NATIONAL INSTITUTE OF TECHNOLOGY DURGAPUR

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

Draft Curriculum

Program Name

Master of Technology in Next Generation Communication and Networks (NGCN)

Effective from the Academic Year: 2022-2023

Recommended by DAC	: 04.10.2021
Recommended in PGAC	: 01.03.2022
Approved by the Senate	: 19.04.2022
Approved by the BoG	: 24.05.2022

Contents

1. CURRICULUM FOR M. TECH. IN NEXT GENERATION COMMUNICATION AND NETWORKS (NGCN)

SEMESTER I

Sl. No	Code	Subject	L	T	S	C	H
1	EC1001	Advanced Digital Communication	3	1	0	4	4
2	EC1002	Advanced Networking	3	0	0	3	0
3	EC1003	mm-Wave and THz Communication	3	0	0	3	3
4	EC 903X	Elective - I	3	1	0	4	4
5	EC 903X	Elective - II	3	1	0	4	4
6	EC1051	Simulation Laboratory	0	0	3	2	3
7	EC1052	Hardware Laboratory	0	0	3	2	3
		TOTAL	**15**	**4**	**6**	**22**	**24**

SEMESTER II

Sl. No	Code	Subject	L	T	S	C	H
1	EC2001	Network Security and Block chain	3	0	0	3	3
2	EC2002	5G Wireless Communication	3	0	0	3	3
3	EC 903X	Elective - III	3	1	0	4	4
4	EC 903X	Elective - IV	3	1	0	4	4
5	EC 903X	Elective - V	3	1	0	4	4
6	EC2051	Design and Measurement Laboratory	0	0	3	2	3
7	EC2052	Term Project/Lab-Based Project	0	0	6	2	6
		TOTAL	**15**	**3**	**9**	**22**	**27**

SEMESTER III

Sl. No	Code	Subject	L	T	S	C	H
1	XX 907x	Audit Lectures / Workshops**	0	0	0	0	2
2	EC3051	Project - I	0	0	24	12	24
3	EC3052	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	EC4051	Project - II	0	0	24	12	24
1	EC4052	Project Seminar	0	0	4	2	4
		TOTAL	0	0	28	14	28

Note:

(i) A student must earn Minimum 72 credit point.

(ii) Project I & II may be done independently or completed in continuation,

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

2. List of Common Pool of 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
33.	EC9033	Embedded Systems	3-1-0	4
34.	EC9034	MEMS & Microsystems Technology	3-1-0	4
35.	EC9035	Nanoelectronics	3-1-0	4

Sl. No.	SUBJECT CODE	SUBJECT	L-T-S	CREDIT
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 EC9045, EC9048, EC9085, and EC9088 are 3, 0 and 2, respectively.**

Assessment Followed

The assessment method adopted in the academic year 2019-2020 is briefly mentioned as follows.

A. Theory Courses (15 + 25 + 60)

In the subjects, total 100 marks consists 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 /behaviour 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.

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, 3 program specific outcomes (PSOs) have been defined by the Department as follows -

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

1. Detailed Syllabus

A. Core Subjects

<table>
<tr><th colspan="8">Department of Electronics and Communication Engineering</th></tr>
<tr><th rowspan="2">Course Code</th><th rowspan="2">Title of the course</th><th rowspan="2">Program Core (PCR) / Electives (PEL)</th><th colspan="4">Total Contact hours: 56</th><th rowspan="2">Credit</th></tr>
<tr><th>Lecture (L)</th><th>Tutorial (T)</th><th>Practical (P)</th><th>Total Hours</th></tr>
<tr><td>EC1001</td><td>Advanced Digital Communication</td><td>PCR</td><td>3</td><td>1</td><td>0</td><td>4</td><td>4</td></tr>
<tr><td colspan="3">Pre-requisites:
EC1001
● Signal & Systems (ECC303)
● Analog Communication (ECC401)
● Digital Communication (ECC501)</td><td colspan="5">Course Assessment methods (Continuous (CT) and end assessment (EA))

Assignments, Quiz, Mid-semester Examination and End Semester Examination</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">● CO1: Identify the fundamental differences between analog and digital communication systems and the explicit need to study digital communication as a separate course. Identify building blocks that constitute a digital communication system.
● CO2: Explain why each building block is necessary and the working principle of each such block.
● CO3: Apply geometric concepts to understand signal constellations and its variants. Apply signal processing tools to infer time and frequency domain representation of signals in context to digital communications.
● CO4: Analyze error performance of digital communication systems in the presence of additive noise.
● CO5: Evaluate and access communication systems based on resource availability (bandwidth, power, etc.) and performance requirement (BER, SER, etc.).
● CO6: Develop strong mathematical foundation and intuition to pursue any advanced topic in communications (wireless communication, detection and estimation theory, etc.).</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Module I. (L-1)
Introduction.

Module II. (L-4, T-2)
Autocorrelation, Cross correlation, Energy Spectral Density (ESD) and Power Spectral Density (PSD).

Module III. (L-4, T-2)
Concept of signal space and vector

Module IV. (L-7, T-3)
Optimum receivers for AWGN channels: Correlation and matched filter receivers

Module V. (L-7, T-2)
Fundamentals of detection: Maximum likelihood decoding etc.

Module VI. (L-6, T-2)
Coherent and noncoherent modulation, M-ary modulation techniques

Module VII. (L-4, T-1)
Digital communication through band-limited channels

Module VIII.(L-4, T-1)
Spread spectrum for digital communications

Module IX. (L-5, T-1)
Multichannel communications with OFDM fundamentals

Total Contact Hours: (L=42, T=14) = 56</td></tr>
</table>

Textbooks, and/or reference material	**Text Books:** [1] S. Haykin, *Digital Communication Systems* , 4th edition, John Willey Singapore, [2] J. G. Proakis and M. Salehi, *Digital Communications*, 6th edition, McGrawhill, Singapore [3] Bernard Sklar, *Digital Communications*, 2nd edition, Pearson Education, New Delhi **Reference Books:** [1] M. K. Simon, S. M. Hinedi and W. C. Lindsey, *Digital Communication Tecniques: Signal Design and Detection*, Prentice Hall India, New Delhi [2] Richard Vvan Nee & Ramjee Prasad, *OFDM for Multimedia Communication*, Artech House, New York

