Sardar Patel Institute of Technology
Bhavan's Campus, Munshi Nagar, Andheri (West), Mumbai-400058-India
(Autonomous Institute Affiliated to University of Mumbai)

Sem-VII

Sardar Patel Institute of Technology

Bhavan's Campus, Munshi Nagar, Andheri (West), Mumbai-400058-India
(Autonomous Institute Affiliated to University of Mumbai)

Course (Category) Code	Course Name	Teaching Scheme (Hrs/week)					Credits Assigned			
		L	T	P	O	E	L	T	P	Total
PC	Mobile and Wireless Communication	2	-	2	2	6	2	-	1	3
EC401		Examination Scheme								
		Component	ISE (%)		MSE (%)		ESE(%)			Total
		Theory	20		20		60			100
		Laboratory	50		--		50			100

Pre-requisite Course Codes, if any.	EC307: Computer Communication Network
Course Objective: The objective of the course is to provide a fundamental understanding of Mobile and Wireless Communication.	
Course Outcomes (CO): ***At the end of the course students will be able to***	
EC311.1	Demonstrate the ability to discuss wireless communication concepts, system capacity and service provided.
EC311.2	Evaluate various path loss and fading effects.
EC311.3	Analyze losses, multipath effects, architecture, and protocols of 3G,4G and 5G systems.
EC311.4	Compare various operational aspects of Wireless Personal Area Networks.

CO-PO Correlation Matrix (3-Strong, 2-Moderate, 1-Weak Correlation)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
EC311.1	2		2									
EC311.2			2	2	2				2	2		
EC311.3	3				2				2	2		2
EC311.4	2	2										

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CO-PEO/PSO Correlation Matrix (3-Strong, 2-Moderate, 1-Weak Correlation)

	PEO1	PEO2	PEO3	PSO1	PSO2	PSO3
EC311.1		2				
EC311.2		2	2			
EC311.3		2	2			
EC311.4		2				

BLOOM'S Levels Targeted (Pl. Tick appropriate)

Remember	Understand√	Apply √	Analyze√	Evaluate	Create

Theory Component

Module	Unit No.	Topics	Ref.	Hrs
1	**Title**	**Introduction to mobile communication**	1	5
	1.1	Frequency Division Multiple access, Time Division Multiple access, Spread Spectrum Multiple access, Space Division Multiple access, and OFDM.		
	1.2	Frequency reuse, channel assignment strategies, handoff strategies, interference and system capacity, trunking and grade of service, improving the capacity of cellular systems and related design problems		
2	**Title**	**Mobile Radio Propagation**	2,3	10
	2.1	Introduction to radio wave propagation, reflection, diffraction, scattering. Indoor and Outdoor propagation Models. Practical Link Budget Design using path loss models.		
	2.2	Small-Scale Multipath propagation, small scale multipath measurements, types of small-scale fading, fading effects due to Doppler spread. Statistical models for multipath fading		

		channels-Clarks model,2-day Rayleigh fading model, Saleh and Valenzuela indoor model.		
3	**Title**	**3G UMTS Network, 4G LTE and 5G Technologies**	4	8
	3.1	UMTS network architecture, Protocol Structure, Channel Structure, Frame slots and symbols, modulation, coding, multiple antenna techniques, WCDMA, Modulation, Handoff and Power Control.		
	3.2	4G LTE network Architecture, LTE Radio Access, Radio-Interface Architecture, Physical Transmission Resources, Downlink and Uplink Physical-Layer Processing, Scheduling and Rate Adaptation.5G Concepts and Architectures, Network Slicing Architecture, mm Wave communication, multiple Cell Types.		
4	**Title**	**Personal Area Network Technologies**	3	5
	4.1	**Bluetooth:** concepts of Piconet , scatternet etc., protocol stack, link types, security, network connection establishments, usage models, etc.		
	4.2	**Wifi and ZigBee:** components, architecture, network topologies, protocol stack etc.		
5	**Self-Study**	Rayleigh fading model, Saleh and Valenzuela indoor model**.** UWB and RFID: technical requirements, components and characteristics, applications.	2,3	4*
			Total (* Not Included)	28

Laboratory Components:

Sr. No	Title of the experiment
1	Study of GSM modem: i] Install and configure minicom, wvdial & AT Commands ii] Python scripting.
2	Channel Allocation Techniques
3	Modulation Techniques using GNU Radio.
4	Spread Spectrum Modulation, OFDM Modulation.
5	Wireless Path Loss Computations: i] Free-space Propagation Path Loss Model ii] Indoor Propagation Model - Okumura Model etc
6	Wireless Path Loss Computations: iii] Outdoor Propagation Model - Hata Model etc
7	Open-Source LTE/EPC Network Simulation using NS-3, Omnet++
8	Open-Source Personal Area Network simulation using NS-3, Omnet++
9	Millimeter Wave (5G) Network, WiFi Network simulation usingNS-3, Omnet++
10	Virtual Lab.

Text Books

Sr. No	Title	Edition	Authors	Publisher	Year
1	Wireless Communications	Third	Theodore S. Rappaport	Prentice Hall of India, PTR publication	-
2	Wireless Communications	Second	Andreas Molisch	Wiley	-
3	Wireless Network Evolution 2G-3G	Third	Vijay Garg	Pearson Education	

4	4 G Roadmap and Emerging Communication Technologies	Second	Young Kyun Kim and Ramjee Prasad	Artech house	

Reference Books

Sr. No	Title	Edition	Authors	Publisher	Year
1	Wireless Communication	Second	Singhal	TMH	
2	Mobile Communication	Second	C.Y Lee	Wiley	

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Course (Category) Code	Course Name	Teaching Scheme (Hrs./week)					Credits Assigned			
		L	T	P	O	E	L	T	P	Total
PE-III	Microwave Communication	2	0	2	6	11	2	0	1	3
EC413 (IT13)		Examination Scheme								
		Component	ISE (%)		MSE (%)		ESE(%)			Total
		Theory	20		20		60			100
		Laboratory	50		--		50			100

Pre-requisite Course Codes, if any.	EC304: Electromagnetic Waves
Course Objective: The objective of the course is to provide a fundamental understanding of Microwave Communication	
Course Outcomes (CO): ***At the end of the course students will be able to***	
EC312.1	Apply EM Wave theory to understand nature of Microwave Signal and their corresponding guiding structures.
EC312.2	Identify Passive Waveguide Components, Sources and Detectors
EC312.3	Analyze Passive Waveguide Components, Sources and Detectors
EC312.4	Compute amplifier and filter design parameters on the basis of application/requirement.
EC312.5	Justify choice of amplifier and filter design parameter.
EC312.6	Design Microwave System components.

CO-PO Correlation Matrix (3-Strong, 2-Moderate, 1-Weak Correlation)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
EC312.1	3	3	3	1	3					3		
EC312.2	2	2	2	2	3					3		
EC312.3	2	2	2	2	3					3		
EC312.4	2	2	2	2	3					3		
EC312.5	2	2	2	2	3					3		
EC312.6	3	3	3		3					3		

CO-PEO/PSO Correlation Matrix (3-Strong, 2-Moderate, 1-Weak Correlation)

	PEO1	PEO2	PEO3	PSO1	PSO2	PSO3
EC312.1		2			-	
EC312.2		2			-	
EC312.3		2			2	
EC312.4		2			2	
EC312.5		2			2	
EC312.6		1				

BLOOM'S Levels Targeted (Pl. Tick appropriate)

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Remember√	Understand√	Apply√	Analyze√	Evaluate	Create

Theory Component

Module No.	Unit No.	Topics	Ref.	Hrs.
1		**Introduction to Microwave Engineering**	1	10
	1.1	Lumped and Distributed Elements, Frequency Bands, Characteristics, Application, Advantages and disadvantages		
	1.2	Rectangular and circular waveguides: TE, TM modes, dominant mode		
	1.3	Microwave Components: Resonators, re-entrant cavities, scattering parameters, tees, hybrid ring, directional couplers, phase shifters, terminations, attenuators, ferrite devices such as isolators, gyrators, and circulators.		
2		**Microwave Tubes and semiconductor devices**	1	10
	2.1	Two Cavity Klystron and Reflex Klystron, Helix Travelling Wave Tube, Cross Field Amplifier, Cylindrical Magnetron.		
	2.2	PIN Diode, Varactor Diode, Schottky Diode, Gunn Diode, Tunnel Diode, IMPATT Diodes.		
3		**Microwave Amplifiers and Filters**	1	08
	3.1	Two port power gain and stability		
	3.2	Microwave Low pass Filter design		
4(Self Study)		**Microwave Frequency Applications:** Radars, Biomedical Devices, Drying materials, Microwave Tomography, Satellite Communication		06
			Total	**28**

Laboratory Component, if any. (Minimum 10 Laboratory experiments using both hardware and software are expected)

Sr. No	Title of the Experiment
1	Model and simulate rectangular waveguide in CAD to study EM wave propagation within it.
2	Model and simulate circular waveguide in CAD to study EM wave propagation within it.
3	Design of Waveguide H-plane TEE using CAD
4	Design of Directional Coupler Using CAD
5	Design of Low pass Filter using CAD
6	Implementation of a technical paper using CAD
7	Microwave bench setup (CO1) A) Introduction to the lab B) Identification of waveguide

	and its components. How to determine the parameters for each component by looking at the data sheet. C) Klystron setup and characterization plotting Vr vs Vo D) Frequency and wavelength measurement of the signal generated by klystron
8	Determination of parameters of passive components using Bench and VNA. Analysis of comparative study to be submitted.
9	Determine the frequency and wavelength in a rectangular waveguide using direct and indirect measurement.
10	Design of Planar Hybrid Ring using CAD

