Curriculum for M.Tech. in
Signal Processing & Communication Engineering (SPCE)
[Effective from A.Y. 2023-24]

Semester I

Subject Name	Code	L-T-P	Credit	Contact Hours
Advanced Communication Engineering	EC6L001	3-1-0	4	4
Applied Probability and Linear Algebra	EC6Lxxx	3-1-0	4	4
Modern Digital Signal Processing	EC6L004	3-1-0	4	4
Elective I		3-0-0/3-1-0	3/4	3/4
Elective II		3-0-0/3-1-0	3/4	3/4
Advanced Communication Engineering Laboratory	EC6P001	0-0-3	2	3
Seminar I	EC6S001	0-0-3	2	3
Total			**22/24**	**24/26**

Semester II

Subject Name	Code	L-T-P	Credit	Contact Hours
Wireless and Mobile Communication	EC6L020	3-0-0	3	3
Statistical Signal Processing	EC6L005	3-0-0	3	3
Elective III		3-0-0/3-1-0	3/4	3/4
Elective IV		3-0-0/3-1-0	3/4	3/4
Elective V		3-0-0/3-1-0	3/4	3/4
Design and Simulation Lab	EC6P002	0-0-3	2	3
Modern Digital Signal Processing Lab	EC6P003	0-0-3	2	3
Seminar II	EC6S002	0-0-3	2	2
Total			**21/24**	**23/24**

Semester III

Subject Name	Code	L-T-P	Credit	Contact Hours
Thesis Part I	EC6D001	0-0-0	16	16
Research Review Paper I	EC6D002	0-0-0	4	4
Total			**20**	**20**

Semester IV

Subject Name	Code	L-T-P	Credit	Contact Hours
Thesis Part II	EC6D003	0-0-0	16	16
Research Review Paper II	EC6D004	0-0-0	4	4
Total			**20**	**20**

Total credits: 83/88

List of Electives

Electives I and II				
Course Name		**Code**	**LTP**	**Credits**
Basket-1: Communication systems	Optical Communication	EC6L012	3-0-0	3
	Antenna Theory	EC6L013	3-0-0	3
	EMI and EMC Techniques	EC6L009	3-0-0	3
	Remote Sensing Systems	EC6L011	3-0-0	3
	Microwave Design and Measurement	EC6L021	3-0-0	3
	Information Theory and Coding	EC6L003	3-1-0	4
Basket-2: Networking	Communication Networks	EC6L010	3-0-0	3
	Sensor Networks	EC6L032	3-0-0	3
Basket-3: Signal Processing	Speech Signal Processing	EC6L028	3-0-0	3
	Array Signal Processing	EC6L024	3-0-0	3
	Pattern Recognition	EC6L027	3-0-0	3
Basket-4: VLSI	Advanced Digital System Design	EC6L033	3-1-0	4
	Neuromorphic VLSI Hardware	EC6L056	3-0-0	3
	Semiconductor Device Modelling	EC6L017	3-0-0	3
	Analog CMOS VLSI Design	EC6L052	3-1-0	4
	Digital Integrated Circuit Design	EC6L053	3-1-0	4
Basket-5: Interdisciplinary	Design and Analysis of Algorithms	EC6L006	3-0-0	3
	Mathematical Methods	MA6LXXX	3-1-0	4
	Machine Learning and Data Analytics-I	ID6L004	3-0-0	3
	Computational Intelligence	CS6L001	3-0-0	3
Electives III—V				
Basket-1: Communication systems	Satellite Communication	EC6L018	3-0-0	3
	Computational Electromagnetics	EC6L016	3-0-0	3
	Modern Radar System	EC6L022	3-0-0	3
	Fiber Optic Sensors	EC6L019	3-0-0	3
	Advanced Coding Theory	EC6LXXX	3-0-0	3
Basket-2: Networking	Computer Networks	EC6L026	3-0-0	3
	Photonic Network	EC6L014	3-0-0	3
	Multimedia Network	EC6L025	3-0-0	3
	Networks and Systems Security	CS6L002	3-0-0	3
Basket-3: Signal Processing	Adaptive Signal Processing	EC6L023	3-0-0	3
	Biomedical Signal Processing	EC6L015	3-0-0	3
	Image and Video Processing	EC6L002	3-1-0	4
	Computer Vision	EC6L031	3-0-0	3

Basket-4: VLSI	Embedded Systems	EC6L030	3-0-0	3
	VLSI Signal Processing	EC6L007	3-0-0	3
	IC Design for Wireless Communications	EC6L039	3-0-0	3
	CAD for VLSI Design	EC6L054	3-0-0	3
	VLSI Testing	EC6L055	3-0-0	3
	Mixed Signal VLSI Design	EC6L057	3-0-0	3
	System-on-Chip Solutions & Architectures Design	EC6L058	3-0-0	3
	VLSI Physical Design	EC6L059	3-0-0	3
	Parallel Systems	EC6L060	3-0-0	3
	Architectural Design of VLSI Systems	EC6L061	3-0-0	3
Basket-5: Interdisciplinary	Advanced Techniques in Operation Research	MA7L002	3-1-0	4
	Machine Learning and Data Analytics-II	ID6L005	3-0-0	3
	Smart Grid Technology	EE6L014	3-0-0	3

Scheme for Choosing Electives:

1. A student is not allowed to take more than one course from a particular basket in a given semester (out of all the baskets offered in that semester).
2. For example, in Semester I, for Electives I and II a student can take courses from two different baskets (out of all the baskets offered in that semester), but a maximum of one course only from each basket.
3. For example, in Semester II, for Electives III, IV, and V, a student can take courses from three different baskets (out of all the baskets offered in that semester), but a maximum of one course only from each basket.

