THE NATIONAL INSTITUTE OF ENGINEERING

Manandavadi Road, Mysuru

DEPARTMENT OF
ELECTRONICS AND COMMUNICATION ENGINEERING

Curriculum Structure and Syllabus

2025-2026

2022 Admitted Batch

The National Institute of Engineering

Department: Electronics and Communication Engineering

Scheme of Teaching & Examination - 2022 **Effective from the Academic Year 2025-26**

B.E. 2022 Admitted Batch **Semester: VII**

Sl. No	Type of the Course	Course Code	Course Title	Teaching Department (TD)	Question Paper Setting Board (PSB)	Teaching Hrs / Week				Examination				Credits
						L	T	P	S	Duration in Hours	CIE Marks	SEE Marks	Total marks	
1	IPCC	BEC701	Integrated Professional Core Course: **Real Time Operating Systems**	EC	EC	3	0	2		3	50	100	100	4
2	PCC	BEC702	Professional Core Course: **Information Theory and Coding**	EC	EC	3	2	0		3	50	100	100	4
3	PEC	BEC713X	Professional Elective Course - Group III	EC	EC	3	0	0		3	50	100	100	3
4	OEC	BEC754X	Open Elective Course - Group III	EC	EC	3	0	0		3	50	100	100	3
5	PROJ	BEC785	Major Project	EC	EC	3	0	0		3	100	100	200	6
										Total	**300**	**300**	**600**	**20**

Professional Elective Course - Group III			
BEC713A	Static Timing Analysis	BEC713H	Vehicular Electronics
BEC713B	Mixed Signal Circuit Design	BEC713I	Radar and Lidar Systems for Autonomous Driving
BEC713C	Deep Learning Techniques	BEC713J	Digital Image Processing
BEC713D	Estimation Theory	BEC713K	Wireless Ad Hoc network
BEC713E	Low Power VLSI Design	BEC713M	Information and Network Security
BEC713F	Semiconductor IC technology	BEC713N	Data Science and Management
BEC713G	5G Wireless Systems and Industry Applications	BEC713P	Integrated Sensing and Communications
Open Elective Course - Group III			
BEC754A	Introduction to Quantum Computing	BEC754C	Mobile Communication
BEC754B	Next-Gen Wireless: 5G Systems and Cross-Industry Use Cases	BEC754D	Neuromorphic Engineering

The National Institute of Engineering **Department: Electronics and Communication Engineering**														
Scheme of Teaching & Examination - 2022											**Effective from the Academic Year 2025-26**			
B.E. 2022 Admitted Batch														**Semester: VIII**
Sl. No	**Type of the Course**	**Course Code**	**Course Title**	**Teaching Department (TD)**	**Question Paper Setting Board (PSB)**	**Teaching Hrs / Week**				**Examination**				**Credits**
						L	**T**	**P**	**S**	**Duration in Hours**	**CIE Marks**	**SEE Marks**	**Total marks**	
1	PEC	BEC801X	Professional Elective - Group IV (Online Course)	EC	EC	-	-	-		-	-	50	100	3
2	OEC	BEC802X	Open Elective - Group IV (Online Course)	EC	EC	-	-	-		-	-	50	100	3
3	INT	BEC803	Internship (Industry/ Research) (14-16 weeks)	EC	EC	0	0	20		3	100	100	200	10
										Total	**100**	**200**	**400**	**16**

Professional Elective Course - Group IV (Online Courses – NPTEL / Coursera)		**Open Elective Course - Group IV (Online Courses – NPTEL / Coursera)**	
BEC801A	Fibre Optic Communication Technology	BEC802A	Understanding Incubation and Entrepreneurship
BEC801B	Microelectronics: Devices to Circuits	BEC802B	Data Analytics with Python
BEC801C	Semiconductor device modelling and Simulation	BEC802C	Economics of Banking and Finance Markets
BEC801D	Photonic integrated circuit	BEC802D	Patent Law for Engineers and Scientists
BEC801E	Computer Vision and Image Processing Fundamentals and Applications	BEC802E	E-Business

The above Professional Elective Course - Group IV and Open Elective Course - Group IV has to be registered in online VTU portal only using the link provided below.

Dr. S Parameshwara
Associate Professor & HoD

Date:22-07-2025

CIRCULAR

All the final year students of 2025-26 academic year (current 6th semester) must register two MOOC courses: (i) Professional Elective Course, (ii) Open Elective course. The pre-final year students (current 4th semester) are also directed to register these courses for the timely completion of the MOOC course and transfer of credit. The following courses are recommended by the department DC members. The registration to these courses to be strictly done through Online VTU portal only.

Professional Elective Course

Sl. No	Course / Title Name	URL iD	Duration in Weeks	Credits
1	Fibre Optic Communication Technology	https://online.vtu.ac.in/coursedetails/Fiber-Optic-CommunicationTechnology	12 Weeks	3
2	Microelectronics: Devices to Circuits	https://online.vtu.ac.in/coursedetails/Microelectronics-Devices-ToCircuits	12 Weeks	3
3	Semiconductor device modelling and Simulation	https://online.vtu.ac.in/course-details/Semiconductor-device-modeling-and-Simulation	12 Weeks	3
4	Photonic integrated circuit	https://online.vtu.ac.in/coursedetails/Photonic-integrated-circuit	12 Weeks	3
5	Computer Vision and Image Processing - Fundamentals And Applications	https://online.vtu.ac.in/course-details/computer-vision-and-image-processing-fundamentals-and-applications-973141	12 Weeks	3

Open Elective Course

Sl. No	Course / Title Name	URL iD	Duration in Weeks	Credits
1	Understanding Incubation and Entrepreneurship	https://online.vtu.ac.in/coursedetails/Understanding-Incubation-andEntrepreneurship-839780	12 Weeks	3
2	Data Analytics with Python	https://online.vtu.ac.in/course-details/Data-Analytics-with-Python	12 Weeks	3
3	Economics of Banking and Finance Markets	https://online.vtu.ac.in/course-details/economics-of-banking-and-finance-markets	12 Weeks	3
4	Patent Law for Engineers and Scientists	https://online.vtu.ac.in/course-details/Patent-Law-For-Engineers-And-Scientists	12 Weeks	3
5	E-Business	https://online.vtu.ac.in/course-details/E-Business	12 Weeks	3

DC Members:

1. Dr. Narsimha Kaulgud, Professor
2. Dr. Anand Srivatsa, Associate Professor (UG Coordinator)
3. Dr. Shashidhara H R, Associate Professor (PG Coordinator)

HoD ECE

Course Code: BEC701 **Course: Real Time operating systems**

Credits: 4 **L:T:P 3-0-2**

CIE: 50 **SEE: 50**

SEE Hours: 3 **Max. Marks: 100**

Prerequisites if any	
Learning objectives	• 1. Understand the architecture and core concepts of the QNX RTOS. • Learn to develop and debug applications using the QNX Momentics IDE. • Gain knowledge of process and thread management, including synchronization techniques. • Explore inter-process communication (IPC) methods and their applications in QNX. • Understand hardware programming concepts, including interrupt handling and memory access. • Learn to build and configure QNX boot/OS images for embedded systems.

Course Outcomes:

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

COs	Course Outcomes	Bloom's level
CO1	Describe the QNX OS architecture and its microkernel-based design.	L2
CO2	Develop and debug QNX-based applications using appropriate tools.	L3
CO3	Apply process/thread management and synchronization techniques in QNX.	L3
CO4	Implement inter-process communication methods for real-time systems.	L4
CO5	Develop strong knowledge on the POSIX standards that help in System Application Development.	L2

Mapping with POs and PSOs:

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12		PSO1	PSO2	PSO3
CO1	3	2	1											2		
CO2	2		3		2					1		1		2	2	
CO3	3	2	3	2	2							1		3	2	1
CO4	3	2	3	2						1		2		3	2	2
CO5	2	2	2											2		

3 – Strong 2 – Medium 1 – Low

Course Structure

Module – 1		No. of Lecture Hours
1.1	Introduction to QNX OS Architecture	2
1.2	Overview of QNX OS architecture: microkernel, process manager, and standards.	2
1.3	Protected address spaces, process/thread model, and scheduling.	2
1.4	Introduction to inter-process communication (IPC) and synchronization.	1
1.5	Resource managers and shared objects.	1
Module – 2		
2.1	Process management: creation, termination, and memory protection.	2
2.2	Thread management: creation, termination, and synchronization.	2
2.3	Synchronization techniques: mutexes, semaphores, and condition variables.	2
2.4	Hands-on exercises: process/thread creation and synchronization.	2
Module – 3		
3.1	Overview of IPC methods in QNX: message passing, pulses, and shared memory.	2
3.2	Comparing IPC methods: advantages and disadvantages.	2
3.3	Practical implementation of IPC in QNX.	2
3.4	Hands-on exercises: message passing and shared memory.	2
Module – 4		

4.1	Hardware access methods: IO-mapped and memory-mapped IO.	2
4.2	Interrupt handling and DMA-safe memory allocation.	2
4.3	Timing architecture: periodic timing, one-shot timing, and timeouts.	2
4.4	Hands-on exercises: interrupt handling and timing mechanisms.	2
Module – 5		
5.1	Overview of QNX boot/OS image structure.	2
5.2	Components of a boot image: startup code, kernel, drivers, and scripts.	2
5.3	Building and loading boot images onto target hardware.	2
5.4	Introduction to resource managers and their implementation.	2
Total No. of Lecture Hours		**40**

Suggested Learning Resources:

Text Books:

1. QNX Neutrino RTOS User's Guide, QNX Software Systems.
2. Programming for Embedded Systems, Michael Barr, O'Reilly Media.\
3. Hands-on RTOS with Microcontrollers, Brian Amos, Packt Publishing, 2020.
4. Operating System Concepts, Abraham Silberschatz, et al., 9th Edition, Wiley, 2018.