Textbooks:

S. N.	**Title**	**Authors**	**Edition**	**Publisher**	**Year**
1	Microwave Engineering	David M Pozar	Fourth	John Wiley & Sons	**2012**
2	Microwave Devices and Circuits	Samuel Y Liao	Third	Pearson Education	

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Course (Category) Code	Course Name	Teaching Scheme (Hrs/week)					Credits Assigned			
		L	T	P	O	E	L	T	P	Total
PE- III	Image and Video Processing	2	-	2	5	8	2	-	1	3
EC423 (1T23)		Examination Scheme								
		Component		ISE (%)		MSE (%)		ESE(%)		Total
		Theory		20		20		60		100
		Laboratory		50		--		50		100

Pre-requisite Course Codes, if any.	EC207: Signals and Systems EC303: Digital Signal Processing
Course Objective: To study the image and video fundamentals and mathematical transforms necessary for processing and enhancement techniques. To study image restoration procedures and compression procedures for different applications.	
Course Outcomes (CO): ***At the end of the course students will be able to***	
EC423.1	Apply the image fundamentals and mathematical models for digital image and video processing.
EC423.2	Analyze time and frequency domain techniques for image enhancement.
EC423.3	Apply segmentation and compression techniques.
EC423.4	Develop image and video processing applications.

CO-PO Correlation Matrix (3-Strong, 2-Moderate, 1-Weak Correlation)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
EC423.1	3	3										
EC423.2			3	2	3							2
EC423.3					3							

EC423.4	2	2			3	2			3	3		3

CO-PEO/PSO Correlation Matrix (3-Strong, 2-Moderate, 1-Weak Correlation)

	PEO1	**PEO2**	**PEO3**	**PEO4**	**PSO1**	**PSO2**	**PSO3**
EC423.1		2					
EC423.2					3		
EC423.3			2				
EC423.4			2			3	

BLOOM'S Levels Targeted (Pl. Tick appropriate)

Remember	**Understand**	**Apply✓**	**Analyze✓**	**Evaluate✓**	**Create**

Theory Component

Module No.	**Unit No.**	**Topics**	**Ref.**	**Hrs.**
1	**Title**	**Fundamental of Image and Video**	1,6	**04**
	1.1	Structure of the Human Eye, Light, Brightness adaption and discrimination, Pixels, coordinate conventions,		
	1.2	Imaging Geometry, Image acquisition, sampling and quantization, image resolution, basic relationship between pixels, colour images, RGB, HSI and other models		
2	**Title**	**Two Dimensional Transforms and Image Enhancement**	1,5	**06**
	2.1	Discrete Fourier Transform, Discrete Cosine Transform, KL Transform, and Discrete Wavelet Transform		
	2.2	Intensity transformations, contrast stretching, histogram equalization, Correlation and convolution, smoothing filters, sharpening filters, gradient and Laplacian, Frequency domain filtering.		
3	**Title**	**Image Segmentation and Compression**	1,5	**05**
	3.1	Point, line and edge detection, edge linking using Hough		

		transform and graph theoretic approach, thresholding, and region-based segmentation, Morphological operations.		
	3.2	JPEG and MPEG compression standard, H.265 video compression standard		
4	**Title**	**Image Restoration**	1,6	**04**
	4.1	Basic Framework, Image degradation model, Noise characterization, Noise restoration filters,		
	4.2	Adaptive filters, and Estimation of Degradation functions, Restoration Techniques.		
5	**Title**	**Video Formation and Representation**	2,3	**05**
	5.1	Digital Video Sampling, Video Frame classifications, I, P and B frames, Notation		
	5.2	Video Capture and display: Principle of color video camera, video camera, digital video Sampling of video Signals: Required sampling rates, sampling in two dimensions and three dimensions, progressive virus interlaced scans		
6	**Title**	**Motion Estimation**	2,3	**04**
	6.1	Optical Flow: Motion Vs optical flow, optical flow equations, motion representation, motion estimation criteria, optimization method.		
	6.2	Pixel based motion estimation, Block Matching Algorithms, Multi resolution Motion Estimation: General formulation.		
7	**Self-Study**	Study of different format of image and video, Basics of image and video terminology, ITU-RBT 601, Digital Video formats, Digital video quality measure.		
			Total	**28**

Laboratory:

Sr. No	**Title of the Experiment**
1.	Image Enhancement
2.	Image Transformations.
3.	Image Filtering
4.	Image Segmentations
5.	Image Compression
6.	Image Restoration
7.	Object Detection in video
8.	Motion Estimation on video
9.	Color Image Segmentation
10.	Discrete Wavelet Transforms on image

Textbook

Sr. No	Title	Edition	Authors	Publisher	Year
1	Computer Vision and applications-A GuideforStudents andPractitioners	First	Bernd Jahne and Host HauBecker	Elsevier	--
2	Digital Image and Video Processing	First	Dhananjay Theckedath	Pearson Education	2019

Reference Books

Sr. No	Title	Edition	Authors	Publisher	Year
1	Digital Image Processing	Third	Rafael C. Gonzalez and Richard E. Woods	Pearson Education	2010
2	Digital Video Processing	Second	Murat Tekalp	Pearson Education	2010
3	Handbook on Image and Video Processing	---	A.I.Bovik	Academic Press	2009

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Course (Category) Code	Course Name	Teaching Scheme (Hrs/week)					Credits Assigned			
		L	T	P	O	E	L	T	P	Total
PE-IV	Space Communication Technologies	3	0	0	3	6	3	0	0	3
		Examination Scheme								
		Component		ISE(%)		MSE(%)		ESE(%)		Total
EC414 (2T14)		Theory		20		20		60		100
		Laboratory		-		-		-		-

Pre-requisite Course Codes, if any.	Electromagnetics, FOA
Course Objective: To provide an in-depth understanding of satellite communication system operation, launching techniques, satellite link design earth station technology and applications.	
Course Outcomes (CO): ***At the End of the course students will be able to***	
EC414 .1	Explain and examine fundamental concepts of frequency allocations, Kepler's laws, satellite different orbits with emphasize on geostationary orbit.
EC414.2	Evaluate different types of losses in satellite communications
EC414.3	Analyze effects of losses on the carrier-to-noise ratio for the uplink, downlink, the combined link and received power at the earth stations.
EC414.4	Analyze different satellite access performance metrics and characteristics with and apply it to some satellite network applications
EC414.5	Evaluate, design and develop new satellite communication products, protocols, and services.
EC414.6	Critically analyze current limitations and future challenges in satellite communications and its applications

CO-PO Correlation Matrix (3-Strong, 2-Moderate, 1-Weak Correlation)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
EC414.1	3	1	2									
EC414.2	1	1	2									
EC414.3	1	1	2									
EC414.4	1	1	2									
EC414.5	1	1	2		2				2			
EC414.6	1	1	2									1

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CO-PEO/PSO Correlation Matrix (3-Strong, 2-Moderate, 1-Weak Correlation)

	PEO1	PEO2	PEO3	PEO4	PSO1	PSO2	PSO3
EC414 .1		1					
EC414.2		2					
EC414.3		2					
EC414.4		2					
EC414.5		2					
EC414.6		2					

BLOOM'S Levels Targeted (Pl. Tick appropriate)

Remember	Understand		✓ Apply	✓ Analyze	✓ Evaluate	Create

Module No.	Unit No.	Topics	Ref.	Hrs.
1	Title	**Satellite Orbits**		08
	1.1	Introduction, Basic definitions, Kepler's Laws, Orbital Parameters, Orbits in Common Use: Geostationary Orbit, Low Earth Orbit, Medium Earth Orbit, Highly Elliptical Orbit and Polar Orbit.		
	1.2	Geometry of GSO Links: Range to Satellite, Elevation Angle to Satellite, Azimuth Angle to Satellite, Sample Calculation.		
2	Title	**Satellite Subsystems & Earth Segment**		08
	2.1	Satellite Bus : Physical Structure, Power Subsystem, Attitude Control , Orbital Control, Thermal Control, Tracking, Telemetry, Command, and Monitoring		
	2.2	Satellite Payload: Transponder and Antennas		
	2.3	Earth Segment: Design consideration, General configuration- Block diagram, receive only type earth, transmit-receive type earth station, Antenna system, Feed system, Tracking system, LNA, HPA.		
3	Title	**Satellite Link and Performance**	6,7	10
	3.1	Transmission Fundamentals: Effective Isotropic Radiated Power, Power Flux Density, Antenna Gain, Free-Space Path Loss, Basic Link Equation for Received Power.		
	3.2	System Noise: Noise Figure, Noise Temperature, System Noise Temperature, Figure of Merit		