Syllabus

Core Courses

Course Code: EC6L001 **L-T-P: 3-1-0**	**Advanced Communication Engineering**

Introduction: Elements of Digital Communication System, Bandpass and Lowpass Signal Representation, Signal Space Representation of Waveforms, Gram Schmidt Orthogonalization. Digital Modulation Schemes: Memoryless modulation schemes (PAM, ASK, PSK, FSK, Hadamard Signaling, Bi-orthogonal Signaling, Simplex Signaling), Memory modulation schemes (NRZI, CPFSK, CPM, DPSK, Trellis Diagram, State Diagrams, Phase Trajectories), Power Spectrum of Digitally Modulated Signals. Optimal Receivers for AWGN Channels, Performance Analysis for Coherent and Noncoherent Communication Systems, Pairwise Error Probability and Union Bound, Viterbi Algorithm for Receiver Design for Memory Modulation Scheme. Carrier and Symbol Synchronization, Digital Communication Through Band-Limited Channels, Signal Design for Band-Limited Channels, Optimum Receiver for Channels with lSI and AWGN, Linear Equalization, Decision-Feedback Equalization, Introduction to Adaptive Equalization, Introduction to Information Theory.

Prerequisites: None

Text Books:

1. Masoud Salehi, John G. Proakis, "Fundamentals of Communication Systems", 5th Edition, McGraw Hill, 2008.

Reference Books:

2. H. Taub, D.L. Schilling and G. Saha, “Principles of communication”, 3rd Edition, Tata McGraw Hill Publishers, 2008.
3. B.P. Lathi, Zhi Ding, “Modern Digital and Analog Communication Systems”, 4th Edition, Oxford University Press, 2009.

Course Code: EC6Lxxx **L-T-P: 3-1-0**	**Applied Probability and Linear Algebra**

Vector spaces, linear independence, bases, dimension, rank, matrices, basis transformations, rank nullity theorem. Norm and its properties, inner product and properties, Gram Schmidt orthogonalization, Cauchy Schwarz inequality, direct sum of vector spaces, projection matrices, least square solutions.
Eigenvalues, eigen vectors, diagonalization of matrices, hermitian matrices, eigenvalue decomposition, positive semidefinite matrices, singular value decomposition and its applications, pseudo inverse, Markov matrices.
Matrix decompositions and its applications: LU, QR decomposition, Cholesky decomposition, Schur decomposition.
Discrete random variables (Bernoulli, binomial, Poisson, geometric, negative binomial, etc.) and their properties like PDF, CDF, MGF. Applications of discrete random variables to communications systems.
Continuous random variables: Gaussian, multivariate Gaussian; whitening of the Gaussian random vector; complex Gaussian random vector, circularity; Rayleigh and Rician; exponential; chi-squared; gamma. Applications of continuous random variables in communications systems. Stochastic convergence, law of large numbers, central limit theorem. Random processes: stationarity; mean, correlation, and covariance functions, WSS random process; autocorrelation and cross-correlation functions; transmission of a random process through a linear filter; power spectral density; white random process; introduction to Markov chains and Markov processes, recurrence of Markov chains, invariant distribution of Markov chains.

Prerequisite: None

Text Books:

1. "Probability and Random Processes", by G. R. Grimmett and D. R. Stirzaker, Oxford University Press, 3rd edition, 2001. ISBN: 9780198572220.
2. "Probability - Random Variables and Stochastic Processes", by Athanasios Papoulis and S Pillai, McGraw Hill Education, 4th edition, 2017. ISBN-13: 978-0070486584.
3. "Probability and Stochastics", by E. Çinlar, Springer, 2011. ISBN: 9780387878584.
4. "Probability with Martingales", by D. Williams, Cambridge University Press, 1991. ISBN: 9780521406055.
5. "Matrix Analysis" by R. A. Horn and C. R. Johnson, Cambridge University Press, 2nd edition, 2013. ISBN: 9780521548236
6. "Linear Algebra and its Application", by Gilbert Strang, Harcourth Brace Jovanovich Pubs, 3rd edition, 1998. ISBN-13: 9789812438607.

