration [L-15]
Fundamentals- Image acquisition; Sampling; Quantization; Resolution; Relationship between pixels; Geometric transforms; Convolution and Correlation; Enhancement- Gray level intensity transforms; Histogram processing; Image sharpening and smoothening operations (spatial and frequency based); Restoration- Model of image degradation; Noise models; Restoration in the presence of noise only spatial filtering; Periodic noise reduction by frequency domain filtering; Estimating the degradation function; Weiner filtering; Constrained least squares filtering; Image interpolation and resampling.

Module II: Compression and Encoding of Image [L-6]
Redundancy; Entropy coding; Lossy compression; Lossless compression; Quality preserving adaptive compression.
Module III: Multi-resolution Image Processing [L-6]
Short time Fourier transform, Wavelet function, Wavelet series, Discrete wavelet transform and multi-resolution analysis, Image decomposition and compression using discrete wavelet transform.
Module IV: Morphological Processing and Segmentation [L-11]
Morphological operations- Dilation and erosion; Opening and closing; Hit or Miss transform; Algorithms for feature extraction; Segmentation- Detection of discontinuities; Edge linking and boundary detection; Thresholding; Region based segmentation; Segmentation by morphological watersheds; Use of motion in segmentation.
Module V: Patterns in Images and their Applications [L-4]
Basics of features, Principal component analysis, Decision tree and feature hierarchy, Scale invariant feature transform, Histogram of oriented gradient.

Module VI: Basics of Python [P-2]
Installing the environment; Python IDE; Python syntax, variables, operators, keywords; Python data types; Python for data analysis-Numpy; Introduction to OpenCV; Installing OpenCV Python

Module VII: Getting started with Images using OpenCV Python [P-4]
Reading an image in different modes; Displaying an image; Writing an image to a different path; Understanding the matrix representation of images; Creating an images; Drawing various shapes; Adding text to images.

Module VIII: Using Matplotlib and Colormaps [P-6]
Image plotting using Matplotlib; Understanding different color maps; Understanding different color spaces; Plotting multiple images through Matplotlib.

Module IX: Fundamental Operations on Images using OpenCV Python [P-4]
Accessing and modifying pixel values; Accessing image properties; Depicting the Region of Interest; Splitting and Merging image channels; Image blending; Image transition; Bitwise operations.</td></tr>
</table>

	Module X: Practical Exercises using OpenCV Python [P-12] Face, Eyes, and Smile detection from Image / Webcam; Object tracking by color; BGR palette with trackbars; Different blurring/smoothing and sharpening algorithms applying filters; Edge detection algorithms. **Total Contact Hours: (L=42, P=28) = 70**
Textbooks, and/or reference material	**Text Books**: 1. Digital Image Processing: R C Gonzalez and R E Woods; Pearson Education. 2. Guide to Signals and Patterns in Image Processing- Foundations, Methods and Applications: Apurba Das; Springer. 3. Digital Image Processing and Computer Vision: Sonka, Hlavac and Boyle; Cengage Learning (India Edition). **Reference Books**: 1. Digital Image Processing: K R Castleman; Pearson Education. 2. Digital Image Processing: S Sridhar; Oxford Higher Education.

EC9003 Applications of Image Processing using Python
[Mapping the Course Outcomes (COs) to the Programme Outcomes (POs) and Programme Specific Outcomes (PSOs)]

CO	Statement	Program Outcomes					
		PO 1	PO 2	PO 3	PSO 1	PSO 2	PSO 3
CO 1	Understand image enhancement and restoration techniques.	3	2	3	3	2	2
CO 2	Analyze digital images through multi-resolution techniques.	3	1	2	3	1	2
CO 3	Understand the application of morphological processing and segmentation in images.	3	2	2	3	1	2
CO 4	Ability to interpret digital image recognition techniques.	3	2	1	3	2	2
Average		3	1.75	2	3	1.5	2

POs:

PO 1: An ability to independently carry out research /investigation and development work to solve practical problems
PO 2: An ability to write and present a substantial technical report/document
PO 3: Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program

PSOs:

PSO 1: Understanding mathematical modelling of communication systems and networks
PSO 2: Enhancing the knowledge of RF front end circuit design and radio propagation phenomena
PSO 3: Equip with modern computational and hardware tools for designing communication systems

<table>
<tr><td colspan="9">Department of Electronics and Communication Engineering</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours: 56</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>EC9004</td><td>Automated Speech Signal Processing</td><td>PEL</td><td>3</td><td>1</td><td>0</td><td>4</td><td>4</td></tr>
<tr><td colspan="3" rowspan="2">Pre-requisites:

1. Signals and Systems (ECC303)
2. Digital Signal Processing (ECC603)
3. Probability Theory for Engineering Application (ECO541)/any equivalent course</td><td colspan="5">Course Assessment methods: (Continuous Assessment (CA), Mid-semester assessment (MA) and end assessment (EA)):</td></tr>
<tr><td colspan="5">Assignments, Quiz/class test, Mid-semester Examination and End Semester Examination</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">CO1: Summarize the various techniques involved in collecting the features from the speech signal in both time and frequency domain.
CO2: Understand the basic algorithms of speech analysis common to many applications.
CO 3: Compare the various techniques involved in speech and speaker detection.
CO4: Design a simple system for speech processing including its implementation into application programs.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Module I: Introduction to Digital Speech Processing [L-5]
Acoustic theory of speech production; auditory perception and intelligibility; psychoacoustics; digital models for speech signals.

Module II: Time Domain Methods for Speech Processing [L-8; T-4]
Window considerations; short time energy and average magnitude; short time average zero crossing rate; speech Vs silence discrimination using energy and zero crossing; pitch period estimation using a parallel processing approach; short time autocorrelation function; short time average magnitude difference function; pitch period estimation using the autocorrelation function.

Module III: Linear Prediction Analysis [L-8; T-4]
Solution of LPC equations- Cholesky decomposition solution for covariance method, Durbin's recursive solution for the autocorrelation equations; comparison between the methods of solutions of the LPC analysis equations; applications of the LPC parameters- pitch detection using LPC parameters; formant analysis using LPC parameters.

Module IV: Homomorphic Speech Processing [L-8; T-4]
Introduction; homomorphic systems for convolution-properties of the complex cepstrum, computational considerations, the complex cepstrum of speech, pitch detection, formant estimation, homomorphic vocoder; speech enhancement- nature of interfering sounds, speech enhancement techniques such as spectral subtraction, enhancement by resynthesis, Comb filter, Weiner filter, and multi microphone approach.

Module V: Automatic Speech and Speaker Recognition [L-10; T-5]
Basic pattern recognition approaches; parametric representation of speech; evaluating similarity of speech patterns; isolated digit recognition system; continuous digit recognition system; recognition using templates and dynamic time warping; Hidden Markov Model for speech- HMM for speech recognition, Viterbi algorithm, training and testing using HMMS; speaker recognition- recognition techniques, features that distinguish speakers, deterministic sequence recognition for ASR; statistical sequence recognition; speaker recognition systems like speaker verification and identification systems; some aspects of computer music synthesis; music signal analysis; music retrieval.

Total Contact Hours: (L=42, T=14) = 56</td></tr>
<tr><td>Textbooks, and/or</td><td colspan="7">Textbooks:
1. L. R. Rabiner and S. W. Schafer , Digital Processing of Speech Signals, Pearson Education,2003.</td></tr>
</table>

reference material	2. S. D. Apte, *Speech and Audio Processing*, Wiley India Edition.2019. 3. Thomas F. Quatieri, *Discrete-Time Speech Signal Processing: Principles and Practice*, Prentice Hall, 2008. **Reference books:** 1. G. Ben, N. Morgan, D. Ellis, *Speech and Audio Signal Processing: processing and perception of speech and music*, John Wiley and Sons, 2011. 2. B. Jacob, M. M. Sondhi, Y. Huang, *Handbook of Speech Processing*, Springer, 2007.

EC9004 Automated Speech Signal Processing
[Mapping the Course Outcomes (COs) to the Programme Outcomes (POs) and Programme Specific Outcomes (PSOs)]

CO	Statement	Program Outcomes					
		PO 1	**PO 2**	**PO 3**	**PSO 1**	**PSO 2**	**PSO 3**
CO 1	**Summarize** the various techniques involved in collecting the features from the speech signal in both time and frequency domain..	**3**	**3**	**3**	**3**	**2**	**2**
CO 2	**Understand** the basic algorithms of speech analysis common to many applications.	**3**	**1**	**2**	**2**	**1**	**2**
CO 3	**Compare** the various techniques involved in speech and speaker detection.	**3**	**2**	**3**	**3**	**3**	**3**
CO 4	**Design** a simple system for speech processing including its implementation into application programs	**3**	**2**	**3**	**2**	**3**	**3**
Average		3	2	2.75	2.5	2.25	2.5

POs:

PO 1: An ability to independently carry out research /investigation and development work to solve practical problems
PO 2: An ability to write and present a substantial technical report/document
PO 3: Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program

PSOs:

PSO 1: Understanding mathematical modelling of communication systems and networks
PSO 2: Enhancing the knowledge of RF front end circuit design and radio propagation phenomena
PSO 3: Equip with modern computational and hardware tools for designing communication systems

Department of Electronics and Communication Engineering								
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total contact hours: 56				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
EC9005	**Probability and Random Processes**	PEL	3	1	0	4	4
Pre-requisites: None		Course Assessment methods (Continuous (CT) and end assessment (EA)) Assignments, Quiz, Mid-semester Examination and End Semester Examination					
Course Outcomes	• **CO1:** Characterize probability models and function of random variables. • **CO2:** Evaluate and apply moments & characteristic functions and understand the concept of inequalities and probabilistic limits. • **CO3:** Recognize, interpret and apply a variety of deterministic and nondeterministic random processes that occur in engineering. • **CO4:** Calculate the autocorrelation and spectral density of a random process and recognize the relation between them.						
Topics Covered	**Module I. (L-3; T-2)** Introduction: Basic of Probability theory, Independence, Bayes' theorem, Bernoulli's Trials **Module II. (L-6; T-2)** Random Variables: Definition, Continuous random variables, Examples of continuous random variables, CDF and PDF of Continuous random variables, Discrete random variables, PMF of discrete random variables, The normal approximation and the Poisson approximation of binomial random variable, Conditional probability density function **Module III. (L-3; T-1)** Function of one random variable; Transformation of random variables **Module IV. (L-5; T-2)** Mean, Variance, Moments, Characteristics functions of random variables, Markov inequality, Chebyshev inequality, Moment generating function, Chernoff's bound, Cumulants, Kurtosis, Skewness. **Module V. (L-5; T-1)** Two random variables, Joint density and distribution function, Marginal statistics, Independence of random variables, One function of two random variables, Central limit theorem, Two functions of two random variables, Jacobian and transformation of random variables **Module VI. (L-6; T-2)** Stationary random processes, Second order stationary, WSS processes, SSS processes, Ergodic processes, Autocorrelation function, Cross correlation function, Covariance, PSD **Module VII. (L-5; T-1)** Linear systems with random inputs, ACF and PSD of the response, Wiener–Khintchine theorem Narrow band process, Cauchy Schwartz Inequality **Module VIII.(L-5; T-1)** Markov Processes, Markov chain, CTMC, DTMC, Discrete time Markov process, continuous time Markov process, Chapman- Kolmogorov equation, Birth- Death process **Module IX. (L-5; T-1)** Poisson process, Poissson distribution, Properties of Poisson processes, Examples, Gaussian process, Properties of Gaussian process, Covariance matrix of a Gaussian process. **Total Contact Hours:(L-43; T-13) 56**						

Text Books, and/or reference material	**Text Books:** [1] A. Popoulis, U. Pillai, *Probability, random variables and stochastic processes*, Tata McGraw-Hill Inc., 4th Ed., New Delhi, 2017 [2] P. Peebles, *Probability, random variables and random signal priniciples*, McGraw-Hill Inc., 4th Ed., New York, USA, 2001 [3] C. W. Therrien, M. Tummala, *Probabilty and random processes for electrical and computer engineers*, 2nd Ed., CRC press, printed in India, 2012 **Reference books:** [1] George R. Cooper, C. D. McGillem, *Probabilistic methods of signal analysis and system analysis*, Oxford University Press, 3rd Ed. , New Delhi, 2007 [2] Alberto Leon-Garcia, *Probability and random processes for electrical engineering*, Pearson Education Inc., 2nd Ed., 2007

EC9005: Probability and Random Processes (Elective)
[(Mapping between course outcomes (COs) and program outcomes (POs)]

CO	**Statement**	**Program Outcomes**					
		PO 1	**PO 2**	**PO 3**	**PSO 1**	**PSO 2**	**PSO 3**
CO 1	Characterize probability models and function of random variables.	1	2	1	3	1	1
CO 2	Evaluate and apply moments & characteristic functions and understand the concept of inequalities and probabilistic limits.	2	1	2	3	1	1
CO 3	Recognize, interpret and apply a variety of deterministic and nondeterministic random processes that occur in engineering.	2	1	2	3	2	1
CO 4	Calculate the autocorrelation and spectral density of a random process and recognize the relation between them.	1	2	1	3	1	2
Average		**1.5**	**1.5**	**1.5**	**3.0**	**1.3**	**1.3**

Department of Electronics and Communication Engineering								
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	**Total contact hours: 57**				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
EC9006	**Error Correction Coding**	PEL	3	1	0	4	4

Pre-requisites: Probability and random variables; Digital Communication (ECC501)	Course Assessment methods: (Continuous Assessment (CA), Mid-semester assessment (MA) and end assessment (EA)): Assignments, Quiz/class test, Mid-semester Examination and End Semester Examination
Course Outcomes	• **CO1: Acquire** idea about different types of error control coding techniques. • **CO2: Understand** generator matrix, encoding and decoding of different codes. • **CO3: Learn** LDPC, BCH, RS and Turbo codes. • **CO4: Analyze** and mitigate errors in channels. • **CO5: Differentiate** between different coding strategies.
Topics Covered	**Module I. (L – 8; T- 2)** Introduction to Linear Algebra: Group, Ring, Field, Vector Space. **Module II. (L – 9; T- 3)** Binary Linear Block Codes: Generator and Parity Check Matrices, Dual Codes, Decoding, General properties of linear block codes, Hamming Code. **Module III. (L – 6; T- 3)** Cyclic Codes: Algebraic description, Encoding and Decoding of Cyclic codes. **Module IV. (L – 4; T- 1)** BCH Codes: Properties, Encoding and Decoding. **Module V. (L – 3; T- 1)** Reed Solomon (RS) Codes: Definition, Decoding of RS codes. **Module VI. (L – 7; T- 2)** Convolution Codes: Definition, Encoding Trellis and State representation, Viterbi decoding, Error probability. **Module VII. (L – 3; T-1)** LDPC Codes: Definition, Construction, Regular and irregular LDPC, Belief Propagation, Tanner Graph, Decoding, Iterative Decoding **Module VIII. (L – 3; T- 1)** Turbo Codes: Definition, Construction methods, Decoding **Total Contact Hours: (L=43, T=14) = 57**
Text Books, and/or reference material	Text Books: [1] Shu Lin and Daniel.J.Costello Jr. , *Error Control Coding; Fundamentals and applications:* 2nd Ed., Pearson India, New Delhi, 2010. [2] J. C. Moreira and P. G. Farrel, *Essentials of Error Control Coding*, 1st Ed., Wiley India, New Delhi, 2006 **Reference Books:** [1] Todd.K. Moon, *Error Correction Coding: Mathematical Methods and Algorithm*, 1st Ed.,Wiley India, New Delhi, 2005.

EC9006: Error Correction Coding (Elective)
[Mapping between course outcomes (Cos) and program outcomes (POs)]

CO	Statement	Program Outcomes					
		PO1	**PO2**	**PO3**	**PSO 1**	**PSO 2**	**PSO 3**
CO 1	Acquire idea about different types of error control coding techniques.	3	1	1	3	2	1
CO 2	Understand generator matrix, encoding and decoding of different codes.	2	2	2	3	1	2
CO 3	Learn LDPC, BCH, RS and Turbo codes.	2	2	1	3	1	2
CO 4	Analyze and mitigate errors in channels.	3	1	3	3	1	1
CO 5	Differentiate between different coding strategies.	1	1	2	3	2	2
Average		**2.2**	**1.4**	**1.8**	**3.0**	**1.4**	**1.6**

<table>
<tr><td colspan="9">Department of Electronics and Communication Engineering</td></tr>
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<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>EC9007</td><td>Detection and Estimation Theory</td><td>PEL</td><td>3</td><td>1</td><td>0</td><td>4</td><td>4</td></tr>
<tr><td colspan="2" rowspan="2">Pre-requisites:
EC1001,
Analog Communication (ECC401)
Digital Communication (ECC501)</td><td colspan="6">Course Assessment methods: (Continuous Assessment (CA), Mid-semester assessment (MA) and end assessment (EA)):</td></tr>
<tr><td colspan="6">Assignments, Quiz/class test, Mid-semester Examination and End Semester Examination</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">CO1: To familiarize students with Classical Statistical Inference Techniques and their applications to Communication and Signal processing
CO2: To familiarize students with Signal Detection Theory
CO3: To develop required mathematical skills for design and implementation of statistical signal processing algorithm</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Module I. Random Signal and Random Process Basics (L – 4; T - 1)
Important probability distribution functions: Gaussian, Chi-square, Rayleigh, Rician, Student's t, F, Cauchy etc. Bivariate and Multivariate Distribution; Random Process, Correlation properties, Stationarity, Ergodicity, Gaussian Process, Power Spectral Density

Module II. Classical Decision Theory (L – 6; T - 2)
Introduction to signal detection problems; Bayes Criterion: Binary Hypothesis testing, M-ary hypothesis testing; Maximum Likelihood based Optimal detection, LRT(Likelihood ratio test) and performance. Neyman Pearson Criterion for optimal detection , Minimum probability of error detector, Minimax Criterion

Module III. Detection of Deterministic signal (L – 4; T - 2)
Matched Filter Detection, Optimal detection for white and Nonwhite noise, Multiple Hypothesis testing;
Module IV. Detection of Random Signal (L – 5; T - 1)
Estimator Correlator, Energy Detector;
Module V. Detection of Signal with unknown parameters (L – 5; T - 2)
Composite Hypothesis Testing : Bayesian Approach and GLRT, Sinusoidal detection;
Module VI. Minimum Variance Unbiased Estimation (L – 6; T - 2)
Introduction to signal Estimation, Minimum variance unbiased estimator (MVUE), Unbiased estimators, MVUE Criterion, Cramer Rao Lower bound(CRLB); General CRLB for signals in white noise.