	3.3	Link Performance Parameters: Carrier-to-Noise Ratio, Carrier-to-Noise Density, Energy-Per-Bit to Noise Density		
	3.4	Link Considerations: Fixed Antenna Size Link, Fixed Antenna Gain Link, Fixed Antenna Gain, Fixed Antenna Size Link , Uplink, Downlink.		
4	**Title**	**Space Transmission Impairments**	1,4	**06**
	4.1	Radio wave Frequency and Space Communication, Radio wave Propagation Mechanisms, Propagation Below About 3 GHz , Ionospheric Scintillation, Polarization Rotation, Group Delay, Dispersion, Propagation Above About 3 GHz, Rain Attenuation, Gaseous Attenuation, Cloud and Fog Attenuation, Depolarization, Tropospheric Scintillation		
	4.2	Radio Noise, Specification of Radio Noise, Noise from Atmospheric Gases, Sky Noise due to Rain, Sky Noise due to Clouds, Noise from Extra-Terrestrial Sources.		
	4.3	Rain Fade Mitigation		
5	**Title**	**Satellite Multiple Access**	1,2	**08**
	5.1	Frequency Division Multiple Access (PCM/TDM/PSK/FDMA PCM/SCPC/PSK/FDMA)		
	5.2	Time Division Multiple Access: PCM/TDM/PSK/TDMA, TDMA Frame Efficiency, TDMA Capacity, Satellite Switched TDMA		
	5.3	Code Division Multiple Access: Direct Sequence Spread Spectrum , Frequency Hopping Spread Spectrum, CDMA Processing Gain, CDMA Capacity.		
	5.4	Application to satellite Network applications		
6	**Self-Study**	**Applications**: VSAT systems: Advantages, configurations, frequency bands, elements, Broadcast services: Television broadcast systems, DAB, Mobile satellite communication: INMARSAT, LMSS, mobile satellite systems with non-GEO satellites, Satellite navigation systems, Laser Recent applications, Modern development and future trends.		
			Total	**42**

Textbooks

Sr. No	**Title**	**Edition**	**Authors**	**Publisher**	**Year**
1	Satellite Communications Systems Engineering Atmospheric Effects,	1st	Louis J. Ippolito, Jr	Wiley	**2008**

	Satellite Link Design and System Performance				
2	Satellite Communications	4th	Dennis Roddy	McGraw-Hill	2006

Reference Books

Sr. No	Title	Edition	Authors	Publisher	Year
1	Satellite Communication Systems Design Principles	2nd	M. Richharia	Macmillan Press Ltd.	2003
2	Satellite Communication	4th	Gerard Maral and Michel Bousquet	Wiley	2001

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Course (Category) Code	Course Name	Teaching Scheme (Hrs/week)					Credits Assigned			
		L	T	P	O	E	L	T	P	Total
PE- IV	Principles of Soft Computing	2	0	2	6	8	2	0	1	3
		Examination Scheme								
		Component	ISE (%)		MSE (%)		ESE(%)			Total
EC424 (2T24)		Theory	20		20		60			100
		Laboratory	50		--		50			100

Pre-requisite Course Codes, if any.	MA101: Engineering Calculus MA102: Differential Equations and Complex Analysis
Course Objective: To implement soft computing-based solutions for solving real-world problems	
Course Outcomes (CO): ***At the end of the course students will be able to***	
EC424.1	Identify soft computing techniques and their roles in building intelligent Machines.
EC424.2	Apply fuzzy logic reasoning to build model for solving various engineering problems.
EC424.3	Analyze optimization issues using Genetic Algorithm.
EC424.4	Design various hybrid soft computing models by using different techniques .

CO-PO Correlation Matrix (3-Strong, 2-Moderate, 1-Weak Correlation)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
EC424.1	2	2			3							
EC424.2		2	2		3							
EC424.3			2		3							
EC424.4				2	3							

CO-PEO/PSO Correlation Matrix (3-Strong, 2-Moderate, 1-Weak Correlation)

	PEO1	PEO2	PEO3	PSO1	PSO2	PSO3
EC424.1	2			2	2	
EC424.2	2			2	2	
EC424.3	2				2	
EC424.4		3			2	3

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BLOOM'S Levels Targeted (Pl. Tick appropriate)

Remember	Understand	✓ Apply	✓ Analyze	✓ Evaluate	Create

Theory Component

Module No.	Unit No.	Topics	Ref.	Hrs.
1	Title	**Introduction To Soft Computing and Neural Networks**	1,2	**04**
	1.1	Introduction to Soft Computing, Difference between Hard and Soft Computing. Conventional AI, Computational Intelligence		
2	Title	**Neural Networks**	1,2	**10**
	2.1	Biological neuron, Artificial Neuron Model, Single layer Multilayer Architecture of Neural Networks Architecture, Activation functions, Learning rules.		
	2.2	Supervised Learning Neural Network: Back Propagation Network, Radial Basis Function Network.		
	2.3	Unsupervised Learning Neural Network: Adaptive Resonance Architecture.		
3	Title	**Fuzzy Logic**	3	**6**
	3.1	Fuzzy Sets, Operations on Fuzzy Sets, Fuzzy Relations		
	3.2	Membership Functions, Fuzzy Rules and Fuzzy Reasoning		
	3.3	Fuzzy Inference Systems, Fuzzy Models.		
4	Title	**Genetic Algorithm**	3	**8**
	4.1	Introduction to Genetic Algorithm, Working Principle of Genetic Algorithm.		
	4.2	Various Encoding methods, Fitness function.		
5	Self-Study	Analyse advanced soft computing techniques.		
			Total	**28**

Laboratory Component

Sr. No	Title of the Experiment
1	Linear & Nonlinear analysis using single & multiplayer neural network
2	Supervised learning neural network
3	Unsupervised learning neural network
4	Fuzzy logic operations

5	Fuzzy system design
6	Genetic Algorithm
7	Design Neuro-fuzzy model
8	Hybrid Design/Expert system Design

Text Books

Sr. No	Title	Edition	Authors	Publisher	Year
1	Introduction to Artificial Neural Systems	--	Jacek M. Zurada	PWS Publishing Company	1995
2	Principles of Soft Computing	Third	S.N.Sivanandam and S.N.Deepa	Wiley Publication,	2018
3	Neural Networks, Fuzzy Logic and Genetic Algorithms	--	S.Rajasekaran and G. A. Vijayalakshami	Prentice-Hall of India	2004

Reference Books

Sr. No	Title	Edition	Authors	Publisher	Year
1	Neural Networks: A Comprehensive Foundation	--	Simon Haykin	Macmillan College Publishing Company	1994
2	Neural Network Design	--	Martin Hagan	CENGAGE Learning, India	2008
3	Fuzzy Sets and Fuzzy Logic: Theory and Applications	--	George J. Klir and Bo Yuan	Prentice-Hall of India	1994

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Course (Category) Code	Course Name	Teaching Scheme (Hrs/week)					Credits Assigned			
		L	T	P	O	E	L	T	P	Total
PE-III	Semiconductor Technologies	2	0	2	6	8	2	0	1	3
		Examination Scheme								
		Component		ISE (%)		MSE(%)		ESE (%)		Total
EC433 (3T33)		Theory		20		20		60		100
		Laboratory		50		--		50		100

Pre-requisite Course Codes		AS101: Engineering Physics ET202: Electronic Devices EC205: Analog Circuits EC101: Digital Systems and Microprocessors T31: Digital CMOS VLSI Design
After successful completion of the course, student will be able to		
Course Outcomes	CO1	Discuss integrated circuit fabrication processes and use modern/open-source tools for process simulation.
	CO2	Apply the sequence of fabrication processes and design rules for layout design and characterization of a given semiconductor device/MOS circuit.
	CO3	Discuss fundamental principles of MEMS devices including physical operation and mathematical modeling.
	CO4	Apply various fabrication processes, choose suitable materials for MEMS device FEM modeling, fabrication and characterization.
	CO5	Illustrate fundamental principles and fabrication process steps for semiconductor memories and displays.

Module No.	Unit No.	Topics	Ref.	Hrs.
1		**Environment and Crystal Growth for VLSI Technology**		04
	1.1	**Environment**: Semiconductor technology trend, clean rooms	1,3	
	1.2	**Semiconductor Substrate:** Phase diagram and solid solubility, Crystal structure, Crystal defects, Czochralski growth, Bridgman growth of GaAs, Float Zone growth, Wafer Preparation and specifications.	1,3	
2		**Fabrication Processes Part 1**		06
	2.1	**Cleaning of Silicon wafer, Deposition:** Evaporation, Sputtering and Chemical Vapor Deposition.	1,3	
	2.2	**Epitaxy:** Molecular Beam Epitaxy, Vapor Phase Epitaxy, Liquid Phase Epitaxy, Evaluation of epitaxial layers	1,3	