EC1001: Advanced Digital Communication (Core)
[(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 fundamental differences between analog and digital communication systems and the explicit need to study digital communication as a separate course. Identify building blocks that constitute a digital communication system.	2	1	2	3	1	1
CO 2	Explain why each building block is necessary and the working principle of each such block.	2	3	1	3	2	2
CO 3	Apply geometric concepts to understand signal constellations and its variants. Apply signal processing tools to infer time and frequency domain representation of signals in context to digital communications.	3	2	1	2	2	1
CO 4	Analyze error performance of digital communication systems in the presence of additive noise.	3	1	1	3	2	1
CO 5	Evaluate and access communication systems based on resource availability (bandwidth, power, etc.) and performance requirement (BER, SER, etc.).	3	1	1	2	1	2
CO 6	Develop strong mathematical foundation and intuition to pursue any advanced topic in communications (wireless communication, detection and estimation theory, etc.).	2	1	3	3	1	1
Average		**2.5**	**1.5**	**1.5**	**2.7**	**1.5**	**1.3**

<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:42</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (S)</td><td>Total Hours</td></tr>
<tr><td>EC1002</td><td>Advanced Networking</td><td>PCR</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="2" rowspan="2">Pre-requisites:
Data Communication and Computer Networks (ECE618), Communication Engineering (ECO441)</td><td colspan="6">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="6">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">• CO1: Understand the basics of traffic engineering.
• CO2: Analyze queue performance in traffic conservation.
• CO3: Explain the information flow in network traffic.
• CO4: Realize the switching classifications.
• CO5: Interpret the importance of interconnection networks.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Module 1: Traffic Engineering [L - 5]
Network traffic load and parameters, grade of service and blocking probability, modelling switching systems, incoming traffic and service time characterization, blocking models and loss estimates.

Module 2: Queuing Analysis [L - 7]
Introduction, queue throughput, access probability, traffic conservation, queue performance (M/M/1, M/M/1/B, M^m/M/1/B, M/M^m/1/B, D/M/1/B, M/D/1/B), systems of communicating Markov chains.

Module 3: Modeling Traffic Flow Control Protocols [L – 3]
Leaky bucket, token bucket analysis through M/M/1/B and M^m/M/1/B protocols, virtual scheduling.

Module 4: Modeling Error Control Protocols [L - 3]
Queuing analysis of stop and wait, go-back-N, selective repeat, hybrid ARQ.

Module 5: Modeling Medium Access Control Protocols [L – 7]
Queuing analysis of IEEE 802.1p, ALOHA, slotted ALOHA, IEEE 802.3(CSMA/CD), CSMA/CA, IEEE 802.11 (DCF function for adhoc wireless LANs & PCF function for infrastructure wireless LANs), IEEE 802.11e.

Module 6: Modeling Network Traffic [L – 4]
Flow traffic models, Continuous time modelling (Poison traffic description), Discrete time modelling (interarrival time for Bernoulli traffic), Self-similar traffic, Heavy tailed distributions, Pareto traffic distribution, Traffic data rate modelling with arbitrary source distribution, Interarrival time traffic modelling with arbitrary source distribution, Destination statistics, Packet length statistics, Packet transmission error description.

Module 7: Switches and Routers [L – 5]
Media access techniques (TDMA, SDMA, FDMA, CDMA), Circuit and Packet switching, Packet switching hardware, Basic switch components, Switch functions, Switch performance measures, Switch classifications (input queuing, output queuing, shared buffer, multiple input queuing, multiple output queuing, multiple input /output queuing, virtual routing/virtual queuing).

Module 8: Interconnection Networks [L – 5]
Network design parameters, classification of networks (static assignment TDMA, random assignment TDMA), space division switching (crossbar network contention, arbitration and analysis), multistage interconnection networks, Routing analysis of Generalized cube network,</td></tr>
</table>

	Banyan network, Augmented data manipulator network, Improved logical neighbourhood. **Module 9: Switch Modelling [L – 3]** Congestion and performance bounds in input and output queuing switch, Performance bounds on shared buffer switch, Comparing these three, modeling other switch types, certain existent types (individual analysis and comparison of Promina 4000 and VRQ switches). **Total Contact Hours: 42**
Text Books, and/or reference material	**Text Books:** 1. T. Vishwanathan and M. Bhatnagar, *Telecommunication Switching Systems and Networks*, 2nd Edition, PHI, 2015. 2. F. Gebali, *Analysis of Computer and Communication Networks*, 1st Edition, Springer, 2008. **Reference Books:** 1. A. Leon Garcia and I. Widjaja, *Communication Networks*, McGraw-Hill Education, 2nd Edition, 2003. 2. B.A. Forouzan, *Data Communications and Networking*, McGraw Hill Education, 5th Edition, 2017.

EC1002: Advanced Networking (Core)
[(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 basics of traffic engineering	3	3	3	3	2	2
CO 2	**Analyze** queue performance in traffic conservation	3	3	3	3	3	3
CO 3	**Explain** the information flow in network traffic	3	3	3	3	3	3
CO 4	**Realize** the switching classifications	3	3	3	3	3	2
CO 5	**Interpret** the importance of interconnection networks	3	3	3	3	2	3
Average		**3**	**3**	**3**	**3**	**2.6**	**2.6**

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total contact hours: 46				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
EC 1003	**mm Wave and THz Communication**	PCR	3	0	0	3	3

Pre requisite: 1. ECC403Electrmagnetic Theory and Transmission Lines 2. 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 mm wave and THz communication channel **CO#2:** Enriched understanding on mm wave and THz Communication devices and circuits **CO#3**: Ability to characterize microwave and mm wave and THz integrated circuits
Topics Covered	mm Wave and THz Characteristics, Standardization and Regulation [L-4] Radio Propagation at mm Waves, THz Propagation and Channel Modeling [L-6] mm Wave and THz Devices [L-6] mm Wave an THz Transceiver Technologies [L-6] mm Wave and THz Integrated Passive Components, Circuits and Interconnects [L-6] mm Wave and THz Modulation [L-6] mm Wave and THz radiating systems [L-6] mm Wave MIMO, Beam Steering and Beam Forming [L-4] mm Wave and THz devices and Circuits measurement and characterization Techniques [L-4] mm Wave and THz component packaging [L-2] **Total Lecture Hours: 46**
Text Books, and/or reference material	**Text Books:** [1] Duixian Liu, Brian Gaucher, Ulrich Pfeiffer and Janusz Grzyb, *Advanced Millimeter-wave Technologies Antennas, Packaging and Circuits*, John Wiley & Sons Ltd, United Kingdom, 2009 [2] Kao-Cheng Huang, Zhaocheng Wang, Millimeter wave communication systems, John Wiley & Sons, Inc., Hoboken, New Jersey 2011 [3] Thomas Kürner, Daniel M. Mittleman and Tadao Nagatsuma, THz Communications. Springer Series in Optical Sciences, vol 234. Springer, Cham. https://doi.org/10.1007/978-3-030-73738-2_1 **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 9036: 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 mm wave and THz communication channel	2	1	2	2	3	1
CO 2	Enriched understanding on mm wave and THz Communication devices and circuits	2	3	1	1	3	1
CO 3	Ability to characterize microwave and mm wave and THz integrated circuits	3	2	1	1	3	1
Average		**2.3**	**2.0**	**1.3**	**1.3**	**3.0**	**1.0**