Online Resources:

- https://blackberry.qnx.com/en/products/qnx-everywhere
- https://gitlab.com/qnx
- https://www.reddit.com/r/QNX/
- https://stackoverflow.com/questions/tagged/qnx
- https://www.youtube.com/qnxcam
- https://gitlab.com/qnx/projects
- https://github.com/qnx-ports

Lab Experiments – 15 Hours

1. QNX configuration and application development using QNX Momentics IDE.
2. Process and thread creation, management, and synchronization.
3. Implementation of IPC methods: message passing and shared memory.
4. Interrupt handling and hardware access programming.
5. Building and deploying QNX boot/OS images.
6. Mini capstone project: Design and implement a QNX-based embedded system.

Course Code: BEC702 **Course: Information Theory and Coding**

Credits: 4 **L:T:P:– 3:2:0**

CIE: 50% **SEE: 50%**

SEE Hours: 3 **Max. Marks: 100**

Prerequisites if any	Communication Theory
Learning objectives	Students will be able to learn: • To calculate channel capacity to support error-free transmission. • Apply encoding algorithms for data compression. • Apply decoding algorithms for data decompression and error correction.

Course Outcomes:

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

COs	**Course Outcomes**	**Bloom's level**
CO1	Analyse the various types of source coding algorithms and their performance.	Analyse
CO2	Analyse entropy, mutual information, and channel capacity for all kinds of channels.	Analyse
CO3	Apply various methods of generating and detecting different types of channel coding techniques	Apply

Mapping with POs and PSOs:

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12		PSO1	PSO2	PSO3
CO1	3	3	2		2						2	1		1	3	3
CO2	3	3	2		2						2	1			3	3
CO3	3	3	2		2						2	1			3	3

3 – Strong 2 – Medium 1 – Low

Course Structure

Module – 1 – Information Theory		**No. of Lecture Hours**	**No. of Tutorial Hours**
1.1	Information Theory: Introduction—Block diagram of information systems, Measure of information	2	6
1.2	Entropy and its properties, Numericals	2	
1.3	Entropy of Long Independent Sequences, Entropy of Long dependent Sequences, Numericals	2	
1.4	Markoff Statistical Model for Information Sources, Entropy and Information Rate of Markoff Sources	2	
Module – 2 – Source Coding			
2.1	Encoding of the source coding, Properties of codes, Noiseless Coding Theorem,	2	6
2.2	Shannon's Encoding Algorithm	2	
2.3	Shannon-Fano Encoding Algorithm for Binary and Ternary Codes	3	
2.4	Huffman Coding	2	
Module – 3 – Discrete Communication Channels			
3.1	Communication Channels—Introduction, Discrete Communication Channel and its representation	2	6
3.2	Mutual Information and its properties	2	
3.3	Capacity of a discrete memoryless channel, Shannon's Channel Capacity Theorem	2	
3.4	Other special channels: Symmetric, BSC, BEC, Noiseless, Deterministic, Cascaded.	2	
Module – 4 – Channel Coding Techniques- I			
4.1	Introduction, Linear block codes: Matrix description, error detection and correction,	2	4
4.2	Hamming codes : description, Hamming bound, error detection and correction,	2	

4.3	Convolution codes -time domain approach, Transform domain approach, State table, State diagram and state table, code tree	2	
Module – 5 – Channel Coding Techniques- II			
5.1	Viterbi codes, Trellis codes: Trellis diagram, calculation of encoder output sequence.	2	4
5.2	Cyclic codes: Systematic and non-systematic cyclic code vectors.	1	
5.3	Generator and parity check matrices, encoding diagram	2	
5.4	Reed Solomon Codes: Parameters, calculation of code words and nearest neighbours, LDPC & Turbo codes	2	
Total No. of Lecture Hours		**40**	**-**
Total No. of Tutorial Hours			**26**

Suggested Learning Resources:

Text Books:

1. Shu Lin and Danic J. Costello Jr., "Error Control Coding: Fundamentals and Applications", Prentice Hall, 2003.
2. James Massey, “Lecture Notes on Applied Digital Information Theory-I.”

Reference Books:

1. Blahut R. E, "Theory and Practise of Error Control Codes", Addison Wesley, 1983

Online Resources:

1. http://www.isiweb.ee.ethz.ch/archive/massey_scr/adit1.pdf

Course Code: BEC713A **Course: Static Timing Analysis**

Credits: 3 **L:T:P – 3:0:0**

CIE: 50% Marks **SEE: 50% Marks**

SEE Hours: 3 Hrs **Max. Marks: 50**

Prerequisites if any	Nil

Course Outcomes:

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

COs	Course Outcomes	Bloom's level
CO1	Ability to apply the learnt basic concepts of STA to evaluate the delay of the circuits and analyse the generated report to identify critical issues and bottleneck for the violation and suggest the techniques to make the design to meet timing.	L1
CO2	Ability to write their own constraint file and create the environment required for the given design and its specification to undergo for analysis using the EDA tool.	L1
CO3	Ability to set constraints, Validate the results and analyse the reports	L2

Mapping with POs and PSOs:

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12		PSO1	PSO2	PSO3
CO1	**3**	**2**	**1**	**1**								**2**		**2**		**2**
CO2	**3**	**2**	**1**	**1**								**2**		**2**		**2**
CO3	**3**	**2**	**1**	**1**								**2**		**2**		**2**
CO4	**3**	**2**	**1**	**1**								**2**		**2**		**2**

3 – Strong 2 – Medium 1 – Low

Course Structure

Module – 1: Introduction		No. of Lecture Hours
1.1	Basics of timing concepts- Propagation delay, slew, timing arcs, min and max timing paths, clock domains.	2
1.2	Delay Concepts for Digital Designing: Types of Delays in Digital Circuits, Different Cause for Delay	2
1.3	Timing parameters of digital circuits: Timing Parameters for Combinational Logic Gates, Timing Parameters for Sequential Circuits, Concept of Delay Path in a Design, Clock Concepts	4
Module – 2		
2.1	The STA Environment- timing path groups, modelling of external attributes, virtual clocks, refining the timing analysis, point-to-point specification	2
2.2	Resources for Static Timing Analysis Flow: Libraries, Netlist, Parasitic for Delay Calculation: Device Parasitic, Interconnects, Parasitic Extraction Formats, linear v/s. non-linear delay model.	2
2.3	Clock Network Optimization: Metrics, clock skew-scheduling, handling variability.	1
2.4	Parallel Timing Optimization: Circuit partitioning for independent timing regions.	2
2.5	Post-Silicon Timing Validation: Introduction, sources of post-silicon timing failure, post-silicon tuning	1
3.1	Coupling Capacitance Concept, Type of Crosstalk Noise or Glitch, Types of Crosstalk Delta Delay,	2
3.2	Noise Libraries, Crosstalk Effect on Timing Analysis,	3
3.3	Strategy of Crosstalk on Nanometre Design: Cause for Crosstalk on Integrated Circuits, Crosstalk Prevention Methods	3
Module – 4: Constraints for STA		
4.1	Clock Constraints, Other Timing Constraints,	2
4.2	External Delays of DUA, Timing Exceptions: Multicycle Path,	2

4.3	False Path, Clock Grouping,	2
4.4	Case Analysis, Disable Timing, Path with Derate	2
Module – 5: Timing Violations and Verification		
5.1	Slack, Critical Path of Timing Report, Setup Violation, Hold Violation, Multicycle Path, Half Cycle Path,	2
5.2	Timing Checks for Asynchronous Timing Paths, Recovery and Removal Violation Check, Input/Output Timing Path Checks	2
5.3	DRC Violation Check, Multi Speed Clock Domain, Crosstalk Checks	2
5.4	Techniques to Fix Timing Violation: Techniques to Fix Setup Violations, Techniques to Fix Hold Violations, Time borrowing.	2
Total No. of Lecture Hours		**40**

Suggested Learning Resources:

Textbooks:

1. "Timing Analysis and Optimization of Sequential Circuits," Naresh Maheshwari and Sachin S. Sapatnekar, Springer Science + Business Media, LLC, Library of Congress Cataloging-in-Publication Data, 1999, ISBN:978-1-4613-7579-1, 978-1-4615-5637-4 (eBook).
2. "Constraining Designs for Synthesis and Timing Analysis - A Practical Guide to Synopsys Design Constraints (SDC)," Sridhar Gangadharan and Sanjay Churiwala, Springer Science + Business Media, LLC, Library of Congress Cataloging-in-Publication Data, 2013, ISBN:978-1-4614-3268-5, 978-1-4614-3269-2 (eBook).
3. "Digital Timing Macro modeling for VLSI Verification," Jeong T.K, David O, Springer Science + Business Media, LLC, Library of Congress Cataloging-in-Publication Data, 1995, ISBN: 978-1-4613-5982-1, 978-1-4615-2321-5 (eBook).