	2.3	**Silicon Oxidation:** Thermal oxidation process, Kinetics of growth, Properties of Silicon Dioxide, Oxide Quality, high κ and low κ dielectrics.	1,3	
	2.4	**Diffusion:** Nature of diffusion, Diffusion in a concentration gradient, diffusion equation, impurity behavior, diffusion systems, problems in diffusion, evaluation of diffused layers.	1,3	
	2,5	**Ion Implantation**: Penetration range, ion implantation systems, process considerations, implantation damage and annealing.	1,3	
3		**Fabrication Processes Part 2**		**06**
	3.1	**Etching:** Wet chemical etching, dry physical etching, dry chemical	1,3	
	3.2	**Lithography:** Photoreactive materials, Pattern generation and mask making, pattern transfer, Electron beam, Ion beam and X-ray lithography.	1,3	
	3.3	Device Isolation, Contacts and Metallization: Junction and oxide isolation, LOCOS, trench isolation, Schottky contacts, Ohmic contacts, Metallization and Packaging: Integrated circuit packages, Electronics package reliability	2	
	3.4	**CMOS Process Flow:** N well, P-well and Twin tub	2	
	3.5	Design rules, Layout of MOS based circuits (gates and combinational logic), Buried and Butting Contact.	2	
4		**Introduction to MEMS, MEMS Materials Properties, Fabrication and Characterization**		**08**
	4.1	Introduction to MEMS Technology, Difference between ICT & MEMS Technology, Difference between ICs and MEMS Devices and Real world Sensors/Actuators examples with brief description, Bulk, Surface & LIGA Micromachining, Die, Wire & Wafer Bonding, Dicing, Packaging	3	
	4.2	Architecture, working and basic quantitative behaviour of MEMS devices like Cantilever, Microheaters, Accelerometers, and Pressure Sensors	3	
	4.2	Materials (eg. Si, SiO2, SiN, SU8, PMMA); Important properties: Young modulus, Poisson's ratio, density, piezoresistive coefficients, TCR, Thermal Conductivity, Material Structure.	3	
		Understanding steps involved and materials used in Fabricating MEMS Cantilevers, and its Characterization for stiffness and Resonant frequency	3	
5		**Semiconductor Memories and Display**		**04**
	5.1	Memory: SRAM, DRAM, MRAM, Flash: Working Principle, structures and fabrication steps of one/two memory structures	4	
	5.2	Display: AMOLED/OLED: Working Principle, structures, fabrication steps	5	
			Total	**28**

ISE Evaluation:

1) **Fault identification and correction of a given CMOS circuit Layout: Group Activity within Laboratory Batch [Evaluation during laboratory session. CO3-CO4. (5 Marks)**
2) **Case Study of MEMS device fabrication and characterization: Group Activity within Laboratory Batch [Evaluation during laboratory session. CO3-CO4. (5 Marks)**
3) **Visit to CEN Lab, IIT Bombay and Report on visit (CO1-CO5) (10 Marks)**

Text Books:

Sr. No.	Title	Edition	Authors	Publishers	Year
1	Silicon VLSI Technology	Indian Edition, First	James D. Plummer, Michael D. Deal and Peter B. Griffin	Pearson	2000
2	Fundamentals of Semiconductor Fabrication	First	G. S. May and S. M. Sze	Wiley	2011
3	Micro Electro Mechanical System Design	ebook	J. Allen	CRC Press	2005
4	Semiconductor Memories Technology, Testing and Reliability	-	A.K. Sharma	IEEE	2022
5	Frontiers in Electrical Engineering Vol. 1: Active-Matrix Organic Light-Emitting Display Technologies	-	Shuming Chen, Jianning Yu, Yibin Jiang, Rongsheng Chen, Tsz Kin Ho	Bentham Books	2015

Recommended Books:

Sr. No.	Title	Edition	Authors	Publishers	Year
1	The Science and Engineering of Microelectronic Fabrication	Second Edition	Stephen A. Campbell	Oxford University Press	2001
2	VLSI Fabrication Principles	Student Edition	Sorab K. Gandhi	Wiley	2008
3	An Introduction to Microelectromechanical Systems Engineering	Second	N. Maluf, K Williams	Artech House Inc	2004
4	Practical MEMS	First	Ville Kaajakari	Small Gear Publishing	2009
5	Microsystem Design	First	S. Senturia	Springer	2005
6	Fundamentals of Microfabrication	Second	M. Madou	CRC Press	2002

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Each Experiment carries 05 Marks. Any 08 Experiments covering all COs.

Rubrics: Performance (3.5M), Oral Questions based on Experiment (0.5) and Documentation (01)

Sr. No.	Topics	CO
1	**Aim:** Use nanohub platform to simulate and analyze the Oxidation process for various process parameters and wafer specifications. **Problem Statement:** Simulate the oxidation process with Deal - Groove model for different conditions (eg. Oxidation type, orientation, time, temperature, thickness etc.) and comment on the results obtained.	CO1
2	**Aim:** Use nanohub platform to simulate and analyze the diffusion process for various given conditions. **Problem Statement:** Simulate the diffusion process for various given conditions. Such as eg. Source, time, temperature, dopant etc. and comment on the results obtained.	CO1
3	**Aim:** Use Virtual Hall Effect Experimental set-up for the measurement of semiconductor material parameter measurements. **Problem Statement:** Use Hall Effect Experimental set-up available at Vlab to determine various parameters of semiconductor material like Hall's coefficient, carrier density, mobility. Compare these values with calculated values. Also study the dependence of Hall voltage on the magnetic field and the current passing through the probe.	CO1
4	**Aim:** To use Industry graded VLSI CAD tools to draw layout and analyze CMOS Inverter circuit. **Problem Statement:** Draw and simulate CMOS Inverter. Carry out static as well as transient simulation. Analyze CMOS Inverter for i) (W/L) PMOS >(W/L) NMOS ii) (W/L) PMOS = (W/L) NMOS iii) (W/L) PMOS < (W/L) NMOS . **Do parasitic extraction. Feed these parasitic in circuit simulator and do the layout versus schematic verification.**	CO2
5	**Aim:** To use Industry graded VLSI CAD tools to draw layout and analyze MOS based circuit. **Problem Statement:** a. Draw and simulate layout for the following circuits. Size them with respect to reference inverter a: CMOS NAND b: CMOS NOR c. 6T SRAM cell for high reliability and lowest area. d. A given flipflop (SR, D, T, JK). e. Half adder.	CO2

	f. Logic equation using Static CMOS, dynamic logic, transmission gate. **(Any one problem statement for a group of students)**	
5	**Aim:** To analyze MEMS cantilever in Sugar Tool using Nanohub platform. **Problem Statement:** a) Choose proper dimensions of MEMS cantilever modelled in Sugar. Choose the proper co-ordinate and node for applying a point contact load (force). Observe and tabulate the maximum displacement at free end of the cantilever for at least two different values of point contact load, verify one of the readings with given analytical expression of maximum displacement of the cantilever. Comment on the results obtained. b) Choose proper dimensions of width and thickness of MEMS cantilever modelled in Sugar. Choose proper co-ordinate and node for applying certain value of point contact load (force). Observe and tabulate the maximum displacement of the cantilever for at least two different values of point contact force applied on cantilever, verify one of the readings with given analytical expression of maximum displacement of the cantilever. Comment on the results obtained.	CO3 -CO 4
6	**Aim:** To model and analyze MEMS cantilever in COMSOL Multiphysics. **Problem Statement:** i. For the given dimensions and material create MEMS cantilever model in COMSOL and observe the dependence of resonance frequency of the cantilever on material. ii. For the cantilever model analyze dependence of fundamental resonance frequency on varying length (given range), plot the result and also compare the result with analytical expression of resonance frequency.	CO3 -CO 4
7	**Aim:** To analyze MEMS capacitive pressure sensor in COMSOL Multiphysics. **Problem Statement:** For the given dimensions, model MEMS capacitive pressure sensor in COMSOL. a) Observe, plot changes in pressure sensor diaphragm displacement and capacitance at constant temperature (room temperature) and varying applied pressure (given range) and compare it with given analytical expressions of diaphragm displacement and capacitance of sensor. b) Observe, plot the change in pressure sensor diaphragm displacement and capacitance for fixed value of applied pressure and varying temperature to analyze the effect of package stress.	CO3 -CO 4
8	**Aim:** To evaluate the static and dynamic performance of the MEMS micro-heater using FEM tool. **Problem Statement:** For the given model of the MEMS micro-heater, a) Measure the temperature of the heated membrane for the input excitation voltage and compare it with the given analytical expression. b) To plot the temperature response of heated membrane to standard test voltages like square, Ramp, and sinusoidal.	CO3 -CO 4

9	9**) Aim:** To model and analyze MEMS electrostatically actuated microcantilever in COMSOL. **Problem Statement:** For the given model of electrostatically actuated microcantilever in COMSOL. a) To plot tip displacement of the microcantilever for different values of applied voltage. b) To plot shape of the microcantilever displacement for different values of applied voltage. c) To plot capacitance of the microcantilver different values of applied voltage.	CO3 -CO 4
10	**Aim:** To model and analyze Piezoresitive Pressure Sensor in MEMS Design and Simulation FEM Tool. **Problem Statement:** i. Choose the proper substrate; define the process flow and Layout of Piezoresitive pressure sensor in MEMS Design and Simulation FEM Tool and create a its 3- D Layout. ii. Observe the change in resistance of piezoresistance for given input pressure. Compare this reading with the given analytical expression of the change in resistance of the piezoresistace.	CO3 -CO 4
11	**Aim:** To analyze the operation of semiconductor memory using NI Tool. **Problem Statement:** Using Multisim configure a word generator, observe the reading and writing of a 2-bit code on a RAM chip, and design, construct and simulate the writing and reading of a 4-bit code on a RAM chip	CO5
12	**Aim:** Develop and test low-cost self-made OLEDs. **Problem Statement:** Develop and test the low-cost standard-OLED on ITO2 glass with three individually controllable emission spots using the process steps described.	CO5

*Student has to perform any one experiment from 8, 9 and 10 as per the allotment by the faculty.