Module VII. Random parameter Estimation: (L – 6; T - 2)
Bayesian Formulation, Minimum mean square error (MMSE) and MAP estimation,Linear MMSE estimation, Wiener and optimum MMSE Filtering;
Module VIII. Non-Random Parameter Estimation: (L – 6; T - 2)
Least squares estimation, Best linear unbiased estimation (BLUE), Geometric interpretations, Maximum likelihood Estimation, Efficiency and consistency of estimators and asymptotic properties

Total Contact Hours: (L=56, T=0)= 56</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Text Books:
[1] Fundamentals of Statistical Signal Processing, (Vol 1 & Vol 2), S.M. Kay, Pearson
[2] Detection, Estimation, and Modulation Theory, Part-1, VanTrees, Jhon Wiley
Reference Books:
[1] Signal Detection and Estimation, Second Edition, Mourad Barkat Artech house.
[2] An Introduction to Signal detection and Estimation: H. Vincent Poor, Springer-Verlag</td></tr>
</table>

EC9007: Detection and Estimation Theory (Elective)

[Mapping between course outcomes (COs) and program outcomes (POs)]

CO	Statement	Program Outcomes					
		PO 1	PO 2	PO 3	PSO 1	PSO 2	PSO 3
CO 1	To familiarize students with Classical Statistical Inference Techniques and their applications to Communication and Signal processing	3	3	3	3	1	2
CO 2	To familiarize students with Signal Detection Theory	3	3	3	3	1	2
CO 3	To develop required mathematical skills for design and implementation of statistical signal processing algorithm	3	3	3	3	1	3
Average		3	3	3	3	1	2.33

Department of Electronic & Communication Engineering								
Course Code	**Title of the course**	Program Core (PCR) / Electives (PEL)	**Total contact hours: 56**					Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours		
EC9008	**Optical Communication & Networks**	PEL	3	1	0	4		4

Pre-requisites: 1. Electronic Devices and Circuits (ECC302 & ECC504) 2. Electromagnetic theory and Transmission Lines (ECC 403) 3. Analog Communication (ECC401), Digital Communication (ECC501)	Course Assessment methods: (Continuous Assessment (CA), Mid-semester assessment (MA) and end assessment (EA)): Assignments, Quiz/class test, Mid-semester Examination and End Semester Examination

Course Outcomes	• **CO1:** Students will be able to learn the intricacies of design constraints at optical frequency. • **CO2:** The basic training for understanding circuits and system level implementation in lightwave technology. • **CO3:** The students can design components and choose appropriate sources and receivers for an optical network. • **CO4:** Understanding the usage of OTDR in monitoring an optical communication system.
Topics Covered	**Module I. Introduction to optical communication: [L – 2; T – 0]** Overview of general communication, advantages of optical communication; Shannon noiseless coding theorem and Shannon noisy coding theorem. **Module II. Optical Fiber: [L – 8; T – 2]** Classification of Fibers, Fiber materials and fabrication methods, Ray optics representation and wave optics representation for step index and graded index fibers, Modes, Phase and group velocity, Power flow in step index fibers. **Module III. Propagation Characteristics in Optical Fibers: [L – 8; T – 2]** signal attenuation in fiber, dispersion, classification and effect of dispersion in information transfer, review of fiber connectors, couplers, optical filter, isolator, circulator and attenuator. **Module IV. Design aspects of optical communication: [L – 8; T – 1]** optical fiber systems, modulation schemes, digital and analog fiber communication system, system design consideration, emitter and detector design, fiber choice, connectors, various amplifiers and its characteristics; OTDR **Module V. Optical transmitter: [L – 4; T – 1]** Basic concepts, characteristics of semiconductor injection LASER, LED, transmitter design **Module VI. Optical Receiver: [L – 6; T – 2]** Basic concepts, p-n and p-i-n photo detectors, Avalanche photo detectors, MSM photo detector, receiver design, receiver noise, receiver sensitivity, optical amplifier and its applications; Direct detection; Coherent communication: Basic concept, detection principles, practical considerations, modulation and demodulation schemes, heterodyne and homodyne detection, single and multicarrier

	systems, DPSK system. **Module VII. Wavelength division multiplexing (WDM): [L – 5; T – 1]** multiplexing techniques, topologies and architectures, wavelength shifting, WDM demultiplexer, optical add/drop multiplexers. **Module VIII. Dense wavelength division multiplexing (DWDM): [L – 5; T – 1]** system considerations, multiplexers and demultiplexers; Fiber amplifier for DWDM, SONET/SDH transmission, modulation formats, NRZ and RZ signaling, DPSK system modeling. Potential applications and future prospects of optical fibers, multimode intensity sensors and single mode, Interferometric sensors. Recent trends in optical communication. **Total Contact Hours: (L=42, T=14) = 56**
Text Books, and/or reference material	**Text Books:** [1] J. M. Senior, "Optical Fiber Communications", PHI, 2nd Ed. [2] G. Keiser, "Optical Fiber Communication", McGraw Hill, 3rd Ed. [3] Ghatak & Thyagarajan, "Introduction to fiber Optics", Cambridge University press. [4] Henry Zanger and Cynthia Zanger, *Fiber Optics Communication and Other Application*, Macmillan Publishing Company, Singapore 1991. **Reference Books:** [1] J.H.Franz&V.K.Jain, "Optical Communications", Narosa Publishing House. [2] Ghatak&Thyagarajan, "Contemporary Optics", Series Title: Optical Physics and Engineering, Springer [3] AmnonYariv and PochiYeh, Photonics: Optical electronics for Modern Communication, 6th Ed., New York, Oxford University Press

EC9008 Optical Communication & Networks
[Mapping between course outcomes (Cos) and program outcomes (POs)]

CO	Statement	Program Outcomes					
		PO1	**PO2**	**PO3**	**PSO1**	**PSO2**	**PSO3**
CO1	Students will be able to learn the intricacies of design constraints at optical frequency.	**1**	**1**	**2**	**2**	**3**	**1**
CO2	The basic training for understanding circuits and system level implementation in light-wave technology.	**3**	**2**	**3**	**2**	**1**	**2**
CO3	The students can design components and choose appropriate sources and receivers for an optical network.	**2**	**1**	**3**	**1**	**2**	**1**
CO4	Understanding the usage of OTDR in monitoring an optical communication system.	**2**	**2**	**3**	**2**	**2**	**2**
Average		**2**	**1.5**	**2.75**	**1.75**	**2**	**2**

<table>
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<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours: 56</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>EC9009</td><td>Cooperative Communication Networks</td><td>PEL</td><td>3</td><td>1</td><td>0</td><td>4</td><td>4</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="6">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="2">NIL</td><td colspan="6">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">● CO1: Apply the knowledge of Wireless Communication in design of Relay Networks
● CO2: Understand different Architectures of Relay Networks and Performance analysis techniques and Performance Comparisons
● CO3: Design Cooperative Communication Systems and analyze Performance</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Topic 1: Review of Fading statistics in Wireless Channel, Characterizing performance through channel capacity, Diversity in Wireless Channel. Overview of Cooperative Communication, Cooperation Protocols, Amplify and forward(AF) relaying – Decode and forward(DF) relaying- Quantize and forward relaying- Compress and forward relaying- Adaptive cooperation strategies- Hierarchical cooperation.
[L -15, T - 5]

Topic 2: Cooperative communication with single relay- Analysis for AF relaying and DF relaying, SER Analysis, Comparison of DF and AF Cooperative Gain. Cooperative communication with multiple relays- Multi-node DF protocol- Multi-node AF protocol-Distributed Space Time Coding- Relay selection, Energy Efficiency in Cooperative Sensor Network. [15 , T - 5]

Topic 3: Coverage expansion with Cooperation, Relay Assignment protocols and analysis, Assignment algorithms and Multi-hop channel, Cognitive Cooperative Communication, Network Lifetime maximization via Cooperation [12, , T - 4]

Total Contact Hours: (L=42, T=14)= 56</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Text Books: 1. K.J. Ray Liu, Ahamed K. Sadek, Weifeng Su and Andres Kwasinski, Cooperative communications and Networking, Cambridge University Press 2009.
Reference Books: 1.Y.-W. Peter Hong, Wan-Jen Huang, C.-C. Jay Kuo, Cooperative Communications and Networking: Technologies and System Design, Springer 2010.</td></tr>
</table>

EC9009: Cooperative Communication Networks
[Mapping between course outcomes (Cos) and program outcomes (POs)]

CO	Statement	Program Outcomes					
		PO1	**PO2**	**PO3**	**PSO1**	**PSO2**	**PSO3**
CO1	CO1: Apply the knowledge of Wireless Communication in design of Relay Networks	3	2	3	3	2	2
CO2	CO2: Understand different Architectures of Relay Networks and Performance analysis techniques and Performance Comparisons	3	2	3	3	2	2
CO3	CO3: Design Cooperative Communication Systems and analyze Performance	3	2	3	3	2	2

Department of Electronics and Communication Engineering								
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours: 56				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
EC9010	**Network Information Theory & Coding**	PEL	3	1	0	4	4

Pre-requisites: Probability Theory, Digital Communication Fundamentals	Course Assessment methods (Continuous (CT) and end assessment (EA))
NIL	CT+EA

Course Objectives	To understand the role of information theory for an efficient, error-free and secure delivery of information using binary data streams.
Course Outcomes	CO 1: Understand the concept of Information and quantitative from of characterization of information CO 2: Gain knowledge about techniques for information compression and its application CO 3: Understand Channel Capacity and Shannon's Law on Information capacity. Appreciate information theoretic results as fundamental limits on performance of communication systems CO 4: Understand the fundamentals of Network Information Theory as basic limitation of information flow in a network.
Topics Covered	1. **Entropy, Relative Entropy and Mutual Information** Introduction, Definition and Measure of Information, Entropy, Joint entropy, Conditional entropy, Relative Entropy and Mutual Information, Chain rules, Jensen inequality, log sum inequality, Data processing Inequality, Fano's inequality. 2. **Source Coding and Data Compression** Source Coding Theorem, Variable length coding, Kraft inequality, Optimal codes, Lempel Ziv coding, Huffman coding, Shannon Fano Elias coding, Rate distortion function **3. Channel Capacity** Channel models, Definition and Properties of Channel Capacity, Binary Symmetric Channel, Binary Erasure channel, Symmetric Channels, **Differential entropy and Gaussian Channel** Differential entropy, properties of differential entropies, Joint and Conditional differential entropy, Relative Entropy and Mutual information, Gaussian Channel, Information Capacity Theorem, Parallel Gaussian Channels **4. Network Information Theory** Discrete Memory less Multiple Access Channel, Gaussian MAC, Interfering MAC, Broadcast Channel, Relay Channel, Capacity Region, Capacity Bound and Achievability, Slepian Wolf Encoding. **Total Contact Hours: (L=42, T=14) = 56**
Text Books, and/or reference material	1. Elements of Information Theory , Thomas M.Cover and Joy.A. Thomas, Wiley 2. Information Theory Coding and Cryptography, Third Edition, Ranjan Bose, McGraw Hill Education Pvt. Limited. 3. Networks Information Theory: Gamal and Kim, Cambridge University Press.

EC9010: Network Information Theory & Coding

[Mapping of CO (Course outcome) and PO & PSO]

PO / CO	PO #1	PO #2	PO #3	PO #4	PO #5	PO #6	PO #7	PO #8	PO #9	PO #10	PO #11	PO #12	PSO #1	PSO #2	PSO #3
CO#1	2	1	2	1	1	2	1	1	1	1	1	1	2	1	1
CO#2	3	2	2	1	1	2	1	1	1	1	1	1	2	1	1
CO#3	3	3	3	1	1	2	1	1	1	2	1	1	3	3	2
CO#4	1	2	1	1	1	3	2	1	1	1	1	1	3	3	2
CO#5	2	3	1	2	1	1	1	1	1	1	1	1	2	3	2

Correlation levels 1, 2 or 3 as defined below:
1: Slight (Low)   2: Moderate (Medium)   3: Substantial (High)

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total contact hours: 56				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
EC9011	**Digital Microwave Communication**	PEL	3	1	0	4	4

Pre-requisite: 1. ECC403Electrmagnetic Theory and Transmission Lines 2. ECC504 Electronics Devices and Circuits II 3. Microwave Engineering	Course Assessment methods: (Continuous Assessment (CA), Mid-semester assessment (MA) and end assessment (EA)) Assignments, Quiz/class test, Mid-semester Examination and End Semester Examination

Course Outcomes	**CO#1:** Students will be able to learn the intricacies of digital microwave long haul and short haul communication and spectrum management **CO#2:** Enriched understanding on equipment for digital microwave radio **CO#3**: Ability to understand the operation of digital microwave terrestrial and non-terrestrial network
Topics Covered	Digital Microwave Transmission Systems: ITU recommendations, spectrum management, standards and regulations; Hierarchy, modulation formats. [L-8] Microwave network performance objectives, Synchronization in passband digital transmission, control of inter-symbol interference, equalization technique in digital microwave radio, bit stream integration in digital transmission system, sources of jitter in digital transmission system, line codes [L-10] Transmission line components and waveguide systems and accessories for digital microwave radio, antennas for digital microwave radio [L-10] Digital microwave communication radio equipments, antenna support structures and mounting, multiplexing equipment [L-10] Designing and operating microwave systems, multipath fading, rain fading, ducting and obstruction fading, reflections and obstructions, digital receiver interference, reliability consideration in long haul microwave networks. [L-8] Transmultiplexer, common problems in the working of transmultiplexers [L-8] Terrestrial microwave long haul, mobile radio systems, data services in next generation communication services and non-terrestrial digital microwave communication services, Synchronous digital hierarchy [L-10] **Total Lecture Hours: (L=42, T=14)=56**
Text Books, and/or reference material	**Text Books:** [1] Kizer, George M., *Digital microwave communication: engineering point-to-point microwave Systems*, John Wiley & Sons, Inc., Hoboken, New Jersey 2013. [2] P. V. Sreekanth, *Digital Microwave Communication Systems*, University Press (India) Pvt Ltd., 2013 **Reference Books:** [1] P A Rizzi, *Microwave Engineering: Passive Circuits*, 2000, PHI [2] R E Collin, *Foundations of Microwave Engineering*, John Wiley and Sons India Pvt. Ltd [3] Kao-Cheng Huang, Zhaocheng Wang, *Millimeter wave communication systems*, John Wiley & Sons, Inc., Hoboken, New Jersey 2011

EC 9011: Digital Microwave Communication
[Mapping between course outcomes (Cos) and program outcomes (POs)]

CO	Statement	Program Outcomes					
		PO1	**PO2**	**PO3**	**PSO1**	**PSO2**	**PSO3**
CO 1	Students will be able to learn the intricacies of digital microwave long haul and short haul communication and spectrum management	3	2	1	2	3	1
CO 2	Enriched understanding on equipment for digital microwave radio	2	3	2	1	2	1
CO 3	Ability to understand the operation of digital microwave terrestrial and non terrestrial network	2	3	1	2	2	1
Average		**2.33**	**2.67**	**1.33**	**1.67**	**2.33**	**1**

Department of Electronic & Communication Engineering							
Course Code	**Title of the course**	Program Core (PCR) / Electives (PEL)	**Total contact hours: 56**				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
EC9012	**Microwave Photonics**	PEL	3	1	0	4	4

Pre requisite: 1. ECC403Electrmagnetic Theory and Transmission Lines 2. ECC504 Electronics Devices and Circuits II 3. Optical Communication 4. Microwave Engineering	Course Assessment methods: (Continuous Assessment (CA), Mid-semester assessment (MA) and end assessment (EA)): Assignments, Quiz/class test, Mid-semester Examination and End Semester Examination

Course Outcomes	**CO#1:** Students will be able to learn the intricacies of microwave photonics. **CO#2:** Enriched understanding on microwave photonics, circuits and components and applications **CO#3**: The students can develop ability to characterize microwave photonics component
Topics Covered	Introduction to microwave photonics, optical fiber categories and principles , basic fiber optic component [4] Analog performance metrics, sources of noise in optical fiber links, distortion in fiber optic links [10] Microwave photonics component technologies, photonic methods for microwave generation, mm Wave photonics, Photonic Oscillators for THz Signal Generation, THz sources, integrated microwave photonics [10] External intensity modulation for direct detection, phase modulation with interferometric detection, analog optical modulation methods, photodetectors, photodetector's power conversion efficiency, High-power Distributed Photodetectors for RF Photonic Applications [12] Propagation effects, double Raleigh scattering, RF Phase in Fiber Optic Links, chromatic dispersion, Stimulated Brillouin Scattering, Stimulated Raman Scattering, cross phase modulation, four wave mixing, polarization effects [10] Microwave photonics signal processing, photonics based RF signal processing, phased array beam forming [10] **Total Contact Hours: (L=42, T=14)=56**
Text Books, and/or reference material	**Text Books:** [1] Vincent J. Urick Jr., Jason D. McKinney, Keith J. Williams., *Fundamentals of microwave photonics*, John Wiley & Sons, Inc., Hoboken, New Jersey 2015 [2] Stavros Iezekiel, *Microwave photonics : devices and applications*, 2009 John Wiley & Sons, Ltd **Reference Books:** [1] Henry Zanger and Cynthia Zanger, *Fiber Optics Communication and Other Application*, Macmillan Publishing Company, Singapore 1991. [2] J. M. Senior, "Optical Fiber Communications", PHI, 2nd Ed. [3] G. Keiser, "Optical Fiber Communication", McGraw Hill, 3rd Ed.

EC 9012: Microwave Photonics
[Mapping between course outcomes (Cos) and program outcomes (POs)]

CO	Statement	Program Outcomes					
		PO1	**PO2**	**PO3**	**PSO1**	**PSO2**	**PSO3**
CO 1	**CO#1:** Students will be able to learn the intricacies of microwave photonics.	2	1	2	2	3	1
CO 2	**CO#2:** Enriched understanding on microwave photonics, circuits and components and applications	2	3	1	1	3	1
CO 3	**CO#3**: The students can develop ability to characterize microwave photonics component	3	2	1	1	3	1
Average		**2.3**	**2.0**	**1.3**	**1.3**	**3.0**	**1.0**

Department of Electronic & Communication Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	**Total contact hours: 56**				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
EC9013	**Radiating Systems for Next Gen Communication**	PEL	3	1	0	4	4

Pre-requisites:	Course Assessment methods: (Continuous Assessment (CA), Mid-semester assessment (MA) and end assessment (EA)):
Electromagnetic Theory and Transmission Lines (ECC403); Analog Communication (ECC401), Digital Communication (ECC501); Antenna and Wave Propagation (ECC601) (Optional)	Assignments, Quiz/class test, Mid-semester Examination and End Semester Examination

Course Outcomes

After the completion of the course the student will be able to

- **CO 1:** Ability to characterize resonance and radiation property of an antenna based on application
- **CO 2:** Learn various design parameters that affects an antenna and antenna array patterns.
- **CO 3:** Understand different types of antenna based on the radiation mechanism like wire antenna, aperture antennas, traveling wave antenna.
- **CO 4:** Understand different types of antenna based on the design mechanism like log periodic antenna, log spiral antenna and electrically long antenna as well as electrically small antenna.
- **CO 5:** Design suitable antenna feeding mechanis
- m as well as matching mechanism.
- **CO 6:** Analyze and synthesize different types of antennas for different wireless communications.

Topics Covered

Module I. Brief review on antenna fundamentals [L – 3; T - 1]
Antenna fundamentals; Vector potentials and solution of the vector potential wave equation; Antenna theorems and definitions.

Module II. Radiation theory and derivation of radiation parameters [L – 6; T - 2]
Dipole, loop antennas, Chu's limit; Log-periodic antenna, Log spiral principle.

Module III. Antenna Array design and characterization [L – 6; T - 2]
Linear, planar and circular array - theorems and pattern synthesis.

Module IV. Integral Equations [L – 3; T - 1]
Moment method, self and mutual impedances

Module V. Scanning antennas [L – 6; T - 2]
Signal processing antennas, travelling wave and broadband antenna; Concept of smart antennas.

Module VI. Microstrip antennas [L – 6; T - 2]
Operating principle, modes, field patterns, impedance, feeding techniques and polarization; Arrays and feed networks.

Module VII. Aperture antennas **[L – 6; T - 2]**
Huygen's principle, Babinet's principle; Fourier transform theory and its applications; The Geometrical theory of diffraction and uniform theory of diffraction techniques and their applications.

Module VIII.Antenna measurements [L – 6; T - 2]
Antenna ranges, Impedance Measurements, Radiation Patterns, Gain Measurements, Directivity Measurements, Radiation Efficiency, Current Measurements, Polarization Measurements.

Total Contact Hours: (L=42, T=14)= 56

Text Books, and/or reference material	**Text Books:** [1] C. A. Balanis, *Antenna Theory : Analysis and Design*, 3rd ed., John Wiley & Sons, Hoboken, New Jersey, 2005 [2] John D.Kraus, Ronald J.Marhefka "*Antennas: for all Applications*" 4th ed.,, Tata McGraw- Hill Inc., New Delhi, 2006. **Reference books:** [1] E C Jordan and K G Balmain, *Electromagnetic Waves & Radiating Systems*, 2nd ed., Pearson, New Delhi, 2015 [2] R. C. Johnson and H. Jasik, "*Antenna Engineering handbook*", 3rd ed., Mc-Graw Hill Inc., New York, 1993. [3] I. J. Bhal and P. Bhartia, "Micro-strip antennas", Artech house, Dedgham, MA, 1980. [4] Online Reference Material(s): 1. https://nptel.ac.in/courses/117107035/

EC9013: Radiating Systems for Next Gen Communication (Elective)
[Mapping between course outcomes (Cos) and program outcomes (POs)]

CO	Statement	Program Outcomes					
		PO1	PO2	PO3	PSO1	PSO2	PSO3
CO1	Ability to characterize resonance and radiation property of an antenna based on application.	2	1	2	2	3	1
CO2	Learn various design parameters that affects an antenna and antenna array patterns.	3	2	3	2	1	2
CO3	Understand different types of antenna based on the radiation mechanism like wire antenna, aperture antennas, traveling wave antenna.	2	1	3	1	2	1
CO4	Understand different types of antenna based on the design mechanism like log periodic antenna, log spiral antenna and electrically long antenna as well as electrically small antenna.	3	2	3	2	2	2
CO5	Design suitable antenna feeding mechanism as well as matching mechanism.	2	2	3	2	3	2
CO6	Analyze and synthesize different types of antennas for different wireless	3	2	3	1	2	2
Average		2.5	1.67	2.83	1.67	2.17	1.67

Department of Electronic & Communication Engineering

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total contact hours: 56				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
EC9014	**Microwave and mm Wave Measurements**	PEL	3	1	0	4	4

Pre requisite:

5. ECC403Electrmagnetic Theory and Transmission Lines
6. ECC504 Electronics Devices and Circuits II

Course Assessment methods: (Continuous Assessment (CA), Mid-semester assessment (MA) and end assessment (EA)):

Assignments, Quiz/class test, Mid-semester Examination and End Semester Examination

Course Outcomes

CO#1: Students will be able to learn the intricacies of measurement constraints at high frequency.
CO#2: Enriched understanding on microwave and mm wave measurement techniques
CO#3: Ability to characterize microwave and mm wave integrated circuits

Topics Covered

Review of microwave and mm Wave transmission line characteristics, scattering parameter and microwave network analysis [L-2]

Uncertainly and confidence in Measurement, high frequency voltage measurement[L-2]

Application of Smith charts in microwave networks. [L-2]

Introduction; slotted line technique; measurement of unknown Impedance using slotted line. [L-6]

Coaxial Connectors in measurement, Vector network analysis and network analyzer; construction; calibration technique – SOLT and TRL calibration; measurement procedure.[L-6]

Microwave and mm Wave power measurement. [L-6]

Time domain reflectometry. [L-2]

Measurement of Quality factor of resonators. [L-4]

Attenuation measurement. [L-2]

Spectrum analyzer measurement and applications. [L-4]

Noise measurements, Measurement accuracy, Mismatch effects, Phase noise measurement techniques and frequency stability. [L-6]

Measurement of dielectric properties of materials at RF and Microwave frequencies [L-7]

RFIC and MMIC measurement techniques, Probe station. **Special Millimeter-wave Measurement Techniques;** Non-destructive IC Package Characterization [L-7]