Course Code: BEC713B **Course: Mixed Signal Circuit Design**

Credits: 3 **L:T:P – 3:0:0**

CIE: 50% Marks **SEE: 50% Marks**

SEE Hours: 3 Hrs **Max. Marks: 50**

Prerequisites if any	Basic electronics, Analog Electronics, LIC, VLSI

Course Outcomes:

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

COs	Course Outcomes	Bloom's level
CO1	Design the building blocks of data conversion systems	L3
CO2	Understand the static and dynamic performance metrics of data converters.	L2
CO3	Design, test, and characterize digital to analog converters and analog to digital converters.	L3
CO4	Design of mixed signal building blocks in Chip/ IC Design and packaging considerations	L3

Mapping with POs and PSOs:

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12		PSO1	PSO2	PSO3
CO1	3	3	3	1			1		1	2	1	2		2	2	2
CO2	3	3	3	1			1		1	2	1	2		2	2	2
CO3	3	3	3	1			1		1	2	1	2		2	2	2
CO4	3	3	3	1			1		1	2	1	2		3	2	2

3 – Strong 2 – Medium 1 – Low

Course Structure

	Module – 1: Introduction	No. of Lecture Hours
1.1	**Basic Building Blocks of Data Conversion Systems**	2
1.2	Sample and Hold Circuits: Sampling Switches, Architectures	2
1.3	Comparators: Static and Dynamic Characteristics, Static Comparator, Dynamic Comparator,	3
1.4	Charge Pump (Voltage generation): Basic Charge pump, The Dickson Charge Pump, Switched capacitor Comparators	2
	Module – 2	
2.1	Gm-ID Methodology for circuit design	3
2.2	Biasing circuits: Supply Independent Biasing, Bandgap Reference circuits- BJT	2
2.3	Amplifiers: Two-stage Amplifier Design, Frequency compensation	3
	Module – 3	
3.1	**Digital to Analog Converters (DACs):** Fundamentals: Non-Idealities and Performance Metrics, Review of state-of-the-art DAC Architectures,	3
3.2	DAC Architectures: Current-steering DAC, Pipeline DAC	3
3.3	Testing & Characterization: General considerations-DAC	1
	Module – 4	
4.1	**Analog to Digital Converters (ADCs):** Fundamentals: Non-Idealities and Performance Metrics, Review of state-of-the-art ADCArchitectures,	3
4.2	ADC Architectures: Integrating ADCs, Oversampling ADC, Pipeline ADC,	3
4.3	Testing & Characterization: General considerations- ADC	1
	Module – 5:	
5.1	**Mixed signal application circuits for Chip Design:** Mixed signal circuits: CMOS Low Dropout voltage regulator (LDO)- working	3
5.2	Bandgap reference (BGR) circuits- CMOS design	2
5.3	CMOS based Phase locked loop (PLL) architecture	2
5.4	VLSI packaging - Bonding pads, design considerations	3
	Total No. of Lecture Hours	**40**

Suggested Learning Resources:

Text Books :

1. Behzad Razavi." *Design of Analog CMOS Integrated Circuits*", McGrawHill, 2002.
2. R. Jacob Baker, Harry W. Li and David E. Boyce,"*CMOS Circuit Design, Layout and Simulation*"

References :

1. Behzad Razavi,"*Fundamentals of Microelectronics*", Wiley, 1st Edition, 2008.
2. R. Jacob Baker, Harry W. Li and David E. Boyce,"*Principles of Data Conversion System Design*", 1995.

Course Code: BEC713C **Course: Deep Learning Techniques**

Credits: 3 **L: T: P– 3:0:0**

CIE: 50% Marks **SEE: 50% Marks**

SEE Hours: 3 Hrs **Max. Marks: 50**

Prerequisites if any	Knowledge of C and/or Python Programming is preferred.
Learning objectives	Introduce the students deep learning techniques and algorithms for some practical applications

Course Outcomes:

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

COs	Course Outcomes	Bloom's level
CO1	Understand the fundamentals of deep learning.	Understand
CO2	Understanding the working of Convolutional Neural Networks and RNN in decision making.	Understand
CO3	Evaluate the strength and weaknesses of many popular deep learning approaches.	Evaluate
C04	Explore major deep learning algorithms, the problem settings, and their applications to solve real world problems	Apply

Mapping with POs and PSOs:

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12		PSO1	PSO2	PSO3
CO1	3	2	1									1		3	2	1
CO2	3	2	1									1		3	2	1
CO3		3	3	2	1							1		3	2	1
CO4			3	2	2	1						1		3	2	1

3 – Strong 2 – Medium 1 – Low

Course Structure

Module-1		No. of Lecture Hours
1.1	Introduction: What is a Neural Network, The Human Brain, Models of a Neuron, Neural Networks Viewed As Directed Graphs, Feedback, Network Architectures,	3
1.2	Rosenblatt's Perceptron: Introduction, Perceptron, The Perceptron Convergence Theorem, Relation Between the Perceptron	3
1.3	Bayes Classifier for a Gaussian Environment	2
Module-2		
2.1	Multilayer Perceptron's: Introduction, Batch Learning and On-Line Learning,	3
2.2	The Back-Propagation Algorithm	2
2.3	XOR Problem, Heuristics for Making the Back- Propagation Algorithm Perform Better, Back Propagation and Differentiation	3
Module-3		
3.1	Regularization for Deep Learning: Parameter Norm Penalties - L2 Parameter Regularization,	3
3.2	Dataset Augmentation, Semi-Supervised Learning.	1
3.3	Optimization for Training Deep Models: Challenges in Neural Network Optimization – Ill Conditioning,	2
3.4	Local Minima, Plateaus, Saddle Points and Other Flat Regions.	2
Module-4		
4.1	Convolution neural networks: The Convolution Operation, Motivation, Pooling	2
4.2	Convolution and Pooling as an Infinitely Strong Prior, Variants of the Basic Convolution Function,	3
4.3	Structured Outputs, Data Types	1
4.4	Efficient Convolution Algorithms, Convolutional Networks and the History of Deep Learning	2
Module-5		

5.1	Sequence Modelling: Recurrent and Recursive Nets: Unfolding Computational Graphs, Recurrent NeuralNetworks	3
5.2	Bidirectional RNNs	1
5.3	Encoder-Decoder Sequence-to- Sequence Architectures, Deep Recurrent Networks, Recursive Neural Networks,	2
5.4	The Long Short-Term Memory and Other Gated RNNs	2
Total No. of Lecture Hours		**40**

Textbooks:

1. Simon Haykin, "Neural networks and Learning Machines", Third Edition, Pearson, 2009/2016
2. Ian Goodfellow, Yoshua Bengio and Aaron Courville, "Deep Learning", MIT Press, 2016 (https://www.deeplearningbook.org/)

Reference books:

1. Eugene Charniak "Introduction to Deep learning", MIT Press, 2018
2. S Lovelyn Rose, L Ashok Kumar, D Karthika Renuka, "Deep learning using Python", Weily, New Delhi, 201

Resources:

- https://www.youtube.com/watch?v=W3_yaf3HvHU
- https://www.youtube.com/watch?v=VyWAvY2CF9c
- https://www.youtube.com/watch?v=7sB052Pz0sQ
- https://www.youtube.com/watch?v=Mubj_fqiAv8
- https://www.coursera.org/learn/neural-networks-deep-learning
- https://onlinecourses.nptel.ac.in/noc20_cs62/preview

Course Code: BEC713D **Course: Estimation Theory**

Credits: 3 **L:T:P-3-0-0**

CIE: 50% Marks **SEE: 50% Marks**

SEE Hours: 3 Hours **Max. Marks:100**

Prerequisites if any	
Learning objectives	• To learn basic concepts of estimation and different estimators • To learn linear estimators. • To learn various parameter and state estimators.