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<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>EC2001</td><td>Network Security and Blockchain</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:
Data Communication and Computer Networks (ECE618), Communication Engineering (ECO441)</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: Understand the concepts of securing computer network protocols based on the application of cryptography techniques.
● CO2: Interpret blockchain as an emerging technological platform for developing decentralized applications and data storage over and above its role underlying the cryptocurrencies.
● CO3: Identify the methods of secure web browsing.
● CO4: Create a distributed and replicated ledger of events, transactions, and data generated through various IT processes with strong cryptographic guarantees.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Module I: Basics of Cryptography [L-5]
Conventional and public key cryptography; Hash functions; Authentication; Digital signatures.

Module II: Key Management and User Authentication [L-5]
Symmetric key distribution; Distribution of public keys; Public key infrastructure; Remote user authentication using symmetric and asymmetric encryption; Kerberos systems.

Module III: Malicious Software [L-4]
Viruses; Worms; System Corruption; Attack Agents; Information theft; Phishing, Spyware Payload Stealthing; Backdoors; Rootkits; Distributed denial of service attacks.

Module IV: Network Access Control and Security [L-10]
Extensible authentication protocol; IEEE802.1X port-based network access control; IP security policy; Encapsulating security payload; Combining security associations; Internet key exchange; Web security considerations; Secure sockets layer; Transport layer security; HTTPS standard; Secure shell (SSH) application; S/MIME; Domain keys identified mail; Mobile device security; IEEE802.11i ; Wireless LAN security.

Module V: Firewalls and Intrusion Detection Systems [L-4]
Intrusion detection password management; Firewall characteristics; Types of Firewalls; Firewall location and configurations.

Module VI: Introduction to Blockchain Technology [L-6]
Need for distributed record keeping; Modeling faults and adversaries; Byzantine generals problem; Consensus algorithms and their scalability problems; Technologies borrowed in Blockchain- hash pointers, consensus, byzantine fault tolerant distributed computing, digital cash.

Module VII: Blockchain I [L-2]
Bitcoin blockchain; Challenges and Solutions; Proof of stake; Alternatives to Bitcoin consensus; Bitcoin scripting language and their use.

Module VIII: Blockchain II [L-2]
Ethereum and Smart contracts; Turing completeness of smart contract languages and verification challenges; Using smart contracts to enforce legal contracts; Comparing Bitcoin scripting Vs. Ethereum Smart Contracts.

Module IX: Blockchain III [L-2]
Hyperledger fabric; Plug and Play platform; Mechanisms in permissioned blockchain.

Module X: Privacy and Security issues in Blockchain [L-2]
Pseudo anonymity Vs. anonymity; Zcash and Zk-SNARKS for anonymity preservation; Attacks on blockchains- Sybil attacks, selfish mining, advent of algorand, and Sharding based consensus algorithms to prevent these.

Total Contact Hours: 42</td></tr>
</table>

Textbooks, and/or reference material	**Textbooks:** 1. W. Stallings, *Cryptography and Network Security: Principles and Practice*, Pearson, 2014. 2. J. M. Stewart, *Network Security, Firewalls, and VPNs*, Jones and Bartlett Learning, 2013. 3. S. Shukla, M. Dhawan, S. Sharma, S. Venkatesan, *Blockchain Technology: Cryptocurrency and Applications*, Oxford University Press, 2019. **Reference books:** 1. M. Speciner, R. Perlman, C. Kaufman, *Network Security: Private Communications in a Public World*, Prentice Hall, 2002. 2. J. Thompson, *Blockchain: The Blockchain for Beginnings, Guild to Blockchain Technology and Blockchain Programming*, Create Space Independent Publishing Platform, 2017.

EC2001: Network Security and Blockchain

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**
CO 1	**CO1: Understand** the concepts of securing computer network protocols based on the application of cryptography techniques.	**3**	**2**	**3**	**3**	**2**	**2**
CO 2	**CO2: Interpret** blockchain as an emerging technological platform for developing decentralized applications and data storage over and above its role underlying the cryptocurrencies.	**3**	**1**	**2**	**3**	**1**	**2**
CO 3	**CO3: Identify** the methods of secure web browsing.	**3**	**2**	**2**	**3**	**1**	**2**
CO4	**CO4: Create** a distributed and replicated ledger of events, transactions, and data generated through various IT processes with strong cryptographic guarantees**.**	**3**	**2**	**2**	**3**	**1**	**2**
Average		**2.3**	**2.0**	**1.3**	**1.3**	**3.0**	**1.0**

<table>
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<tr><th rowspan="2">Course Code</th><th rowspan="2">Title of the course</th><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><th colspan="4">Total contact hours: 42</th><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>EC2002</td><td>5G Wireless Communication</td><td>PCR</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="2" rowspan="2">Pre-requisites: EC1001 Digital Communication (ECC501)</td><td colspan="6">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="6">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">On successful completion of this course, students should have the skills and knowledge to :

CO1: Apply Cellular concepts to evaluate the signal reception performance in a cellular network and traffic analysis to design cellular network with given quality of service constraints.
CO2: Determine the type and appropriate model of wireless fading channel based on the system parameters and the property of the wireless medium.
CO3: Analyze and design receiver and transmitter diversity techniques. Determine the appropriate transceiver design of multi-antenna systems and evaluate the data rate performance.
CO4: Application of Fundamental Digital Communication Concepts in Fading Channel. Understanding suitable Modulation Schemes for Wireless Channel
CO5: Describe and differentiate four generations of wireless standard for cellular networks. Understand wireless communication systems with key 3G (e.g., CDMA); 4G (OFDM) and 5G technologies</td></tr>
<tr><td>Topics Covered/ Syllabus</td><td colspan="7">Module I. (L - 2)
Introduction to Wireless Personal Communication, Mobile radio systems. Introduction to 5G.