Total Lecture Hours: (L=42, T=14)=56

Text Books, and/or reference material

Text Books:
[1] David. M. Pozar, *Microwave Engineering*, 2/e, 1998 (John Wiley & Sons).
[2] Samuel Y Liao, *Microwave Devices and Circuits*, 3/e, PHI.
[3] R.J. Collier and A.D. Skinner, *Microwave Measurement*, 3/e, IET Electrical Measurement Series 12,United Kingdom, 2007
[4] Liu, Duixian. *Advanced millimeter-wave technologies : antennas, packaging and circuits*, John Wiley and Sons, Great Britain 2009

Reference Books:
[1] P A Rizzi, *Microwave Engineering: Passive Circuits*, 2000, PHI

	[2] R E Collin, *Foundations of Microwave Engineering*, John Wiley and Sons India Pvt. Ltd [3] Sorin Voinigescu, *High Frequency Integrated Circuits*, Cambridge University Press, UK, 2013

EC 9014: Microwave and Millimeter Wave Measurements
[Mapping between course outcomes (Cos) and program outcomes (POs)]

CO	Statement	Program Outcomes					
		PO1	**PO2**	**PO3**	**PSO1**	**PSO2**	**PSO3**
CO 1	Students will be able to learn the intricacies of measurement constraints at high frequency.	2	1	2	2	3	1
CO 2	Enriched understanding on microwave and mm wave measurement techniques	2	3	1	1	3	1
CO 3	Ability to characterize microwave and mm wave integrated circuits	3	2	1	1	3	1
Average		**2.3**	**2.0**	**1.3**	**1.3**	**3.0**	**1.0**

<table>
<tr><td colspan="9">Department of Electronic & Communication Engineering</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total contact hours: 56</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>EC9015</td><td>Microwave Solid State Devices</td><td>PEL</td><td>3</td><td>1</td><td>0</td><td>4</td><td>4</td></tr>
<tr><td colspan="3">Pre requisite:
7. ECC403Electrmagnetic Theory and Transmission Lines
8. ECC504 Electronics Devices and Circuits II</td><td colspan="5">Course Assessment methods: (Continuous Assessment (CA), Mid-semester assessment (MA) and end assessment (EA)):
Assignments, Quiz/class test, Mid-semester Examination and End Semester Examination</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">CO#1: Students will be able to learn the intricacies of high frequency devices.
CO#2: Enriched understanding on microwave and mm wave solid state circuits
CO#3: The students can develop ability to design circuits using compound semiconductors and Si-SiO2 devices</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Physical properties of semiconductor, carrier modeling, carrier action, revisiting pn junction [6]

Schottky effect, Schottky barrier diode; varactor diode; PIN diode; Applications. [8]

Tunnel diodes, Impact ionization, IMPATT, small-signal analysis and model of IMPATT diode TRAPATT, BARRITT. [10]

Transferred electron devices; Differential negative resistance and two-valley model of Gunn effect devices; modes of operation; Waveguide cavity microwave and mm Wave Gunn oscillator design. [10]

Characteristics and modeling of MOSFET, nanoscale MOSFET, Short Channel effects, BSIM models [10]

MESFET, HEMT, pHEMT– device physics, characteristics, model and noise performance and comparison with MOSFETs.[10]

Fabrication and packaging of semiconductor devices[2]
Total Lecture Hours: (L=42, T=14)=56</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Text Books:
[5] David. M. Pozar, Microwave Engineering, 2/e, 1998 (John Wiley & Sons).
[6] Samuel Y Liao, Microwave Devices and Circuits, 3/e, PHI.
[7] Sorin Voinigescu, High Frequency Integrated Circuits, Cambridge University Press, UK, 2013
Reference Books:
[1] S M Sze, Physics of Semiconductor Devices, John Wiley New York,1981
[2] B. G. Streetman and S. Banerjee, Solid State Electronic Devices, 5th ed. Upper Saddle River, NJ:Prentice Hall, 2006.
[3] D. A. Neamen, Semiconductor Physics and Devices: Basic Principles, 3rd ed. New York, NY: McGraw-Hill, 2003.
[4] Ivan Chee-Hong Lai, Minoru Fujishima, Design and Modeling of Millimeter-wave CMOS Circuits for Wireless Transceivers, Springer Netherlands,2008</td></tr>
</table>

EC 9015: Microwave Solid State Devices
[Mapping between course outcomes (Cos) and program outcomes (POs)]

CO	Statement	Program Outcomes					
		PO1	**PO2**	**PO3**	**PSO1**	**PSO2**	**PSO3**
CO 1	Students will be able to learn the intricacies of high frequency devices	2	1	2	2	3	1
CO 2	Enriched understanding on microwave and mm wave solid state circuits	2	3	1	1	3	1
CO 3	The students can develop ability to design circuits using compound semiconductors and Si-SiO2 devices	3	2	1	1	3	1
Average		**2.3**	**2.0**	**1.3**	**1.3**	**3.0**	**1.0**

Department of Electronics and Communication Engineering								
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	**Total Number of contact hours: 56**				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
EC9016	**Digital Satellite and Navigation Systems**	PEL	3	1	0	4	4

Pre-requisites:	Course Assessment methods (Continuous (CT) and end assessment (EA)):
· Electromagnetic Theory · Microwave Engineering · Analog and Digital Communication · Antennas and Wave Propagation	Assignments, Mid Semester and End Semester Examination

Course Outcomes	CO#1 To compute the satellite orbit parameters, design orbits and be able to classify them based on Kepler's six elements. CO#2 Understand the concept of satellite launching and positioning of satellites in orbits CO#3 Ability to understand the digital satellite communication principles and techniques CO#4 To introduce students in engineering and the sciences to the methods of satellite radio navigation. CO#5 Assimilatethe ability to develop new satellite navigation technology
Topics Covered	**Radio regulatory considerations relating to satellite communication systems**[L-4] Basic concepts, Frequency allocation for satellite services, orbital & spacecraft problems, comparison of networks and services, modulation techniques used for satellite communication. Spectrum Management **Satellite Orbits [L-10]** orbital mechanics, geostationary orbit, and change in longitude, orbital manoeuvres, orbital transfer, and orbital perturbations. Launch Vehicles- principles of Rocket propulsion, powered flight, Lauch vehicles for communication satellite **Satellite subsystems and satellite link design-[L-8]** Altitude and orbit control (AOC) Subsystem, TT&C, power system, spacecraft antenna, transponder, Friis transmission equation, G/T ratio of earth station. **Satellite RF link-[L-8]** Noise, the basic RF link, satellite links (up and down) , optimization RF link, inter satellite link, noise temperature, Antenna temperature, overall system temperature, propagation factors, rain attenuation model. Tropospheric and Ionospheric effect. **Satellite Access Techniques [L-8]** FDMA, TDMA, CDMA techniques, comparison of multiple access techniques, error connecting codes. **Mathematical Models for Positioning:** Differential and relative positioning. concepts of hyperbolic position fixing systems; concepts and applications to satellite based navigation systems [L-8] **Satellite Based Navigation[L-10]:** GPS, GLONASs, Galileo, GNSS **Total Lecture Hours: (L=42, T=14)=56**

Text Books, and/or reference material	**Text Books** [1]Dennis Roddy, *Satellite Communication*, 4/e, Mc Graw Hill [2]Louis J. Ippolito, Jr.*Satellite Communications Systems Engineering: Atmospheric Effects, Satellite Link Design and System Performance*,2/e, John Wiley [3]Bernhard Hofmann-Wellenhof, Herbert Lichtenegger, Elmar Wasle, *GNSS — Global Navigation Satellite Systems*, 1/e, Springer, Vienna 2008 **Reference Books** [4]Recommendation ITU-R P.618-11, P Series Radio Wave Propagation. [5] Pratt and Bostian, *Satellite Communication*, 2/e, John Wiley and Sons. [6]Tri T Ha, *Digital Satellite Communication*, Mc Graw Hill

EC9016: Digital Satellite and Navigation Systems
[Mapping between course outcomes (Cos) and program outcomes (POs)]

CO	Statement	Program Outcomes					
		PO1	**PO2**	**PO3**	**PSO1**	**PSO2**	**PSO3**
CO 1	To compute the satellite orbit parameters, design orbits and be able to classify them based on Kepler's six elements.	2	1	2	2	3	1
CO 2	Understand the concept of satellite launching and positioning of satellites in orbits	2	3	1	1	3	1
CO 3	Ability to understand the digital satellite communication principles and techniques	3	2	1	1	3	1
CO 4	To introduce students in engineering and the sciences to the methods of satellite radio navigation.	2	3	2	1	2	1
CO 5	Assimilate the ability to develop new satellite navigation technology	3	2	1	2	1	1
Average		**2.3**	**2.0**	**1.3**	**1.3**	**3.0**	**1.0**

<table>
<tr><th colspan="9">Department of Electronics and Communication Engineering</th></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Contact hours: 56</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>EC9017</td><td>Bio-molecular Communication</td><td>PEL</td><td>3</td><td>1</td><td>0</td><td>4</td><td>4</td></tr>
<tr><td colspan="3" rowspan="2">Pre-requisites:
• Analog and Digital communication
• Information theory
• Introduction to Biology</td><td colspan="5">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="5">Assignments, Quiz, Mid-semester Examination and End Semester Examination</td></tr>
<tr><td>Course Objective</td><td colspan="7">This course will cover basics of molecular communication and mathematical tools to model and analyze these systems.</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">• CO1: Identify the intersection of communication engineering and cell biology in the context of molecular communication.
• CO2: Explain bio-nano-machines and their communication methodology.
• CO3: Apply information theoretical and mathematical modelling concepts to molecular communication.
• CO4: Analyse engineering of molecular communication systems in different application areas.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Module I. (L-4)
Molecular communication: Why, what, and how? Evolution. Application areas.
Module II. (L-5, T-2)
Nature-made biological nanomachines: Protein, DNA/RNA, Lipid membrane.
Module III. (L-5, T-2)
Molecular communication in biological systems: Scales, modes and examples of molecular communication. Biomolecular topologies that work as signal differentiators of high accuracy to arbitrary input signals around their nominal operation and relevance to natural regulatory networks.
Module IV. (L-7, T-3)
Molecular communication paradigm: Molecular communication model, general characteristics, network architecture.
Module V. (L-7, T-2)
Mathematical modelling: Discrete diffusion and Brownian motion. Benchmarking the communication fidelity of biomolecular signalling cascades.
Module VI. (L-6, T-2)
Communication and information theory of molecular communication: Detection and estimation in molecular communication, Information theory of molecular communication.
Module VII. (L-4, T-1)
Design and engineering of molecular communication systems: Protein/ DNA/ Liposome, Molecular programming and self assembled systems. Realizing nanoscale communications considering both electromagnetic and biological communications to design minimally invasive, biocompatible, and targeted healthcare solutions.
Module VIII.(L-4, T-2)
Application areas: Targeted drug delivery, lab-on-a-chip in-vitro model system designed with next generation electrical and biological wearable and implantable devices, i.e. Internet of Bio-NanoThings.
Total Lecture Hours: (L=42, T=14) = 56</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7"><u>Text Books</u>:
[1] Tadashi Nakano, Andrew W. Eckford and Tokuko Haraguchi, Molecular Communication, Cambridge University Press, 2013.
[2] Massimiliano Pierobon and Ian F. Akyildiz, Fundamentals of Diffusion-Based Molecular Communication in Nanonetworks, NoW Publishers, 2014.
[3] Junichi Suzuki, Tadashi Nakano and Michael John Moore, Modeling, Methodologies and Tools for Molecular and Nano-scale Communications: Modeling, Methodologies and Tools, Springer, 2017.
[4] Martin Bossert, Information- and Communication Theory in Molecular Biology, Springer, 2018.
<u>References</u>:
[1] Abhishek Gupta, IITK, Molecular Communication, Course EE698U.
Youtube: https://youtu.be/mrbhkvwZpKE</td></tr>
</table>

EC9017: Bio-molecular Communication
[(Mapping between course outcomes (COs) and program outcomes (POs)]

CO	Statement	Program Outcomes					
		PO1	PO2	PO3	PSO 1	PSO 2	PSO 3
CO 1	Identify the intersection of communication engineering and cell biology in the context of molecular communication.	2	2	3	3	2	2
CO 2	Explain bio-nano-machines and their communication methodology.	2	3	2	2	2	1
CO 3	Apply information theoretical and mathematical modelling concepts to molecular communication.	3	2	3	3	3	1
CO 4	Analyse engineering of molecular communication systems in different application areas.	3	2	3	3	2	1
Average		**2.5**	**2.25**	**2.75**	**2.75**	**2.25**	**1.25**

PO 1: An ability to independently carry out research /investigation and development work to solve practical problems

PO 2: An ability to write and present a substantial technical report/document

PO 3: Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program

PSO 1: Understanding mathematical modelling of communication systems and networks

PSO 2: Enhancing the knowledge of RF front end circuit design and radio propagation phenomena

PSO 3: Equip with modern computational and hardware tools for designing communication systems

<table>
<tr><td colspan="8">Department of Electronics and Communication Engineering</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total contact hours: 56</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>EC9018</td><td>Queuing Theory for Telecommunication</td><td>PEL</td><td>3</td><td>1</td><td>0</td><td>4</td><td>4</td></tr>
<tr><td colspan="3" rowspan="2">Pre-requisites:
EC1001</td><td colspan="5">Course Assessment methods: (Continuous Assessment (CA), Mid-semester assessment (MA) and end assessment (EA)):</td></tr>
<tr><td colspan="5">Assignments, Quiz/class test, Mid-semester Examination and End Semester Examination</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">CO1: To understand the concept of queuing models and apply in Engineering
CO2: To understand significance of advanced queuing theory in Communication Networks
CO3: To develop expertise to analyse and design Communication Networks</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Module I. Review of Probability Concepts [L – 5; T – 2]
Random variables, Binomial, Geometric, Poisson, Exponential, Gamma, Normal, Moments of random variables, Moment Generating Functions, Markov’s inequality, Chebyshev’s inequality, Laws of large number, Transformation of random variables.
Module II. Poisson Process [L – 6; T – 2]
Exponential distribution and memoryless property, Counting process, Inter arrival and waiting time distribution, Properties of Poisson process, Non homogeneous Poisson, Compound Poisson process, sum of independent Poisson, random splitting of Poisson process.

Module III. Markov Chains and Renewal Theory [L – 9; T – 3]
Discrete time Markov Chain, Chapman Kolmogorov Equation, Limiting probabilities, Time reversal Markov Chains, Continuous time Markov Chain, Birth Death process, Transition probability function, Computation of Transition Probability, Reward Renewal Process, Semi Markov process, Regenerative Process.

Module IV. Markovian Queues [L – 9; T – 3]
Queuing process, system performance, Notation for Queuing Systems, Little’s Formula, Analysis of M/M/1, M/M/1/K, M/M/S, M/M/S/S, Queues with unlimited service (M/M/∞ queues). Distribution of queuing delays in FIFO case, M/M/1 and M/M/S cases Erlang’s Formula M/M/S/S, M/M/S; Queues with parallel channels and Truncation (M/M/S/K)

Module V. Non-Markovian Queues [L – 9; T – 3]
Poisson input General service Time model, Poisson input Constant Service time model. Queuing system with Bulk service. Analysis of M/G/1, M/D/1, M/G/1 system with delay distribution. Generalization of M/G/1 Theory. M/G/1 with geometrically distributed message. M/G/1 with random size batch arrival.

Module VI. Network of Queues [L – 4; T – 1]
Traffic rate equation, Little Theorem for whole network, Burke Theorem, Jackson Theorem, Priority Queues
Total Contact Hours: (L=42, T=14)= 56</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Text Books:
[1] Fundamentals of Queuing Theory: Gross and Harris, John Wiley & Sons
[2] Queuing Theory and Telecommunications Networks and Applications: Giovanni Giambene, Springer
Reference Books:
[1] Data Networks – D. Bertsekas and R. Gallager (Prentice Hall).
[2] Introduction to Queuing Networks, Theory and Practice – Smith, J. MacGregor (Springer).
[3] Teletraffic Theory and Applications: Haruo Akimaru and KonosukeKawashima,Springer
[4] Introduction to Probability Models: Sheldon M. Ross, Academic Press</td></tr>
</table>

	[5] Probability & Statistics with Reliability Queuing and Computer Science Applications: Kishore Trivedi, Wiley

EC9018: Queuing Theory for Telecommunication
[Mapping between course outcomes (COs) and program outcomes (POs)]

CO	Statement	Program Outcomes					
		PO1	**PO2**	**PO3**	**PSO1**	**PSO2**	**PSO3**
CO1	To understand the concept of queuing models and apply in Engineering	**3**	**3**	**3**	**3**	**1**	**2**
CO2	To understand significance of advanced queuing theory in Communication Networks	**3**	**2**	**3**	**3**	**1**	**1**
CO3	To develop expertise to analyse and design Communication Networks	**3**	**2**	**3**	**3**	**1**	**1**
Average		**3**	**2**	**3**	**3**	**1**	**1.33**

PO 1: An ability to independently carry out research /investigation and development work to solve practical problems

PO 2: An ability to write and present a substantial technical report/document

PO 3: Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program

PSO 1: Understanding mathematical modelling of communication systems and networks

PSO 2: Enhancing the knowledge of RF front end circuit design and radio propagation phenomena

PSO 3: Equip with modern computational and hardware tools for designing communication systems

Department of Electronics and Communication Engineering								
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	**Total Number of contact hours: 56**				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
EC9019	**Quantum Communication and Computing**	PEL	3	1	0	4	4
Pre-requisites: Engineering Mathematics, Quantum Mechanics		Course Assessment methods: (Continuous Assessment (CA), Mid-semester assessment (MA) and end assessment (EA)):					
		Assignments, Quiz/class test, Mid-semester Examination and End Semester Examination					
Course Outcomes	After the completion of the course the student will be able to ● **CO 1:** Understand the concept of quantum mechanics in the context of quantum computing and quantum communication ● **CO 2:** Understand the scope of quantum communication and information ● **CO 3:** Understand the perspective of quantum computing						
Topics Covered	**Module I: Fundamental Concepts of Quantum Mechanics [L-10; T-4]** Revision of fundamental concepts of quantum mechanics on the context of quantum computing and quantum communication **Module II: Quantum Communication and Information [L-10; T-3]** Information Theoretic Interpretations of von Neumann Entropy Information Theory, Entropy, Channel Capacity and Quantum Minimax Decision **Module III: Quantum Computing [L-12; T-4]** Quantum Computing and Decoherence in Quantum Optical Systems Unitary Dynamics for Quantum Codewords Quantum Error Correction with Imperfect Gates Eliminating the Effects of Spontaneous Emission in Quantum Computations Integrability and Computability in Simulating Quantum Systems Slowing Down the Decoherence of Quantum Bits Quantum Capacity of Noisy Quantum Channel **Module IV: Quantum Measurement Theory and Statistical Physics [L-10; T-3]** On Covariant Instruments in Quantum Measurement Theory Generalised Uncertainties for Quantum Signal Processing An Open System Approach to Quantum Computers **Total Lecture Hours: (L=42, T=14)= 56**						
Text Books, and/or reference material	**Text Books:** 1. Osamu Hirota, A.S. Holevo, C.M. Caves, *Quantum Communication, Computing, and Measurement*, Springer, 2012 2. Mladen Pavicic, *Quantum computation and quantum communication: Theory and experiments*, Springer, 2006 **Reference books:** 1. Research Articles						

EC9019: Quantum Communication and Computing
[Mapping between course outcomes (COs) and program outcomes (POs)]

CO	Statement	Program Outcomes					
		PO 1	PO 2	PO 3	PSO 1	PSO 2	PSO 3
CO 1	Understand the concept of quantum mechanics in the context of quantum computing and quantum communication	2	2	2	2	2	1
CO 2	Understand the scope of quantum communication and information	2	2	2	2	2	1
CO 3	Understand the perspective of quantum computing	2	2	2	2	2	1
Average		**2**	**2**	**2**	**2**	**2**	**1**

PO 1: An ability to independently carry out research /investigation and development work to solve practical problems

PO 2: An ability to write and present a substantial technical report/document

PO 3: Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program

PSO 1: Understanding mathematical modelling of communication systems and networks

PSO 2: Enhancing the knowledge of RF front end circuit design and radio propagation phenomena

PSO 3: Equip with modern computational and hardware tools for designing communication systems

Department of Electronics and Communication Engineering								
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	**Total Number of contact hours: 56**				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
EC9020	**Cloud Computing**	PEL	3	1	0	4	4

Pre-requisites:	Course Assessment methods: (Continuous Assessment (CA), Mid-semester assessment (MA) and end assessment (EA)):
Computer architecture, Computer Networking	Assignments, Quiz/class test, Mid-semester Examination and End Semester Examination

Course Outcomes	After the completion of the course the student will be able to ● **CO 1:** Understand the concept of cloud computing ● **CO 2:** Learn the mechanism and architecture of cloud computing ● **CO 3:** Apply concept of cloud computing in real application
Topics Covered	**Module I:** **Fundamental cloud computing** **[L-12; T3]** Introduction, Understanding Cloud Computing, Fundamental Concepts and Models, Cloud Enabling Technology, Fundamental Cloud Security **Module II:** **Cloud computing mechanisms** **[L-10; T3]** Cloud Infrastructure Mechanisms, Specialized Cloud Mechanisms, Cloud Management Mechanisms, Cloud Security Mechanisms **Module III:** **Cloud computing architecture** **[L-10, T4]** Fundamental Cloud Architectures, Advanced Cloud Architectures, Specialized Cloud Architectures **Module IV:** **Working with clouds** **[L-10; T-4]** Cloud Delivery Model Considerations, Cost Metrics and Pricing Models, Service Quality Metrics and SLAs **Total Lecture Hours: (L=42, T=14)= 56**
Text Books, and/or reference material	**Text Books:** 3. Thomas Erl, Zaigham Mahmood, and Ricardo Puttini, *Cloud Computing: Concepts, Technology & Architecture*, Pearson Education India; 1st edition, 2014 4. Toby Velte, Anthony Velte, Robert Elsenpeter, *Cloud Computing, A Practical Approach*, McGraw Hill Education; 1st edition, 2017 **Reference books:** 2. Research Articles

EC9020 Cloud Computing
[Mapping between course outcomes (COs) and program outcomes (POs)]

CO	Statement	Program Outcomes					
		PO 1	**PO 2**	**PO 3**	**PSO 1**	**PSO 2**	**PSO 3**
CO 1	Understand the concept of cloud computing	2	3	1	3	1	2
CO 2	Learn the mechanism and architecture of cloud computing	2	3	1	2	2	2
CO 3	Apply concept of cloud computing in real application	2	2	2	2	1	2
Average		**2**	**2.7**	**1.3**	**2.3**	**1.3**	**2**

Department of Electronic & Communication Engineering

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total contact hours : 56				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
EC9021	**Machine Learning and Deep Learning using Python**	PEL	3	1	0	4	4

Pre-requisites: **Basic computer programming languages like Python, C++ ,Matlab etc.**	Course Assessment methods: (Class Assessment (CA), Mid-semester assessment (MA) and end semester examination (EA)): Assignments, Quiz/class test, Mid-semester Examination and End Semester Examination

Course Outcomes

After the completion of the course the student will be able to learn:

- **CO1:** Using Python libraries, import and wrangle data, then partition it into training and test datasets
- **CO2:** Understand Machine Learning(ML) concepts and types of ML
- **CO3:** Interpret unsupervised learning and learn to use clustering algorithms
- **CO4:** Implement linear and non-linear regression
- **CO5:** Implement various types of classification methods such as SVM, decision tree and random forest
- **CO6:** Implement supervised learning with the help of Artificial neural Network
- **CO7:** Learn dimensionality reduction, Deep learning and Convolutional neural network

Topics Covered

Module I. Python for Machine Learning [L-8;T-3]
Programming basics, Applications of machine learning, Supervised vs Unsupervised Learning, Python libraries for machine learning

Module II. Regression [L-5;T-2]
Linear Regression, Non-linear Regression, Model evaluation methods

Module III. Unsupervised Learning and Regenerative model[L-8;T-2]
Introduction to Unsupervised Learning, K-Means Clustering, Auto encoder, Restricted Boltzmann Machine

Module IV. Supervised Learning and Discriminative Models [L-10;T-3]
Introduction to Supervised Learning, Perceptron, Multilayer Perceptron, MLP: Backpropagation and Applications, Radial Basis Function Neural Networks (RBF),Training of RBF, Decision Trees, Random Forest, Support Vector Machines (SVM), Building, training and evaluation of Machine Learning Model.