Course Outcomes:

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

COs	**Course Outcomes**	**Bloom's level**
CO1	Explain the basic concepts of estimation and different estimators	L2
CO2	Explain the notion of Linear estimation in static systems, discrete time dynamic systems	L3
CO3	Explain Discrete time non-Linear Dynamic Systems	L3

Mapping with POs and PSOs:

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12		PSO1	PSO2	PSO3
CO1	3	3	2	2					3		2			3	2	
CO2	3	3	2	2					3		2			3	2	
CO3	3	3	2	2					3		2			3	2	
CO4	3	32	2	2					3		2			3	2	

3 – Strong 2 – Medium 1 – Low

Course Structure

Module – 1 -Introduction		No. of Lecture Hours
1.1	Introduction	1
1.2	Problem of parameter estimation	2
1.3	ML Estimator	1
1.4	MAP Estimator	2
1.5	LS Estimator	2
1.6	MMSE Estimator	1
Module – 2 – Unbiased and Consistent Estimators		
2.1	Unbiased Estimators	2
2.2	The Variance and MSE of an Estimator	2
2.3	Consistency and Efficiency of Estimators	3
Module – 3 – Linear Estimation in Static Systems		
3.1	Introduction	1
3.2	Estimation of Gaussian Random Vectors	2
3.3	Linear MMSE	2
3.4	LS Estimation	2
3.5	Polynomial Fitting	1
Module – 4 –Discrete time Linear Dynamic Systems		
4.1	Introduction	1
4.2	The Kalman Filter	4
4.3	Example of A Filter	1
4.4	Consistency of State Estimator	2
4.5	Initialization of State Estimators	2
Module – 5 –Discrete time non-Linear Dynamic Systems		
5.1	Introduction	1
5.2	Estimation in nonlinear stochastic systems	2
5.3	The EKF	2
5.4	Error Compensation in Linearized Filters	2
5.5	Some error reduction methods	1
Total No. of Lecture Hours		**40**

Suggested Learning Resources:

Textbooks:

1. Bar-Shalom, Yaakov, X. Rong Li, and Thiagalingam Kirubarajan. *Estimation with applications to tracking and navigation: theory algorithms and software*. John Wiley & Sons, 2001.

Reference Books:

1. Bar-Shalom, Yaakov, Peter K. Willett, and Xin Tian. *Tracking and data fusion*. Vol. 11. Storrs, CT, USA:: YBS publishing, 2011**.**

2. Bar-Shalom, Yaakov, and Xiao-Rong Li. *Multitarget-multisensor tracking: principles and techniques*. Vol. 19. Storrs, CT: YBS publishing, 1995**.**

Online Resources:

1. https://www.coursera.org/videos/pre-mbastatistics/sOn5B?query=Estimation%20theory&page=2&sortBy=BEST_MATCH&source=search
2. https://onlinecourses.nptel.ac.in/noc20_ee53/preview

Course Code: BEC713E **Course: Low power VLSI Design**

Credits: 3 **L:T:P – 3:0:0**

CIE: 50% Marks **SEE: 50% Marks**

SEE Hours: 3Hrs **Max. Marks: 100**

Prerequisites if any	
Learning objectives	1.understand the impact of source of power dissipation in VLSI circuits 2. learn about different design approaches for power optimization 3.understand the impact of power on system performance

Course Outcomes:

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

COs	Course Outcomes	Bloom's level
CO1	Identify the source of power dissipation in VLSI Circuits	L2
CO2	Understand the power optimization at circuit and logic level	L2
CO3	Applying the power optimization approaches to VLSI architecture and systems	L3
CO4	Illustrate the different techniques involved in special circuits like memory, adder, and multiplier with reference to speed and power	L2

Mapping with POs and PSOs:

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12		PSO1	PSO2	PSO3
CO1	2	2	2	1	2	-	-	-	-					2	1	2
CO2	1	1	2	2	2									2	1	2
CO3	2	2	1	2	2									2	1	2
CO4	2	2	2	2	2									2	1	2

3 – Strong 2 – Medium 1 – Low

Course Structure

	Module – 1: Device & Technology Impact on Low Power:	**No. of Lecture Hours**
1.1	Need for low power VLSI chips, Dynamic dissipation in CMOS	2
1.2	Sources of power dissipation on Digital Integrated circuits, Emerging Low power approaches, physics of power dissipation in CMOS devices	2
1.3	Transistor sizing & gate oxide thickness, Impact of technology Scaling	2
1.4	Technology & Device innovation, low power figure of merits	2
	Module – 2: Low Power Design at Circuit and logic level	
2.1	Transistor and Gate sizing, equivalent pin ordering, Network restructuring and reorganization	2
2.2	Special latches and Flip Flops, low power digital cell library	2
2.3	Adjustable device threshold voltage, gate reorganization, signal gating, logic encoding	2
2.4	state machine encoding, Precomputation logic	2
	Module – 3: Low Power Architecture and systems	
3.1	Power and performance management	2
3.2	switching activity reduction	2
3.3	Parallel architecture with voltage reduction, flow graph transformation	2
3.4	power reduction in clock networks	2
	Module – 4: Low power Memory Design	
4.1	Introduction, sources and reductions of power dissipation in memory subsystems,	2
4.2	Sources of power dissipation in SRAM, DRAM	2
4.3	low power SRAM and DRAM circuits	2
4.4	**Low power Arithmetic components:** adders, multipliers, division	2
	Module – 5: Power estimation, Simulation Power analysis:	
5.1	SPICE circuit simulation, gate level logic simulation, capacitive power dissipation	2

5.2	Static state power, gate level capacitance estimation,	2
5.3	architecture level analysis	2
5.4	Data Correlation Analysis in DSP Systems, adiabatic computation	2
Total No. of Lecture Hours		**40**

Suggested Learning Resources:

Textbooks:

1. Gary K. Yeap, "**Practical Low Power Digital VLSI Design**", KAP, 2002.
2. Rabaey, Pedram, "**Low Power Design Methodologies**", Kluwer Academic, 1997
3. Online resource link, if any. Nptel lecture on low power VLSI circuits and systems

Reference Books:

1. Kaushik Roy, Sharat Prasad, "**Low-Power CMOS VLSI Circuit Design**", Wiley, 2000
2. Anantha P. Chandrakasan& Robert W. Brodersen, **"Low Power Digital CMOS Design",** Kluwer AcademicPublications, 1994

Course Code: BEC713F **Course: Semiconductor IC Technology & Chip Design**

Credits: 3 **L:T:P – 3:0:0**

CIE: 50% Marks **SEE: 50% Marks**

SEE Hours: 3 Hrs **Max. Marks: 50**

Prerequisites if any	--

Course Outcomes:

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

COs	**Course Outcomes**	**Bloom's level**
CO1	Ability to apply the learnt basic concepts of device fabrication methods, challenges involved in lower nanometre technologies, new 3D device structures and interconnects	L2
CO2	Ability to design the device structure and characterize using TCAD tools	L3
CO3	To Demonstrate assembly and packaging of semiconductor technology and Attain exposure to do assembly and packaging tools and operations	L3

Mapping with POs and PSOs:

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12		PSO1	PSO2	PSO3
CO1	3	2	1	1								2		2		2
CO2	3	2	1	1								2		2		2
CO3	3	2	1	1								2		2	2	2

3 – Strong 2 – Medium 1 – Low

Course Structure

Module – 1: Introduction		**No. of Lecture Hours**
1.1	Historical perspective, processing overview, crystal growth,	3
1.2	Wafer fabrication and basic properties of Silicon Wafers	2
1.3	Fabrication Process flow in detail	3
1.4	Clean Room standards	2
Module – 2		
2.1	Epitaxy, Thermal Oxidation of Silicon, Lithography Wet and Dry Etching, Thin film deposition, Diffusion, Ion Implantation, Metallization,	4
2.2	Process Integration: Passive components,	2
2.3	Bipolar Technology, MOSFET Technology,	1
2.4	MESFET Technology, MEMS Technology,	2
2.5	FINFET, GAAFET	1
Module – 3		
3.1	IC Manufacturing: Electrical Testing	2
3.2	Packaging, Yield	3
3.3	Future trends and Challenges: Challenges for integration, system on chip.	3
Module – 4		
4.1	Introduction to Semiconductor Packaging: Definition of packaging and its significance in various industries	2
4.2	Introduction to packaging, and its importance in Modern Electronics	2
4.3	Exploring different packaging technologies, such as leaded and leadless packages, surface mount technology (SMT), and ball grid array (BGA)	2
4.4	interconnect technologies used in advanced packaging, such as flip chip bumping, solder balls, and through-silicon vias (TSVs)	2
Module – 5:		

5.1	Substrates and materials used in advanced packaging, such as organic substrates, build-up substrates, redistribution layers (RDLs), interposers, and fan-out substrates.	2
5.2	substrates and materials, their properties, fabrication techniques, and performance characteristics	2
5.3	Introduction to the importance of thermal management in advanced packaging. Discussion on various thermal management techniques, such as heat sinks, thermal interface materials (TIMs), and thermal vias	2
5.4	Testing and Reliability in Advanced Packaging, Future Trends and Emerging Technologies:	2
Total No. of Lecture Hours		**40**

Suggested Learning Resources:

Textbooks:

1. G. S. May and S. M. Sze, *Fundamentals of Semiconductor Fabrication*, Wiley India, 2004.
2. J. D. Plummer, M. D. Deal and P. B. Griffin, *Silicon VLSI Technology, Fundamentals, Practice and Modeling*, Pearson education, 2000.
3. S. M. Sze, *VLSI Technology*, 2nd Edn., TMH, 2004.
4. S. M. Sze, *Semiconductor Devices: Physics and Technology*, 2nd Edn., Wiley India, 2011.
5. W. R. Runyan and K. E. Bean, *Semiconductor Integrated Circuit* Processing Technology, Addison Wesley Publishing Company, 1990.
6. S. A. Campbell, *The Science and Engineering of Microelectronic* Fabrication, Oxford University Press, 1996.
7. M. J. Madou, *Fundamentals of Microfabrication*, 2nd Edition, CRC Press, 2011.
8. Fundamentals of Device and Systems Packaging: Technologies and Applications by Rao R. Tummala, McGrawHill Publications
9. Microelectronics Packaging Handbook by Rao R. Tummala, Eugene J. Rymaszewski, and AlanG. Klopfenstein
10. Semiconductor Advanced Packaging by John H. Lau

Course Code: BEC713G **Course: 5G Wireless Systems and Industry Applications**

Credits: 3 **L: T: P: 3:0:0**

SEE: 50% Marks **CIE:50% Marks**

SEE Hours: 3 hrs **Max.Marks:100**

Prerequisites if any	Communication systems, Wireless Communication
Learning objectives	Students will be able to learn: • Understand the architecture and enabling technologies of 5G systems. • Analyze the performance and challenges of 5G networks. • Explore practical applications and use cases of 5G in real-world scenarios.

Course Outcomes:

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

COs	Course Outcomes	Bloom's level
CO1	Understand the architecture and enabling technologies of 5G systems.	L1
CO2	Analyze the performance and challenges of 5G networks.	L3
CO3	Explore practical applications and use cases of 5G in real-world scenarios.	L3

Mapping with POs and PSOs:

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO12	PSO 1	PSO 2	PSO 3
CO1	3	3	2	2	2								3	2	3
CO2	3	3	2	2	2								3	2	3
CO3	3	3	2	2	2								3	2	3

3 – Strong 2 – Medium 1 – Low

Course Structure

Module 1		**No. of Lecture Hours**
1.1	Introduction to 5G & 3GPP Specs	2
1.2	Evolution of Mobile Technologies from 1G to 5G, 5G vision, KPIs (Key Performance Indicators)	1
1.3	Use cases (eMBB, mMTC, URLLC), ITU and 3GPP 5G standardization timeline	1
1.4	**5G Architecture and Network Components:** Overall 5G system architecture: Access, Core, and Transport	2
1.5	Functional split between gNB and CU/DU, 5G NR and NG Core (AMF, SMF, UPF, AUSF)	1
1.6	Comparison with LTE architecture	1
Module – 2		
2.1	Radio Interface in 5G NR :Frequency ranges (FR1 and FR2 – Sub-6 GHz and mmWave)	2
2.2	Numerology and flexible frame structure, Channel bandwidths and SCS (Sub-Carrier Spacing)	1
2.3	Massive MIMO and beamforming	1
2.4	Key Enabling Technologies Massive MIMO, Beamforming and Beam Management, Millimeter Wave Communication	2
2.5	Network Slicing and Virtualization (NFV, SDN)	1
2.6	Mobile Edge Computing (MEC), Energy Efficiency and Green 5G.	1
Module – 3		
3.1	**Protocol Stack and Resource Management ,**5G NR protocol layers: PHY, MAC, RLC, PDCP, RRC	2
3.2	Scheduling and HARQ in 5G, Uplink/Downlink channel structures Mobility management and handover procedures.	2
3.3	5G Applications and Security: Smart cities, IoT, Connected Vehicles, Healthcare, Industrial Automation.	2

3.4	5G Security Framework: Threats and Solutions, Authentication and encryption in 5G.	2
	Module – 4	
4.1	Call Management: Registration Management, Connection Management, Access Control	2
4.2	5G Signalling: Signalling Radio Bearers, PDU Sessions, QoS	3
4.3	Active Antenna, Passive Antenna, polarizations, Antenna arrays, Power Splitter fundamentals, Antenna Basics – Dipole, Antenna arrays	3
	Module – 5	
5.1	SS/PBCH based Beamforming Codebook based Beamforming, SRS based Beamforming, Eigenmode Beamforming, Static Beamforming, Dynamic Beamforming – Beam Steering.	1
5.2	Dynamic Beamforming – Beam Switching Digital Beamforming vs. Analog Beamforming, Pilot Signals, Spatial Multiplexing, Spatial Multiplexing vs Beamforming.	2
5.3	Creating a Beam, Narrow Beams and Beam Steering Massive MIMO Antennas.	1
5.4	MIMO in a Handset, Multiple Panel Antenna, Beam Forming Evolution	1
5.5	5G ORAN, 5G Cloud, Femto Cells .	1
5.6	5G Testbeds and Future Research Trends Open source 5G testbeds (OpenAI Interface, SRSRAN, NI USRP) Beyond 5G (6G vision), AI/ML for 5G optimization	2
Total No. of Lecture Hours		**40**

Suggested Learning Resources:

Books:

1. *Fundamentals of 5G Mobile Networks* – Jonathan Rodriguez
2. *5G NR: The Next Generation Wireless Access Technology* – Erik Dahlman, Stefan Parkvall.

Reference books:

1. 3GPP Specifications (TS 38.ECx series)
2. Research papers and white papers from IEEE, ITU, Qualcomm, Ericsson

Course Code: BEC713H **Course: Vehicular Electronics**

Credits: 3 **L:T:P – 3:0:0**

CIE: 50% Marks **SEE: 50% Marks**

SEE Hours: 3 Hrs **Max. Marks: 100**

Prerequisites if any	
Learning objectives	• Understanding electronics in Automobiles and sensors & actuators used in modern vehicles • Understanding Engine control systems and networking • Analysing of battery systems and Diagnostics • performance and configuration of Electric, Hybrid and Fuel cell vehicles.

Course Outcomes:

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

COs	**Course Outcomes**	**Bloom's level**
CO1	Explain the need of electronics in Automobiles and sensors & actuators used in modern vehicles.	L1
CO2	Understand the Engine control systems and networking concepts in automotive systems.	L1
CO3	Analysis of various battery systems and Diagnostics techniques used in automobiles	L2
CO4	Paraphrase the performance and configuration of Electric, Hybrid and Fuel cell vehicles.	L3

Mapping with POs and PSOs:

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12		PSO1	PSO2	PSO3
CO1	3	2	1	1								2		2		2
CO2	3	2	1	1								2		2		2
CO3	3	2	1	1								2		2		2
CO4	3	2	1	1								2		2		2

3 – Strong 2 – Medium 1 – Low

Course Structure

Module – 1: Introduction to Automotive Systems		**No. of Lecture Hours**
1.1	Automotive fundamentals overview: four stroke cycle, engine control,	2
1.2	Ignition system, spark plug, spark pulse generation, drive train, transmission, brakes- Power Brakes	2
1.3	steering system, Anti-Lock Brake System (ABS), Electronic Steering Control-Power Steering,	2
1.4	Traction Control, electronically controlled suspension, starting system.	2
Module – 2: Sensors and Actuators		
2.1	Oxygen (O2/EGO) Sensors, Throttle Position Sensor (TPS), Engine Crankshaft Angular Position (CKP) Sensor,	2
2.2	magnetic reluctance, position sensor, engine speed sensor, ignition timing sensor, hall effect position sensor, shielded field sensor, optical crankshaft position sensor, Manifold Absolute Pressure (MAP) Sensor - strain gauge and capacitor capsule,	2
2.3	Engine Coolant Temperature (ECT) sensor, Intake Air Temperature (IAT) Sensor, knock sensor, airflow rate sensor, Operating Principles of Fuel Cells, Electrode Potential and Current-Voltage Curve	2

2.4	Actuators: Automotive Engine Control Actuators, Fuel Injection, Exhaust Gas Recirculation Actuator, Variable Valve Timing, Electric Motor Actuators, fuel metering actuator, Ignition actuator, catalytic converter.	2
Module – 3 : Electronic Engine Control and Automotive Networking		
3.1	Electronic Engine Control: Engine parameters, variables, engine performance terms, electronic fuel control system,	2
3.2	electronic ignition control, idle speed control, air/fuel systems fuel handling, air intake system, Protection, Remote Keyless Entry	2
3.3	Automotive communication/networking: Automotive networking, cross system function, Requirements for bus systems, Classification of bus systems,	2
3.4	Applications in the vehicle, Coupling of networks, Examples of networked vehicles. Bus systems: CAN, LIN.	2
Module – 4: Diagnostics and Battery systems		
4.1	On and Off board diagnostics: Electronic Control System Diagnostics, Service Bay Diagnostic Tool, Onboard Diagnostics	2
4.2	Model-Based Sensor Failure Detection, Expert Systems in Automotive Diagnosis, Occupant Protection Systems.	2
4.3	Battery Systems: Energy Storages: Batteries in Electric and Hybrid Vehicles, Battery Basics,	2
4.4	Battery Parameters, Electrochemical Cell Fundamentals, Battery Modelling, Electrochemical Batteries, Ultracapacitors, Battery Pack Management	2
Module – 5: Electric and Hybrid Vehicles		
5.1	Electric Vehicles: Configurations of Electric Vehicles, Performance of Electric Vehicles, Tractive Effort in Normal Driving	2
5.2	Hybrid Electric Vehicles: Concept of Hybrid Electric Drive Trains, Architectures of Hybrid Electric Drive Trains.	3
5.3	Fuel Cell Vehicles: Fuel and Oxidant Consumption, Fuel Cell System Characteristics, Fuel Cell Technologies, Fuel Supply, Non-Hydrogen Fuel Cells.	3
Total No. of Lecture Hours		**40**