Module II. (L - 6)
Cellular systems concepts, principles, system design fundamentals, spectrum efficiency, frequency management, channel assignment, handoff, power control, Call blocking, Erlang B, Erlang C, Cell splitting and Directional antenna etc.

Module III. (L - 8)
Characterization of wireless radio channel, propagation path models. Fading and Shadowing, Statistical Characterization of fading Channel.

Module IV. (L -7)
Receiver Techniques for fading Channel. Detection of Signal in Fading Channel, Coherent and Non coherent detection Diversity Techniques, Time and Frequency Diversity, Repetition Code, Receive Diversity (SC, MRC, EGC, Switch & Stay), BER and Outage with Diversity, Transmit Diversity, Alamouti Code, MIMO fundamentals, Equalization, Fading mitigation.

Module V. (L - 4)
Capacity of fading Channels: Slow fading Channel, Capacity with Receive Diversity and Transmit diversity, Multi User Capacity

Module VI. (L - 4)
Modulation schemes for wireless Communication (MSK, GMSK), OFDM

Module VII. (L - 5)
Multiple access techniques: Spread spectrum techniques, Cellular CDMA, Wide-band CDMA, Multiple access Performance of CDMA, Capacities of multiple access schemes, Comparison, NOMA

Module VIII. (L - 3)
Wireless Networks and Standards: GSM, CDMA Cellular standard, 3G, 4G

Module IX. (L-3)
The challenges of 5G; Key technologies of 5G; Design issues for 5G; Spectrum, regulation and standardization for 5G;</td></tr>
</table>

	Total Contact Hours: (L=42) = 42
Text Books, and/or Reference material	**Text Books:** [1] Andrea Goldsmith, "*Wireless Communication*", Cambridge University Press [2] Aditya K Jagannathan, "*Principles of Modern Wireless Communication Systems Theory and Practice"*, McGraw-Hill India. [3] David TSE and Pramod Viswanathan, "*Fundamentals of Wireless Communication*", Cambridge University Press **Reference Books:** [1] Theodore Rappaport, "*Wireless Communications: Principles and Practice*", Pearson, 2nd Edition [2] Andreas. F. Molisch, "*Wireless Communication*", John Wiley and Sons [3] Mark and Zhuang, "*Wireless Communication and Networking*", PHI [4] J. G. Andrews *et al.*, "*What Will 5G Be*?," in *IEEE Journal on Selected Areas in Communications*, vol. 32, no. 6, pp. 1065-1082, June 2014, doi: 10.1109/JSAC.2014.2328098. [5] Recent IEEE papers

EC2002: 5G Wireless Communication (Core)
[(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	Apply Cellular concepts to evaluate the signal reception performance in a cellular network and traffic analysis to design cellular network with given quality of service constraints.	3	3	3	3	1	3
CO 2	Determine the type and appropriate model of wireless fading channel based on the system parameters and the property of the wireless medium.	3	3	3	3	3	2
CO 3	Analyze and design receiver and transmitter diversity techniques. Determine the appropriate transceiver design of multi-antenna systems and evaluate the data rate performance.	3	3	3	3	2	3
CO 4	Application of Fundamental Digital Communication Concepts in Fading Channel. Understanding suitable Modulation Schemes for Wireless Channel	3	3	3	3	1	3
CO 5	Describe and differentiate four generations of wireless standard for cellular networks. Understand wireless communication systems with key 3G (e.g., CDMA) and 4G (OFDM) technologies	3	3	3	3	2	3
Average		**3**	**3**	**3**	**3**	**1.8**	**2.8**

B. Laboratories

(i) Simulation Laboratory (EC1051)

<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 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>EC1051</td><td>Simulation Laboratory</td><td>Lab</td><td>0</td><td>0</td><td>4</td><td>4</td><td>2</td></tr>
<tr><td colspan="3" rowspan="2">Pre-requisites / Co-requisites:

Advanced Digital Communication (1002), Information Theory & Coding (1003)</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/ 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

CO 1: To understand discrete event simulation of Discrete and Continuous random variables and generating PDF by simulation and analysis

CO 2: To learn simulation of Digital modulation and coding, BER, effect of fading etc.

CO 3: Get familiarity with simulation of a simple access protocol and develop capability of writing own program in MATLAB

CO 4: Understand the interfacing of real-world analog signals with digital simulation platforms.</td></tr>
<tr><td>Topics Covered/ Syllabus</td><td colspan="7">List of experiments

Expt.1: Generation of Discrete and Continuous random variables.
(a) Discrete (i) Poisson (ii) Binomial (iii) Geometric
(b) Continuous (i) Gaussian (ii) Exponential (iii) Lognormal (iv) Rayleigh
(v) Erlang (all rvs from (ii) to (v) are to be generated using Gaussian r.v s only)
(vi) Generate Gaussian from uniform r.v-s
Generate the r.v-s with suitable chosen parameters.

Expt.2: (a) Generate the pdf of the r.v-s by simulation. Match the simulated pdf with the corresponding analytical pdf-s. [show this for (b) i , b(iii) and b(iv) cases].
(b)Generation of pdf of any arbitrary random variable
(i) U = X+Y, where X and Y are exponential r.v.
(ii) V=X/Y, X & Y are exponential r.v.

Expt.3: Record your own speech via MATLAB for 3 seconds. Plot the time domain waveform and the amplitude spectrum.

Expt.4: Record your own speech via MATLAB for 3 seconds. Save the sound as a MAT file. Load the MAT file, add noise to signal and listen. Change SNR and find the acceptable SNR level.