Reference Books:

1. "Introduction to Probability", by D. P. Bertsekas and J. N. Tsitsiklis, Athena Scientific, 2nd edition, 2008. ISBN: 9781886529236.
2. "Probability and Measure", by P. Billingsley, Wiley, 3rd edition, 1995. ISBN: 9780471007104.
3. "Probability: Theory and Examples", by R. Durrett, Duxbury Press, 3rd edition, 2004, ISBN: 9789534424411.
4. "Linear Algebra", by K. Huffman and R. Kunze, Pearson Education Ltd., 2nd Edition, ISBN-139789332550070

Course Code: EC6L004 **L-T-P: 3-1-0**	**Modern Digital Signal Processing**

Review of fundamentals of digital signal processing: DFT and FFT, digital filter structure, FIR and IIR filter design and realization.
Multi-rate digital signal processing: decimation, interpolation, sampling rate conversion, digital filter banks, two-channel quadrature mirror filter bank, M-channel QMF bank.
Linear prediction and optimum linear filters: forward and backward linear prediction, normal equations, AR lattice and ARMA lattice-ladder filters, Wiener filters
Power spectrum estimation: nonparametric and parametric methods, filter bank methods, Eigen analysis algorithms
Time-frequency analysis: uncertainty principle, Short-time Fourier transform, Wigner distribution, Kernel design, Gabor wavelets, multi-resolution analysis

Prerequisite: None

Text/Reference Books:

1. Digital Signal Processing: Principles, Algorithms and Applications, Proakis and Manolakis, 4th edition, Pearson, 2012
2. Time-frequency analysis, Cohen, Prentice-Hall, 1995
3. Advanced digital signal processing, Vaseghi, 4th edition, Wiley, 2008
4. Multi-rate systems and filter banks, Vaidyanathan, Pearson, 1992

Course Code: EC6L005 **L-T-P: 3-0-0**	**Statistical Signal Processing**

Review of Probability and Stochastic Process Estimation Theory: Minimum-variance unbiased estimator (MVUE), Cramer-Rao Lower bound, Best Linear Unbiased Estimator, Maximum likelihood Estimator, General Bayesian Estimator.
Detection Theory: Neyman Pearson Theorem, Receiver Operating Characteristics, Matched Filters, Composite Hypothesis Testing.
Nonparametric Spectral Estimation: Estimation of power spectrum of stationary random signal using periodogram-various methods, Joint signal analysis and estimation of cross power spectrum Linear Signal Model: Synthesis of coloring filter and Analysis of whitening filter, Rational power spectra (AR, MA, ARMA), Relationship between filter parameters and autocorrelation sequences, Lattice-Ladder filter realization.
Parametric Spectral Estimation: Order selection criterion of AR model , Minimum-variance, Maximum entropy and Maximum likelihood spectrum estimation Harmonic models and frequency estimation techniques Harmonic Decomposition, MUSIC algorithm, ESPRIT algorithm
Linear Optimum Filter: Optimum FIR Filter, PCA of optimum linear estimator and its frequency domain interpretation, Forward and Backward Linear prediction and optimum reflection coefficients Optimum causal and non-causal IIR Filters, Deconvolution and Signal restoration Algorithms and Structure of Optimum Linear Filters Levinson Recursion for optimum estimate, Order-recursive algorithms for optimum FIR filters and its lattice structures.

Prerequisite: None

Texts Books:

1. Steven Kay, *Fundamentals of Statistical Signal Processing*, Vol I: Estimation Theory, Vol II: Detection Theory, Prentice Hall, 1993/1998.

Reference Books:

1. Harry L. Van Trees, *Detection, Estimation, and Modulation Theory*, Part I, Wiley-Inter science, 2001
2. Monson H. Hayes, *Statistical Digital Signal Processing and Modeling*, John Wiley, 1996.

Course Code: EC6L020 **L-T-P: 3-0-0**	**Wireless and Mobile Communication**

Wireless Channels, Fading Wireless Channel Modeling, Delay Spread, Doppler Spread, Coherence Time, Coherence Bandwidth, Jakes Model, Frequency flat, Frequency selective, Slow Fading, and Fast Fading Channels.
Statistical Modeling of Fading Channels (Rayleigh, Rician, Nakagami-m), BER Performance in SISO Wireless Systems Fading, Receive Diversity Combining Techniques (MRC, SC, EGC), BER Performance Analysis with diversity for SIMO Systems. Introduction to Transmit Diversity (MISO) Systems, Passive Beamforming, Alamouti Coding, Orthogonal and Semi-orthogonal Space Time Block Codes (STBCs), Water Filling Algorithm, Performance Analysis of MISO Systems with STBCs, Introduction to MIMO, MIMO Channel Capacity, SVD and Eigenmodes of the MIMO Channel, MIMO Spatial Multiplexing – VBLAST. Introduction to Multicarrier Modulation, OFDM, Cyclic Prefix, OFDM Issues, Introduction to OTFS. Introduction to Cellular Communications, Orthogonal Multiple Access Techniques (FDMA, TDMA, CDMA, SDMA), Non-orthogonal Multiple Access Techniques (Code-Domain and Power-Domain NOMA, SOMA, RSMA).

Prerequisite: None

Text Books/ Reference Books:

1. Fundamentals of Wireless Communications, David Tse and Pramod Viswanath, Cambridge University Press, 2005.
2. Wireless Communications, Andrea Goldsmith, Cambridge University Press, 2005.
3. Wireless Communications: Principles and Practice, Theodore Rappaport, Prentice Hall, Second Edition.