Suggested Learning Resources:

Text Books:

1. William B. Ribbens, "Understanding Automotive ELectronics"6thEdition, SAMS/Elsevier Publisher, 2010.
2. Robert Bosch Gambh, "Automotive Electrics, Automotive Electronics systems and Componenets", 5thEdition, John Wiley& Sons Ltd., 2007.
3. Mehrdad Ehsani, Yimin Gao, Sebastien E. Gay, Ali Emadi, "Modern Electric, Hybrid Electric, and Fuel Cell Vehicles- Fundamentals, Theory and Design", CRC Press, 2004.
4. Iqbal Husain, "Electric and Hybrid Vehicles Design Fundamentals"2ndedition, CRC press.

Online Resources:

https://www.youtube.com/watch?v=_Bjn-tGKPvc

Course Code: BEC713I Course: Radar and Lidar Systems for Autonomous Driving

Credits: 3 **L:T:P – 3:0:0**

CIE: 50% Marks **SEE: 50% Marks**

SEE Hours: 3 Hrs **Max. Marks: 50**

Prerequisites if any	
Learning objectives	• To learn principles of radar systems. • To use radar techniques for target detection and tracking in autonomous driving scenario. • To examine real-world case studies and applications of radar and Lidar systems in autonomous cars, including adaptive cruise control (ACC), collision avoidance, pedestrian detection, and intersection management. • To learn principles of LiDAR systems.

Course Outcomes:

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

COs	**Course Outcomes**	**Bloom's level**
CO1	Explain working principle of radar systems	L2
CO2	Use radar techniques for target detection and tracking in autonomous driving scenario.	L3
CO3	Examine real-world case studies and applications of radar systems in autonomous cars, including adaptive cruise control (ACC), collision avoidance, pedestrian detection and intersection management.	L3
CO4	Explain working principles of LiDAR systems	L2

Mapping with POs and PSOs:

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12		PSO1	PSO2	PSO3
CO1	3	3	2	2					3		2			3	2	
CO2	3	3	2	2					3		2			3	2	
CO3	3	3	2	2					3		2			3	2	
CO4	3	3	2	2					3		2			3	2	

3 – Strong 2 – Medium 1 – Low

Course Structure

Module – 1: Fundamentals of Radar Systems		**No. of Lecture Hours**
1.1	Introduction, Essential Functions of Radar, Radar System Fundamentals,	2
1.2	Antennas for Radar Measurements, Challenges for Automotive Radar Developers,	2
1.3	Mathematical model of Radar Range Equation,	2
1.4	Radar Equation for Automotive Applications.	2
Module – 2: FMCW Radars		
2.1	Fundamentals, Block diagram of FMCW radars, Range and Velocity measurement using FMCW radars,	4
2.2	Range resolution, velocity resolution, Application of FMCW radars for Autonomous driving, Case Study: TI FMCW Radar.	4
Module – 3: LiDAR for Autonomous Driving		
3.1	Introduction to LiDAR, Types of LiDAR, Components and architecture of a typical LiDAR system, Role of LiDAR in autonomous vehicles	4
3.2	Object detection and classification using LiDAR, Range measurement using LiDAR, Current limitations and challenges in LiDAR technology	4
Module – 4: Modern Radar Sensors		

4.1	**Modern Radar Sensors in Advanced Automotive Architectures*:*** Motivation for Advanced Systems, The Evolving Automotive Radar Landscape, Vehicle Network and Compute Considerations, Design Considerations for Automotive Radar.	4
4.2	Vehicle Network and Compute Considerations, Design Considerations for Automotive Radar.	4
Module – 5: Automotive Radar Applications		
5.1	Introduction, Short-Range Radar (SRR, Long-Range Radar (LRR)), Trends in Automotive Applications	4
5.2	Future Roadmaps Automotive Applications, Future Contributions of Automotive Applications	4
Total No. of Lecture Hours		**40**

Suggested Learning Resources:

Text Books:

1. Jonah Gamba "Radar Signal Processing for Autonomous Driving", Springer, 2020
2. Matt Markel" Radar for Fully Autonomous Driving", Artech House, 2022.

Reference Books:

1. Merrill I. Skolnik Handbook of Radar Systems, McGraw Hill; 3rd edition, 2008.
2. Pinliang Dong LiDAR Remote Sensing and Applications, CRC Press, 2017.

E-Resources:

1. https://www.coursera.org/specializations/self-driving-cars
2. https://www.edx.org/course/self-driving-cars-with-duckietown

Course Code: BEC713J **Course: Digital Image Processing**

Credits: 3 **L:T:P 3:0:0**

CIE: 50% **SEE: 50%**

SEE Hours: 3hours **Max. Marks:100**

Prerequisites if any	Digital Signal Processing
Learning objectives	• To analyse the fundamental concepts of Image Processing. • To realize and implement filters for Image processing applications.

Course Outcomes:

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

COs	**Course Outcomes**	**Bloom's level**
CO1	Understand basic principles of digital images and image processing techniques	L1, L2
CO2	Apply transformation tools on a digital image	L2, L3
CO3	Apply filtering techniques in both the spatial and frequency (Fourier) domains.	L2, L3
CO4	Analyze and apply enhancement and restoration techniques	L2, L3

Mapping with POs and PSOs:

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12		PSO1	PSO2	PSO3
CO1	3	3												2	2	
CO2	3	3	2	3	3						3			3	3	3
CO3	3	3	2	3	3						3			3	3	3
CO4	3	3	2	3	3						3			3	3	3

3 – Strong 2 – Medium 1 – Low

Course Structure

Module – 1 - Introduction to Image Processing System		**No. of Lecture Hours**
1.1	Overview of Image Processing, Image Processing and Related Fields.	3
1.2	Digital Image Representation, Types of Images.	3
1.3	Fundamental Steps in image processing, Image Processing Applications.	2
Module – 2 - Digital Imaging Systems		
2.1	Digital Imaging System, Image Sampling and Quantization.	3
2.2	Image Display Devices and Resolution.	3
2.3	Image Storage and File formats.	2
Module – 3 – Convolution and Image Transforms		
3.1	2-D Convolution, Need for Image transform, Fourier Transform.	3
3.2	2D DFT, Walsh Transform, Hadamnd transform, Haar Transform.	3
3.3	Slant Transform, DCT, SVD and DWT, Comparison of Different Image Transform.	2
Module – 4 – Image Enhancement		
4.1	Image Enhancement, Enhancement through point operation, Types of point operation. Histogram Manipulation.	2
4.2	Linear gray-level transformation, Local or Neighbourhood operation.	2
4.3	Median filter, Spatial domain high pass filtering or image sharpening. Bit-place slicing.	2
4.4	Image enhancement in the frequency domain, homomorphic filter, Zooming operation, Image arithmetic, Image Rotation.	2
Module – 5 – Image Restoration		
5.1	Image Degradation, Types of image Blur, Classification of image – restoration techniques, image-restoration model.	2
5.2	linear image restoration techniques, non-linear image-restoration techniques.	2
5.3	Blind Deconvolution, classification of Blind-deconvolution techniques Image Denoising.	2

5.4	classification of noise in image, median filtering, Trained Average filter, Performance Metrics in Image restoration, Machine Learning in Image Processing.	2
Total No. of Lecture Hours		**40**

Suggested Learning Resources:

Textbooks:

1. S Sridhar, Digital Image Processing, by Oxford University press, New Delhi, 2nd Ed., 2016.
2. S. Jayaraman, S. Esakkirajan, T. Veerakumara, **'Digital Image Processing',** Tata McGraw Hill Education Pvt. Ltd., 2009.

Reference Book:

1. Gonzalez', **Image Processing',** Gatesmark Publishing, 2nd Edition, 2009
2. Anil K Jain, **Digital Image Processing',** Prentice Hall, 1998.
3. Rafael C Gonzalez, Richard E Digital Image Processing Using MATLAB, Pearson Prentice Hall, 2004.