Expt.5: (a)Simulation of AWGN channel and BER performance of BPSK.
(Generate BPSK at baseband, Tx through a channel corrupted by Gaussian noise of a given noise var. Rx the signal bit, compare it with Tx bit and estimate BER via no. of iteration). Plot the BER vs Eb/No.
(b) Simulation of BPSK Performance in Rayleigh fading Channel.
(Repeat the above Expt. for a Rayleigh faded channel)
(c) Simulation of BER for Maximal Ratio Combining in Rayleigh faded channel with BPSK Tx.
Expt. 6: Simulate the arrival process in a Poisson based arrival with a given mean arrival rate.</td></tr>
</table>

	Using above Simulate Throughput for ALOHA and S-ALOHA protocol(s). **Expt. 7:** Design of encoder and decoder for a linear block code. BER simulation for linear block codes and find coding gain of a linear block code. **Expt. 8:** Design and implementation of source codes using software.
Text/ Reference material	**Text Books:** [1] A. M. Law and D. Kelton, "*Simulation Modeling and Analysis*", McGraw-Hill Education, 3rd Ed., New Delhi, 2000. [2] M. F. Mesiya, "*Contemporary Communication Systems*", McGraw-Hill Education, 1st Ed., USA, 2012. [3] G. Bauch, J. G. Proakis, and M. Salehi, "*Modern Communication Systems Using MATLAB*", 3rd Ed., Cengage Learning, India, 2012. [4] K. C. Raveendranatha, "*Communication Systems Modeling and Simulation using MATLAB and SimuLink*", 1st Ed., University Press, India, 2011. **Reference Books:** [1] M. Viswanathan, "*Simulation of Digital Communication Systems Using Matlab*", Gaussian Waves (online), 2019. [2] J. W. Leis, "*Communication Systems Principles Using MATLAB*", Wiley, 2018.

EC1051: Simulation Laboratory

[(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 understand discrete event simulation of Discrete and Continuous random variables and generating PDF by simulation and analysis	3	3	3	3	1	3
CO 2	To learn simulation of Digital modulation, BER, and effect of fading	3	3	3	3	2	3
CO 3	Get familiarity with simulation of a simple access protocol and develop capability of writing own program in MATLAB	3	3	3	3	1	3
CO4	Understand the interfacing of real world analog signals with digital simulation platforms.	3	3	3	3	1	3
Average		**3**	**3**	**3**	**3**	**1.25**	**3**

(ii) Hardware Laboratory (EC1052)

<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 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>EC1052</td><td>Hardware Laboratory</td><td>Lab</td><td>0</td><td>0</td><td>4</td><td>4</td><td>2</td></tr>
<tr><td colspan="3" rowspan="2">Pre-requisites / Co-requisites:
Advanced Digital Communication (EC1001), Preferable: mm-Wave and THz Communication (EC1003)</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/ 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
CO 1: Analyze and design advanced waveform coding techniques
CO 2: Study and design of advanced CW digital modulation techniques
CO 3: Learn the design principles of RF front end circuits in a transceiver with a defined specification
CO 4: Understand the characteristics of transceiver circuits</td></tr>
<tr><td>Topics Covered/ Syllabus</td><td colspan="7">List of experiments
Expt. 1: Study and analysis of DPCM and ADPCM
Expt. 2: Study and analysis of OQPSK and DQPSK
Expt. 3: Design of Telecommunication Hardware (anyone)
(a) Design a PN sequence generator
(b) Design a BPSK/ QPSK Transmitter and Receiver
(c) Design a Delta Modulator and Demodulator
Expt. 4: (a) Study of a WR-90 waveguide with UG-39 flange and observing the filed characteristics of the TE_{10} mode as well as that of the next higher mode. Also study the current distribution on the inner walls of the waveguide.
(b) Study the characteristics of a Type N to WR-90 waveguide transition using electromagnetic simulation.
Expt. 5: (a) Analysis of a 50 Ω microstrip line using electromagnetic simulation.
(b) Design and simulation of a 90º bent 50-Ohm microstrip line with and without metering. Study the characteristics of a Type N to WR-90 waveguide transition using electromagnetic simulation.
Expt. 6: Characterization of a 2.4 GHz quadrature hybrid coupler using electromagnetic simulation.</td></tr>
</table>

	Expt. 7: (a) Characterization of a half wavelength planar resonator using electromagnetic simulation. (b) Design and characterization of a planar bandpass filter. **Expt. 8:** Design of an up-conversion mixer (single ended and double ended type)
Text/ Reference material	**Text Books:** [1] R. Sobot, "*Wireless Communication Electronics by Example*", Springer, 2014. [2] R. Ludwig and P. Bretchko, "*RF Circuit Design: Theory and Application*", Pearson Education, New Delhi. [3] D M Pozar, "*Microwave Engineering*", 4th Edition, New Delhi, John Wiley 2008. **Reference books:** [1] Sorin Voinigescu, "*High Frequency Integrated Circuits*", Cambridge University Press, UK, 2013.

EC1052: Hardware Laboratory
[(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 and design advanced waveform coding techniques	2	3	2	3	2	3
CO 2	Study and design of advanced CW digital modulation techniques	2	3	2	3	2	3
CO 3	Learn design principles of RF front end circuits in a transceiver with a defined specification	1	3	2	3	3	2
CO 4	Understand the characteristics of transceiver circuits	3	2	2	3	3	2
Average		**2**	**2.3**	**2**	**3**	**2.5**	**2.5**

(iii) Design and Measurement Laboratory (EC 2051)

<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>EC2051</td><td>Design and Measurement Laboratory</td><td>Lab</td><td>0</td><td>0</td><td>4</td><td>4</td><td>2</td></tr>
<tr><td colspan="3" rowspan="2">Pre-requisites / Co-requisites:
EC 1002
Preferable - EC 9031, EC 9036 and EC9038</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/ test, and End Semester Examination</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">CO 1: Design methods of analog and digital filters
CO 2: Design subsystems of a waveform coder/decoder and study the effects of different system non-idealities.
CO 3: Design a band-limited communication channel and study its effects on digital transmission.
CO 4: To design various types of antennas and analyze their radiation characteristics using Electromagnetic Simulation Software
CO 5: Understand the use of RF and Microwave Test and Measurement Instruments for Telecommunication Systems</td></tr>
<tr><td>Topics Covered/ Syllabus</td><td colspan="7">List of experiments
Expt. 1: Design a minimum order low-pass FIR filter and an IIR filter with your own specifications (sampling frequency, passband ripple, stopband attenuation etc.). Plot the frequency and phase response. Verify whether the design meets your specifications.
Expt. 2: Design of fractional order low pass Butterworth filter (FOLBF).
Expt. 3: PCM Transmitter and Receiver Design with MATLAB
(a) Realize four blocks of PCM transmitter in MATLAB, namely, sampling, quantization, encoding and parallel-in-serial-out (PISO).
(b) Realize four blocks of PCM receiver in MATLAB, namely, serial-in-parallel-out (SIPO), decoding, sample-and-hold and low-pass filtering.
Expt. 4: Band-limited channel Design with MATLAB
(a) Design a band-limited channel exhibiting inter symbol interference (ISI).
(b) Explain the effect of ISI by constructing time domain waveforms and eye-patterns.
Expt. 5: Microwave Circuits and Antenna
(a) Design and characterization of a half wavelength dipole as well as a quarter wavelength monopole.
(b) Design and analysis of log periodic antenna using electromagnetic simulation
(c) Design of microstrip antenna
(d) Design of feed network for linear and planar microstrip antenna array</td></tr>
</table>