Course Code: EC6P001 **L-T-P: 0-0-3**	**Advanced Communication Engineering Laboratory**
Simulation and measurements of Dipole Antenna; Design, fabrication and measurements of Microstrip Patch Antenna; Simulation and Performance analysis of Analog and Digital Systems (Matlab and Simulink); Identification and Demodulation of FM signals using USRP, Transmission and Reception of signals using WARP Lab, CC3200 SimpleLink WI-Fi For IoT	

Course Code: EC6P002 **L-T-P: 0-0-3**	**Design and Simulation Lab**
Familiarization with software simulation tools including MATLAB, NS2, HFSS, Labview; Design of communication systems using link-budget analysis, real-time implementation using SDR boards; Filter design and simulation using software tools; Simulation of signal detection algorithms; Simulation of Wiener filter, LMS, RLS, Kalman filter	

Course Code: EC6P003 **L-T-P: 0-0-3**	**Modern Digital Signal Processing Lab**
Review: DFT, FFT, FIR and IIR filter design; Facial Recognition using optimal tradeoff filter (OTF) & minimum average correlation energy (MACE) filter; facial recognition & object tracking in video using minimum output sum of squared error (MOSSE) filter; facial recognition using principal component analysis (PCA) and kernel principal Component analysis (KPCA); audio denoising using PCA and KPCA; power spectrum estimation using WELCH and multiple signal classification (MUSIC) methods; optical character recognition using PaddleOCR	

Course Code: EC6S001 **L-T-P: 0-0-3**	**Seminar I**
The objective of this course is to hone the skills of scientific and technical presentation and writing, with focus on (1) the contents and organization of technical documents and their styles of presentation, following the internationally accepted standards, and (2) oral presentation skills.	

Course Code: EC6S002 **L-T-P: 0-0-3**	**Seminar II**
The objective of this course is to hone the skills of scientific and technical presentation and writing, with focus on (1) the contents and organization of technical documents and their styles of presentation, following the internationally accepted standards, and (2) oral presentation skills.	

Electives

Course Code: CS6L001 **L-T-P: 3-0-0**	**Computational Intelligence**
Soft Computing: Artificial Neural Network: Artificial neuron, single layer and multilayer architecture, nonlinear function like sigmoid function, back propagation learning algorithm. Functional link artificial neural network, trigonometric, Chebyshev and Legendre polynomial. Readial basis function neural network, its learning algorithm, recurrent neural network and its learning algorithm. Fuzzy Logic: Types of fuzzy logic, membership functions, fuzzification and defuzzification, rule-based fuzzy inference engine, Type-1 and Type-2 fuzzy logic, typical applications. Evolutionary Computing and Swarm Intelligence: Derivative based and derivative free optimization, multivariable and multiconstraint optimization. Genetic algorithm and its variants, Differential evolution and its variants, particle swarm optimization and its variants, Cat swarm optimization, bacterial foraging optimization, Artificial immune system, multiobjective optimization like NSGA-II. **Prerequisite:** None	
Texts/References: 1. S. Haykin, *'Neural Networks and Learning Machines'*, Prentice Hall, 2009. 2. Y.H. Pao, *'Adaptive pattern recognition and neural networks'*, Addison-Wesley, 1989. 3. Jang, J.S.R., Sun, C.T. and Mizutani, E., *'Neuro-fuzzy and Soft Computing: A Computational Approach to Learning and Machine Intelligence'*, Prentice Hall, 2009. 4. Hagan, M., *'Neural Network Design'*, Nelson Candad, 2008. 5. K.A.D. Jong, *'Evolutionary Computation – A Unified Approach'*, PHI Learning, 2009. 6. (Research publications that will be suggested during the course.)	

Course Code: EC6L002 **L-T-P: 3-1-0**	**Image and Video Processing**
Introduction to digital image processing, intensity transformation, spatial filtering, frequency domain filtering, point and line detection, edge detection, Hough Transform, image restoration, color processing, thresholding, image segmentation, affine transformation, image transforms, multi-resolution image analysis, shape and texture representation and description, introduction to object recognition, image compression, JPEG, introduction to digital video, video compression standards, motion estimation. **Prerequisite:** None	
Text Books/ Reference Books: 1. Digital Image processing, Gonzalez and Woods, 3rd edition, Pearson and Prentice Hall, 2009 2. W.K. Pratt: Digital image processing, 4th edition, Wiley India, 2007. 3. K.R. Castleman: Digital image processing, 2nd edition, Pearson, 2012. 4. A.K. Jain: Fundamentals of digital image processing, Prentice Hall, 1989.	

Course Code: EC6L003 **L-T-P: 3-0-0**	**Information Theory and Coding**
Introduction: entropy and mutual information theory: joint entropy, conditional entropy, relationship between entropy and mutual information, chain rules for entropy, relative entropy, mutual information, jensen's inequality fano's inequality. An introduction to codes: coding: kraft inequality, optimal codes, bounds on optimal code length, kraft	

inequality for uniquely decodable codes, shannon and huffman codes, shannon, fano, elias codes, block codes, linear block codes, cyclic codes
Efficient encoding, information sources; average code word length; huffman encoding; noiseless coding: the noiseless coding theorem
Channel capacity: discrete memoryless channels and capacity, examples of channel capacity, symmetric channels, properties of channel capacity, channel coding theorem
Theory and practice of error-control coding: trellis diagram and the viterbi algorithm, convolution coding in mobile communications and modern graph-based codes (turbo-codes and ldpc codes), the main coding theory problem.