Module V. Dimensionality Reduction[L-4;T-2]
Feature Selection, Principal Component Analysis

Module VI. Deep Learning [L-07;T-2]
Introduction to Deep Neural Network, Architectures of Convolutional Neural Network ,Implementation of ConvNet/CNN from scratch using Python

Total Lecture Hours: (L=42, T=14)= 56

Text Books, and/or reference material

Text Books:

1. Shai Shalev-Shwartz and Shai Ben-David, *"Understanding Machine Learning: From Theory to Algorithms, "*Cambridge University Press",2014

	2. Manaranjan Pradhan , U Dinesh Kumar, "*Machine Learning using Python"*,First edition,2019,Wiley 3. Gowrishankar S., Veena A, *"Introduction to Python Programming"*, CRC Press Taylor & Francis Group,2019 4. Abhishek Kumar Pandey, Pramod Singh Rathore, Dr. S. Balamurugan, *"A Practical Approach for Machine Learning and Deep Learning Algorithms"*, BPB Publications, India, First Edition 2019 **Reference books:** 1. Simon Haykin, "*Neural networks and learning machines*," Pearson,3rd edition,2009 2. Charu C.Aggarwal, *"Neural Networks and Deep learning,"*Springer,2018

EC9021: Machine Learning and Deep Learning using Python
[Mapping between course outcomes (Cos) and program outcomes (POs)]

The correlation levels are 1, 2 or 3, denoting:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High).

CO	Statement	Program Outcomes					
		PO1	PO2	PO3	PSO1	PSO2	PSO3
CO1	Using Python libraries, import and wrangle data, then partition it into training and test datasets	3	2	3	1	1	3
CO2	Understand Machine Learning(ML) concepts and types of ML	3	2	2	1	1	3
CO3	Interpret unsupervised learning and learn to use clustering algorithms	2	2	2	1	1	3
CO4	Implement linear and non-linear regression	2	2	3	1	1	3
CO5	Implement various types of classification methods such as SVM, decision tree and random forest	2	2	2	1	1	3
CO6	Implement supervised learning with the help of Artificial neural Network	3	2	2	3	1	1
CO7	Learn dimensionality reduction, Deep learning and Convolutional neural network	2	2	3	2	1	2
Average		**2.42**	**2.0**	**2.42**	**1.0**	**1.42**	**2.57**

Department of Electronics and Communication Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	**Total Number of contact hours: 56**				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
EC9022	**Big Data Computing**	PEL	3	1	0	4	4

Pre-requisites: Machine Learning (ECE715), Database Management Systems (CSC502)	Course Assessment methods: (Continuous Assessment (CA), Mid-semester assessment (MA) and end assessment (EA)): Assignments, Quiz/class test, Mid-semester Examination and End Semester Examination

Course Outcomes	• **CO1: Understand** the Hadoop Framework and Ecosystem • **CO2: Explain and Analyze** the Big Data using MapReduce programming in both Hadoop and Spark Framework. • **CO 3: Demonstrate** Spark programming with different programming languages. • **CO4: Identify** the most suitable machine learning algorithm for handling massive data**.** • **CO5: Mine** social network graphs using MapReduce. • **CO6: Implement and Evaluate** the data manipulation procedures using Pig, Hive and Sqoop.
Topics Covered	**Module I: Introduction to Big Data [L-4]** 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. **Module II: Hadoop Framework [L-6]** Requirement; Design principle; 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. **Module III: MapReduce based Machine Learning [L-5; T-2]** K-means; PLANET; Parallel SVM, Association rule mining in MapReduce; Inverted index; Page ranking; Expectation maximization; Bayesian networks. **Module IV: Mining Social-Network Graphs [L-3; T-1]** Clustering of social network graphs; Direct discovery of communities; Partitioning of graphs finding overlapping communities; Counting triangles using MapReduce; Neighborhood properties of graphs. **Module V: Hadoop Ecosystem [L-3]** Introduction to Hadoop ecosystem technologies; Serialization- AVRO; Coordination- Zookeeper; Databases-HBase, Hive; Scripting language-Pig; Streaming- Flink, Storm. **Module VI: Apache Pig and Apache Hive [L-9; T-4]** Apache Pig - Introduction, Parallel processing using Pig, Pig architecture, Grunt, Pig data model: scalar and complex types, Pig Latin: input and output, Relational operators, User defined functions; Apache Hive- Hive modules, Data types and file formats, Hive QL data definition, Data manipulation, Hive QL queries, Hive QL views: reduce query complexity, Hive scripts, Hive QL indexes: create- show- drop, Aggregate functions; Bucketing Vs Partitioning. **Module VII: Importing and Handling Relational Data in Hadoop using Sqoop [L-5; T-2]** Relational database management in Hadoop- Bidirectional data transfer between Hadoop and external database; Import data- transfer an entire table, import subset data, use different file format, incrementally importing new data, preserving the value; Export transfer data from Hadoop- update the data, update at the same time, export subset of columns; Hadoop ecosystem integration- import data to Hive, using partitioned Hive tables, replace special delimiters. **Module VIII: Spark Framework and Data Analytics with Spark Shell [L-4; T-4]** Introduction to GPU programming; CUDA programming model; CUDA API; Simple matrix;

	Multiplication in CUDA; CUDA memory model; Shared memory matrix multiplication; Additional CUDA API features; Writing Spark application in Scala, Python, R, Java and execution. **Module IX: Spark SQL, GraphX, and Spark Streaming [L-3; T-1]** SQL context; Importing and saving data using SQL; GraphX overview; Overview on Spark streaming including errors and recovery; Streaming source; Streaming live data with Spark. **Total Contact Hours: (L=42, T=14) = 56**
Textbooks, and/or reference material	**Textbooks:** 5. J. Lescovek, A. Rajaraman, J. Ullman, *Mining of Massive Datasets*, Stanford Press, 2011. 6. T. White, *Hadoop: The Definitive Guide*, O'Reilly, 2015. *7.* M. Guller, *Big Data Analytics with Spark*, Apress, 2015. *8.* A. Gates, D. Dai, *Programming Pig Data Flow scripting with Hadoop*, O'Reilly Media, 2017. *9.* E. Capriolo, D. Wampler, J. Rutherglen, *Programming Hive*, O'Reilly Media, 2012.

EC9022: Big Data Computing
[Mapping the Course Outcomes (COs) to the Programme Outcomes (POs) and Programme Specific Outcomes (PSOs)]

CO	Statement	Program Outcomes					
		PO1	PO2	PO3	PSO1	PSO2	PSO3
CO1	**Understand** the Hadoop Framework and Ecosystem	**3**	**3**	**3**	**2**	**2**	**2**
CO2	**Explain and Analyze** the Big Data using MapReduce programming in both Hadoop and Spark Framework.	**3**	**1**	**2**	**3**	**1**	**2**
CO3	**Demonstrate** Spark programming with different programming languages.	**3**	**1**	**3**	**3**	**3**	**3**
CO4	**Identify** the most suitable machine learning algorithm for handling massive data**.**	**3**	**2**	**2**	**3**	**2**	**3**
CO5	**Mine** social network graphs using MapReduce	**3**	**1**	**2**	**3**	**1**	**2**
CO6	**Implement and Evaluate** the data manipulation procedures using Pig, Hive and Sqoop.	**3**	**1**	**3**	**3**	**3**	**3**
Average		**3**	**1.5**	**2.5**	**2.83**	**2**	**2.5**

Department of Electronics and Communication Engineering								
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)/OEL	Total contact hours: 56				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
EC9023	**Internet of Things (IoT)**	PEL	3	1	0	4	4

Pre-requisites: Basic Electronics (ECC01), Introduction to Computing (CSC01)	Course Assessment methods: (Continuous Assessment (CA), Mid-semester assessment (MA) and end assessment (EA)): Assignments, Quiz/class test, Mid-semester Examination and End Semester Examination
Course Outcomes	After the completion of the course the student will be able to ● **CO1**: Understand the concept of IoT systems ● **CO2**: Analyze electronic systems and IoT architecture ● **CO3:** Apply data analysis techniques in IoT ● **CO4**: Analyze case studies
Topics Covered	**Module I. Introduction to IoT** **[L-1]** Evolution of IoT, Applications of IoT in different domain. **Module II. Building Blocks of IoT** **[L-5; T-3]** Functional physical building blocks of IoT architecture, Sensors, Actuators, Signal conditioning elements and Data acquisition blocks, Data processing units. **Module III. Data Communication** **[L-4; T-2]** Data communication schemes, Basics of Networking, Communication Protocols, MQTT, HTTP, Sensor Networks, Intranet, Internet, NFC, Bluetooth, Zigbee, Wifi, 4G, 5G **Module IV. IoT System using Arduino board and Arduino programming** **[L-8; T-2]** Introduction to Arduino Programming, Integration of Sensors and Actuators with Arduino board, Data acquisition using Arduino board, Arduino communication shields, Data communication using Arduino-integrated-computer system. **Module V. IoT System using Arduino, Raspberry Pi and Python Programming** **[L-6; T-2]** Introduction to Raspberry Pi, Raspberry Pi OS and Python programming, Integration of Sensors and Actuators with Arduino and Raspberry Pi, Data acquisition using Arduino and Raspberry Pi, Integrated Sensor Network, Data communication using Raspberry Pi, Data communication using Raspberry Pi -integrated-computer system. **Module VI. Data processing** **[L-8; T-2]** Introduction to SDN, SDN for IoT, Introduction to Cloud Computing, Sensor-Cloud, Introduction to Fog Computing, Introduction to Edge Computing, Data analysis **Module VII. IoT applications and Case Studies** **[L-8; T-3]** Smart Homes, Smart Cities, Connected vehicles, Smart Grid, Industrial IoT, Smart-agriculture, Tele-medicine, Body activity monitoring **Module VIII. IoT and Industry 4.0** **[L-2]** Industry standards, Scope of IoT in Industry 4.0. **Total Lecture Hours: (L=42, T=14)= 56**

Text Books, and/or reference material	**Test Books:** 1. E. A. Lee, S. A. Seshia, *Introduction to Embedded Systems - a Cyber Physical Systems Approach*, MIT Press; Second edition, 2019 2. D. Hanes, G. Salgueiro, P. Grossetete, R. Barton, J. Henry, *IoT fundamentals: Networking technologies, protocols, and use cases for the internet of things*. Pearson Education; First edition, 2017 3. Shriram K Vasudevan; Abhishek S Nagarajan; RMD Sundaram, *Internet of Things*, 2nd Edition, Wiley, New Delhi, 2020. 4. S. Mishra, A. Mukherjee, A. Roy, *Introduction to IoT*, 1st Ed., Cambridge University, UK, 2021. 5. A. Bahga and V. Madisetti. *Internet of Things: A hands-on approach*. Orient Blackswan Private Limited; First edition, 2015 4. B. A. Forouzan, *Data Communications and Networking*, McGraw Hill Education; 4th edition, 2017 **Reference books:** 1. S. Monk, *Programming Arduino: getting started with sketches*. McGraw-Hill Education, 2nd edition, 2016 2. F. Brown, *Python: the complete reference*, McGraw Hill Education; 4th edition, 2018 3. E. Upton, and G. Halfacree. *Raspberry Pi user guide*. Wiley, 1st edition, 2012 4. Research articles

EC9023: Internet of Things (IoT) (Elective)
[Mapping between course outcomes (COs) and program outcomes (POs)]

CO	Statement	Program Outcomes					
		PO1	PO2	PO3	PSO 1	PSO 2	PSO 3
CO 1	Understand the concept of IoT systems	**2**	**3**	**1**	**2**	**1**	**3**
CO 2	Analyze electronic systems and IoT architecture	**3**	**3**	**2**	**2**	**1**	**3**
CO 3	Apply data analysis techniques in IoT	**2**	**3**	**3**	**2**	**1**	**1**
CO 4	Analyze case studies	**3**	**3**	**3**	**1**	**1**	**3**
Average		**2.5**	**3**	**2.25**	**1.75**	**1**	**2.5**

<table>
<tr><td colspan="9">Department of Electronics and Communication Engineering</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours: 56</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>EC9024</td><td>Virtual Reality and Augmented Reality</td><td>PEL</td><td>3</td><td>1</td><td>0</td><td>4</td><td>4</td></tr>
<tr><td colspan="2" rowspan="2">Pre-requisites:
Engineering Mathematics, Data Structures and Algorithms, Fundamentals of Image Processing</td><td colspan="6">Course Assessment methods: (Continuous Assessment (CA), Mid-semester assessment (MA) and end assessment (EA)):</td></tr>
<tr><td colspan="6">Assignments, Quiz/class test, Mid-semester Examination and End Semester Examination</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">After the completion of the course the student will be able to

● CO 1: Explain basic concepts of computer graphics/ AR/ VR
● CO 2: Apply the concepts of computer graphics/AR to build and process the 2D/3D models
● CO 3: Learn programming using modern tools to create and process 2D/3D models
● CO 4: Develop AR/VR application</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Module I: Introduction to Augmented Reality - Part 1: History of AR, AR Scenarios, the future of AR, Applications of AR. Calibration and Registration: Transformations, Coordinate Systems. [L-8; T-2]

Module II: Introduction to Augmented Reality - Part 2: Projections, Image formation in a pinhole camera, camera calibration, camera calibration techniques, camera calibration tools. [L-8; T-3]

Module III: Pose Estimation and Tracking: Pose Estimation; Pose Tracking in AR, Classification of Tracking, Stationary Tracking Systems, Mobile Sensor-Based Tracking, Optical Tracking, Hybrid Tracking, Marker-Based Tracking and AR, Diminished Reality, Marker less Tracking and AR. [L-8; T-3]

Module IV: Computer Vision for AR: Image Processing, Computer Vision-Definition and Scope, Object Detection and Tracking, Spatial Mapping, 3D Reconstruction for outdoor Tracking, OCR and Text Recognition for AR. [L-9; T-3]

Module V: 3D Graphics in AR: Basics of 3D Computer Graphics, 3D Rendering for C++ & C# Developers, 3D Model Importers/loaders, 3D Modeling Software, Graphics Libraries, Graphics Library Dependencies for AR, Graphics Dependency on AR Application Performance, OpenCV and OpenGL to Create AR. [L-9; T-3]

Total Lecture Hours: (L=42, T=14)= 56</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Text Books:
5. Chetankumar G Shetty, Augmented Reality: Theory, Design and Development, McGrawHill Publications 2020.
6. Schmalstieg and Hollerer, Augmented Reality: Principles & Practice, Paperback–12, Pearson Education India, October 2016.

Reference books:
3. Research Articles</td></tr>
</table>

EC9024: Virtual Reality and Augmented Reality
[Mapping between course outcomes (COs) and program outcomes (POs)]

CO	Statement	Program Outcomes					
		PO 1	PO 2	PO 3	PSO 1	PSO 2	PSO 3
CO 1	Explain basic concepts of computer graphics/ AR/ VR	2	3	1	3	1	2
CO 2	Apply the concepts of computer graphics/AR to build and process the 2D/3D models	2	3	1	2	2	2
CO 3	Learn programming using modern tools to create and process 2D/3D models	2	2	2	2	1	2
CO 4	Develop basic AR/VR application	2	2	2	2	1	2
Average		**2**	**2.5**	**1.5**	**2.25**	**1.25**	**2**

Department of Electronics and Communication Engineering								
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	**Total Number of contact hours: 54**				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
EC9025	**Network Functions Virtualization (NFV) and Software Defined Networks (SDN)**	PEL	3	1	0	4	4

Pre-requisites: Computer Network; Communication Engineering	Course Assessment methods: (Continuous Assessment (CA), Mid-semester assessment (MA) and end assessment (EA)): Assignments, Quiz/class test, Mid-semester Examination and End Semester Examination
Course Outcomes	• **CO 1: Understand** the concept of NFV and SDN • **CO 2: Apply** virtualization concept in modern networking • **CO 3: Recognize** and **interpret** the basic building blocks of SDN and NFV • **CO4: Design** and **analyze** a complete network with SDN and NFV
Topics Covered	**Module I: Introduction to the Basics of Virtualization [L-5; T-2]** Virtual Machine, virtual networks, hypervisor, managing virtual resources, virtualizing data centers, VM connectivity, VMware, Vmotion etc. **Module II: Network Functions Virtualization [L-8; T-3]** NFV: concepts and architecture, NFV functionality, network virtualization, modern networking approaches to virtualization, virtualizing core network functions, scalability and performance, open flow, open stack, etc. **Module III: Software Defined Networks [L-10; T-3]** SDN: background and motivation; review of networking; SDN: application, control, infrastructure layer; SDN data plane, SDN control plane and SDN application plane **Module IV: SDN Controllers [L-6; T-3]** Centralized control: commercial versus open-source controllers; network virtualization; the open day light (ODL) project; SDN use case examples. **Module V: Virtualized Networks [L-7; T-2]** Connecting it all together; building and managing virtualized network; service chaining in SDN; SDN and NFV working together. **Module VI: Security and Visibility [L-4; T-1]** Storage virtualization; preventing data leakage; encryption in virtual network; overlay networks; network management tools; monitoring traffic between virtual switches. **Total Lecture Hours: (L=40, T=14) = 54**
Textbooks, and/or reference material	**Textbooks:** 10. J. Doherty, *SDN and NFV simplified*, Pearson Education, U.S., 2016. 11. W. Stallings, *Foundations of Modern Networking: SDN, NFV, QoE, IoT (Internet of things) and Cloud*, Pearson Education, 2015. **Reference books:** 3. R. Chayapathi, S. F. Hassan, P. Shah., *Network functions virtualization with a touch of SDN*, Pearson Education, U.S., 2016.