References:

[1] www.nanohub.org
[2] www.vlab.com
[3] www.microwind.com
[4] ICMT Laboratory Manual
[5] https://www.sciencedirect.com/science/article/pii/S0187893X137

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Course (Category) Code	Course Name	Teaching Scheme (Hrs/week)					Credits Assigned			
		L	T	P	O	E	L	T	P	Total
PE-III	Embedded and Digital Control of PE Systems	3	0	2	5	10	3	0	1	4
EC443 (4T43)		Examination Scheme								
		Component			ISE (%)		MSE (%)		ESE(%)	Total
		Theory			20		20		60	100
		Laboratory			50		--		50	100

Pre-requisite Course Codes, if any.	Basic Electrical Engineering
Course Objective: To study controlling aspects of major types of power electronic converters in analog and digital domain with appropriate signal conditioning and sensing circuits	
Course Outcomes (CO): ***At the End of the course students will be able to***	
EC443.1	To study role of digital hardware in modern power control
EC443.2	To study different digital signal processing hardware and their organizations
EC443.3	To study different discretization techniques
EC443.4	To master the Practical Power control techniques with digital hardware

CO-PO Correlation Matrix (3-Strong, 2-Moderate, 1-Weak Correlation)

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
EC443.1	**2**											
EC443.2	**2**	**3**										
EC443.3		**2.5**										
EC443.4		**3**	**2.5**									

CO-PEO/PSO Correlation Matrix (3-Strong, 2-Moderate, 1-Weak Correlation)

CO/PEO/PSO	PEO1	PEO2	PEO3	PEO4	PSO1	PSO2	PSO3
EC443.1	**2**	**1**					
EC443.2	**2**				**3**		
EC443.3	**2**				**2**		
EC443.4	**2**				**2**		

BLOOM'S Levels Targeted (Pl. Tick appropriate)

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Remember	Understand	Apply	Analyze	Evaluate	Create
	✓	✓	✓		

Theory Component

Module No.	Unit No.	Topics	Ref.	Hrs.
1	**Title**	**Organization of Digital Signal Processors**		
	1.1	Numbering System, Architecture, memory maps, Assemblers, cross compilers, ADCs, Analog Comparators, PWM Blocks, Communication protocols, FPGAs with Logic blocks and ARM core, Dual-core DSP for control and communication, interfacing of Voltage and Current sensing Circuits		**09**
2	**Title**	**Discrete-time implementations of Fundamental Functional Blocks**		
	2.1	Implementation of Discrete time equations (IIR and FIR), Representations with Discrete Time Structures		
	2.2	Low Pass and High-pass filters, Proportional Integral and Derivative Controller, Harmonic Oscillators, Reference frame transformations, Phase-shift and quadrature filters, Phase lock-loop, higher order digital filters, etc.		**09**
3	**Title**	**Digital Control of grid connected systems**		
	Implementation of control blocks of an Active Power Filter on DSP Platform Selected Active Power Filter Control Algorithms. DSP controllers for grid-connected three-phase voltage-sourced inverters			**09**
4	**Title**	**Digital Control of DC-to-DC Converters**		
	Closed loop discrete time control of Buck and Boost Switched Mode PWM Power Supplies and Battery Chargers with voltage and Current Mode Control. FPGA-DSP controllers for DC-DC converters in renewable energy applications			**09**
5	**Title**	**DSP Implementation of Modulators**		
		SPWM, Space Vector Modulation, Inverter Flux Control		
		Hardware in the Loop Simulation		**09**
6	***Self-Study**	Laplace transformations, z-transformations, s-z transformations, discretization techniques, control system stability in continuous and discrete time mode. SOGI		**05**
			Total Hours (*excluded)	**45**

Laboratory Component (Indicative): To be completed minimum of 4 Lab Project Assignments with Practical Implementation on Digital Platforms

LAB Project-1
Grid Connected Inverters / Active Power Filter Implementation
Lab Project-2
Closed Loop Control of DC-DC Converter / LED Drivers/SMPS control
Lab Project-3
Closed loop control of a Sine Wave Inverter with LC Filter using Inverter Flux Modulation Control
Lab Project-4
Implementation of a EV Battery Charger using CC/CV Mode of Operation

Sr. No	Title	Edition	Authors	Publisher	Year
1	Power Electronics: converters, Application and design	Third	Ned Mohan, Undeland and Robbin	John Wiley and sons	2003
2	Power Electronics Circuits, Devices and Applications	Fourth	Rashid M.H.	Pearson Education	2004
3	Discrete Time Control Systems	second edition,	K. Ogata	Pearson International	

Reference Books

Sr. No	Title	Edition	Authors	Publisher	Year
1	Simulation of Power Electronic Circuits	First	M. B. Patil, V. Ramanarayanan, V.T. Ranganathan	Narosa Publishing House	2013
2	The switching function analysis of Power Electronic Circuits	First	Christos Marouchos	IET, Devices and Circuits	2008
3	Digital Signal Processing in Power Electronics Control Circuits	Second	Krzysztof Sozański	Springer	2017
4	Control Circuits in Power Electronics Practical issues in design and implementation	First	Miguel Castilla	The Institution of Engineering and Technology	2016

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Course (Category) Code	Course Name	Teaching Scheme (Hrs/week)					Credits Assigned			
		L	T	P	O	E	L	T	P	Total
PE- III	Artificial Intelligence and Machine Learning	2	0	2	2	6	2	0	1	3
EC451 (1P)		Examination Scheme								
		Component	ISE (%)		MSE (%)		ESE(%)			Total
		Theory	20		20		60			100
		Laboratory	50		--		50			100

Pre-requisite Course Codes, if any.	MA201: Linear Algebra MA203: Probability and Stochastic Processes
Course Objective: To provide a strong foundation and basic exposition to the goals and methods of Artificial Intelligence and Machine Learning. To enable them to apply these techniques in applications which involve perception, reasoning and learning.	
Course Outcomes (CO): ***At the end of the course students will be able to***	
EC431.1	Describe the basic concepts and techniques of Machine Learning.
EC431.2	Evaluate Supervised and Unsupervised Machine Learning Algorithms based on applications.
EC431.3	Analyze the deep learning algorithms for various types of learning tasks in various domains.
EC431.4	Apply knowledge representation, reasoning, and machine learning techniques to real-world problems.

CO-PO Correlation Matrix: (1-Weak, 2-Medium 3-Strong)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO9	PO10	PO12
EC431.1		3								
EC431.2		3	2		3					
EC431.3				2	3	2	3			
EC431.4				2	3			2	3	2

CO-PEO/PSO Correlation Matrix : (1-Weak, 2-Medium 3-Strong)

	PEO1	PEO2	PEO3	PSO1	PSO2	PSO3
EC431.1	2					
EC431.2		3		3		
EC431.3			2		2	
EC431.4				3		

BLOOM'S Levels Targeted (Pl. Tick appropriate)

Remember	Understand	✓ Apply	✓ Analyze	✓ Evaluate	Create

Theory Component

Module No.	Unit No.	Topics	Ref.	Hrs.
1	Title	**Fundamental of Machine Learning and Artificial Intelligence**	1	06
	1.1	Notation of Dataset, Training Set and Test Set, No Free Lunch Rule, Relationships with Other Disciplines, Basic definitions of ML and AI, Machine Learning vs AI, Machine Learning vs Deep Learning.		
	1.2	Types of Machine Learning-Supervised, Unsupervised, Reinforcement, General Steps or Process of Machine Learning-Feature Extraction, Feature Correlation, Feature Transform, Train Model, Ensemble, Evaluate, Data cleaning, data transform/fitting.		
2	Title	**Supervised Learning**	2	07
	2.1	Regression: Linear Regression, Regularization Techniques (LASSO), Polynomial Regression, Support Vector Machine (SVM) and Regression (SVR, Extension to Multi-class Problems and usage) etc.		
	2.2	Classification, Random Forest, Decision Trees, Logistic Regression Support Vector Machines, KNN, Naïve Bayes.		
3	Title	**Unsupervised Learning and Reinforcement Learning**	1,3	06
	3.1	Clustering, K-Means, K Nearest Neighbours, Association Rule Learning, Dimensionality Reduction, PCA, SVD, tSNE		
	3.2	Markov Decision, Monte Carlo Prediction.		
4	Title	**Neural Networks/Deep Learning**	2	07
	4.1	Introduction to ANN CNN, RNN/LSTM/GRU, Transfer Learning, Case Study (CNN)		

	4.2	**Natural Language Processing:** Text Mining. Generation, Applications		
	4.3	**Predictive Analytics – Forecasting,** Logistic, Time Series (ARIMA), etc. Case Study (Time Series)		
5	**Title**	**Applications of AI and Machine Learning.**	3,6	**02**
6	**Self-Study**	Multivariate Regression, Gaussian Mixture Models, Ensemble Methods		**04**
			Total	**28**

Laboratory Component

Sr. No	Title of the Experiment
1	FIND-S algorithm used for finding the most specific hypothesis
2	Implement and demonstrate the Candidate-Elimination algorithm.
3	Write program to demonstrate the working of the decision tree based ID3 algorithm
4	Implement program for classifier
5	Implement the naïve Bayesian Classifier model to classify set of documents that you have assumed Calculate the accuracy, precision, and recall for your data set.
6	Apply EM algorithm to cluster a set of data stored. (k-Mean's algorithm)
7	Write program to implement k-Nearest Neighbor algorithm to classify the data set.
8	Implement the non-parametric Locally Weighted Regression algorithm in order to fit data points while selecting appropriate data set for your experiment and draw graphs.
9	Build an Artificial Neural Network (ANN) by implementing the Back-propagation algorithm
10	Case Study on Clustering/Anomaly/Fraud Detection