Prerequisite: None

Text Books/ Reference Books:

1. T. M. Cover and J. A. Thomas, Elements of Information Theory, 2nd ed. Wiley-Interscience, 2006. ISBN-13: 978-0471241959.
2. S. Lin and D. J. Costello, Error Control Coding, 2nd ed. Pearson Prentice Hall, 2004, ISBN-13: 978-0130426727.

Reference Books:

1. R. G. Gallager, Information Theory and Reliable Communication. Wiley, 1968, ISBN-13: 978-0471290483
2. I Csiszar and J. Korner, Information Theory: Coding Theorems for Discrete Memoryless Sys-tems. Akademiai Kiado, December 1981, ISBN-13: 978-9630574402.
3. T. S. Han, Information-Spectrum Methods in Information Theory. Springer, 2002, ISBN-13: 978-3642078125.
4. Andre Neubauer, Jurgen Freedenberg, Volker Kuhn, “Coding theory Algorithm, Architectures and Applications”,Willey India Editions, ISBN: 978-81-265-3432-6, 2007
5. Ranjan Bose, “Information theory, Coding and Cryptography”, TMH publication, ISBN: 978-0-07-0669017, 2008
6. Roman, Steven, “Introduction to Coding and Information Theory”, Springer, ISBN 978-0-387-94704-4
7. Journal readings

Course Code: EC6L006 **L-T-P: 3-0-0**	**Design and Analysis of Algorithms**

Introduction: Order notations, induction, floor and ceiling functions, pigeon-hole principle, recurrence relations; Algorithm design techniques: Greedy algorithms, divide-and-conquer algorithms, dynamic programming, amortization, optimal algorithms; Algorithms on arrays: Selection and median-finding, counting, radix and bucket sorts, string matching (Rabin-Karp and Knuth-Morris-Pratt algorithms); Geometric algorithms: Convex hulls, sweep paradigm, Voronoidiagrams; Algorithms on graphs: Traversal, topological sort, minimum spanning trees, shortest path, network flow; NP-completeness: Classes P and NP, reduction, NP-completeness, examples of NP-complete problems; Approximation algorithms: PTAS and FPTAS, examples; Randomized algorithms: Monte Carlo and Las Vegas algorithms, examples.

Prerequisite: None

Texts/References Books:

1. T. H.Cormen, C. E.Lieserson, R. L.Rivest and C. Stein, *"Introduction to Algorithms"*, 3rd Ed., PHI, 2010.
2. J. Kleinberg and É. Tardos, *"Algorithm Design"*, Pearson, 2012.
3. M. T. Goodrich and R.Tamassia, "Algorithm Design: Foundations, Analysis, and Internet Examples", Second Edition, Wiley, 2006.
4. R.Motwani and P. Raghavan, *"Randomized* Algorithms", MHE, 2010.
5. V.V. Vazirani, *"Approximation Algorithms",* Springer, 2010.

Course Code: EC6L010 **L-T-P: 3-0-0**	**Communication Network**

Transmission Fundamentals, Protocols and the TCP/IP Suite. An Overview/History of Wireless Systems, Tele traffic Engineering, Radio Propagation and Propagation Path Loss Models, An Overview of Digital Communication and Transmission, Fundamentals of Cellular Communications, Multiple Access Techniques, Speech Coding and Channel Coding, Modulation Schemes, Antennas Diversity and Link Analysis, Spread Spectrum SS and CDMA Systems, Mobility Management in Wireless Networks, Security in Wireless Systems, Mobile Network and Transport Layer, Wide Area Wireless Networks WANs ,GSM Evolution, Wide Area Wireless Networks , CDMA One Evolution, Planning and Design of Wide Area Wireless Networks, Wireless Personal Area Network Bluetooth, Wireless Local Area Networks , Fourth Generation Systems and New Wireless Technologies,

Prerequisites: None

Texts/References Books:

1. William Stallings "*Wireless Communications and Networks*", Prentice Hall, second edition, 2005
2. Vijay Garg, Morgan Kaufmann *"Wireless Communications & Networking",* June 2007
3. Theodore Rappaport, *"Wireless Communications: Principles and Practice"*, Prentice Hall, Second Edition.

Course Code: EC6L009 **L-T-P: 3-0-0**	**EMI and EMC Techniques**

Basic Concepts: Definition of EMI and EMC, Classification of EMI/EMC, Sources of EMI, EMI coupling modes, ESD Phenomena and effects, Transient phenomena and suppression, EMC requirements for electronic systems, Non-ideal Behaviors of Components.
EMI Measurements: Basic principles of EMI measurements, EMI measuring instruments.
EMI Control Methods: Conducted and radiated emissions and susceptibility, Crosstalk and shielding, Grounding, Bonding, Filtering, EMI gasket, Isolation transformer, opto isolator.
EMC Standard And Regulations: National and Intentional standardizing organizations, Frequency assignment, Spectrum conversation.
EMC Design And Interconnection Techniques: Cable routing and connection, Component selection and mounting, PCB design (Trace routing, Impedance control, decoupling, Zoning and grounding).
EMC analysis and detection techniques: Using tools for signal integrity analysis, Study eye diagrams for communication systems.