EC9025: Network Functions virtualization (NFV) and Software Defined Networks (SDNs)
[Mapping between course outcomes (Cos) and program outcomes (POs)]

CO	Statement	Program Outcomes					
		PO1	PO2	PO3	PSO 1	PSO 2	PSO 3
CO 1	**Understand** the concept of NFV and SDN	3	3	3	3	2	2
CO 2	**Apply** virtualization concept in modern networking	3	1	2	2	1	2
CO 3	**Recognize** and **interpret** the basic building blocks of SDN and NFV	3	2	3	3	3	3
CO 4	**Design** and **analyze** a complete network with SDN and NFV	3	2	3	2	3	3
Average		3	2	2.75	2.5	2.25	2.5

POs:

PO 1: An ability to independently carry out research /investigation and development work to solve practical problems
PO 2: An ability to write and present a substantial technical report/document
PO 3: Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program

PSOs:

PSO 1: Understanding mathematical modelling of communication systems and networks
PSO 2: Enhancing the knowledge of RF front end circuit design and radio propagation phenomena
PSO 3: Equip with modern computational and hardware tools for designing communication systems

<table>
<tr><th colspan="9">Department of Electronics and Communication Engineering</th></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours: 56</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>EC9027</td><td>Multiphysics Analysis and Modeling</td><td>PEL</td><td>3</td><td>1</td><td>0</td><td>4</td><td>4</td></tr>
<tr><td colspan="2" rowspan="2">Pre-requisites:

Basic Electronics (ECC01),
Engineering Mechanics (XEC01)</td><td colspan="6">Course Assessment methods: (Continuous Assessment (CA), Mid-semester assessment (MA) and end assessment (EA)):</td></tr>
<tr><td colspan="6">Assignments, Quiz/class test, Mid-semester Examination and End Semester Examination</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">After the completion of the course the student will be able to
● CO 1: Understand characteristics of multiphysics systems
● CO 2: Apply quantitative analysis techniques to multiphysics systems
● CO 3: Understand modeling of multiphysics systems
● CO 4: Investigate complex designs of multiphysics systems and case studies</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Module I: Introduction to physical systems [L-1]

Module II: Characteristics of Physical Elements and Systems [L-14; T-3]
Static, dynamic and quasi static characteristics of physical elements and systems, Linearity, nonlinerity, hysteresis, time domain and frequency domain characteristics, response time, delay time, frequency response.

Module III: Loading effects in two port network [L6; T-2]
Loading effects in physical systems, Loading effect modelling, Two port network representation of physical elements and systems, Lumped parameter representation of Transducer, Amplifiers, Filters.

Module IV: Error analysis and modelling [L-4; T-2]
Sources of signal errors, Systematic and Random errors, Signal error analysis, sources of noise, wide-band noise, narrow-band noise, Error modelling, Statistical methods of error measurements, statistical averages, standard deviation, Gaussian distribution, correlation, autocorrelation, regression, Static hysteresis modelling.

Module V: System Representation, Modelling, Analysis [L-13; T-4]
Bond graph representation of multiphysics system, Energy methods, Hamilton's principle, Lagrange equations for multiphysics system, Representation of electrical circuits, electromechanical systems using Lagrange equations, Nonlinear dynamics, Time-varying Hysteresis model, Preisach model of hysteresis.

Module VI: Reliability analysis of physical systems [L-4; T-1]
Concept of reliability, mathematical modelling of reliability, bathtub model in reliability, reliability analysis of physical elements and physical systems, Several schemes for improving reliability of physical systems.

Total Lecture Hours: (L=42, T=14)= 56</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Text Books:
1. S. H. Crandall, D. C. Karnopp, Dynamics of Mechanical and Electromechanical, Medtech Pub, 2017
2. J. Bentley, Principles of measurement systems. Pearson Education India; 3rd edition, 2002

Reference books:
1. A. Preumont Mechatronics, Dynamics of Electromechanical and Piezoelectric Systems, Springer, 2011
2. S. Banerjee, Dynamics for Engineers, Wiley; 1st edition, 2005
3. Research articles</td></tr>
</table>

EC9027: Multiphysics Analysis and Modeling
[Mapping between course outcomes (Cos) and program outcomes (POs)]

CO	Statement	Program Outcomes					
		PO1	PO2	PO3	PSO 1	PSO2	PSO 3
CO 1	Understand characteristics of multiphysics systems	1	3	1	3	1	1
CO 2	Apply quantitative analysis techniques to multiphysics systems	3	3	3	3	1	2
CO 3	Understand modeling of multiphysics systems	2	3	3	3	1	2
CO 4	Investigate complex designs of multiphysics systems and case studies	3	3	3	3	1	2
Average		**2.25**	**3**	**2.5**	**3**	**1**	**1.75**

POs:

PO 1: An ability to independently carry out research /investigation and development work to solve practical problems
PO 2: An ability to write and present a substantial technical report/document
PO 3: Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program

PSOs:

PSO 1: Understanding mathematical modelling of communication systems and networks
PSO 2: Enhancing the knowledge of RF front end circuit design and radio propagation phenomena
PSO 3: Equip with modern computational and hardware tools for designing communication systems

Department of Electronics & Communication Engineering								
Course Code	Title of the course	Program Core (PCR) / **Elective (PEL)**	**Total contact hours: 56**					Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours		
EC9028	**Mixed Signal IC Design**	**PEL**	3	1	0	4		4
Pre-requisites: Analog IC Design[EC1012], Digital IC Design[EC1013], DSP[ECC603]			Course Assessment methods: (Continuous Assessment (CA), Mid-semester assessment (MA) and end assessment (EA)): Assignments, Quiz/class test, Mid-semester Examination and End Semester Examination					
Course Outcomes	After the completion of the course, the student will be able to: • **CO1:** Explain the operation of various High performance OTAs/Opamps. • **CO2:** Design Analog Circuits using gm/ID techniques. • **CO3:** Create the Layout of a CMOS Mixed Signal System. • **CO4:** Analyze a Comparator. • **CO5:** Interpret the use of Switched Capacitor Circuits in Sampled data Systems • **CO6:** Compare Data converter architectures based on Area/Power/Speed.							
Topics Covered	**Module I. Introduction [L – 7; T - 2]** Overview of Mixed-Signal Design flow. Design of high performance Fully Differential Opamps: Telescopic cascode, Folded cascode, two-stage, Rail-to-Rail, Gain boosted OTAs/Opamps, Comparison. **Module II. g_m over I_D Design Process [L – 4; T - 2]** Gm over ID technique: Transconductor efficiency in subthreshold, moderate and strong inversions. Various design plots: g_m/I_D, g_m/g_{ds}, f_T etc., and their use in Analog Design. Design of a CS Amplifier, and Two stage Opamp using g_m/I_D technique. **Module III. Opamp performance Metrics: [L – 4; T - 1]** Slew rate & Settling time, CMRR, PSRR, Linearity, Distortion : Gain Compression, THD, IIP3 calculation. Offset Cancellation techniques. **Module IV. Layout Techniques [L – 3; T - 2]** Introduction to CMOS process, CMOS Layers, Design rule basics, DRC, LVS, Passive and Transistor layout, Fingering, Interdigitization. Matching components: Common centroid, Use of Dummy. Matching error, error propagation. **Module V. Switched Capacitor Circuits [L – 5; T - 1]** Basic philosophy of Switched capacitor circuits, design of switched-capacitor amplifiers and integrators, effect of opamp finite gain, bandwidth and offset, circuit techniques for reducing effects of opamp imperfections, switches and charge injection and clock feed-through effects. **Module VI. Sample and Hold [L – 4; T - 1]** Operation of sample and holds circuits and theirs non-idealities. Comparators: OPAMP based, Strong Arm Regenerative Latch, Latch dynamics, Offset reduction. **Module VII. Data Converters [L – 12; T - 4]** Fundamentals of data converters; Introduction to data converter metrics: SNR, DNL, INL, Offset & Gain Error, SINAD, ENOB, SFDR, SDNR, Settling time etc. Nyquist rate D/A converters - voltage, current and charge mode converters, hybrid and segmented converters. Nyquist rate A/D converters (Flash, interpolating, folding flash, SAR and pipelined architectures); Oversampled A/D converters. **Module VIII. Phase Locked Loop [L – 3; T - 1]** Basic PLL topology, dynamics of simple PLL, Multiplier, phase detectors, lock acquisition, Phase							

	frequency detector, Loop filters, Charge Pump PLLs, non-ideal effects in PLLs. **Total Lecture Hours: (L=42, T=14) =56**
Text Books, and/or Reference materials	**Textbooks:** 1. Behzad Razavi, "*Design of Analog CMOS Integrated Circuits*", McGraw Hill, 2nd Ed. 2017 2. Tony Chan Carusone; David Johns; Kenneth Martin, "*Analog Integrated Circuit Design*", Wiley, 2nd Ed. 2013, 3. Behzad Razavi, "*Principles of Data Conversion System Design*", Wiley-IEEE Press, 1994 4. Adel Sedra , Kenneth Smith Tony Chan Carusone, Vincent Gaudet, "*Microelectronic Circuits*", Oxford ; 8th Ed.; 2020 **Reference Books/Materials:** 1. R.Gregorian, "*Introduction to CMOS Opamps and comparators*", Wiley, 1999 2. Rudy J. Van De Plassche, "*CMOS Integrated Analog-to-Digital and Digital-to-Analog Converters*", Springer, 2nd Ed. 2003. 3. Nagendra Krishnapura, IIT Madras, "*Analog Systems Design*" https://www.youtube.com/watch?v=4PxwecUfcHs&list=PLtTAxS17nYhJnIp5_P8sm7iAQIN11XmOe https://www.youtube.com/watch?v=eLTpf_5di2o&list=PLtTAxS17nYhLs4rJGpK2aBhBgCVtavGNh 4. Ali Hajimiri, Caltech, "*New Analog Circuit Design"*, https://www.youtube.com/watch?v=403CnTftB4M&list=PLc7Gz02Znph-c2-ssFpRrzYwbzplXfXUT

EC9028: Mixed Signal IC Design
[Mapping between Course Outcomes (COs) and Program Outcomes (POs)]

CO	Statement	Program Outcomes					
		PO1	PO2	PO3	PSO1	PSO2	PSO3
CO1	Explain the operation of various High performance OTAs/Opamps.	2	1	2	3	1	1
CO2	Design Analog Circuits using gm/ID techniques.	2	3	1	3	2	2
CO3	Create the Layout of a CMOS Mixed Signal System.	3	2	1	2	2	2
CO4	Analyze a Comparator.	3	1	1	3	2	1
CO5	Interpret the use of Switched Capacitor Circuits in Sampled data Systems	3	1	1	2	1	2
CO6	Compare Data converter architectures based on Area/Power/Speed	2	1	3	3	1	1
Average		**2.5**	**1.5**	**1.5**	**2.66**	**1.5**	**1.5**

<table>
<tr><td colspan="9">Department of Electronics & Communication Engineering</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Elective (PEL)</td><td colspan="4">Total contact hours : 56</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>EC9029</td><td>Architectural Design of Integrated Circuits</td><td>PEL</td><td>3</td><td>1</td><td>0</td><td>4</td><td>4</td></tr>
<tr><td colspan="3" rowspan="2">Pre-requisites:
Digital IC Design, DSP</td><td colspan="5">Course Assessment methods: (Continuous Assessment (CA), Mid-semester assessment (MA) and end assessment (EA)):</td></tr>
<tr><td colspan="5">Assignments, Quiz/class test, Mid-semester Examination and End Semester Examination</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">After the completion of the course, the student will be able to:
• CO1: Map any algorithm to VLSI Architecture.
• CO2: Compare Adder architectures and select the optimum one based on application
• CO3: Analyze and employ Multiplier architectures
• CO4: Describe CORDIC block with any applications.
• CO5: Illustrate the timing issues and adopt necessary steps to meet the timing constraints.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Module IX. Introduction [L – 5, L – 2]
VLSI Design flow, general design methodologies, Fundamentals of Efficient Design and Implementation strategies of Digital VLSI Design, One bit incrementer, four bit incrementer, N-bit incrementer, ones' complement, two's complement, sum of N –natural numbers, prioritization, greatest common divisor (GCD).

Module X. Mapping Algorithms to Architectures [L – 6, L – 2]
Mapping algorithms into Architectures: Signal flow graph, data dependences, datapath synthesis, control structures, critical path and worst case timing analysis, concept of hierarchical system design;

Module XI. Adder, Subtractor Architectures: [L – 4, L – 2]
Adder architectures: Single bit addition, Carry – Ripple adder, Carry – Skip adder, Carry-Look-ahead adder, Carry –Select adder, Carry – Increment adder, Tree adder. Subtractor architectures.

Module XII. Multiplier Architectures [L – 5, L – 2]
Tree multiplication, Array multiplication, signed multi-operand addition, squaring, shift and add multiplier, synchronous shift and add multiplier, Booth algorithm.

Module XIII.CORDIC Architecture [L – 5, L – 1]
CORDIC method, rotation and vectoring mode, convergence, precision and range, scaling factor and compensation, implementations: word-serial and pipelined, New techniques – Micro rotation to Angel Recoding (MAR), Binary to Bipolar Recoding (BBR).

Module XIV. Timing Analysis [L – 6, L – 2]
Static and Dynamic timing analysis, System Considerations - edge triggered, clock skew, handling asynchronous inputs, sequential machine, clock cycle time, Violation – maximum propagation delay, race through, Re-timings.

Module XV. Architectural Design of DSP Blocks [L – 4, L – 2]
Efficient VLSI Architectures for Various DSP blocks (FIR filter, CORDIC, FFT etc).

Module XVI. Trade-off Issues [L – 7, L – 1]
Trade-off issues: Optimization with regard to speed, area and power, asynchronous and low power</td></tr>
</table>

	system design, ASIC (application specific integrated circuits) and ASISP (application specific instruction set processors) design. **Total Lecture Hours (L=42, T=14)=56**
Text Books, and/or Reference materials	**Text Books:** 5. M. D. Ercegovac and T. Lang, " Digital Arithmetic", Morgan Koffman, 2003 6. K. W. Ulrich, "Advanced Arithmetic for the Digital Computer", Springer, 2002 **Reference Books/Materials:** 5. B. Parhami, "Computer Arithmetic: Algorithms and Hardware Designs", Oxford, 2009

EC 9029: Architectural Design of ICs
[Mapping between Course Outcomes (COs) and Program Outcomes (POs)]

CO	Statement	Program Outcomes					
		PO1	PO2	PO3	PSO1	PSO2	PSO3
CO1	Map any algorithm to VLSI Architecture.	2	1	2	3	1	1
CO2	Compare Adder architectures and select the optimum one based on application	2	3	1	3	2	2
CO3	Analyze and employ Multiplier architectures	2	3	1	3	2	2
CO4	Describe CORDIC architecture with any applications.	3	1	1	3	2	1
CO5	Illustrate the timing issues and adopt necessary steps to meet the timing constraints.	3	1	1	2	1	2
Average		**2.4**	**1.8**	**1.2**	**2.8**	**1.6**	**1.6**

Department of Electronics and Communication Engineering								
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total contact hours: 57				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
EC9030	**RF IC Design**	PEL	3	1	0	4	4
Pre-requisites / Co-requisites: Analog IC Design (ECE722), Analog Communication (ECC401) Electromagnetic theory and Transmission Lines (ECC 403)		Course Assessment methods: (Continuous Assessment (CA), Mid-semester assessment (MA) and end assessment (EA)): Assignments, Quiz/class test, Mid-semester Examination and End Semester Examination					

Course Objective

The objective of the course is to give the student fundamental knowledge on Radio Frequency (RF) integrated circuits design. The course discusses methods and techniques for RF front-end design oriented to CMOS technology.

Course Outcomes

After going through the course, student will be able to

CO 1: Analyze various architectures of today's digital radio transmitters and receivers.

CO 2: Analyze and design basic RF building-blocks in CMOS technology.

CO 3: Define basic RF measurements parameters such as S-parameters, sensitivity, noise figure, IIP3

CO 4: Assimilate the design techniques of VCO, LNA as well as other front-end circuits

Topics Covered/ Syllabus

Module-I: Introduction to RF IC Design Concepts [L – 6; T – 2]
Basic Concepts in RF Design, passive on chip components and layouts, transceiver architectures, circuit analysis techniques at radio frequencies.

Module-II: Semiconductor radio frequency components [L – 8; T – 3]
RF diodes, MOS transistor, determination of model parameters, parasitics of MOS transistors and high frequency behaviour of basic amplifier.RF Transistor Materials – The Transistor Equivalent Circuit – Y Parameters – S Parameters – Understanding RF Transistor Data Sheets; BSIM3 parameters of NMOS and PMOS transistors, matching and biasing networks for transistors

Module-III: Noise and non-linearity. [L – 3; T – 1]
Noise Figure and representation of non-linearity, intermodulation products and intercept points

Module-IV: Filter Design [L – 4; T – 1]
Resonator and filter configurations, realization of filter for specific transfer function, implementation of filters a coupled line filter.

Module V: RF Transistor Amplifier [L – 8; T – 3]
Stability consideration, constant, gain and noise figure circles. Low Noise Amplifiers: SNR, LNA topologies, power constrained CMOS LNA design, low-current CMOS inverter LNAs, low-voltage LNA topologies, differential LNA design methodology, process variation in tuned LNAs, impact of temperature variation in tuned LNAs, low-noise bias networks for LNAs, MOSFET layout of LNA.

Module-VI: RF Mixers [L – 5; T – 1]
Basic design concepts, single end diode mixer single balanced and double balanced diode mixer design. Transistor mixers, conversion loss.

Module-VII: RF Oscillators [L – 6; T – 2]
Basic Principles, Phase Noise, negative resistance oscillators, transistor oscillators, VCO design methodology, frequency scaling of CMOS VCO, VCO layout Phase lock loops, frequency synthesizers

Module-VIII: RF power amplifiers [L – 3; T – 1]

	Class A, AB, B, C, D, E and F amplifiers, modulation of power amplifiers, linearity consideration, Layout in CMOS. **Total Contact Hours: (L=43, T=14) = 57**
Text Books, and/or Reference material	**<u>Text Books</u>:** [1] Behzad Razavi, RF Microelectronics Prentice Hall of India, 2001 [2] Cam Nguyen, Radio Frequency Integrated Circuit Engineering, John Wiley and Sons, New York 2015 [3] Sorin Voinigescu, *High Frequency Integrated Circuits*, Cambridge Univeity Press,UK, 2013
	<u>Reference Books:</u> [1] Thomas H. Lee, The Design of CMOS Radio Frequency Integrated Circuits, Cambridge University Press. [2] R Ludwig and P Bretchko, *RF Circuit Design: Theory and Application*, Pearson Education, New Delhi [3] Bosco Leung, "*VLSI for Wireless Communication*", Springer (2011). [4]Ivan Chee-Hong Lai, Minoru Fujishima, *Design and Modeling of Millimeter-wave CMOS Circuits for Wireless Transceivers*, Springer Netherlands,2008

EC9030: RF IC Design (Elective)
[Mapping between course outcomes (COs) and program outcomes (POs)]

CO	Statement	Program Outcomes					
		PO 1	**PO 2**	**PO 3**	**PSO 1**	**PSO 2**	**PSO 3**
CO 1	Analyze various architectures of today's digital radio transmitters and receivers	2	1	2	2	1	1
CO 2	Analyze and design basic RF building-blocks in CMOS technology	3	1	3	3	3	1
CO 3	Define basic RF measurements parameters such as S-parameters, sensitivity, noise figure, IIP3	3	2	3	2	2	1
CO 4	Define basic RF measurements parameters such as S-parameters, sensitivity, noise figure, IIP3	3	2	3	2	2	1
CO 5	CO#4:Assimilat the design techniques VCO, LNA as well as other front end circuits	2	1	2	3	3	2
Average		**2.50**	**1.33**	**2.50**	**2.67**	**2.50**	**1.33**

<table>
<tr><td colspan="8">Department of Electronics and Communication Engineering</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total contact hours: 56</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>EC9031</td><td>SoC Design</td><td>PEL</td><td>3</td><td>1</td><td>0</td><td>4</td><td>4</td></tr>
<tr><td colspan="2" rowspan="2">Pre-requisites:
Basics hardware description language (Verilog or VHDL) from VLSI Design (ECC602)</td><td colspan="6">Course Assessment methods: (Continuous Assessment (CA), Mid-semester assessment (MA) and end assessment (EA)):</td></tr>
<tr><td colspan="6">Assignments, Quiz/class test, Mid-semester Examination and End Semester Examination</td></tr>
<tr><td>Course Objective</td><td colspan="7">The course aims to produce students who are capable of developing Arm Cortex-M0 and Cortex-M3 based SoCs from high level functional specifications to design, implementation and testing on real FPGA hardware using standard hardware description and software programming languages.</td></tr>
<tr><td>Course Outcomes

After going through the course, student will be able to</td><td colspan="7">On successful completion of this course, students should have the skills and knowledge to:
CO1:
Knowledge and understanding of:
Arm processor architectures and Arm-based SoCs
Capture the design of Arm-based SoCs in a standard hardware description language
Low-level software design for Arm-based SoCs and high-level application development
CO2:
Intellectual
Ability to use and choose between different techniques for digital system design and capture.
Ability to evaluate implementation results (e.g., speed, area, power) and correlate them with the corresponding high-level design and capture.
CO3:
Practical
Ability to use a commercial tool to develop Arm-based SoCs</td></tr>
<tr><td>Topics Covered/ Syllabus</td><td colspan="7">Module I. Design and Technology Trends [L – 1, T -0]
Introduction to design trends in deep-submicron (DSM) era, including scaling trend, clock cycle and power issues.

Module II. Role of Interconnect in Contemporary SoC Design [L – 2, T -0]
Characteristics of wire delay in DSM, crosstalk minimization, delay in long wire and performance limitations, interconnect coupling capacitance and its effect on wire delay, crosstalk avoidance coding schemes (CAC), fault modeling in presence of crosstalk, interconnect inductance.

Module III. System-on-Chip and Platform based Design [L – 2, T -0]
Emerging SoC trends: IP based design and reusability, multiprocessor SoC platform design, design for testability (DFT), Test Access Mechanism (TAM), concepts of core based test and IEEE P1500 standard for SoC test.

Module IV. Importance of Power and Low Power SoC Design Methodology [L – 2, T -0]
Different low power design methodologies, physics of power dissipation in CMOS, design and test of low-voltage CMOS circuits, multi-threshold CMOS (MTCMOS), variable threshold CMOS and other related methodologies, coding for low power, power dissipation through architecture level optimization.