Text Books

Sr. No	Title	Edition	Authors	Publisher	Year
1	Machine Learning	--	Andriy Burkov	McGraw Hill Education	2009
2	Neural Networks and Deep Learning	-	Michael Nielsen	-	-

Reference Books

Sr. No	Title	Edition	Authors	Publisher	Year
1	Introduction to Machine Learning	Second	Ethem Alpaydın	MIT Press Cambridge, Massachusetts London, England	2010
2	Introduction to Machine Learning with Python	--	Andreas C. Muller and Sarah Guido	Oreilly Publication	---
3	Artificial Intelligence. A Modern Approach,	Third	Stuard Russell and Peter Norvig	Prentice Hall	2010
4	Pattern Recognition and Machine Learning		Christopher M. Bishop	Springer	2006

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Course (Category) Code	Course Name	Teaching Scheme (Hrs/week)					Credits Assigned			
		L	T	P	O	E	L	T	P	Total
PE-IV	Analog CMOS VLSI Design	3	--	--	5	8	3	--	--	3
		Examination Scheme								
		Component		ISE (%)		MSE (%)	ESE(%)			Total
EC434 (3T34)		Theory		20		20	60			100
		Laboratory		--		--	--			--

Pre-requisite Course Codes, if any.	ET101: Basic Electrical Engineering EC101: Digital Systems and Microprocessors ET202: Electronic Devices ET205: Analog Circuits PE-1T11: Digital CMOS VLSI Design
Course Objective:	
Course Outcomes (CO): After successful completion of the course, student will be able to	
EC434.1	Recognize trade-offs involved in analog VLSI Circuits
EC434.2	Analyze current mirrors and bandgap references
EC434.3	Analyze single stage amplifier using small signal model as well as large signal methodology
EC434.4	AnalyzeMOSFET based differential and operational amplifier

Theory Component

Module No.	Unit No.	Topics	Ref.	Hrs
1	Title	**CMOS analog building blocks**	1	08
	1.1	Necessity of CMOS analog design		
	1.2	**MOS Models:** Structure of MOSFET, Review of characteristics of MOS device, Second order effects, MOS small signal model, MOS spice models		
2	Title	**Current Mirrors and Bandgap References**	1	08
	2.1	**Passive and Active Current Mirrors:** Basic current mirrors, Cascode current mirrors and Active current mirrors		
	2.2	**Band Gap References:** General Considerations, Supply-independent biasing, Temperature independent references, PTAT current generation and Constant Gm biasing		

3	**Title**	**Single Stage Amplifiers**	1	**10**
	3.1	Basic concepts, Common source stage: resistive load, diode-connected load, current-source load, triode load and source degeneration		
	3.2	Source follower, Common gate stage, Cascode stage		
4	**Title**	**Differential Amplifiers**	1	**06**
	4.1	Single ended and differential operation, Basic differential pair, Common-mode response, Differential pair with MOS loads and Gilbert cell		
5	**Title**	**MOS Operational Amplifiers**	1,2,3	**10**
	5.1	**Op-amp:** General Considerations, performance parameters, One-stage op-amps, Two-stage op-amps, Gain Boosting, Common-mode feedback, Input range limitations, Slew Rate, Power supply rejection		
	5.2	**Stability and Frequency Compensation:** General Considerations, Multipole systems, Phase margin, Frequency compensation, compensation of two stage op-amps		
			Total	**42**

Reference Books

Sr. No.	Title	Edition	Author	Publisher	Year
01	Design of Analog CMOS Integrated Circuits	1st Edition	B Razavi	Tata McGraw Hill	
02	CMOS Circuit Design, Layout, and Simulation	Student Edition	R. Jacaob Baker, Harry W. Li, David E. Boyce	Wiley	
03	CMOS Analog Circuit Design	3rd Edition	P. E. Allen and D. R. Holberg	Oxford University Press	

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		L	T	P	O	E	L	T	P	Total
PE-IV	Selected topics in Power Electronics and Drives	3	0	0	5	10	3	0	0	3
		Examination Scheme								
		Component			ISE (%)		MSE (%)		ESE(%)	Total
EC444 (4T44)		Theory			20		20		60	100
		Laboratory			-		-		-	-

Pre-requisite Course Codes, if any.	Basic Electrical Engineering
Course Objective: To study controlling aspects of major types of power electronic converters in analog and digital domain with appropriate signal conditioning and sensing circuits	
Course Outcomes (CO): ***At the End of the course students will be able to***	
EC444.1	To introduce with the different applications of PE Converters
EC444.2	To find innovative techniques of power control at specific industrial applications
EC444.3	To get exposure to cutting edge research in power electronics through scientific journals and research papers

CO-PO Correlation Matrix (3-Strong, 2-Moderate, 1-Weak Correlation)

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
EC444.1	2											
EC444.2	2	3										
EC444.3		2.5										
EC444.1		3	2.5									

CO-PEO/PSO Correlation Matrix (3-Strong, 2-Moderate, 1-Weak Correlation)

CO/PEO/PSO	PEO1	PEO2	PEO3	PEO4	PSO1	PSO2	PSO3
EC444.1	2	1					
EC444.2	2				3		
EC444.3	2				2		
EC444.1	2				2		

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BLOOM'S Levels Targeted (Pl. Tick appropriate)

Remember	Understand ✓	Apply ✓	Analyze ✓	Evaluate	Create

The students are exposed to different applications of Power Electronics and Drives in the field of
Electronic Communications, Energy storage, Pulse Power Control, illumination, industrial heating and refrigeration, reactive power control, electric vehicles, renewable energy, wireless energy transfer, Hydrogen electroliers, distributed generations, etc.

The students are asked to refer to cutting age research from different publications and archives not limited to the following list of research journals:

IEEE Transactions in Power Electronics,
IEEE Transactions in Industrial Electronics,
IEEE Transactions in Industrial Applications,
IEEE Transactions on Vehicular Technology
IEEE Transactions on smart-grid
IET journal of Power Electronics
IEEE journal of Emerging and selected topics in Industrial Electronics, etc.

At the end of the course students are asked to submit their thesis on any one selected topics and make presentation in presence of experts in the related field.

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Course (Category) Code	Course Name	Teaching Scheme (Hrs/week)					Credits Assigned			
		L	T	P	O	E	L	T	P	Total
PE- IV	Telecom Network Operations and Management	2	0	2	2	6	2	0	1	3
		Examination Scheme								
		Component		ISE (%)		MSE (%)		ESE(%)		Total
EC454 (1Q)		Theory		20		20		60		100
		Laboratory		50		--		50		100

Pre-requisite Course Codes, if any.	EC307: Computer Communication Network
Course Objective: To develop understanding the concept of Telecommunication network management, architecture and protocol. Appreciate the need for interoperable network management. This course offers students a hands-on experience managing network hardware and essential network services such as DHCP, DNS, ARP, FTP, Telnet, HTTP, SSH, SMTP, TFTP, and SNMP through the use of scripting and python programming.	
Course Outcomes (CO): ***At the end of the course students will be able to***	
EC432.1	Identify network requirements and apply the concept of structured wiring, structured Network Design and select the best solutions to meet the needs of a business.
EC432.2	Analyze the network management standards and protocols to support FCAPS Model of Network Management.
EC432.3	Identify the functions of the Network Manager and show how management information is stored & accessed within a managed object.
EC432.4	Apply effective troubleshooting and debugging techniques to resolve the network problems.
EC432.5	Apply fundamental components of Network Management and implement server and agent architectures to monitor and control networks, devices and applications.
EC432.6	Develop programs in Python to solve real problems in Network Management.

CO-PO Correlation Matrix (3-Strong, 2-Moderate, 1-Weak Correlation)

	PO1	PO2	PO3	PO4	PO5	PO 6	PO 7	PO8	PO9	PO10	PO11	PO12

EC432.1			2	2								
EC432.2			2	2								
EC432.3					3							
EC432.4					3							
EC432.5					3							
EC432.6					3							

CO-PEO/PSO Correlation Matrix (3-Strong, 2-Moderate, 1-Weak Correlation)

	PEO1	**PEO2**	**PEO3**	**PSO1**	**PSO2**	**PSO3**
EC432.1			2			
EC432.2		2				
EC432.3			2			
EC432.4		2		3	2	
EC432.5			2		3	
EC432.6		2			2	

BLOOM'S Levels Targeted (Pl. Tick appropriate)

Remember	**Understand**	✓ **Apply**	✓ **Analyze**	✓ **Evaluate**	✓ **Create**

Theory Component

Module No.	Unit No.	Topics	Ref.	Hrs.
1	Title	**Introduction to Enterprise Network Design**	2,1,3	08
	1.1	Introducing Network Design Concepts: Medium Enterprise Design Profile (MEDP)—LAN Design, LAN design principles, LAN design model for the medium enterprise, Considerations of a multi-tier LAN design model for medium enterprises, Designing network foundation services for LAN designs in medium enterprise, Scalability, Service uptime, WAN Design, Business and network-based economy.		
	1.2	Challenges of IT managers, Network management architecture and organization network management perspectives management: Goals, organization and functions		
2	Title	**OSI Network Management**	1,2,3	02
	2.1	Network management standards, Network management models, Organization model, Information model Communication model and functional model, Abstract syntax notation – encoding structure, macros, functional model CMIP/CMISE		
3	Title	**Internet Management (SNMP)**	1,2,3	08
	3.1	SNMP-organizational model-System overview. Information model, communication model, functional model, SNMP proxy server, Management information, Protocol SNMPv1,v2 and V3, Remote monitoring. RMON, Limitations of SNMP, Beyond SNMP, NETCONF/YANG		
4	Title	**Telecommunication Management Networks (TMN)**	1,2.3	03
	4.1	Need for TMN, Conceptual TNM model, TMN Network Management Architecture, TMN management services architecture and TMN implementation		
5	Title	**Network Management Tools and Applications**	1,4,5	07
	5.1	System Utilities for network management, Network statistics and measurements, NMS Design, NMS components, NMS Server Architecture, Network Management Systems and FCAPS, Automatic Fault Management and Event correlation Techniques,		