Prerequisites: None

Text Books:

1. Clayton R.Paul, *Introduction to Electromagnetic compatibility*, Wiley & Sons, 1992.

Reference Books:

1. Kenneth L. Kaiser, *Electromagnetic Compatibility Handbook*, CRC Press, 1st edition, 2004.
2. Mark I. Montrose, *Printed Circuit Board Design Techniques for EMC Compliance: A Handbook for Designers (IEEE Press Series on Electronics Technology)*, Wiley-IEEE Press, 2nd edition, 2000.

Course Code: EC6L011 **L-T-P: 3-0-0**	**Remote Sensing Systems**

Electromagnetics basis: Electromagnetic waves, Polarization, Spectra and Fourier transform, Doppler effect, Angular distribution of radiation, Thermal radiation, diffraction
Interactions of electromagnetic radiation: Propagation through homogeneous materials, Reflection and emission from real materials, Propagation through the atmosphere Molecular absorption and scattering, Radiative transfer equation.
Electro optical remote sensing system: Spectral Imagery, VIR imaging systems, Thermal infrared imagers.
Passive Microwave Systems: Antenna Theory, Microwave Radiometry
.Ranging Systems: Laser profiling, Radar altimetry.
Scattering Systems: Lidar, Microwave Scatterometry, Synthetic Aperture Radar.
Data Processing: Image Processing, Classification and Segmentation.
Applications of Remote Sensing Systems

Prerequisites: None

Text Books:

1. W. G. Rees, *Physical Principles of Remote Sensing*, Cambridge University Press; 3rd edition, 2013.

Reference Books:

1. *Remote Sensing from Air And Space* by R. C. Olsen, SPIE Press, 2007.
2. James B. Campbell, Randolph H. Wynne, *Introduction to Remote Sensing*, 5th Edition, The Guilford Press, 2011.

Course Code: EC6L012 **L-T-P: 3-0-0**	**Optical Communication**

Introduction: overview of optical fiber communications, optical spectral bands, fundamental of data communication concepts, network information rate.
Optical fibers: introduction to the optical fibres: evolution of optical fibres, itu-t standards g652, g655, optical fibres cables, measurements on optical links: the otdr principles.
Optical sources: light-emitting diodes, power–current characteristics, led spectrum, semiconductor lasers, optical gain, feedback and laser threshold, laser structures. Distributed feedback lasers, coupled-cavity semiconductor lasers, tunable semiconductor lasers, laser characteristics, reliability considerations.
Optical detection: photo detectors, optical receivers, detector responsivity, rise time and bandwidth, common photo detectors, *p–i–n* photodiodes, avalanche photodiodes, receiver design, receiver noise, coherent receiver, noise mechanisms, receiver sensitivity, bit-error rate, minimum received power, quantum limit of photo detection, intensity noise, timing jitter, receiver performance.
Digital: point-to-point links, power penalties, error control, intensity modulation, coherent modulation,

wavelength multiplexing (wdm) techniques, components for wdm, optical amplifier and optical filters for wdm links.
Optical networks: network concept, network topology, sonet/sdh, components for optical networks: characteristics and evolution trends- oadm (optical add and drop multiplexers)- oxc (optical cross connecters)- wavelength converters (w-c)

Prerequisites: None

Text Books:

1. G. P. Agrawal, *Fiber-Optic Communication Systems*, Third Ed., John Wiley & Sons, Inc., 2002
2. G. Keiser, *Optical Fiber Communications*, McGraw-Hill, 2000

Reference Books:

1. J. Senior, *Optical Fiber Communications. Principle and Practice*, Prentice Hall
2. J.P. Laude, *DWDM Fundamentals, Components and Applications*, Ed. Artech House, 2002.
3. R. Ramaswami Optical Networks. A Practical Perspective, Morgan Kaufmann Publishers, Inc. ITU-T Recommendations
4. R. L. Freeman, Fiber-Optic Systems for Telecommunications, John Wiley & Sons, Inc., 2002
5. Eugene Hecht , Optics, 4th Edition, (Addison-Wesley)
6. Djafar K. Mynbaev and Lowell L. Scheiner, Fiber-Optic Communications Technology, (Prentice-Hall)
7. Joseph C. Palais , Fiber Optic Communications, 4th Edition, (Prentice Hall)
8. Selvarajan and Kar, “Optical Fiber Communications”, Tata McGraw-Hill Education, 2003.

Course Code: EC6L013 **L-T-P: 3-0-0**	**Antenna Theory**

Introduction, Definitions, EM radiation, Friis and Radar Equations. Basic antenna elements (Dipole, Monopole, Loop). Antenna arrays (Linear and End-fire arrays) and Pattern synthesis. Complex Wire Antennas (Helical, Spiral, LPDA, Turnstile). Aperture antennas. Broadband and Ultra-wideband Antennas
Antennas in Communication Link Budgets. Introduction to Computational Methods (including Integral Equations, Method of Moments). Novel Antenna Concepts and Emerging Trends (e.g. Metamaterial Antennas, Fractal Antennas, Reconfigurable Antennas, Nanoantennas)

Prerequisites: None

Text Books:

1. C.A. Balanis, *Antenna Theory Analysis and Design*, 3rd edition, John Whiley & Sons, 2005.

Reference Books:

1. *Antenna Theory and Design*, revised Ed., by Robert S. Elliott, Willey-Interstice & IEEE Press, 2003.
2. *Antenna Theory and Design*, 2nd Ed., by Warren L. Stutzman, and Gary A. Thiele, John Wiley, 1997.
3. *Microwave Antenna Theory and Design*, by Samuel Silver, M.I.T. Radiation Laboratory Series.