Module V. ARM based SoC: [L – 2, T -0]
Introduction to Programmable SoCs; Why the SoC Design Concept Developed, Moore’s Law, Why Scaling?, The Design Productivity Gap, Bridging the Design Productivity Gap, What Is an SoC?,</td></tr>
</table>

What Is Inside an SoC?, Example Arm-based SoC, Advantages of SoCs, Limitations of SoCs, SoC v Microcontroller v Processor, SoC Design Flow, SoC Example: NVIDIA Tegra 2, SoC Example: Apple SoC Families.

Module VI. The Arm Cortex-M0 Processor Architecture: Part 1[L – 3, T -1]
Building a System on a Chip, Arm Holdings, What Is Arm Architecture?, Example Design of an Arm-based SoC, Arm Processor Families, Arm Cortex-M Series Family, Cortex-M0 Processor, Arm Processor v Arm Architectures, Cortex-M0 Overview, Cortex-M0 Block Diagram, Cortex-M0 Three-stage Pipeline, Cortex-M0 Block Diagram, Cortex-M0 Registers, Cortex-M0 LR, Cortex-M0 PSRs, Cortex-M0 Memory Map, Cortex-M0 Executable Memory Space, Cortex-M0 Device Memory Space, Cortex-M0 Private Peripheral Bus, Cortex-M0 Reserved Memory Space, Cortex-M0 Memory Map Example, Cortex-M0 Endianness

Module VII. The ARM Cortex-M0 Processor Architecture part-2 [L – 3, T -1]
Building a System on a Chip, Thumb Instruction Set, Thumb-2 Instruction Set, Cortex-M0 Instruction Set, Cortex-M0: Generic Format of Instructions, Cortex-M0 Instruction Set, Register Access: The Move Instruction, Memory Access: The LOAD Instruction, Memory Access: LOAD, Memory Access: The STORE Instruction, Memory Access: STORE, Multiple Data Access, Stack Access: PUSH and POP, Arithmetic ADD, Arithmetic SUB, MUL, Arithmetic CMP, Logic Operation, Arithmetic Shift Operation, Logical Shift Operation, Rotate Operation, Reverse Ordering Operation, Extend Operation, Program Flow Control, Suffixes for Conditional Branch (B <cond>), Conditional Branch Example, Memory Barrier Instructions, Exception-Related Instructions, Other Instructions, Sleep Mode Related Instructions, Low-Power Requirements, Cortex-M0 Low Power Features, Cortex-M0 Sleep Mode, Sleep-on-Exit Feature, How to Enable Sleep Features, Processor Wakeup Conditions, Wakeup Interrupt Controller, Enter and Exit Deep Sleep Mode, Developing Low-Power Applications

Module VIII. The AMBA3 AHB Lite Bus Architecture [L – 3, T -1]
Building a System on a Chip, What Is a Bus?, Bus Terminology, Bus Operation in General, A Typical Bus Operation Example, Communication Architecture Standards, Arm AMBA System Bus, Arm AMBA Bus Families, AMBA 3 AHB-Lite Bus, AHB-Lite Bus Block Diagram, AHB-Lite Master Interface, AHB-Lite Slave Interface, Address Decoder, Slave Multiplexor, Hardware Implementation, AHB-Lite Operation Principles, AHB-Lite Bus Timing, Basic Read Transfer, Basic Write Transfer, Read Transfer with Wait State.

Module IX. ARM AHB Bus Peripherals: [L – 2, T -1]
Design and Implementation of an AHB VGA Peripheral: Building a System on a Chip, VGA Overview, How VGA Signals Work, VGA Timing, AHB VGA Peripheral, Additional Design Requirement, AHB VGA Peripheral Hardware Architecture, VGA Interface, VGA Image Buffer, Text Console, AHB Interface, Memory Space.

Module X. Design and Implementation of an AHB UART peripheral [L – 2, T -1]
Building a System on a Chip (SoC), Serial Communication, Types of Serial Communication, Parallel Communication, Serial v Parallel Communication, UART Overview, UART Protocol, Character-Encoding Scheme, ASCII Encoded Characters, AHB UART Peripheral, Baud Rate Generator, UART Transmitter, UART Receiver, First In First Out (FIFO), Why Do We Need an FIFO in UART?, First In First Out (FIFO), FIFO Implementation, Memory Space

Module XI. Design and Implementation of an AHB timer, a GPIO peripheral, and a 7-segment display peripheral [L – 2, T -1]
Building a System on a Chip (SoC), Timer Overview, Standard Architecture of Hardware Timers, Timer Operation Modes, Timer Operation Mode, Timer Operation Modes, Hardware Module Overview, AHB Timer, Timer Registers, Hardware Module Overview, GPIO Overview, AHB GPIO, GPIO Registers, Hardware Module Overview, 7-Segment Display Overview, AHB 7-Segment Display, 7-Segment Display Registers, Memory Space.

Module XII. Design and Implementation of Interrupt Mechanism [L – 2, T -1]
Building a System on a Chip (SoC), Polling v Interrupts, Exception and Interruption, Interrupt Preemption, Cortex-M0 Block Diagram, Armv6-M Exception Model, Cortex-M0 Interrupt Controller, NVIC Registers, NVIC Registers, Building a System on a Chip (SoC), The Interrupt Mechanism Process, Interrupt Implementation for Timer, Interrupt Implementation for UART, Connect Interrupts to Processor, Enable Interrupts in Software, Entering an Exception Handler, Exiting an Exception Handler.

Module XIII. Software Programming of ARM SoC: [L – 2, T -1]
Programming an SoC Using C Language; Building a System on a Chip (SoC), C and Assembly Language Review, Typical Program-Generation Flow, Program-Generation Flow with Arm Tools, Program Image, Program Image in Global Memory, Program Data Types, Data Qualifiers in C Language, How Is Data Stored in RAM, Example of Data Storage, Define Interrupt Vector in C, Define Stack and Heap, Accessing Peripherals in C, Calling a C Function from Assembly, Calling an Assembly Function from C, Embedded Assembly

Module XIV. ARM CMSIS and Software Drivers [L – 2, T -1]
Building a System on a Chip (SoC), What Is CMSIS?, What Is Standardized in CMSIS?, CMSIS Components, Access NVIC Using CMSIS, Access Special Registers Using CMSIS, Execute Special Instructions Using CMSIS, Access System Using CMSIS, Benefits of CMSIS, Device Driver, AHB Peripheral Drivers, Using Pointer to Access Peripherals, Define Data Structure for Peripherals, Functions Reuse Between Multiple Units, Define AHB Peripherals, Examples of Simple Functions

Module XV. Application Programming Interface (API) and Final Application: The SNAKE Game [L – 3, T -1]
Building a System on a Chip (SoC), API Overview, Develop a Simple API, Hardware-Dependent Functions, Call-Back Functions, Retargeting, Retargeting Examples, Example of API Functions, Game Application: Snake, More Game Applications, Cortex-M0 Low-Power Features Review, Cortex-M0 Sleep Mode, System Control Register, Sleep-on-Exit, Polling v Interrupts, Developing Low-Power Applications.

Module XVI. ARM DS-5 Development Studio [L –3, T -1]
Arm DS-5 Development Studio Overview, ARM DS-5 Code, ARM DS-5 Build, ARM DS-5 Debug, Debug Hardware, Virtual Debug Interface – VSTREAM, ARM DS-5 Analyzer – Streamline, ARM DS-5 Analyzer – Energy Probe, ARM DS-5 Simulation, ARM DS-5 Device Configuration Database

Module XVII. ARM v7-A/R ISA [L – 2, T -1]
Why do u need to know Assembler?, ARM assembler file syntax, Single/ Double register data transfer, Addressing Memory, Pre- and Post -Indexed Addressing, Multiple Register Data Transfer, Data Processing Instructions, Shift/Rotate Operations, Instructions for loading constants, Multiply/Divide, Bit Manipulation Instructions, Byte Reversal, Flow control, Branch instructions, Interworking, Compare and Branch if zero, Conditional Instructions, If Then, Coprocessor instructions, PSR access, DSP instructions overview, Saturated Maths and CLZ, Saturation, SIMD

Module XVIII. ARM Cortex-A9 Processor [L – 2, T -1]
Cortex- A9, Cortex-A9 MP Core, Cortex-A9 MPE Configuration, Cortex-A9 Media Processing Engine, Register Renaming, Virtual Flags Registers, Small Loop Mode, Program Flow Prediction, Performance Monitoring Unit (PMU), Cortex A9 supports ARMv7-A Architecture, caches, Data Cache, Memory Management Unit, ARM v7 Architecture Effects.

Module XIX. AMBA AXI4 Bus Architecture [L – 2, T -1]
What is a Bus, Bus Types, Bus Terminology, Bus Operation, Communication Architecture Standards, ARM AMBA System Bus, AMBA 3 AXI Interface, AMBA 4 Specifications, AXI Components and Topology, Transcation Channels, Basic Signals, Clock and Reset, Channel Timing Example, Relationship between the Channels.

	Total Contact Hours: (L=42, T=14)= 56
Text Books, and/or Reference material	**Text Books:** [1] Steve B. Furber, ARM System-on-Chip Architecture. [2] William Hohl, ARM Assembly Language: Fundamentals and Techniques. [3] Joseph Yiu, The Definitive Guide to the ARM Cortex-M0.
	Reference Books/materials: [1] Cortex-A Series Programmer's Guide for ARMv7-A by Arm [2] http://infocenter.arm.com/help/topic/com.arm.doc.den0013d/index.html [3] Louise H Crockett, Ross A Elliot, Martin A Enderwitz, The Zynq Book Tutorials for Zybo and ZedBoard

EC9031: SoC Design (Elective)

[Mapping between course outcomes (Cos) and program outcomes (POs)]

CO	Statement	Program Outcomes					
		PO1	**PO2**	**PO3**	**PSO 1**	**PSO 2**	**PSO 3**
CO 1	**Knowledge and understanding of:** Arm processor architectures and Arm-based SoCs Capture the design of Arm-based SoCs in a standard hardware description language, Low-level software design for Arm-based SoCs and high-level application development	2	3	2	3	2	3
CO 2	**Intellectual:** Ability to use and choose between different techniques for digital system design and capture; Ability to evaluate implementation results (e.g. speed, area, power) and correlate them with the corresponding high level design and capture;	3	3	3	3	2	3
CO 3	**Practical:** Ability to use a commercial tool to develop Arm-based SoCs	3	3	3	3	3	3
Average		**2.66**	**3**	**2.66**	**2.5**	**2.33**	**3**

Department of Electronics and Communication Engineering								
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total contact hours: 70 (L-42 + P-28)				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
EC9032*	**FPGA based Design**	PEL	3	0	2	5	4

Pre-requisites/Co-requisites: Digital Circuits and Systems (ECC402)	Course Assessment methods: (Continuous Assessment (CA: 15%), Mid-Term Assessment (MA:25%) and End-Term Assessment (EA:60%)) Continuous Assessment (CA): Quizzes/Class tests/Assignments/Attendance

Course Outcomes

- **CO1:** Learn logic synthesis techniques – two level and multilevel synthesis.
- **CO2:** Be able to design systems using FPGAs and CPLDs.
- **CO3**: Learn sequential machine design using FPGAs.
- **CO4**: Learn to design systems for low power operation.

Topics Covered

Total Lecture hours: Lecture – 42; Practical/Sessional – 28: Total Contact Hours – 70

Module-I: (L – 06)
Logic design fundamentals: Two level synthesis – SOP/POS forms, Logic minimization, Limitations of two-level synthesis, introduction to multi-level synthesis.

Module-II: (L – 10)
Programmable Logic Devices: Programmable Logic Array (PLA) architecture; Programmable Array Logic (PAL), PAL vs. PROM, Fan-in expansion feature, Architecture for sequential circuit implementation, Typical PAL chips; Complex Programmable Logic Devices (CPLD).

Module-III: (L – 10)
Programmable Gate Arrays: Gate Array concept, Mask programmable and Field Programmable Gate Arrays; Look up tables (LUT) Configurable logic blocks (CLB), logic design using LUT's; Multi-level synthesis techniques – Factoring and Functional decomposition, Shannon's Expansion Theorem; Generalized FPGA Architecture; Introduction to CAD Tools for FPGA based design, design entry and simulation – introduction to HDL, synthesis, post synthesis simulation, interfacing external devices.

Module-IV: (L – 08)
Sequential Circuit Design: Finite State Machines, Moore and Mealy Machines; State diagrams, State table, State assignment, derivation of next-state and output expressions, state minimization; State assignment for low power operation; CAD tools for FSM synthesis; Designing a simple CPU, concept of embedded system.

Module-V: (L – 02)
Advanced features of modern FPGAs: Block RAMs, Embedded processor, Communication ports, Analog interface.

Module-VI: (L – 06)

FPGA as a Hardware Debugging platform: Hardware troubleshooting methods, Looking into the chip – Logic State Analyzer and its use; Concept of Hardware emulation – simulation vs. Emulation, FPGA as a Hardware emulator, Break-points and their utility, setting break-points in FPGA based design.

Module-VII: (P – 18)
Familiarizing with CAD tools, Design and synthesis of simple logic functions – Basic gates, adder/Subtractor, decoder, encoder, multiplexer, demultiplexer; Interfacing external devices – setting user constraint file, interfacing input (switch) and output (LED) devices, BCD to seven-segment decoder, keyboard/display interface; designing memory elements and arrays; sequential machine design – sequence generators, timing generators, a typical machine design (example: vending

	machine); A simple CPU design, constructing a basic embedded system – interfacing on-chip CPU, memory and I/O ports. **Module-VIII:** (P – 10) Design analysis: Static timing analysis, Power analysis, Resource utilization, noise, clock network, DRC, debugging methods. **Total Contact Hours: (L=42, P=28) = 70**
Text Books, and/or Reference Materials	Text Books: 1. S. Brown and Z. Vranesic, "*Fundamentals of Digital Logic with Verilog Design*," McGraw Hill Education Special India Edition (SIE), 2017. Reference Books: 1. J. Bhasker, "*A Verilog HDL Primer*", B.S. Publications, Hyderabad in arrangement with Star Galaxy Publishing, USA, 1999.

EC9032: FPGA based Design* (Elective) [Mapping between Course Outcomes (COs) and Program Outcomes (POs)]							
CO	**Statement**	**Program Outcomes**					
		PO 1	**PO 2**	**PO 3**	**PSO 1**	**PSO 2**	**PSO 3**
CO 1	Learn logic synthesis techniques – two level and multilevel synthesis.	2	1	2	2	1	1
CO 2	Be able to design systems using FPGAs and CPLDs.	3	1	3	3	3	1
CO 3	Learn sequential machine design using FPGAs.	3	2	3	3	3	1
CO 4	Learn to design systems for low power operation.	3	2	3	2	2	1
Average		**2.75**	**1.5**	**2.75**	**2.5**	**2.25**	**1**

Department of Electronics and Communication Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours: 56				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
EC9033	**Embedded Systems**	PEL	3	1	0	4	4

Pre-requisites	Course Assessment methods
Pre-requisites: Basic Electronics (ECC01), Introduction to Computing (CSC01) Digital Circuits and Systems (ECC402) Microprocessors and Microcontrollers (ECC503)	Course Assessment methods: (Continuous Assessment (CA), Mid-semester assessment (MA) and end assessment (EA)): Assignments, Quiz/class test, Mid-semester Examination and End Semester Examination

Course Outcomes

After the completion of the course the student will be able to

- **CO 1:** Understand use of Microprocessor in Microcontrollers and Microcomputer
- **CO 2:** Interface I/O devices with Microprocessor in Microcontrollers and Microcomputer
- **CO 3:** Design software controlled hardware systems
- **CO 4:** Investigate application specific embedded systems

Topics Covered

Module I: Intel 8051 Microcontroller [L-4;]
Architecture of Intel 8051 Microcontroller using functional blocks, Crystal oscillators, Digital I/O Pins, Digital I/O ports, 8051 Microcontroller programmer, limitations of Intel 8051 Microcontroller.

Module II: ATmega Microcontrollers and Arduino [L-4;]
Architecture of ATmega Microcontrollers using functional blocks, Hardware components of Arduino boards, ADC, Analog input pins, Digital I/O pins, PWM signals, PWM pins, Serial communication pins, Arduino shields, Limitations of ATmega Microcontrollers and Arduino.

Module III: Raspberry Pi Micro-Computer [L-4]
ARM processor, Hardware components of Raspberry Pi Micro-computer, GPIO pins in Raspberry Pi board, PWM signals, Raspberry Pi OS, In-built data communication devices, Limitations of Raspberry Pi Micro-Computer.

Module IV: I/O devices for Micro controllers and Microcomputers [L-5; T-2]
Sensors, Resistive sensors, Capacitive sensors, Inductive sensors, Actuators, Motors, Signal conditioning circuits, Amplifiers, Filters, Display elements, Data storage devices, Compatibility of several transducers with Intel 8051 Microcontroller, ATmega Microcontrollers and Arduino, Raspberry Pi Micro-Computer

Module V: Embedded System Programming using Keil [L-7; T-3]
Keil editor and compiler, Keil Programming for Intel 8051 Microcontroller, Program uploading to 8051 Microcontroller, I/O programming, Interfacing Analog and Digital sensors and actuators with Intel 8051 Microcontroller, Interrupt programming in 8051, Keypad and Display element interfacing with 8051.

Module VI: Embedded System Programming using Arduino language [L-7; T-3]
Arduino editor and compiler, Arduino Programming, Program uploading to Arduino board, I/O programming, Interfacing Analog and Digital sensors and actuators with Arduino, Serial communication and Data transmission in Arduino, Interrupt programming in Arduino, Keypad and Display element interfacing with Arduino.

	Module VII: **Embedded System Programming using Python** **[L-7; T-3]** Raspberry Pi OS, Python programming, Interfacing Analog and Digital sensors and actuators with Raspberry Pi, I/O programming in Raspberry Pi, Serial communication and Data transmission in Raspberry Pi, Interrupt programming, Keypad and Display element interfacing with Raspberry Pi. **Module VIII:** **Case studies** **[L-4; T-3]** Application specific embedded system design using 8051 Microcontroller, Arduino, Raspberry Pi, Password lock device using Embedded system, Smart home using embedded system, Motor controller using Embedded system **Total Lecture Hours: (L=42, T=14)= 56**
Text Books, and/or reference material	**Text Books:** 7. T. Givargis, F. Vahid , *Embedded System Design: A Unified Hardware / Software Introduction*, Wiley; Student edition, 2006 8. E. A. Lee, S. A. Seshia, *Introduction to Embedded Systems - a Cyber Physical Systems Approach*, PHI Learning Pvt Ltd, MIT Press; Second edition, 2019 9. M. A. Mazidi, *The 8051 Microcontroller and Embedded Systems: Using Assembly and C*, Pearson Education India; 2nd edition, 2007 **Reference books:** 4. J. Bentley, *Principles of measurement systems*. Pearson Education India; 3rd edition, 2002 5. T. W. Schultz, *C and the 8051, Vol.I: Hardware, Modular Programming & Multitasking*, Prentice Hall; 2nd edition, 1997 6. S. Monk, *Programming Arduino: Getting Started with Sketches*, Second Edition, McGraw-Hill, 2nd edition, 2016 7. J. Yiu, *The Definitive Guide to ARM® Cortex®-M3 and Cortex®-M4 Processors*, Newnes; 3rd edition, 2013 8. S. Monk, *Raspberry Pi Cookbook: Software and Hardware Problems and Solutions*, Shroff/O'Reilly; Second edition, 2016 9. D. Molloy, *Exploring Raspberry Pi: Interfacing to the Real World with Embedded Linux*, Wiley; 1st edition, 2016 10. Research Articles

EC9033: Embedded Systems
[Mapping between course outcomes (COs) and program outcomes (POs)]

CO	Statement	Program Outcomes					
		PO 1	**PO 2**	**PO 3**	**PSO 1**	**PSO 2**	**PSO 3**
CO 1	Understand use of Microprocessor in Microcontrollers and Microcomputer	2	3	3	2	1	2
CO 2	Interface I/O devices with Microprocessor in Microcontrollers and Microcomputer	3	3	3	2	1	3
CO 3	Design software controlled hardware systems	3	3	3	2	1	3
CO 4	Investigate application specific embedded systems	2	2	2	2	1	2
Average		**2.5**	**2.75**	**2.75**	**2**	**1**	**2.5**

Department of Electronics and Communication Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total contact hours: 56				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
EC9034	MEMS & Microsystems Technology	PEL	3	1	0	4	4
Pre-requisites: Basic Elle EC9086ctronics (ECC01), Engineering Mechanics (XEC01)		Course Assessment methods: (Continuous Assessment (CA), Mid-semester assessment (MA) and end assessment (EA)): Assignments, Quiz/class test, Mid-semester Examination and End Semester Examination					

Course Outcomes

After the completion of the course the student will be able to

- **CO 1**: Understand characteristics of MEMS system
- **CO 2**: Understand fundamental building blocks of general MEMS systems
- **CO 3**: Apply qualitative and quantitative analysis techniques in general MEMS systems
- **CO 4**: Understand fabrication technology of MEMS system
- **CO 5**: Investigate application specific MEMS systems

Topics Covered

Module I: Introduction to MEMS & Microsystems Technology [L1]

History of MEMS technology, Commercial MEMS devices, Application of MEMS devices

Module II: Electromechanical transduction techniques [L-5; T-2]

Electrostatic transduction, Electromagnetic transduction, Piezoelectric transduction, Piezoresistive transduction

Module III: Characteristics of MEMS Devices [L-6; T-2]

Static characteristics, linearity, nonlinearity, Sensitivity, Resolution, Hysteresis, Dynamic characteristics, Response time, Delay time, Gain, Bandwidth, Quasi static characteristics of MEMS devices.