	Expt. 6: Working with Test and Measurement Instruments (a) Understanding the working of Spectrum Analyzer using a known source of RF signal. (b) Detection of signal and measurement of frequency and PSD of an unknown mobile radio signal using spectrum analyzer. (c) Measurement of signal power using a power meter. **Expt. 7:** Characterization of microwave front end components using vector network analyzer
Text/ Reference material	**Text Books:** [1] K. Choi, and H. Liu, "*Problem-based Learning in Communication Systems using Matlab and Simulink*", IEEE Press/ John Wiley & Sons, 2016. [2] C. A. Balanis, "*Antenna Theory: Analysis and Design*", 3rd ed., John Wiley & Sons, Hoboken, New Jersey, 2005. [3] S. K. Mitra, "*Digital Signal Processing: A Computer - Based Approach*", McGraw-Hill Higher Education. [4] J. P. Dunsmore, "*Handbook of Microwave Component Measurements: with Advanced VNA Techniques*", 2nd Edition, John Wiley, New York. [5] T. S. Laverghetta, "*Modern Microwave Measurements and Techniques*", Artech House, Boston, 198.8 **Reference Books:** [1] A. A. Giordano and A. H. Levesque, "*Modeling of Digital Communication Systems using SIMULINK*", John Wiley & Sons, 2015.

EC2051: Design and Measurement Laboratory
[Mapping between course outcomes (COs) and program outcomes (POs)]

CO	Statement	Program Outcomes					
		PO1	PO2	PO3	PSO1	PSO2	PSO3
CO1	Design methods of analog and digital filters	3	3	2	2	2	2
CO2	Design subsystems of a waveform coder/decoder and study the effects of different system non-idealities	2	3	2	2	1	3
CO3	Design a band-limited communication channel and study its effects on digital transmission	2	3	2	3	2	3
CO4	To design various types of antennas and analyze their radiation characteristics using Electromagnetic Simulation Software	3	2	2	3	2	3
CO5	Understand the use of RF and Microwave Test and Measurement Instruments for Telecommunication Systems	3	2	2	2	3	3
Average		**2.6**	**2.6**	**2**	**2.4**	**2**	**2.8**

C. Elective Subjects

<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 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>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="3" rowspan="2">Pre-requisites:
Signals and Systems (ECC303)
Mathematics – II (MAC02)</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 Objective</td><td colspan="7">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="7">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="7">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 - 2)
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 - 2)
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.

Module V. (L – 5; P - 4)
Digital filter structures: system describing equations, filter categories, All Pass Filters, Comb Filters,</td></tr>
</table>

	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 - 4)** 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 - 4)** 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 - 2)** 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 - 4)** 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 - 2)** 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 - 2)** 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 - 2)** 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	**Text Books:** [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*".**
	Reference Books/materials: [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**

<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 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>EC9002</td><td>Statistical 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="2" rowspan="2">Pre-requisites: EC1001</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: 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.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">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</td></tr>
</table>

	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><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 Number of contact hours: 70</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="3">Pre-requisites:

Signals and Systems (ECC303), Digital Signal Processing (ECC603)</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">• 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.

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</td></tr>
</table>

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="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 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 reference material</td><td colspan="7">Textbooks:
1. L. R. Rabiner and S. W. Schafer , Digital Processing of Speech Signals, Pearson Education,2003.
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.</td></tr>
</table>

	Reference books: 3. G. Ben, N. Morgan, D. Ellis, *Speech and Audio Signal Processing: processing and perception of speech and music*, John Wiley and Sons, 2011. 4. 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

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<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>EC9005</td><td>Probability and Random Processes</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:
None</td><td colspan="6">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="6">Assignments, Quiz, Mid-semester Examination and End Semester Examination</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">• 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.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">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</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">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</td></tr>
</table>

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**

<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 contact hours: 57</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>EC9006</td><td>Error Correction Coding</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:
Probability and random variables;
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: 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.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">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</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">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.</td></tr>
</table>

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="8">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="3">Pre-requisites:
EC1001,
Analog Communication (ECC401)
Digital Communication (ECC501)</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">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

<table>
<tr><td colspan="8">Department of Electronic & 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>EC9008</td><td>Optical 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="3">Pre-requisites:
1. Electronic Devices and Circuits (ECC302 & ECC504)
2. Electromagnetic theory and Transmission Lines (ECC 403)
3. Analog Communication (ECC401), Digital Communication (ECC501)</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">● 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.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">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]</td></tr>
</table>

	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>
<tr><td colspan="8">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 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 [L -12, , T - 4]

Total Contact Hours: 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

<table>
<tr><td colspan="8">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>EC9010</td><td>Network Information Theory & Coding</td><td>(CORE)</td><td>3</td><td>1</td><td>0</td><td>4</td><td>4</td></tr>
<tr><td colspan="3">Pre-requisites: Probability Theory, Digital Communication Fundamentals</td><td colspan="5">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="3">NIL</td><td colspan="5">CT+EA</td></tr>
<tr><td>Course Objectives</td><td colspan="7">To understand the role of information theory for an efficient, error-free and secure delivery of information using binary data streams.</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">1 Understand the concept of Information and quantitative from of characterization of information
2. Gain knowledge about techniques for information compression and its application
3. Understand Channel Capacity and Shannon’s Law on Information capacity. Appreciate information theoretic results as fundamental limits on performance of communication systems
4. Understand the fundamentals of Network Information Theory as basic limitation of information flow in a network.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">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: 56</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">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.</td></tr>
</table>

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)