		Security Management		
6	**Self Study**	**Broadband Network Management:** ATM Network Management and Wireless Network Management		**04**
			Total	**28**

Laboratory Component

Sr. No	Title of the Experiment
1	Network Monitoring tools: a) Status b) Route c) Traffic Tools d) Audit
2	Monitoring and management network using SNMP: a) Basic SNMP b) Advanced SNMP v3 Authentication/Encryption and ACL c) SNMP Trap Daemon Implementation
3	Configuration SNMP Protocol on Cisco Router using Packet Tracer
4	Configuration manageable Switch: L2/L3 Switch
5	LAN Troubleshooting using tcpdump and Wireshark
6	Monitoring of services and Servers using a) Observium/ Cacti b)Nagios/Icinga
7	Implementation of Centralized Logging infrastructure and security event correlation
8	Open Source SIEM Project
9	Python scripts for Network Monitoring
10	Network Management using Python

Reference Books

Sr. No	Title	Edition	Authors	Publisher	Year
1	Network Management Principles and Practice	--	Mani Subramaniam	Addison Wisely, New York	2000
2	Designing and Supporting Computer Networks, CCNA Discovery Learning Guide	--	Kenneth Stewart, Aubrey Adams, Allan Reid, Jim Lorenz	Cisco Press	---

3	Network Management: Concepts and Practice, A Hands-On Approach	--	J. Richard Burke	Pearson Publications.	--
4	Network Management: Accounting and Performance Strategies	--	Benoit Claise- CCIE No. 2686; Ralf Wolter	Cisco Press	--
5	Network Management Fundamentals	--	Alexander Clemm	Cisco Press, ISBN-13: 978-158720137	2006
6	Python for Software Design	--	Allen B. Downey	Cambridge University Press ISBN-13: 978-0521725965	2009

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Sem-VIII

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Course (Category) Code	Course Name	Teaching Scheme (Hrs/week)					Credits Assigned			
		L	T	P	O	E	L	T	P	Total
(PCC-)	Software Defined Networks	2	-	2	3	7	2	-	1	3
EC501		Examination Scheme								
		Component		ISE (%)		MSE (%)		ESE (%)		Total
		Theory		20		20		60		100
		Laboratory		80		--		20		100

Pre-requisite Course Codes, if any.	EC-: Analog and Digital Communication
Course Objective: The objective of the course is to provide a fundamental understanding of software defined networks.	
Course Outcomes (CO): ***At the end of the course students will be able to***	
EC501.1	Understand the fundamental concepts of computer networks, including networking devices, layering architectures, and the OSI model, as well as the working of IPv4 addressing schemes and the TCP/IP protocol suite.
EC501.2	Apply virtualization concepts to implement network virtual machines using hypervisors (KVM, Xen, VMware ESXi) and understand cloud infrastructure by working with different types of virtualized data centres (clouds).
EC501.3	Understand the principles of Network Function Virtualization (NFV) and Software Defined Networks (SDN) to virtualize network appliances such as firewalls, VPNs, and load balancers.
EC501.4	Analyse the benefits of Software Defined Networks (SDN) and Network Function Virtualization (NFV) in modern networking, evaluating the differences between open-source and commercial SDN controllers, and their role in virtualizing traditional data centres.

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CO-PO Correlation Matrix (3-Strong, 2-Moderate, 1-Weak Correlation)

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO8	PO9	PO10	PO12
EC501.1	3	3			3			2	3	3
EC501.2			2	2		2	2	3	3	3
EC501.3			3		3		3		3	3
EC501.4			2.5		3	2	3	3	3	3

CO-PEO/PSO Correlation Matrix (3-Strong, 2-Moderate, 1-Weak Correlation)

CO	**PEO1**	**PEO2**	**PEO3**	**PSO1**	**PSO2**	**PSO3**
EC501.1			2	2		
EC501.2		2		2		
EC501.3				3		
EC501.4	2				2	

Module No.	**Unit No.**	**Topics**	**CO**	**Ref.**	**Total Hrs.**
1	1.1 1.2	**Fundamental of Computer Networks**: Basic definitions. networking devices, layering architecture: The OSI model, description of layers, TCP/IP protocol suite. Working with IPv4 family: IP addressing schemes, subnet masks, network-id, host-id, Classful vs. classless addressing, Private and public IP addresses.	CO1	1,2	06
2	2.1 2.2	**Network Function Virtualization:** Primer on virtualization, benefits of virtual machine, Hypervisors-KVM, Xen and VMware ESXi. Virtualized Data Centre a.k.a. Clouds, types of clouds	CO2	3,4	06

3	3.1 3.2	**Network Function Virtualization (NFV)**: How to virtualize a network, use of virtualization in NFV and Software Defined Networks (SDN) Virtualization of network appliances such as firewalls, VPN's, SSL offload and load balancer.	CO3	3,4	08
4	4.1 4.2	**Modern Networking approaches to Virtualization:** Software Defined Networks: Virtualizing the traditional data centres, working of SDN, SDN and OSI model, SDN and NFV benefits. SDN Controllers: convergence in SDN, Commercial Vs Open Source Controllers, Open Daylight common framework for SDN	CO4	3,4	08
5	Self-Study	Transmission media, Network Topologies, SDN in Data Centres, SDN and Cloud Computing.			*3
				Total (*Not included)	**28**

Laboratory:

Sr. No	Title of the Experiment
[1]	Identify and observe the behaviour of networking command line tools in Ubuntu/Windows OS environment
[2]	To build and test straight through UTP ethernet network cables.
[3]	Write a program in C/C++/Python/Java/Scilab to identify the IP address, Subnet mask, DNS server address and Hardware address of the client device.
[4]	Building Networks by using Packet Tracer/GNS3
[5]	Write a program in C/C++/Python/Java/Scilab to determine the administrator's requirement to define the number of subnets, host/subnet, customized subnet masks and valid subnet ranges for a IP addressing scheme.

[6]	OSI Model Layer Analysis using Wireshark
[7]	Basic Network Configuration with VMs in VirtualBox
[8]	Setting up Virtual Machines using KVM or Xen
[9]	Building a Private Cloud using OpenStack
[10]	Virtualizing Network Appliances (Firewalls, VPNs, Load Balancers)
[11]	Use of Open Source network emulator to simulate a SDN

Text Books

Sr. No	Title	Edition	Authors	Publisher	Year
1	TCP/IP protocol suit	4th	Behrouz A. Forouzan (Author)	McGraw Hill Education	2009
2	Data Communication and Networking	5th	B. Forouzan	McGraw Hill	2017

Reference Books

Sr. No	Title	Edition	Authors	Publisher	Year
3	Foundations of Modern Networking: SDN, NFV, QoE, IoT, and Cloud	2nd s	William Stallings	Addison-Wesley ISBN: 9780134175393	2015
4	SDN and NFV Simplified	1st	Jim Doherty	Pearson Education	2016

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Course(Category) Code	Course Name	Teaching Scheme (Hrs/week)					Credits Assigned			
		L	T	P	O	E	L	T	P	Total
PC	Fundamentals of Antenna	3	-	-	6	09	3	-	-	3
		Examination Scheme								
		Component		ISE (%)		MSE (%)		ESE(%)		Total
EC306		Theory		20		20		60		100
		Laboratory		--		--		--		--

Pre-requisite Course Codes, if any.	EC304: Electromagnetic Waves
Course Objective: The objective of the course is to provide a fundamental understanding of Antennas	
Course Outcomes (CO): ***At the end of the course students will be able to***	
EC306.1	Calculate the fundamental parameters of Antenna.
EC306.2	Describe fundamental theory of antennas.
EC306.3	Select antenna based on applications.
EC306.4	Evaluate antenna based on applications.
EC306.5	Design Antenna Arrays.
EC306.6	Design antenna based on given requirements.