Module IV: Analysis and Modelling of MEMS devices [L-6; T-2]

Concept of Energy, Co-energy, Energy methods, Lagrange equations, Physics based model, Lumped model, Finite element model

Module V: Effect of noise [L-2; T-1]

Sources of different types of noise, Thermal noise, Environmental noise, Noise modelling techniques, Statistical methods of noise modelling

Module VI: Integration and packaging [L-6; T-3]

Transducers in MEMS, MEMS sensors, MEMS actuators, Integration of MEMS transducers with signal conditioning /driver circuits, Signal amplifiers, Signal filters

Module VII: MEMS device fabrication processes [L-10; T-2]

MEMS materials, Bulk micromachining, Silicon anisotropic etching, Surface micromachining,

Module VIII: Scaling effect, Reliability of MEMS devices [L-2; T-1]

Effect of inertia in MEMS devices, Scaling effect of MEMS devices, Concept of reliability, Mathematical modelling of reliability, Reliability analysis of MEMS devices.

Module IX: Case studies in MEMS [L-4; T-1]

	Application specific MEMS devices, MEMS blood pressure sensors, MEMS microphone, MEMS accelerometer, MEMS gyro **Total Lecture Hours: (L=42, T=14)= 56**
Text Books, and/or reference material	**Text Books:** 1. S. D. Senturia, *Microsystem Design*, Springer; 1st edition, 2004 2. K.J. Vinoy, S. Gopalakrishnan, K.N. Bhat, V.K. Aatre, G.K. Ananthasuresh, *Micro and Smart Systems*, Wiley India Pvt Ltd, 2010 **Reference books:** 1. Research Articles

EC9034: MEMS & Microsystems Technology (Elective)
[Mapping between course outcomes (Cos) and program outcomes (POs)]

CO	Statement	Program Outcomes					
		PO 1	PO 2	PO 3	PSO 1	PSO 2	PSO 3
CO 1	Understand characteristics of MEMS system	2	3	2	3	1	1
CO 2	Understand fundamental building blocks of general MEMS systems	3	3	2	3	1	2
CO 3	Apply qualitative and quantitative analysis techniques in general MEMS systems	3	3	3	3	1	1
CO 4	Understand fabrication technology of MEMS system	2	3	2	3	1	2
CO 5	Investigate application specific MEMS systems	3	3	2	3	1	2
Average		**2.6**	**3**	**2.2**	**3**	**1**	**1.6**

Department of Electronics and Communication Engineering

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	**Total contact hours: 56**				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
EC9035	**Nanoelectronics**	PEL	3	1	0	4	4

Pre-requisites:
Microelectronics and Semiconductor Device Physics [PHC331, EC1011]

Course Assessment methods: (Continuous Assessment (CA), Mid-semester assessment (MA) and end assessment (EA)):
Assignments, Quiz/class test, Mid-semester Examination and End Semester Examination

Course Outcomes

- **CO 1:**Demonstrate understanding of fundamental of nanodevices fabrication techniques.
- **CO 2:**Demonstrate understanding of nanotechnology concepts for device fabrication and characterization.
- **CO 3:**To acquire a fundamental understanding of electronics and optical properties of nanomaterials.
- **CO 4:**To acquire knowledge of basic nanodevice principles and fabrication approaches for various nanoscale devices.

Topics Covered

Module I. Introduction to nanotechnology [L –8; T - 2]
Introduction to nanotechnology, the size of things, history of nanotechnology, fabrication method (top-down and bottom-up), emerging applications of nanotechnology.

Module II. Electronic and optical properties of nanostructures [L – 10; T -5]
Electronic and Optical properties of nanostructures. Energy sub-bands. Electron transport in two –dimensional electron gas (density of states), Carrier scattering, the resistance of a ballistic conductor, Transmission probability calculation, Electron tunnelling, Resonant tunnelling, Coupled nanoscale structures, and Superlattices.

Module III. Nanomaterials, deposition and characterization techniques [L – 11; T - 4]
Nanotechnology: Deposition techniques for Nanoscale Devices, Nanolithography, Self-Assembly Techniques, Nanomaterials, Nanoparticles, Nanowires, Nanomagnetic Materials, Nanostructure Surfaces; Instrumentation for nanoscale electronics: The Atomic Force Microscope (AFM), Scanning Tunneling Microscope and scanning near field optical microscope.

Module IV. Electronic devices based on nanostructures [L –13; T - 3]
Shrink-down approaches: Electronic devices Based on Nanostructures: Advance Heterostructure Devices, Downscaling of the MOSFET. Nanoscale FET Transistors, the Ballistic FET, Resonant Tunneling Devices and Circuits, Single Electron Transistor and Related Devices. Devices based on carbon nanotubes, Spintronic Devices; Optoelectronic Devices using Nanostructures: Quantum well and Quantum Dot LASERS, Quantum Cascade LASER, Quantum well-infrared photodetector, Superlattice LASER.

Total Contact Hours: (L=42, T=14)= 56

Text Books and/or reference material

Text Books:

1. C.P. Poole Jr., F.J. Owens, *Introduction to Nanotechnology*, John Wiley & Sons, Hoboken, New Jersey, 2003.
2. W.Ranier,Nanoelectronics and Information Technology (Advanced Electronic Materials and Novel Devices), 3rd ed., Wiley-VCH, 2003.

Reference books:

1. J. H. Davies,*The Physics of Low-Dimensional Semiconductors*, Cambridge University Press, 1998.
2. Y. Taur and T. Ning, *Fundamentals of Modern VLSI Devices*, Cambridge University Press, 1988.
3. K. Goser, *Nanoelectronics and Nanosystems*,Springer, 2004.

EC 9035: Nanoelectronics (Elective)
[Mapping between course outcomes (COs) and program outcomes (POs)]

CO	Statement	Program Outcomes					
		PO1	**PO2**	**PO3**	**PSO 1**	**PSO 2**	**PSO 3**
CO 1	Demonstrate understanding of fundamental of nanodevices fabrication techniques	2	1	2	2	1	1
CO 2	Demonstrate understanding of nanotechnology concepts for device fabrication and characterization.	3	1	3	3	3	1
CO 3	To quire fundamental understanding for electronics and optical properties of nanomaterials.	3	2	3	3	3	1
CO 4	To acquire knowledge of basic nanodevice principles and fabrication approaches for various nanoscale devices.	3	2	3	2	2	1
Average		**2.75**	**1.5**	**2.75**	**2.5**	**2.25**	**1**

Department of Electronic & Communication Engineering								
Course Code	Title of the course	Program Core (PCR) / **Elective (PEL)**	**Total contact hours: 70 (Lecture – 42; Practical/Sessional – 28)**				Credit	
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours		
EC9036*	**ASIC Design using Verilog***	PEL	3	0	2	5	4	
Pre-requisites: [Digital Circuits and Systems [ECC402]]			Course Assessment methods: (Continuous Assessment (CA), Mid-semester assessment (MA) and end assessment (EA)): Assignments, Quiz/class test, Mid-semester Examination and End Semester Examination					

Course Outcomes

After the completion of the course the student will be able to

- **CO 1: Explain VLSI design flow using HDL.**
- **CO 2: Analyze and design combinational and sequential digital systems.**
- **CO 3: Employ Verilog to model a digital system.**
- **CO 4: Write test benches to verify the design.**
- **CO 5: Compare between blocking and non-blocking statement and their uses.**
- **CO 6: Create a System from simulation to synthesizable design**.

Topics Covered

Total Lecture hours: Lecture – 42; Practical/Sessional – 28: Total Contact Hours – 70

Module I. Brief introduction to VLSI using CAD tools [L - 3]
Overview of Digital Design with Verilog HDL: Evolution of CAD, emergence of HDLs, typical HDL-based design flow, Verilog HDL, Trends in HDLs.

Module-II. Hierarchical Modelling Concepts [L – 3]
Top-down and bottom-up design methodology, differences between modules and module instances, parts of a simulation, design block, stimulus block.

Module-III. Basic Concepts [L – 3]
Lexical conventions, data types, system tasks, compiler directives. Memory modelling Logic Synthesis: Introduction synthesis of different Verilog constructs.

Module-IV. Modules and Ports [L – 3]
Module definition, port declaration, connecting ports, hierarchical name referencing.

Module-V. Gate-Level Modelling [L – 2, P-2]
Modeling using basic Verilog gate primitives, description of and/or and buf/not type gates, rise, fall and turn-off delays, min, max, and typical delays.

Module-VI. Dataflow Modelling [L – 3, P-2]
Continuous assignments, delay specification, expressions, operators, operands, operator types.

Module-VII. Behavioural Modelling [L – 3, P-2]
Structured procedures, initial and always, blocking and nonblocking statements, delay control, generate statement, event control, conditional statements, multiway branching, loops, sequential and parallel blocks.

Module-VIII. Tasks and Functions [L – 4]
Differences between tasks and functions, declaration, invocation, automatic tasks and functions.

Module-IX. Useful Modelling Techniques [L – 4. P-2]
Procedural continuous assignments, overriding parameters, conditional compilation and execution, useful system tasks.

	Module-X. Flip-Flop and Counter Design: [L – 4, P-6] Synchronous and asynchronous flip flop design with set and reset, design of basic counters. **Module-XI. FSM & Processor Design: [L – 6, P-10]** FSM modelling, Data path and Controller design, Modelling Memory, Pipelining, Design of a Processor. Introduction to Reconfigurable computing, FPGAs, the Altera /Xilinx flow. **Module-XII. Essential SystemVerilog for UVM: [L – 4, P-4]** Overview of basic System Verilog, UVM verification environment: introduction to UVM methodology and universal Verification Components (UVC) structure, stimulus modelling, creating a simple environment, DUT, TLM, functional coverage modelling, register modelling in UVM. **Total Contact Hours: (L=42, P/S=28) = 70**
Text Books, and/or reference material	**Text Books:** 1. Samir Palnitkar, Verilog HDL, , Second Edition, Pearson Education, 2004 2. J. Bhaskar, Verilog HDL Synthesis, BS publications, 2001. **References:** 1. S. Brown and Z. Vranesic, Fundamentals of Digital Logic with Verilog Design, McGraw Hill 3rd Ed. 2013. 2. G. De Micheli. Synthesis and optimization of digital circuits, McGraw Hill, India Edition, 2003 3. Indranil Sengupta, IIT Kharagpur, NPTEL Course (2017) https://www.youtube.com/watch?v=NCrlyaXMAn8&list=PLRsFfXmDi9IYCNlvNjrsD8bLMmNE0UxBH

EC9036: ASIC Design using Verilog/VHDL* (Elective)
[Mapping between course outcomes (COs) and program outcomes (POs)]

CO	Statement	Program Outcomes					
		PO 1	PO 2	PO 3	PSO 1	PSO 2	PSO 3
CO 1	**Explain VLSI design flow using HDL.**	1	1	3	2	2	1
CO 2	**Analyze and design combinational and sequential digital systems.**	2	1	3	2	2	2
CO 3	**Employ Verilog to model a digital system.**	3	2	3	3	3	1
CO 4	**Write test benches to verify the design.**	3	2	3	3	3	1
CO 5	**Compare between blocking and non-blocking statement and their uses.**	2	1	3	3	2	2
CO 6	**Create a System from simulation to synthesizable design**	3	1	3	3	3	1
Average		**2.33**	**1.33**	**3**	**2.66**	**2.5**	**1.33**

Department of Electronics and Communication Engineering								
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours: 56				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
EC9037	Low Power Circuits and Systems	PEL	3	1	0	4	4

Pre-requisites: EC1013: Digital IC Design.	Course Assessment methods: (Continuous Assessment (CA), Mid-semester assessment (MA) and end assessment (EA)): Assignments, Quiz/class test, Mid-semester Examination and End Semester Examination
Course Objectives	• This course deals with issues and models to design low-power VLSI circuits and systems, and fundamentals of power dissipation, • Students will be able to estimate power dissipation due to switching, short circuit.
Course Outcomes	**CO#1: Learn** to design and optimize CMOS logic circuits and extract parasitic elements. **CO#2: Understand** sources of power dissipation and be able to estimate energy dissipation in typical circuits **CO#3: Apply** different techniques to minimize dynamic dissipation. **CO#4: Learn** the different sources of leakage in MOS transistors and how to minimize leakage dissipation at the device level as well as in circuit design.
Syllabus/Topics Covered	**Total Contact hours: Lecture – 42; Tutorial – 14. Total Contact Hours – 56** **Module-I:**(L – 05: T – 02) Introduction: Need for Low power VLSI chips, MOS Transistor structure and device model, The CMOS inverter and other gates; why CMOS for Low Power? CMOS Logic design methodology, Circuit optimization for performance. **Module – II:** (L – 06; T - 02) CMOS layout and Fabrication: Typical CMOS circuit layout, IC fabrication overview, CMOS process flow, Imperfections in fabrication steps, Design rules and their importance; MOS device details – parasitic elements and their estimation, importance of device scaling. **Module – III:** (L- 06; T - 02) Power dissipation mechanisms in CMOS circuits: Static and Dynamic dissipation, Dynamic power dissipation – switching loss, short circuit dissipation, concept of switching activity; Concept of signal activity, signal probability and activity, Signal activity computation – Boolean difference, estimation of probability and activity in complex logic circuits; **Module – IV**: (L – 08, T – 03) **Dynamic dissipation management –Supply voltage scaling approaches:** Static Voltage Scaling; Single-level Voltage Scaling (SVS), Speed vs dissipation, Speed management approaches, circuit level – Transistor sizing, Architecture level – Parallel and pipeline architectures, Algorithm level transformations; Static Voltage Scaling Design Procedure, Critical path and its management; Multi-level Voltage Scaling (MVS), MVS issues – Layout, Level converters, Power up/down sequencing; Dynamic Voltage Scaling; Dynamic Voltage and Frequency Scaling (DVFS), DVFS architecture. **Module-V:** (L – 06: T - 02) **Dynamic dissipation management – Switched capacitance minimization approaches**: What is switched capacitor? Switched capacitor minimization techniques – Hardware/Software trade-off, Bus Encoding, Use of Number system, Glitching Power minimization, Architecture Level

<table>
<tr><td></td><td>Optimization, Clock gating, State Encoding of FSM's.

Module-VI: (L – 06: T - 02)
MOS Transistor revisited: Review of quantum theory of solids, concept of quantum mechanical tunneling, Leakage mechanisms in MOS transistor – diode leakage, sub-threshold current, sub-threshold swing; short channel effects – Gate tunneling, reducing gate tunneling – high-k technology, DIBL and GIDL effects; Recent advances in MOS transistor design – SOI technology, FinFET, Gate All Around (GAA) FET.

Module-VII: (L – 03; L – 01)
Static Power Optimization Techniques: Comparison of static and dynamic loss in modern chips; Stand-by and Run-time leakage; Stand-by leakage reduction techniques, Transistor stacking, VT CMOS approach, Power gating, MT CMOS technology, Power gating issues, DVFS with Power gating; Run-time leakage reduction, Dynamic V_{DD} scaling, Dual V_t approach, V_t hopping.

Module-VIII: (L – 02)
Battery operated system design: Battery construction and working principle, Battery capacity and energy density, comparison of different storage cell technologies; Battery charging and discharging profiles and their effects on battery capacity and life; Design of multi-battery system installations.
Total Contact Hours: (L=42, T=14) = 56</td></tr>
<tr><td>Text / Ref. Books</td><td>Text Books:
[1] Ajit Pal, Low Power VLSI Circuits and Systems, Springer, 2015.
[2] Kaushik Roy and Sharat C Prasad, Low Power CMOS VLSI circuit Design, John Wiley and Sons, 2000.
References:
[1] Anantha P Chandrakasan and Robert W Brodersen, Low Power Digital CMOS Design, Kluwer Academic Publishers, Holland, 1995.
[2] Gary B Yeap K, Practical Low Power Digital VLSI Design, Kluwer Academic Publishers, 1998.
[3] Kuo J B and Lou J H, Low Voltage CMOS VLSI Circuits, John Wiley and Sons, Singapore, 1999.</td></tr>
</table>

EC9037: Low Power Circuits and Systems (Elective)
[Mapping between course outcomes (Cos) and program outcomes (POs)]

CO	Statement	Program Outcomes					
		PO 1	PO 2	PO 3	PSO 1	PSO 2	PSO 3
CO 1	**Acquire** knowledge of the fundamentals and applications of Low-power circuits	2	1	2	2	1	1
CO 2	**Identify** various leakage/ switching power sources in a MOSFET and a digital circuits.	3	1	3	3	3	1
CO 3	**Analyze the v**arious issues to power dissipation and techniques to minimize/optimize	3	2	3	3	3	1
CO 4	**Learn** various leakage/ switching power reduction mechanisms at device level and circuit level.	3	2	3	2	2	1
CO 5	**Design and implementation** of a power-aware circuits and systems	2	1	2	3	3	2
CO 6	**Evaluate** the performance of low power circuits and systems	2	1	2	3	3	2
Average		**2.50**	**1.33**	**2.50**	**2.67**	**2.50**	**1.33**

Department of Electronics and Communication Engineering								
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total contact hours: 56					Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours		
EC9038	Testing and Verification of VLSI Circuits	PEL	3	1	0	4		4

Pre-requisites: Digital Circuits and Systems (ECC402)	Course Assessment methods (Continuous (CT) and end assessment (EA))
	Assignments, Quiz/ Class Test, Mid-semester Examination and End Semester Examination
Course Objectives	To expose the students, the basics of testing and verification techniques for the digital IC design.
Course Outcomes	After the completion of the course the student will be able to • **CO1:** Extend knowledge of the requirement of fault modeling in VLSI circuits. • **CO2:** Generate test vectors to test a circuit efficiently covering maximum faults. • **CO3:** Demonstrate the concept of Memory testing techniques. • **CO4:** Discuss about Built-in-Self Test and its application in modern digital design. • **CO5:** Use modern tools for testing and verification.
Syllabus/Topics Covered	**Module XVII. Introduction [L –4; T - 1]** Physical faults and their modeling. Fault equivalence and dominance; fault collapsing, Fault simulation: parallel, deductive and concurrent techniques; critical path tracing. **Module XVIII. Test generation for combinational circuits [L – 4; T - 1]** Boolean difference, D-algorithm, Podem, random etc. Exhaustive, random and weighted test pattern generation; aliasing and its effect on fault coverage. **Module XIX.PLA testing [L – 4 T - 1]** Cross-point fault model, test generation, easily testable designs. **Module XX. Memory testing [L – 4; T - 1]** Permanent, intermittent and pattern-sensitive faults; test generation. **Module XXI.Delay faults and hazards [L – 6; T - 2]** Test pattern generation techniques, ATPG and its different types. **Module XXII. Test pattern generation for sequential circuits [L – 6; T - 2]** Ad-hoc and structures techniques scan path and LSSD, boundary scan. **Module XXIII. Built-in Self-Test techniques [L – 8; T - 4]** LBIST and MBIST. Verification: logic level (combinational and sequential circuits), RTL-level (data path and control path). Verification of embedded systems. Use of formal techniques: decision diagrams, logic-based approaches. **Module XXIV. ASIC/IP Verification [L – 6; T - 2]** Direct and random testing, Error detection and correction codes. **Total Contact Hours: (L=42, T=14) =56**
Text / Ref. Books	**Text Books:** [1] M. L. Bushnell and V. D. Agrawal, "*Computer architecture and organization*", Springer, 2nd edition, 2004.

	Reference books: [1] A. Krstic and K-T Cheng, "*Delay Fault Testing for VLSI Circuits*", Kluwer Academic Publishers, 3rd edition,. 2003. [2] N. K. Jha and S. Gupta, "*Testing of Digital Systems*", Cambridge University Press, 2nd Edition, 2003. [3] M. Abramovici, M. A. Breuer and A. D. Friedman, "*Digital Systems Testing and Testable Design*", Wiley-IEEE Press, 3rd Edition, 1994. [4] P. K. Lala, "*Fault Tolerant and Fault Testable*", Prentice-Hall, 4th Edition, 1986.

EC9038: Testing and Verification of VLSI Circuits (Elective)
[Mapping between course outcomes (Cos) and program outcomes (POs)]

CO	Statement	Program Outcomes					
		PO 1	**PO 2**	**PO 3**	**PSO 1**	**PSO 2**	**PSO 3**
CO 1	Extend knowledge of the requirement of fault modeling in VLSI circuits.	1	1	1	2	1	1
CO 2	Generate test vectors to test a circuit efficiently covering maximum faults.	2	2	3	2	1	1
CO 3	Introduce students to the concepts Memory testing techniques.	2	2	2	3	2	1
CO 4	Understanding Built-in-Self Test and its application in modern digital design	2	2	3	2	2	1
CO 5	Use modern tools for testing and verification.	2	2	3	3	2	2
Average		**1.8**	**1.8**	**2.4**	**2.4**	**1.6**	**1.2**

Department of Electronic & Communication Engineering								
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total contact hours : 56				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
EC9039	Advanced Computer Architecture	PEL	3	1	0	4	4

Pre-requisites/Co-requisites: Digital Circuits & Systems [ECC402] Digital Circuits & Systems Laboratory [ECS452]	Course Assessment methods: (Continuous Assessment (CA), Mid-semester assessment (MA) and end assessment (EA)): Assignments, Quiz/class test, Mid-semester Examination and End Semester Examination

Course Outcomes

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

- **CO 1:** Acquire idea about computer architecture and organization.
- **CO 2:** Understand the fundamental concepts of ISA.
- **CO 3:** Illustrate the operations of memory unit.
- **CO 4:** Analyze control and data flow of a computer.
- **CO 5:** Design and implementation of multiprocessors.
- **CO 6:** Evaluate the performance of a computer system.