<table>
<tr><th rowspan="2">Course Code</th><th rowspan="2">Title of the course</th><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><th colspan="4">Total contact hours: 56</th><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>EC9011</td><td>Digital Microwave Communication</td><td>PCR</td><td>4</td><td>0</td><td>0</td><td>4</td><td>4</td></tr>
<tr><td colspan="3">Pre-requisite:
3. ECC403Electrmagnetic Theory and Transmission Lines
4. ECC504 Electronics Devices and Circuits II
5. Microwave Engineering</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 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</td></tr>
<tr><td>Topics Covered</td><td colspan="7">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: 56</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">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</td></tr>
</table>

EC 9019: 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**

<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 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>EC9012</td><td>Microwave Photonics</td><td>PEL</td><td>4</td><td>0</td><td>0</td><td>4</td><td>4</td></tr>
<tr><td colspan="4">Pre requisite:
1. ECC403Electrmagnetic Theory and Transmission Lines
2. ECC504 Electronics Devices and Circuits II
3. Optical Communication
4. Microwave Engineering</td><td colspan="4">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 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</td></tr>
<tr><td>Topics Covered</td><td colspan="7">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: 56</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">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.</td></tr>
</table>

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: Electromagnetic Theory and Transmission Lines (ECC403); Analog Communication (ECC401), Digital Communication (ECC501); Antenna and Wave Propagation (ECC601) (Optional)	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:** 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

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<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>EC9014</td><td>Microwave and mm Wave Measurements</td><td>PEL</td><td>3</td><td>0</td><td>2</td><td>5</td><td>4</td></tr>
<tr><td colspan="3">Pre requisite:
5. ECC403Electrmagnetic Theory and Transmission Lines
6. ECC504 Electronics Devices and Circuits II</td><td colspan="4">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="6">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</td></tr>
<tr><td>Topics Covered</td><td colspan="6">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: 56</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="6">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</td></tr>
</table>

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**

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	
EC9015	**Microwave Solid State Devices**	PEL	3	1	0	4	4

Pre requisite: 7. ECC403Electrmagnetic Theory and Transmission Lines 8. 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 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
Topics Covered	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: 56**
Text Books, and/or reference material	**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

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		2	1	2	2	3	1
CO 2		2	3	1	1	3	1
CO 3		3	2	1	1	3	1
Average		**2.3**	**2.0**	**1.3**	**1.3**	**3.0**	**1.0**

<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 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>EC9016</td><td>Digital Satellite and Navigation Systems</td><td>PEL</td><td>3</td><td>1</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="3">Pre-requisites:
· Electromagnetic Theory
· Microwave Engineering
· Analog and Digital Communication
· Antennas and Wave Propagation</td><td colspan="5">Course Assessment methods (Continuous (CT) and end assessment (EA)):

Assignments, Mid Semester and End Semester Examination</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">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</td></tr>
<tr><td>Topics Covered</td><td colspan="7">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: 56</td></tr>
</table>

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**

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<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">Pre-requisites:
● Analog and Digital communication
● Information theory
● Introduction to Biology</td><td colspan="4">Course Assessment methods (Continuous (CT) and end assessment (EA))
Assignments, Quiz, Mid-semester Examination and End Semester Examination</td></tr>
<tr><td>Course Objective</td><td colspan="6">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="6">● 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="6">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="6"><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

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<tr><td colspan="8">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>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="2" rowspan="2">Pre-requisites:
EC1001</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 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
[5] Probability & Statistics with Reliability Queuing and Computer Science Applications: Kishore Trivedi, Wiley</td></tr>
</table>

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

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<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>EC9019</td><td>Quantum Communication and Computing</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:
Engineering Mathematics, Quantum Mechanics</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

● 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</td></tr>
<tr><td>Topics Covered</td><td colspan="7">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</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">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</td></tr>
</table>

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: Computer architecture, Computer Networking		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 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**

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<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>EC9021</td><td>Machine Learning and Deep Learning using Python</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:
Basic computer programming languages like Python, C++ ,Matlab etc.</td><td colspan="5">Course Assessment methods: (Class Assessment (CA), Mid-semester assessment (MA) and end semester examination (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 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</td></tr>
<tr><td>Topics Covered</td><td colspan="7">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</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">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</td></tr>
</table>

	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**

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

POs:
The following three POs have been defined 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

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

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<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>EC9022</td><td>Big Data Computing</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:

Machine Learning (ECE715), Database Management Systems (CSC502)</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: 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.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">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.</td></tr>
</table>

	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:** 8. J. Lescovek, A. Rajaraman, J. Ullman, *Mining of Massive Datasets*, Stanford Press, 2011. 9. T. White, *Hadoop: The Definitive Guide*, O'Reilly, 2015. *10.* M. Guller, *Big Data Analytics with Spark*, Apress, 2015. *11.* A. Gates, D. Dai, *Programming Pig Data Flow scripting with Hadoop*, O'Reilly Media, 2017. *12.* 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

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 modeling 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>
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<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>EC9023</td><td>Internet of Things (IoT)</td><td>PG Elective</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:
Basic Electronics (ECC01),
Introduction to Computing (CSC01)</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: Understand the concept of IoT systems
● CO2: Analyze electronic systems and IoT architecture
● CO3: Apply data analysis techniques in IoT
● CO4: Analyze case studies</td></tr>
<tr><td>Topics Covered</td><td colspan="7">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</td></tr>
</table>

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>
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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>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**

<table>
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<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>EC9025</td><td>Network Functions Virtualization (NFV) and Software Defined Networks (SDN)</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:

Computer Network; Communication Engineering</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">● 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</td></tr>
<tr><td>Topics Covered</td><td colspan="7">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</td></tr>
<tr><td>Textbooks, and/or reference material</td><td colspan="7">Textbooks:
13. J. Doherty, SDN and NFV simplified, Pearson Education, U.S., 2016.
14. W. Stallings, Foundations of Modern Networking: SDN, NFV, QoE, IoT (Internet of things) and Cloud, Pearson Education, 2015.

Reference books:
5. R. Chayapathi, S. F. Hassan, P. Shah., Network functions virtualization with a touch of SDN, Pearson Education, U.S., 2016.</td></tr>
<tr><td></td><td colspan="7"></td></tr>
</table>

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

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<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="3">Pre-requisites:

Basic Electronics (ECC01), Engineering Mechanics (XEC01)</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">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

<table>
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<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>EC9028</td><td>Mixed Signal 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:
Analog IC Design[EC1012],
Digital IC Design[EC1013], DSP[ECC603]</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: 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.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">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.</td></tr>
</table>

	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**

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	
EC9029	**Architectural Design of Integrated Circuits**	**PEL**	3	1	0	4	4

Pre-requisites: Digital IC Design, DSP	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:** 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.