CO-PO Correlation Matrix (3-Strong, 2-Moderate, 1-Weak Correlation)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
EC306.1	2	3						2	2	2		
EC306.2	2	3						2	2	2		
EC306.3		2						2	2	2		
EC306.4		2		2				2	2	2		
EC306.5		2		2				2	2	2		
EC306.6	2	1						2	2	2		

CO-PEO/PSO Correlation Matrix (3-Strong, 2-Moderate, 1-Weak Correlation)

	PEO1	PEO2	PEO3	PEO4	PSO1	PSO2	PSO3
EC306.1		2				-	
EC306.2		2				2	
EC306.3		2				2	
EC306.4		2				2	
EC306.5		2				2	
EC306.6		1				1	

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BLOOM'S Levels Targeted (Pl. Tick appropriate)

Remember√	Understand√	Apply√	Analyze√	Evaluate	Create

Theory Component

Module No.	Unit No.	Topics	Ref.	Hrs.
1 (CO1)		**Fundamental Concepts:**	1	08
	1.1	Introduction, types of Antennas, Radiation mechanism, Poynting vector, Steradian concept, Power intensity		
	1.2	Antenna Parameter: Radiation pattern, Radiation power density, Radiation Intensity, Gain, Directivity, HPBW, FNBW, Beam efficiency, Bandwidth, Polarization, Input Impedance, Reflection coefficient, Return loss, VSWR, Antenna Efficiency, Effective Aperture, Communication link and Friis transmission equation.		
2 (CO2, CO3)		**Radiation from wires and loops**	1	10
	2.1	Introduction, Infinitesimal dipole: Radiation zones, Total radiated power, Radiation resistance, Directivity, Effective area, Short dipole, Finite-length dipole: Radiated power, Radiation resistance, Directivity, Effective area, Half-wave dipole and its properties, Loop antenna.		
3 (CO3, CO4)		**Aperture Antennas**	1	06
	3.1	Introduction, Field equivalence principle, Love's equivalence principle, Electrical and magnetic conductor equivalence principle, Computation of field quantities of aperture antenna, Relation between wire and aperture antennas, Horn antenna design principle.		
4 (CO5)		**Antenna Arrays**	1	10
	4.1	Introduction, Two-element array, Example problems, Pattern multiplication concept, N-element array, Uniform array, Array factor, Broad-side and end-fire arrays, Phased array, Directivity and pattern characteristic of linear uniform array, non-uniform array, Binomial array, Dolph-Chebyshev array concept, Design principle of Chebyshev array and examples, Planar arrays		
5 (CO6)		**Microstrip Antennas**		
	3.1	Introduction: Rectangular Patch, Circular Patch, Parametric study, Circularly polarized antennas, Axial Ratio, MSA suspended	1,4	08

		Configuration.		
	3.2	MSA Arrays and Feed Networks, Corporate and Series Feeds		
6 (Self Study)		**Advanced Antennas:** Reflector antenna, Dielectric Resonator antenna, Metamaterial based antennas, Wearable antenna, Reconfigurable antennas, Ultra-wideband antennas, Smart Antennas		06
			Total	**42**

Text Books:

S. N.	Title	Authors	Edition	Publisher	Year
1	Antenna Theory: Analysis and Design	Constantine A. Balanis	Fourth	Wiley	1982

Reference Books:

S. N.	Title	Authors	Edition	Publisher	Year
1	Antennas & Wave Propagation	J.D. Kraus, R.J. Marhefka, and A.S. Khan	Fourth	McGraw Hill	2011
2	Handbook of Microstrip Antennas	R. James and P.S. Hall	Third	Peter Peregrinus	1989
3	Antennas and Radio Wave Propagation	R. E. Collin	Fourth	McGraw-Hill	1985
4	Broadband Microstrip antennas	Girish Kumar and K.P. Ray	First	Artech House	2003

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Course (Category) Code	Course Name	Teaching Scheme (Hrs/week)					Credits Assigned			
		L	T	P	O	E	L	T	P	Total
PC	Computer Communication Networks	3	-	-	5	08	3	-	-	3
		Examination Scheme								
		Component	ISE (%)		MSE (%)		ESE(%)			Total
EC307		Theory	20		20		60			100
		Laboratory	--		--		--			--

Pre-requisite Course Codes, if any.	EC301: Analog and Digital Communication
Course Objective: The objective of the course is to provide a fundamental understanding of ComputerCommunication networks.	
Course Outcomes (CO): ***At the end of the course students will be able to***	
EC307.1	Apply Conceptual understanding and functional aspects of computer communication and telecom networks.
EC307.2	Analyze design and configure small and medium sized computer network that meets a specific need for communications.
EC307.3	Simulate computer networks and analyze the simulation results including troubleshoot connectivity problem occurring at layers of TCP/IP model.
EC307.4	Apply the principles behind the Modern Network approaches such as SDN NFV and IoT and security issues.

CO-PO Correlation Matrix: (1-Weak, 2-Medium, 3-Strong)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
EC307.1	3	3										
EC307.2			3	2	3							2
EC307.3			3		3	2						
EC307.4	2	2							3	3		3

CO-PEO/PSO Correlation Matrix : **(1-Weak, 2-Medium 3-Strong)**

	PEO1	PEO2	PEO3	PSO1	PSO2	PSO3
EC307.1		2				
EC307.2		2		3		
EC307.3		2			3	
EC307.4		2				

BLOOM'S Levels Targeted (Pl. Tick appropriate)

Remember	Understand	Apply	Analyze	Evaluate	Create

Theory Component

Module No.	Unit No.	Topics	Ref.	Hrs.
1	**Title**	**Fundamental of Computer Networks**	1	08
	1.1	Basic definitions. Networking devices. Layering architecture: The OSI model. Description of layers.		
	1.2	The Internet protocols TCP/IP protocol suit, IP Protocol and address. What is the Internet? Delay in the Internet (trace route and ping). History of the Internet. Security in the Internet.		
2	**Title**	**Enterprise Network Design**	2	06
	2.1	Network requirements, Planning and Design, Structured Wiring and Structured Network Design consist of Core Layer, Distribution Layer, and Access.		
	2.2	Network Design methodology &Network Design considerations Core La yer Technologies. Investigating Server Farms and Security Integrating, Remote Sites into the Network Design.		
3	**Title**	**Transport and Application Layer**	1,3	06
	3.1	Transport Protocols introduction. Reliable data transfer - Stop-and-wait and Go-back-N design and evaluation. TCP and UDP semantics and syntax. TCP RTT estimation. Principles of congestion control - efficiency and fairness, reactive and proactive. Socket's programming A simple client-server implementation.		
	3.2	Application layer: Application layer protocols, Client-server as a key model. Web, HTTP, FTP, SMTP, POP3, and DNS. Peer-to-peer file sharing networks.		

4	**Title**	**Software Defined Network and Network Function Visualization**	5	10
	4.1	Network Requirements - The SDN Approach - SDN- and NFV-Related Standards - SDN Data Plane - OpenFlow Logical Network Device - OpenFlow Protocol - SDN Control Plane Architecture - REST API - SDN Application Plane Architecture.		
	4.2	NFV Concepts - NFV Reference Architecture - NFV Infrastructure - Virtualized Network Functions - NFV Management and Orchestration - NFV Use Cases - SDN and NFV		
5	**Title**	**Internet of Things (IoT) SECURITY**	1,3	10
	5.1	Threats and attacks. Symmetric and public key cryptography. IPsec-Authentication Header-Encapsulating security payload,		
	5.2	Secure sockets-Secure Socket Layer (SSL) - Firewalls and Internet access- Packet filter firewall- Proxy firewall- VPNs – Mobile IP – Header Compression – Voice over IP –		
	Title	**Networks**		5
6	Self-Study	Types of Networks, Transmission media, Network Topologies		
Total				**42**

Textbooks

Sr. No	Title	Edition	Authors	Publisher	Year
1	TCP/IP protocol suit	Fourth	Behrouz A. Forouzan (Author)	McGraw Hill Education	2009
2	Introducing Network Design Concepts	-	CCNA Discovery Learning Guide	-	-
3	Computer Networking: A Top-Down Approach	Fifth	J. F. Kurose and K. W. Ross	Prentice Hall	2009
4	Data Communication and Networking	Fourth	B.A.Forouzan	McGraw Hill	2017
5	Information Security: Principles and Practice	First	Deven Shah	Wiley	2007

Reference Books

Sr. No	Title	Edition	Authors	Publisher	Year
1	Foundations of Modern Networking: SDN, NFV, QoE, IoT, and Cloud	--	William Stallings	Addison-Wesley ISBN: 9780134175393	2015
2	Computer Networks	Fifth	A.Tanenbaum	Pearson Education	2013
3	Data and Computer Communications	Tenth	William Stallings	Pearson Education	2013

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PROGRAM ELECTIVE COURSES

- 4 Electives are sufficient to specialize in a particular vertical/thread/area.
-

TD/ PE	PE1	PE2	PE3	PE4	PE5	PE6
THREAD 1: **Communication**	**T11:** Information Theory & Coding	**T12:** Optical Fiber Communication	**T13:** Microwave Communication	**T14:** Space Communication Technologies	T11, T12, T21, T22, T31, T32, T41, T42, X, Y P, Q	T11, T12, T21, T22, T31, T32, T41, T42, X, Y P, Q
THREAD 2: **Signal Processing**	**T21:** Speech and Audio Processing	**T22**: Wavelet Transform	**T23:** Image & Video Processing	**T24:** Principles Soft Computing		
THREAD 3: **VLSI & Embedded Systems**	**T31:** Digital CMOS VLSI Design	**T32:** Real Time Embedded Systems	**T33:** Semiconductor Technologies	**T34:** Mixed VLSI Design		
THREAD 4: **Power Electronics and Energy Systems**	**T41:** Control of Power Electronics Converters	**T42:** Electric Motor Drive Systems	**T43:** Embedded & Digital Control of PE Systems	**T44:** Selected topic in Power Electronics & Drives		
GENERAL	**X:** Computer Communication Network (Cat2) T11, T12, T21, T22, T31, T32, T41, T42	**Y:** Fundamentals of Antenna (Cat2) T11, T12, T21, T22, T31, T32, T41, T42	**P:** Artificial Intelligence & Machine Learning T13, T14 T23, T24 T33, T34 T43, T44	**Q:** Telecomm Network Operations & Management T13, T14 T23, T24 T33, T34 T43, T44		