Topics Covered

Module I. Introduction and Basics [L – 4; T - 1]
History of computers, introduction to computer architecture, level of transformation, abstract layers, their benefits of comfortably crossing them, instruction set architecture I, instruction set architecture II, instruction set architecture III, architecture examples, example problem and solution ideas.

Module II. Fundamental Concepts and ISA [L – 6; T - 2]
Fundamental concepts in computer architecture: Von Neumann model and data flow model, ISA principles and trade-off, elements of an ISA, RISC vs. CISC, MIPS ISA, ISA vs. microarchitecture level trade-off, property of ISA vs. microarchitecture.

Module III. Arithmetic Operations [L – 5; T - 3]
Binary arithmetic, ALU Design, multiplier design, divider design, fast addition, multiplication, floating point arithmetic.

Module IV. Processor Design [L – 8; T - 2]
Single-cycle microarchitecture, multi-cycle microarchitecture, microprogrammed microarchitecture, pipelining: issues in pipelining, data and control dependence handling, branch prediction, precise exceptions, state maintenance, state recovery; Out-of-Order execution and issues in OoO execution.

Module V. SIMD, GPUs, VLEW and DAE [L – 5; T - 1]
SIMD processing: array and vector processors, SIMD operation in modern ISAs, VLIW, Decoupled Access Execute (DAE), Systolic Array.

Module VI. Memory Hierarchy and Caches [L - 7; T - 2]
Memory hierarchy, physical memory and virtual memory, emerging memory technologies, main memory, memory controller, memory management, memory latency tolerance: prefetching, Cache organization and operation, high performance caches, memory consistency and cache coherence, in-memory processing

Module VII. Multiprocessor [L – 7; T - 3]
Multiprocessor types, multiprocessing and issues in multiprocessor, limits of parallel speedup, difficulty in parallel programming, heterogeneous systems, input/output subsystem, interfaces, I/O operations, interconnection networks: bus based and NoC based architectures.

	Total Contact Hours: (L=42, T=14)=56
Text Books, and/or reference material	**Text Books:** 1. Patterson and Hennessy, “Computer Organization and Design: The Hardware/Software Interface”, 4th Edition, Morgan Kaufmann/ Elsevier, 2009. **Reference Books:** 1. Andrew Tanenbaum, “Structured Computer Organization”6th Edition, Pearson, 2016. 2. Patt and Patel, “Introduction to Computing Systems: From Bits and Gates to C and Beyond”, Morgan Kaufman, Elsevier, 2th Edition, McGraw-Hill Education 2003. 3. Harvey Cragon, “Computer Architecture and Implementation”, Cambridge University Press, 2000. 1. C. Hamacher, Z. Vranesic, S. Zaky, “Computer Organization”, McGraw Hill Education; 5th Edition, 2011.

EC9039: Advanced Computer Architecture
[Mapping between course outcomes (COs) and program outcomes (POs)]

CO	Statement	Program Outcomes					
		PO1	PO2	PO3	PSO1	PSO2	PSO3
CO1	Acquire idea about computer architecture and organization.	1	1	2	2	3	2
CO2	Understand the fundamental concepts of ISA	1	1	2	2	3	1
CO3	Illustrate the operations of memory unit	1	1	2	3	3	3
CO4	Analyze control and data flow of a computer	2	1	2	3	3	1
CO5	Design and implementation of multiprocessors.	1	1	2	3	3	2
CO6	Evaluate the performance of a computer system.	1	1	2	3	3	1
Average		**1.17**	**1.17**	**1**	**2**	**2.67**	**3**

<table>
<tr><th colspan="9">Department of Electronics & Communication Engineering</th></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Elective (PEL)</td><td colspan="4">Total contact hours: 56</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>EC9040</td><td>DSP Architectures in VLSI</td><td>PEL</td><td>3</td><td>1</td><td>0</td><td>4</td><td>4</td></tr>
<tr><td colspan="3" rowspan="2">Pre-requisites/Co-requisites:
Signals & Systems, DSP, Digital Design [ECC744, ECC603, ECC404]</td><td colspan="5">Course Assessment methods: (Continuous Assessment (CA), Mid-term assessment (MA) and End term assessment (EA)):</td></tr>
<tr><td colspan="5">CA comprises of: Assignment(s), Quiz(zes) /Class test(s)</td></tr>
<tr><td>Course Objectives</td><td colspan="7">This course is designed to give a comprehensive coverage of the VLSI architectures for digital signal processing. The central theme of the course is to design efficient VLSI architectures for computing algorithms frequently encountered in DSP systems. It focuses on algorithm transformation and architecture design techniques to improve the design with high throughput, less area, and power.</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">After the completion of the course, the student will be able to:
● State VLSI design methodology for signal processing systems.
● Describe VLSI algorithms and architectures for DSP.
● Implement/Simulate basic architectures for DSP using Matlab/CAD tools.
● Analyze DSP architectures and evaluate their performance.
● Discuss various issues that need to be addressed when implementing DSP algorithms in real hardware with finite resources such as processing speed, memory, and bit resolution.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Module I. Introduction to Digital Signal Processing [L – 4; T - 2]
Review of DSP fundamentals: Discrete Systems: Representation of Systems, Properties of DSP systems, Difference equation and its relationship with system function, Impulse response and frequency response.

Module II. Digital Signal Processing Algorithms [L – 4; T - 2]
Introduction for DSP algorithms: VLSI Design flow, Mapping algorithms into Architectures: Graphical representation of DSP algorithms – signal flow graph (SFG), data flow graph (DFG), critical path, dependence graph (DG). Data path synthesis, control structures, Optimization at Logic Level and architectural Design, Loop bound and iteration bound, Algorithms for computing iteration bound, Iteration bound of Multirate data-flow graphs. – Retiming.

Module III. Introduction to DSP systems [L – 2; T - 1]
DSP Systems, Parallel and pipeline of signal processing application: Architecture for real-time systems, latency and throughput related issues, clocking strategy, power-aware structures, array architectures; Pipelining processing of Digital filter, Parallel processing, Parallel and pipelining for Low power design, Optimization with reference to speed, area and power, asynchronous and low power system design, ASIC (application-specific integrated circuits) and ASISP (application-specific instruction-set processors) design.

Module IV. Systolic Array Architecture [L – 3; T - 2]
Methodology of systolic array architecture, FIR based Systolic Array, Selection of Scheduling Vector, Matrix multiplication of systolic array.

Module V. Signal processing Architectures [L – 7; T - 2]
Convolution technique, Retiming concept, Folding/Unfolding Transformation, Fast convolution, Cook-Toom algorithm, modified Cook-Toom algorithm. CORDIC architecture.

Module VI. Scaling and Round-off noise [L – 5; T - 2]</td></tr>
</table>

	Scaling and round-off noise, scaling operation, round-off noise, state variable description of digital filters, scaling and round-off noise computation, round-off noise in pipelined IIR filters. **Module VII. Low Power Design [L – 5; T - 2]** Theoretical background, Scaling v/s power consumption, power analysis, Power estimation approach, Power reduction techniques. **Total Contact Hours: (L=42, T=14)= 56**
Text Books, and/or Reference materials	**Text Books:** 1. Keshab K. Parhi, "*VLSI Digital Signal Processing Systems, Design and Implementation*", Wiley-Interscience, 1999. **Reference Books:** 1. Uwe Meyer-Baese, "*Digital Signal Processing with Field Programmable Gate Arrays*", Springer, Third Edition, 2007. **NPTEL/SWAYAM/Other Video Lectures:** 1. Prof. N. Chandrachoodan, IITM, (2019) *Mapping Signal Processing Architectures in VLSI*

EC9040: DSP Architectures in VLSI
[Mapping between course outcomes (COs) and program outcomes (POs)]

CO	Statement	Program Outcomes					
		PO1	PO2	PO3	PSO1	PSO2	PSO3
CO1	State VLSI design methodology for signal processing systems.	2	1	2	3	1	1
CO2	Describe VLSI algorithms and architectures for DSP.	2	3	1	3	2	2
CO3	Implement/Simulate basic architectures for DSP using Matlab/CAD tools.	3	2	1	2	2	1
CO4	Analyze DSP architectures and evaluate their performance.	3	1	1	3	2	1
CO5	Discuss various issues that need to be addressed when implementing DSP algorithms in real hardware.	3	1	1	2	1	2
Average		**2.50**	**1.50**	**1.50**	**2.67**	**1.50**	**1.33**

<table>
<tr><td colspan="8">Department of Electronics & Communication Engineering</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Elective (PEL)</td><td colspan="4">Total contact hours : 56</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>EC9041</td><td>Power Management IC Design</td><td>PEL</td><td>3</td><td>1</td><td>0</td><td>4</td><td>4</td></tr>
<tr><td colspan="3" rowspan="2">Pre-requisites/Co-requisites:
Analog IC Design[EC1012, EC722],
Signals & Systems[EC503]</td><td colspan="5">Course Assessment Methods:
Continuous Assessment (CA-15/100), Mid-Term (MT-25/100) and End-Term assessment (ET-60/100))</td></tr>
<tr><td colspan="5">Assignments, Quiz/class tests, Mid-term Exam and End-term</td></tr>
<tr><td>Course Objective</td><td colspan="7">The course is to develop understanding of why power management circuits are needed in a VLSI system. It primarily deals with different components of a power management system with focus on dc-dc converters. It aims to design a chip level dc-dc converter from the given specifications.</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">After the completion of the course the student will be able to:

● CO1: Define different types of DC-DC converters.
● CO2: Describe the concept of power management ICs.
● CO3: Employ Miller compensation to obtain better time response.
● CO4: Design a compensator for Buck converter.
● CO5: Compare between Buck and Boost Converter.
● CO6: Evaluate the performance of a Switched Capacitor DC-DC Converter.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Module I. Introduction [L – 4; T - 0]
Introduction to Power Management -Voltage regulators, Need of DC-DC Converters, Types of DC-DC Converters, Linear versus Switching Regulator, Performance Parameters - Efficiency, Accuracy, Line and Load Regulation, Line and Load Transient, PSRR; Point-of-Load Regulator, Kelvin Sensing, Droop Compensation; Current Regulators and their Applications; Bandgap Voltage Reference, Brokaw Bandgap Circuit.

Module II. Linear Regulators [L – 8; T - 3]
Bandgap Voltage Reference, Low Drop-Out Regulator (LDO), Source and sink regulators, shunt regulator, pass transistor, error amplifier, small signal and stability analysis, compensation techniques, current limiting, power supply rejection ratio (PSRR), NMOS vs. PMOS regulator, current regulator.

Module III. Switching Regulator [L – 6; T - 3]
Basic Concept of a Switching Regulator, Synchronous and Non-Synchronous Switching Converters; PWM Control Techniques, Losses in Switching DC-DC Converter- Conduction Loss, Control Techniques for DC-DC Converters; Voltage Mode Control, Small-Signal Modeling of a DC-DC Converter, Loop Gain and Stability Analysis using Continuous-Time Model.

Module IV. Compensator Design [L – 6; T - 2]
Compensating a Voltage-Mode-Controlled Buck Converter; Designing Type-I (Integral), Type-II (PI) and Type-III (PID) Compensators; compensation of a voltage mode dc-dc converter, Implementation of Compensators using Op Amp-RC and Gm-C Architectures.

Module V. Gate Driver Circuits [L – 6; T - 2]
Designing the Gate-Driver (Gate Buffer and Non-Overlap Clock Generator), Designing the Ramp Generator using a Pulse-Width Modulator, Design Considerations of the Error Amplifier; Delays Associated with Pulse-Width Modulators; Designing a Zero-Cross Detector/Comparator.

Module VI. Buck Boost Converter [L – 6; T - 2]</td></tr>
</table>

	Introduction to the Buck-Boost Converter, Introduction to Switched-Capacitor DC-DC Converters, Applications of SC DC-DC Converters in Open-Loop, Output Regulation in SC DC-DC Converters using Feedback Control. . **Module VII. Advanced Topics [L – 6; T - 2]** Digitally controlled dc-dc converters, digitally controlled LDOs, adaptive compensation, dynamic voltage scaling (DVS), Single-Inductor Multiple-Outputs (SIMO) Converters, dc-dc converters for LED lighting, Li-ion battery charging circuits. **Total Lecture Hours: (L=42, T=14)=56**
Text Books, and/or reference material	**Text Books:** 1. Switch-Mode Power Supplies: SPICE Simulations and Practical Designs by Christophe P. Basso, McGraw-Hill Professional, 2008. 2. Design of Analog CMOS Integrated Circuits by Behzad Razavi, McGraw-Hill, 2017 **Reference books:** 1. Power Management Techniques for Integrated Circuit Design By Ke-Horng Chen, Wiley-Blackwell, 2016. 2. Fundamentals of Power Electronics, 2nd edition by Robert W. Erickson, Dragan Maksimovic, Springer, 2001.

EC9041: Power Management IC Design
[Mapping between Course Outcomes (COs) and Program Outcomes (POs)]

CO	Statement	Program Outcomes					
		PO1	PO2	PO3	PSO1	PSO2	PSO3
CO1	Define different types of DC-DC converters	2	2	2	2	3	2
CO2	Explain techniques of Stabilizing a Regulator.	2	1	2	2	3	1
CO3	Employ Miller compensation to realize good phase margin	1	2	1	2	3	3
CO4	Design a compensator for Buck converter.	2	1	2	3	3	1
CO5	Compare between Buck and Boost Converter	1	1	2	3	3	2
CO6	Evaluate the performance of a Switched Capacitor DC-DC Converter	1	2	3	3	3	1
Average		**1.5**	**1.5**	**2**	**2.5**	**3**	**1.67**

Department of Electronics and Communication Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	**Total Number of contact hours: 56**				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
EC9042	**Cyber Physical Electronic System Design**	PEL	3	1	0	4	4
Pre-requisites: Basic Electronics (ECC01), Engineering Mechanics (XEC01)		Course Assessment methods: (Continuous Assessment (CA), Mid-semester assessment (MA) and end assessment (EA)): Assignments, Quiz/class test, Mid-semester Examination and End Semester Examination					

Course Outcomes

After the completion of the course the student will be able to

- **CO 1**: Understand application based electronic systems
- **CO 2**: Understand basic building blocks of electronic systems
- **CO 3**: Apply quantitative analysis techniques to electronic systems
- **CO 4**: Learn fundamentals of cyber-physical electronic systems
- **CO 5**: Investigate complex designs of cyber physical embedded systems through case studies

Topics Covered

Module I. Introduction to cyber physical electronic system [L-1]
Concept of Cyber Physical Electronic Systems (CPES), Applications of CPES

Module II. Hardware Elements of Physical Systems [L-14; T-5]
Sensors, Resistive sensor, Capacitive sensors, Inductive sensors, Piezoelectric sensors, Piezoresistive sensors, MEMS sensors, MEMS Accelerometers, MEMS Gyro, Signal conditioning circuits, Signal Processing unit, Data presentation, Data storage, and Data communication units, Actuators, Motors, BLDC, Stepper Motors, Servo motors, AC motors, Linear actuators, Linear servo actuators, Mechanisms

Module III. Physical Embedded Systems [L-10; T-5]
Microcontrollers, Mini computers, Embedded systems, Vibration sensing, Force sensing, Pressure sensing, voltage sensing, Actuation systems, Open-loop system, Closed loop system, Embedded control strategies, Embedded PID controller.

Module IV. Physical Systems in Network [L-10; T-1]
Intranet, Internet, NFC, Bluetooth, Zigbee, WiFi, 4G, 5G, Industrial Ethernet, Industrial data communication Protocols, HART, MQTT, HTTP, Cyber physical systems, IoT, Industry 3.0, Industrial IoT

Module VI. Data Security Issues [L-1]
Requirement of data securities, Data encryption strategies.

Module VII. Case studies [L-6; T-3]
Cyber Physical motor speed control system, Cyber physical 3D printing systems, Cyber physical structural health monitoring systems, Industry 4.0.

Total Lecture Hours: (L=42, T=14)= 56

Text Books, and/or reference material

Text Books:

1. J. Bentley, *Principles of measurement systems*. Pearson Education India; 3rd edition, 2002
2. E. A. Lee, S. A. Seshia, *Introduction to Embedded Systems - a Cyber Physical Systems Approach*, MIT Press; Second edition, 2019
3. B. A. Forouzan, *Data Communications and Networking*, McGraw Hill Education; 4th edition, 2017

Reference books:

1. A. Gilchrist *Industry 4.0 the industrial internet of things*, Apress; 1st edition, 2017
2. Research Articles

EC9042: Cyber Physical Electronic System Design
[Mapping between course outcomes (Cos) and program outcomes (POs)]

CO	Statement	Program Outcomes					
		PO 1	PO 2	PO 3	PSO 1	PSO 2	PSO 3
CO 1	Understand application based electronic systems	2	3	1	3	1	1
CO 2	Understand basic building blocks of electronic systems	2	3	1	3	1	1
CO 3	Apply quantitative analysis techniques to electronic systems	2	3	1	3	1	1
CO 4	Understand fundamentals of cyber-physical electronic systems	3	2	2	1	1	3
CO 5	Investigate complex designs of cyber physical embedded systems through case studies	3	2	3	1	1	3
Average		**2.4**	**2.6**	**1.6**	**2.2**	**1**	**1.8**

Department of Electronics and Communication Engineering								
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	**Total Number of contact hours: 56**				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
EC9043	**Smart Materials based Devices**	PEL	3	1	0	4	4
Pre-requisites: Basic Electronics (ECC01), Engineering Mechanics (XEC01)		Course Assessment methods: (Continuous Assessment (CA), Mid-semester assessment (MA) and end assessment (EA)): Assignments, Quiz/class test, Mid-semester Examination and End Semester Examination					
Course Outcomes	After the completion of the course the student will be able to • **CO 1:** Understand concept of Smart Materials based Electronic Devices • **CO 2:** Apply quantitative analysis techniques to Smart Materials based Electronic Devices • **CO 3:** Understand basic building blocks of Smart Materials based Electronic systems • **CO 4:** Learn design techniques of Smart Materials based Electronic systems • **CO 5:** Investigate application specific Smart Materials based Electronic systems						
Topics Covered	**Module I: Introduction to Smart Materials based Electronic Devices [L-1]** Smart Materials, Smart Materials based Electronic Devices, Applications of Smart Materials based Electronic Devices **Module II: Characteristics of Smart Materials based Electronic Devices [L-7; T-1]** Static, dynamic and quasi static characteristics **of** Smart Materials based Electronic Devices **Module III: Analysis and Modelling of Smart Materials based Electronic Devices [L-12; T-5]** Energy, Co-energy, Energy methods, Hamilton's principle, Lagrange's Equations, Analysis and modelling of Smart material based electromechanical devices **Module IV: Piezoelectric Devices [L-8; T-4]** Piezoelectric sensors, actuators, transformers, motors, resonators **Module V: Shape Memory Alloy devices [L-4; T-1]** Shape Memory effect , Shape Memory Alloy elements, Shape Memory Alloy elements as actuators, Shape Memory Alloy element as sensor **Module VI: Electroactive polymer devices [L-3; T-1]** Electroactive polymers, Electroactive polymer actuators **Module VII: FEM Modelling of Smart Materials based Electronic Devices [L-2]** Concept of FEM, FEM-based CAD software for Smart materials based electronic Devices **Module VIII: Case studies [L-5;T-2]** Piezoelectric transducers for ultrasound generation, SMA actuator driven finger exoskeleton **Total Lecture Hours: (L=42, T=14)= 56**						
Text Books, and/or reference material	**Text Books:** 12. V. K.Varadan, K.J.Vinoy, S.Gopalakrishnan , *Smart Material Systems and MEMS: Design and Development Methodologies*, Wiley, 2006 13. J. Bentley, *Principles of measurement systems*. Pearson Education India; 3rd edition, 2002 14. S. H. Crandall, D. C. Karnopp, *Dynamics of Mechanical and Electromechanical*, Medtech Pub, 2017 **Reference books:** 4. D. J. Leo, Engineering Analysis of Smart Material Systems, John Wiley & Sons Inc, 2007 5. A. Preumont *Mechatronics, Dynamics of Electromechanical and Piezoelectric Systems*, Springer, 2011						

	6. D. K. Gehmlich, S. B. Hammond, *Electromechanical system*, McGraw-Hill, 1967 7. D. Hutton, *Fundamentals of Finite Element Analysis*, McGraw Hill, 2003 8. Research articles

EC9043: Smart Materials based Devices
[Mapping between course outcomes (Cos) and program outcomes (POs)]

CO	Statement	Program Outcomes					
		PO 1	PO 2	PO 3	PSO 1	PSO 2	PSO 3
CO 1	Understand concept of Smart Materials based Electronic Devices	**3**	**3**	**3**	**1**	**1**	**1**
CO 2	Apply quantitative analysis techniques to Smart Materials based Electronic Devices	**2**	**3**	**2**	**3**	**1**	**2**
CO 3	Understand basic building blocks of Smart Materials based Electronic systems	**3**	**3**	**3**	**3**	**1**	**1**
CO 4	Learn design techniques of Smart Materials based Electronic systems	**3**	**3**	**2**	**3**	**2**	**3**
CO 5	Investigate application specific Smart Materials based Electronic systems	**2**	**3**	**2**	**2**	**1**	**2**
Average		**2.6**	**3**	**2.4**	**2.4**	**1.2**	**1.8**