Topics Covered

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 system design, ASIC (application specific integrated circuits) and ASISP (application specific instruction set processors) design.

	Total Lecture Hours 42(L)+14(T): 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**

<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: 57</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>EC9030</td><td>RF IC Design</td><td>PEL (Open Elective)</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 (ECE722), Analog Communication (ECC401) Electromagnetic theory and Transmission Lines (ECC 403)</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 Objective</td><td colspan="7">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.</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">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</td></tr>
<tr><td>Topics Covered/ Syllabus</td><td colspan="7">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</td></tr>
</table>

Text Books, and/or Reference material	**Text Books:** [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
	Reference Books: [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>
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<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?, 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,</td></tr>
</table>

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**

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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 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>EC9032*</td><td>FPGA based Design*</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/Co-requisites: Digital Circuits and Systems (ECC402)</td><td colspan="6">Course Assessment methods: (Continuous Assessment (CA: 15%), Mid-Term Assessment (MA:25%) and End-Term Assessment (EA:60%))</td></tr>
<tr><td colspan="6">Continuous Assessment (CA): Quizzes/Class tests/Assignments/Attendance</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">● 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.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">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:</td></tr>
</table>

	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**

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<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>EC9033</td><td>Embedded Systems</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:
Basic Electronics (ECC01),
Introduction to Computing (CSC01)
Digital Circuits and Systems (ECC402)
Microprocessors and Microcontrollers (ECC503)</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

• 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</td></tr>
<tr><td>Topics Covered</td><td colspan="7">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</td></tr>
</table>

	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**

<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>EC9034</td><td>MEMS & Microsystems Technology</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:
Basic Elle EC9086ctronics (ECC01), Engineering Mechanics (XEC01)</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
• 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</td></tr>
<tr><td>Topics Covered</td><td colspan="7">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</td></tr>
</table>

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**

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<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>EC9035</td><td>Nanoelectronics</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:
Microelectronics and Semiconductor Device Physics [PHC331, EC1011]</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">● 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.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">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</td></tr>
<tr><td>Text Books and/or reference material</td><td colspan="7">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.</td></tr>
</table>

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**

<table>
<tr><td colspan="8">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) / Elective (PEL)</td><td colspan="4">Total contact hours: 70
(Lecture – 42; Practical/Sessional – 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>EC9036*</td><td>ASIC Design using Verilog*</td><td>PEL</td><td>3</td><td>0</td><td>2</td><td>5</td><td>5</td></tr>
<tr><td colspan="3" rowspan="2">Pre-requisites:
Digital Circuits and Systems [ECC402]</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
● 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.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">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]
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]
Continuous assignments, delay specification, expressions, operators, operands, operator types.

Module-VII. Behavioural Modelling [L – 3]
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]
Procedural continuous assignments, overriding parameters, conditional compilation and execution, useful system tasks.

Module-X. Flip-Flop and Counter Design: :(L – 04) [L – 4]
Synchronous and asynchronous flip flop design with set and reset, design of basic counters.</td></tr>
</table>

	Module-XI. FSM & Processor Design: (L – 06) **[L – 6]** 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 System Verilog for UVM** (L – 04) **[L – 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**

<table>
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<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>EC9037</td><td>Low Power Circuits and Systems</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:
EC1013: Digital IC Design.</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 Objectives</td><td colspan="7">● 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.</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">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.</td></tr>
<tr><td>Syllabus/Topics Covered</td><td colspan="7">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 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-</td></tr>
</table>

	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**
Text / Ref. Books	**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.

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**

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<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>EC9038</td><td>Testing and Verification of VLSI Circuits</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:
Digital Circuits and Systems (ECC402)</td><td colspan="6">Course Assessment methods (Continuous (CT) 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 Objectives</td><td colspan="7">To expose the students, the basics of testing and verification techniques for the digital IC design.</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">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.</td></tr>
<tr><td>Syllabus/Topics Covered</td><td colspan="7">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</td></tr>
<tr><td>Text / Ref. Books</td><td colspan="7">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.</td></tr>
</table>

[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**

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<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>EC9039</td><td>Advanced Computer Architecture</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-requisites/Co-requisites:
Digital Circuits & Systems [ECC402]
Digital Circuits & Systems Laboratory [ECS452]</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">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.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">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</td></tr>
</table>

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><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>EC9040</td><td>DSP Architectures in VLSI</td><td>CORE</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, Selectionof 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]
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.</td></tr>
</table>

	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**

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	
EC9041	**Power Management IC Design**	**PEL**	3	1	0	4	4

Pre-requisites/Co-requisites: Analog IC Design[EC1012, EC722], Signals & Systems[EC503]	Course Assessment Methods: Continuous Assessment (CA-15/100), Mid-Term (MT-25/100) and End-Term assessment (ET-60/100)) Assignments, Quiz/class tests, Mid-term Exam and End-term

Course Objective	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.
Course Outcomes	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.
Topics Covered	**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]** 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**

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<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>EC9042</td><td>Cyber Physical Electronic System 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">Pre-requisites:

Basic Electronics (ECC01), Engineering Mechanics (XEC01)</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">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</td></tr>
<tr><td>Topics Covered</td><td colspan="7">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</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">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</td></tr>
</table>

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**

<table>
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<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>EC9043</td><td>Smart Materials based 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-requisites:

Basic Electronics (ECC01), Engineering Mechanics (XEC01)</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">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</td></tr>
<tr><td>Topics Covered</td><td colspan="7">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</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Text Books:
15. V. K.Varadan, K.J.Vinoy, S.Gopalakrishnan , Smart Material Systems and MEMS: Design and Development Methodologies, Wiley, 2006
16. J. Bentley, Principles of measurement systems. Pearson Education India; 3rd edition, 2002
17. S. H. Crandall, D. C. Karnopp, Dynamics of Mechanical and Electromechanical, Medtech Pub, 2017
Reference books:
6. D. J. Leo, Engineering Analysis of Smart Material Systems, John Wiley & Sons Inc, 2007
7. A. Preumont Mechatronics, Dynamics of Electromechanical and Piezoelectric Systems, Springer, 2011
8. D. K. Gehmlich, S. B. Hammond, Electromechanical system, McGraw-Hill, 1967
9. D. Hutton, Fundamentals of Finite Element Analysis, McGraw Hill, 2003
10. Research articles</td></tr>
</table>

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