Course Code: EC6L032 **L-T-P: 3-0-0**	**Sensor Networks**

Introduction: Overview, Broad application areas of WSN, Speciality and constrains;
Hardware and software: Overview of hardware architecture of the sensor motes, Types of operating systems for WSN, TinyOS and Contiki, Basic programming in TinyOS, Concepts of protothreads, Basic programming in Contiki, Network stack overview;
MAC layer issues: Types of MAC protocols for WSN, Contention-based and reservation based protocols. Detailed study of specific protocols such as SMAC, RMAC, TMAC, DW-MAC, DMAC, Aloha, CSMA-CA, BMAC, LPL, LPP, AMAC, TICER, RICER, RC-MAC, ZMAC, Y-MAC etc.;
Network layer issues: Routing, classification of the protocols, specific protocols such as SPIN, LEACH etc. Transport layer issues: TCP/IP for WSN and other related issues, Study of specific transport layer protocols. Application layer protocols: Data collection, Data dissemination, Data aggregation, Time synchronization. Standard based protocols: IEEE 802.15.4. Case Studies: one case study related to IOT

Prerequisite: Programming and Data Structures

Text Books:

1. Holger Karl, Andreas Willig, Protocols and Architectures for Wireless Sensor Network, John Wiley & Sons, 2005, ISBN 0470095105

Reference Books:

1. Ibrahiem M. M. El Emary, S. Ramakrishnan, Wireless Sensor Networks: From Theory to Applications, CRC Press, 2013, ISBN 9781466518100.
2. Ian F. Akyildiz, Mehmet Can Vuran, Wireless Sensor Networks, John Wiley & Sons, 2010, ISBN 9780470036013.
3. J Zheng, and A Jamalipour. Wireless sensor networks: a networking perspective, John Wiley & Sons, 2009, ISBN 9780470167632.
4. Anna Hac, Wireless Sensor Network Designs, John Wiley & Sons, 2003, ISBN 0470867361.
5. A. Bellamour and M. I. Elmasri, Low-power VLSI CMOS Circuit Design, Kluwer Academic Press, 1995.
6. Kaushik Roy and Sharat C. Prasad, Low-power CMOS VLSI Design, Wiley-Interscience, 2000

Course Code: EC6L033 **L-T-P: 3-1-0**	**Advanced Digital System Design**

Advanced topics in combinational and sequential design: Use of CAD, design methodologies, system decomposition, arithmetic modules, and design of complex sequential systems. Introduction to FPGA architectures: Overview, programming technologies, configurable logic block, FPGA routing architectures. Logic design with Verilog: Introduction to Verilog, logic design with behavioral models of combinational and sequential logic, synthesis of combinational and sequential logic, design and synthesis of data path controllers, programmable logic and storage devices, algorithms and architectures for digital processors, architectures for arithmetic processors, coding for FPGAs. Designing with FPGAs: Design flow for FPGAs, prototyping with FPGAs, and debugging. (Utilize commercial FPGA development tools for compilation, simulation, synthesis, implementation, and debugging).

Prerequisite: Digital Electronics

Text Books:

1. Advanced Digital Design with the Verilog HDL (2nd Edition 2017) by Michael D.Ciletti. ISBN: 9789332584464, Publisher: Pearson.
2. Advanced FPGA Design: Architecture, Implementation, and Optimization by Steve Kilts. ISBN: 9780470054376, Publishers: Wiley, 2007
3. Verilog HDL (2nd Edition) by Samir Palnitkar. ISBN: 9788177589184, Publisher:Pearson, 2003.
4. Field-Programmable Gate Arrays: Reconfigurable Logic for Rapid Prototyping and Implementation of Digital Systems by Richard C. Dorf, John V. Oldfield. ISBN: 9788126516612, Publisher: Wiley, 2008.
5. Digital System Design with FPGA: Implementation Using Verilog and VHDL by Cem Unsalan, Bora Tar, ISBN: 9781259837906, McGrawHill Publications.
6. Designing with Xilinx FPGAs using Vivado, Editor, Sanjay Churiwala, Springer 2016.

Reference Books:

1. Verilog: Frequently Asked Questions: Language, Applications, and Extensions by Shivakumar S. Chonnad, Needamangalam B. Balachander. ISBN: 978-0387228341, Publisher: Springer, 2007.
2. Advanced Digital Logic Design: Using VHDL, State Machines, and Synthesis for FPGAs by Sunggu Lee. ISBN: 978-0534466022, Nelson Engineering, 2005.
3. Programming FPGAs-Getting Started with Verilog by Simon Monk, ISBN: 978- 1259643767, McGrawHill Publications. ISBN: 978-0982497098, LBE Books.
4. Digital Design Using Digilent FPGA Boards: Verilog / Vivado Edition by Richard EHaskell, Darrin M Hanna
5. Zynq-7000 SoC, Technical Reference Manual, https://www.xilinx.com/products/silicondevices/soc/zynq-7000.html
6. ZedBoard, https://www.xilinx.com/products/boards-and-kits/1-8dyf-11.html