Online Resources:

a. Online NPTEL : https://nptel.ac.in/courses/117105135
: https://archive.nptel.ac.in/courses/117/105/117105135/

b. Coursera : https://www.coursera.org/learn/digital
https://www.coursera.org/learn/image-segmentation

c. Virtual Lab : https://cse19-iiith.vlabs.ac.in/

Course Code: BEC713K **Course: Wireless Adhoc Networks**

Credits: 03 **L:T:P:– 3:0:0**

CIE: 50% **SEE: 50%**

SEE Hours: 3 **Max. Marks: 100**

Prerequisites if any	Communication Networks
Learning objectives	Students will be able to learn: • Understand the architecture, characteristics, and challenges of wireless ad-hoc networks. • Analyze MAC and routing protocols tailored for dynamic, infrastructure-less networks. • Explore multicast communication strategies and transport-layer adaptations for ad-hoc environments. • Evaluate security mechanisms, including key management and secure routing techniques. • Examine Quality of Service (QoS) provisioning and energy management strategies for efficient network performance.

Course Outcomes:

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

COs	**Course Outcomes**	**Bloom's level**
CO1	Understand the architecture, issues, and protocol stack of wireless ad-hoc networks	Understand
CO2	Analyze the design principles and functionalities of MAC and routing protocols in ad-hoc networks	Analyze
CO3	Examine multicast routing, transport layer solutions, and security frameworks in ad-hoc networks	Apply
CO4	Evaluate Quality of Service (QoS) mechanisms and energy management techniques	Evaluate
CO5	Design and propose protocol-level improvements for performance, security, or energy efficiency	Create

Mapping with POs and PSOs:

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12		PSO1	PSO2	PSO3
CO1	3	2													3	
CO2	3	3	2	2										1	3	2
CO3	3	2	2	2										1	2	2
CO4	2	2	3	2										2	2	3

3 – Strong 2 – Medium 1 – Low

Course Structure

Module – 1		**No. of Lecture Hours**
1.1	Introduction to Ad-hoc Wireless Networks, Issues in Ad-hoc Networks	2
1.2	Ad-hoc Wireless Internet, and Introduction to MAC Protocols	2
1.3	Issues and Design Goals of MAC Protocols, Classification of MAC Protocols	2
1.4	Contention-Based Protocols: with Reservation Mechanisms, with Scheduling Mechanisms, Directional Antennas	2
Module – 2		
2.1	Introduction and Design Issues in Routing for Ad-hoc Wireless Networks	2
2.2	Classification of Routing Protocols	2
2.3	Table-Driven and On-Demand Routing Protocols	2
2.4	Hybrid, Hierarchical, and Power-Aware Routing Protocols	2
Module – 3		
3.1	Introduction to Multicast Routing, Design Issues	2
3.2	Operation and Architecture Reference Model of Multicast Routing Protocols	2
3.3	Classification of Multicast Routing Protocols	2
3.4	Tree-Based and Mesh-Based Multicast Routing Protocols	2

Module – 4		
4.1	Introduction, Design Issues, and Goals of Transport Layer Protocols	2
4.2	Classification of Transport Layer Solutions; TCP over Ad-hoc Networks	2
4.3	Other Transport Protocols, Overview of Security Issues in Ad-hoc Networks	2
4.4	Information and Network Security Attacks, Key Management, Secure Routing in Ad-hoc Networks	2
Module – 5		
5.1	Introduction to QoS, Issues and Challenges	2
5.2	Classification of QoS Solutions: MAC Layer Techniques	2
5.3	Network Layer Solutions for QoS, Real-time Support	2
5.4	Energy Management Schemes: Battery, Transmission, System Power Management	2
Total No. of Lecture Hours		**40**

Suggested Learning Resources:

Textbooks:

1. C. Siva Ram Murthy & B. S. Manoj: Ad-hoc Wireless Networks, 2nd Edition, Pearson Education, 2011

Reference Books:

1. Ozan K. Tonguz and Gianguigi Ferrari: Ad-hoc Wireless Networks, John Wiley, 2007.
2. Xiuzhen Cheng, Xiao Hung, Ding-Zhu Du: Ad-hoc Wireless Networking, Kluwer Academic Publishers, 2004.
3. C.K. Toh: Ad-hoc Mobile Wireless Networks- Protocols and Systems, Pearson Education, 2002

Online Resources:

nptel.ac.in/courses/106105160

Course Code: BEC713M **Course: Information and Network Security**

Credits: 3 **L:T:P – 3:0:0**

CIE: 50% Marks **SEE: 50% Marks**

SEE Hours: 3 Hrs **Max. Marks: 50**

Prerequisites if any	
Learning objectives	• Apply the symmetric key crypto systems. • Apply the concepts of public key encryption techniques and explain applications of hash functions. • Explain Digital Signatures along with Web and IP security. • Explain Firewall and Cloud security concepts.

Course Outcomes:

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

COs	**Course Outcomes**	**Bloom's level**
CO1	Apply the symmetric key crypto systems.	Understand, Apply
CO2	Apply the concepts of public key encryption techniques and explain applications of hash functions.	Understand, Apply
CO3	Explain Digital Signatures along with Web and IP security.	Understand, Apply
CO4	Explain Firewall and Cloud security concepts.	Understand, Apply

Mapping with POs and PSOs:

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12		PSO1	PSO2	PSO3
CO1	3	1		3	3							1		2	2	2
CO2	3	1		3	3							1		2	2	2
CO3	3	1		3	3							1		2	2	2
CO4	3	1		3	3							1		2	2	2

3 – Strong 2 – Medium 1 – Low

Course Structure

Module – 1		**No. of Lecture Hours**
1.1	Need for Information and Network Security, Services, mechanisms and attacks,	1
1.2	Model of symmetric cryptosystem, Cryptanalysis and Brute-Force Attack, Substitution Techniques;	1
1.3	Caesar Cipher, Affine Ciphers, Monoalphabetic Cipher, Frequency/Statistical analysis, Homophones, Playfair Cipher, Hill Cipher	2
1.4	Vigenère Cipher, Autokey Cipher, One Time Pad.	2
1.5	Single and Double transposition ciphers, Stream Ciphers and block Ciphers, Data Encryption Standard (DES), avalanche effect, Diffusion and Confusion, strength of DES; use of 56-Bit Keys,	2
Module – 2		
2.1	Plaintext, Nature of DES algorithm, timing attacks, Cryptanalytic attacks; Differential cryptanalysis and Linear cryptanalysis. DES Design Criteria: Criteria for the S-boxes, overview of criteria for the permutation P. Strict	2

2.2	Avalanche Criterion (SAC), Bit Independence Criterion (BIC), Guaranteed Avalanche (GA) criterion,	2
2.3	Block cipher modes of operation. Simplified Advanced Encryption Standard (AES) cipher.	2
2.4	Block cipher design principles; Number of rounds, design of function F, S-BOX Design, Key Schedule Algorithm	2
Module – 3		
3.1	Principles and applications of public-key cryptosystems, requirements for public-key cryptosystems,	1
3.2	One-way function, Trap-door one-way function, public-key cryptanalysis, probable-message attack.	1
3.3	Rivest-Shamir-Adleman (RSA) algorithm, description of the algorithm, computational aspects, security of RSA. Other Public-Key Cryptosystems;	2
3.4	Diffie-Hellman key exchange algorithm, discrete logarithm, Key exchange protocol, man in the middle attack, Elliptic Curve Cryptography (ECC), security of elliptic curve cryptography	2
3.5	Applications of Message Authentication Functions.	1
Module – 4		
4.1	Digital signatures; Requirements, Generic Model, Properties, Direct Digital Signature, Arbitrated Digital Signature, Digital Signature Standard;	2
4.2	RSA approach and DSS approach, Elgamal digital signature scheme, web security consideration, security socket layer (SSL) and transport layer security, secure electronic transaction,	2
4.3	IP Security: Overview of IP Security (IPSec), IP Security Architecture, Security Associations (SA), Transport and Tunnel Modes,	2
4.4	Authentication Header (AH), Encapsulating Security Payload (ESP).	1
4.5	Wireless Network threats, Wireless security measures, Mobile Device security threats, Mobile Device security strategy	1
Module – 5		
5.1	Need for Firewalls, Firewall characteristics, Firewall control techniques, types of Firewalls;	1

5.2	Packet filters, Stateful Inspection Firewalls, Application-level gateways and Circuit-level gateways. Firewall configurations.	2
5.3	Cloud Computing, Cloud Computing Elements, Cloud Computing Reference Architecture, cloud security risks and countermeasures, data protection in the cloud,	2
5.4	An Encryption Scheme for a Cloud-Based Database, cloud security as a service, Steps and Approaches for cloud deployment.	2
5.5	Intruders; classes of intruders, Intrusion detection techniques;	2
Total No. of Lecture Hours		**40**

Suggested Learning Resources:

Text Books:

1. William Stalling, "Cryptography and Information and Network Security", Pearson Education, 4th Edition, 2011.
2. Cloud Security: A Comprehensive Guide to Secure Cloud Computing, Ronald L. Krutz, Russell Dean Vines, Wiley- India, 2010.

Reference Books:

1. William Stalling, "Cryptography and Information and Network Security", Pearson Education, 6th Edition, 2014.
2. Behrouz A. Forouzan, "Cryptography and Information and Network Security", TMH, 3rd Edition, 2015.

Online Resources:

https://www.w3schools.com/cybersecurity/index.php

Course:BEC713N **Course: Data Science and Management**

Credits: 3 **L:T:P - 3:0:0**

SEE: 100 Marks **CIE: 100 Marks**

SEE Hours: 3 **Max. Marks: 100**

Prerequisites if any	Basics of Linear Algebra and Statistics
Learning objectives	• Explain the foundational concepts of data science, including its history, significance, and the data science process. • Apply statistical methods and data analysis techniques to interpret and draw insights from complex datasets. • Implement various machine learning algorithms and assess their performance using appropriate evaluation metrics in real-world scenarios. • Utilize data visualization tools and techniques to effectively communicate findings and insights to diverse audiences.

Course Outcomes:

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

COs	**Course Outcomes**	**Bloom's level**
CO1	Explore the foundational concepts of data science, history, significance, and process.	L1 and L2
CO2	Apply statistical methods and data analysis techniques to interpret and draw insights from complex datasets.	L3
CO3	Implement various machine learning algorithms and assess their performance using appropriate evaluation metrics in real-world scenarios.	L3
CO4	Utilize data visualization tools and techniques to effectively communicate findings and insights to diverse audiences.	L3
CO5	Understanding data and analysing outcomes through real-world case studies in data science.	L4

Mapping with POs and PSOs:

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12		PSO1	PSO2	PSO3
CO1	3	3	1	1					1	1	1	1		3	2	
CO2	3	3	3	2					1	1	1	1		3	2	
CO3	3	3	3	2					1	1	1	1		3	2	
CO4	3	3	3	2					1	1	1	1		3	2	

3 – Strong 2 – Medium 1 – Low

Course Structure

Module 1 – Introduction to Data Science and R Tool		**No. of Lecture Hours**
1.1	Overview of Data Science Importance of Data Science in Engineering, Data Science Process, Data Types and Structures,	2
1.2	Introduction to Python Programming, Basic Data Manipulation in Python, Simple programs using Python using Data Science pakcages.	3
1.3	Introduction to RDBMS: Definition and Purpose of RDBMS Key Concepts: Tables, Rows, Columns, and Relationships, SQL Basics: SELECT, INSERT, UPDATE, DELETE Importance of RDBMS in Data Management for Data Science.	3
Module 2 – Linear Algebra and Statistics for Data Science		
2.1	Solutions of Over determined Equations, Pseudo inverse	2
2.2	Vectors and Distances, Projections, Eigenvalue Decomposition.	2
2.3	Understanding Univariate and Multivariate Normal Distributions,	3
2.4	Mean, Variance, Covariance, and Covariance Matrix, Introduction to Hypothesis Testing, Confidence Intervals for Estimates.	
Module 3 – Optimization in Data Science		

3.1	Optimization and Data Science Problem Solving, Introduction to Optimization.	4
3.2	Understanding Optimization Techniques, Typology of Data Science Problems, Solution Framework for Data Science Problems	4
Module 4 – Regression and Classification Techniques		
4.1	Linear Regression , Simple Linear Regression and Assumptions, Multivariate Linear Regression.	4
4.2	Model Assessment and Variable Importance, Subset Selection, Classification Techniques , Classification using Logistic Regression	4
Module 5 – Case Studies on Predictions		
5.1	Predict presence/absence of a disease (e.g., diabetes or heart disease).	2
5.2	Predict whether a voter will participate in an upcoming election.	2
5.3	Predict next-day stock price movement (up/down) for a given stock.	2
5.4	Predict whether a customer is likely to cancel their telecom subscription.	2
Total No. of Lecture Hours		**40**

Suggested Learning Resources:

Textbook/s:

1. "Python for Data Analysis" by Wes McKinney, 2nd Edition (2018)
2. "Data Science from Scratch: First Principles with Python" by Joel Grus, 2nd Edition (2019)

Reference Books:

1. "An Introduction to Statistical Learning" by Gareth James, Daniela Witten, Trevor Hastie, and Robert Toshigami, 2nd Edition (2021)
2. "The Elements of Statistical Learning" by Trevor Hastie, Robert Toshigami, and Jerome Friedman, 2nd Edition (2009)
3. "Data Science for Business: What You Need to Know about Data Mining and Data-Analytic Thinking" by Foster Provost and Tom Fawcett, 2nd Edition (2013)

Online Resources:

1. https://www.coursera.org/specializations/jhu-data-science
2. https://www.kaggle.com/learn/data-science
3. https://www.edx.org/professional-certificate/harvardx-data-science
4. https://www.youtube.com/playlist?list=PL4cUxeGkcC9g1s4L6G8p8Fq5XK6Pq7b1k

Course Code: BEC713P **Course: Integrated Sensing and Communications**

Credits: 3 **L:T:P-3-0-0**

CIE: 50% Marks **SEE: 50% Marks**

SEE Hours: 3 Hours **Max. Marks:100**

Prerequisites if any	Communication Theory
Learning objectives	• To understand the principles, architecture, and benefits of integrating sensing and communication systems. • To analyze and design signal processing and communication techniques that support radar and wireless transmission. • To explore advanced use cases and emerging technologies such as Reconfigurable Intelligent Surfaces (RIS) and their role in enhancing ISAC systems.

Course Outcomes:

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

COs	Course Outcomes	Bloom's level
CO1	Apply the foundational concepts of integrated sensing and communication systems to analyse their architecture and operational trade-offs in real-world applications.	L3
CO2	Analyze the signal processing techniques used in ISAC systems to understand target detection and parameter estimation under various operating conditions.	L3
CO3	Evaluate communication system components such as modulation, channel estimation, and interference management strategies for their effectiveness in ISAC environments.	L4
CO4	Analyze diverse radar-based ISAC use cases like automotive radar, smart cities, and indoor positioning to identify technological requirements and challenges	L3
CO5	Evaluate the role of Reconfigurable Intelligent Surfaces in enhancing ISAC performance through adaptive beamforming and intelligent environment reconfiguration.	L4

Mapping with POs and PSOs:

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12		PSO1	PSO2	PSO3
CO1	3	3	2	2					3		2			3	2	
CO2	3	3	2	2					3		2			3	2	
CO3	3	3	2	2					3		2			3	2	
CO4	3	3	2	2					3		2			3	2	
CO5	3	3	2	2					3		2			3	2	

3 – Strong 2 – Medium 1 – Low

Course Structure

Module – 1 - Fundamentals of Integrated Sensing and Communications (ISAC)		**No. of Lecture Hours**
1.1	Introduction, Motivation, Vision, and Applications	2
1.2	Evolution from traditional sensing and communications to ISAC, System architecture and classification of ISAC systems	2
1.3	Benefits and challenges of integrating sensing and communication, Spectrum sharing in ISAC systems,	2
1.4	Key performance metrics: trade-offs between sensing and communication.	2
Module – 2 – Signal Processing Fundamentals for ISAC		
2.1	Signal models for joint radar and communication systems, Detection theory and estimation fundamentals for sensing,	2
2.2	Target detection and parameter estimation (range, velocity, angle), Sensing parameter estimation in noisy environments.	3
2.3	Waveform design and optimization for dual-purpose operation, Time-frequency analysis for ISAC signals.	3
Module – 3 – Communication Fundamentals for ISAC		
3.1	Modulation techniques suitable for ISAC (OFDM, chirp signals, etc.), Multiple access and MIMO techniques for ISAC,	2

3.2	Channel estimation and equalization in joint systems - Interference management and mitigation in shared spectrum,	3
3.3	Information theory perspectives of ISAC, Sensing-aided communication enhancements (e.g., adaptive beamforming).	2
Module – 4 – Use Cases for ISAC		
4.1	Automotive radar and vehicular communications (V2X), ISAC in smart cities and intelligent transportation systems,	2
4.2	Indoor sensing and positioning using ISAC, Surveillance and security applications, Healthcare monitoring using ISAC technologies,	3
4.3	Case studies: mmWave automotive radar, joint communication-radar prototypes.	3
Module – 5 – Emerging Trends for ISAC		
5.1	Introduction to Reconfigurable Intelligent Surfaces (RIS), Role of RIS in ISAC system enhancement,	3
5.2	Channel modeling and estimation in RIS-assisted ISAC,	2
5.3	RIS-aided waveform design for joint sensing and communication, 6G ISAC networks.	3
Total No. of Lecture Hours		40

Suggested Learning Resources:

Text Books:

1. Cui, Yuanhao, Fan Liu, Christos Masouros “Integrated sensing and communications" Springer Nature Singapore, 2023.
2. Kaushik, Aryan “Integrated Sensing and Communications for Future Wireless Networks: Principles, Advances and Key Enabling Technologies” Elsevier, 2024.

Online Resources:

1. https://youtu.be/pIv9xJEElQA?si=RUFL6LXcRYqrEjfT
2. https://youtu.be/avppIElwuI4?si=lkgJav-kvhS68x7m