Course Code: MA6LXXX **L-T-P: 3-0-0**	**Mathematical Methods**

Probability and Statistics : Random variables (rv) and their properties, some standard discrete and continuous rv, Expectation, Variance, moments, moment generating functions,
functions of a rv, their distribution and moments, joint, marginal and conditional distribution and independence of rvs, Hypothesis testing.
Numerical solutions of systems of linear equations: Gauss elimination, LU decomposition, Gauss-Jacobi and Gauss-Seidel methods.
Numerical methods of ODE and PDE: Runge-Kutta and finite difference methods for ODE, Finite difference methods for solving 2-D Laplace's equation, Poisson's equation, 1-D heat equation : Bender Schmidt, Crank Nicholson method and Du Fort Frankel methods, 1-D wave equation using Explicit method. Consistency and stability analysis.

Prerequisites: None

Text Books:

1. B.S. Grawel, Numerical Methods
2. M.K. Jain, S.R.K. Iyengar and R.K. Jain, Numerical Methods-problem and solutions, Wiley Eastern Limited, 2001.
3. S. Ross, Introduction to Probability Models, Wiley India
4. A.M. Gun, M.K. Gupta and B.S. Gupta, Fundamentals of Statistics

Reference Books:

1. A.J. Hayter, Probability and Statistics, Duxbury, 2002
2. J.B. Scarborough, Numerical mathematical analysis, oxford & IBH Publishing Co.Pvt.,2000
3. R.W. Hamming, Numerical Methods for Scientist and Engineers, McGraw Hill, 1998
4. J.H. Mathews and K.D. Fink, Numerical Methods using MATLAB, Pearson Education, 2004.

Course Code: EC6L014 **L-T-P: 3-0-0**	**Photonic Network**

Introduction to photonics networks, bandwidth management, internet growth, topology, osi reference model, photonic system technologies and issues, tdm and wdm multiplexing and demultiplexing. Routing. Wavelength blocking and conversion.
Photonic network topologies and architectures, modulation and demodulation techniques, modulation related effects & nonlinear optical effects, photonic components, signal amplification and regeneration, link budget, network technologies and issues.
Photonic network components: multiplexer/demultiplexer, switches/routers, cross connectors-converter.
Network protocols: ip, g-ethernet, sdh/sonet, fddi, atm, etc.
System performance and management, dispersion management, ber & sources of noise, power budgets; optical switching & routing, network safety, regulations & standards, current issues of photonic systems.

Prerequisite: Optical Communication

Text Books:

1. Giancarlo Prati "Photonic Networks: Advances in Optical Communications" Springer Verlag, 1997
2. R Ramaswami and K.N.Sivarajan, "Optical networks: A practical perspective 2nd ed", Morgan Kaufman, ISBN 1-55860-655-6
3. U Black, "Optical Networks: Third Generation Transport Systems", Prentice Hall
4. Roberto Sabella, Paolo Lugli, "High speed optical communications", Kluwer, IEEE Journals

Course Code: EC6L015 **L-T-P: 3-0-0**	**Bio-Medical Signal Processing**

EEG and ECG signals: Genesis, monitoring, measurement and uses. Time and frequency domain analysis of signals: Morphological studies, correlation, spectral analysis. Linear prediction technique: AR model and its implementation, inverse filter. Homomorphic processing: generalized superposition, complex cepstrum, minimum phase component. Nonlinear dynamics and chaos: fractal dimension, correlation dimension, Lyapunovexponent. Artifacts: Types, detection and minimization. Applications to biomedical signals.

Prerequisite: None

Text Books:

1. E. N. Bruce, 'Biomedical Signal Processing And Signal Modeling', Wiley, 2009
2. R. M. Rangayyam, 'Biomedical Signal Analysis – A Case-Study Approach', Wiley, 2009.

Course Code: EC6L016 **L-T-P: 3-0-0**	**Computational Electromagnetics**

Applications of electromagnetics in the 21st century. Numerical Methods: ODE solvers, Euler, Runge-Kutta. Review of Basic Electromagnetics: Electrostatics, Magnetostatics, Wave Equations. Numerical Techniques: Method of Moements, Finite Difference Method, Finite Element method, Charge Simulation Method, Monte carlo method. Time Varying Electromagnetic Fiels: Eddy currents & skin depth, introduction to wavelets, families of wavelets. Microwaves, Optics, Micromagnetics, Bio-electromagnetics. Tutorials and demonstration on PC, programming assignments.

Prerequisite: None

Text Books:

1. Numerical Techniques in Electromagnetic, 2nd edition, M.N.O. sadiku, CRC Press.
2. Weber, E., Electromagnetic Fields, Dover 1951

3. Silvester, P. P. and Ferrari, R. L., Finite Elements for Electrical Engineers, Cambridge University Press 1996.
4. Numerical Methods in Engineering with Python, Jaan Kiusalaas, Cambridge.

Course Code: EC6L017 **L-T-P: 3-0-0**	**Semiconductor Device Modeling**

Review of semiconductor physics: Quantum foundation, Carrier scattering, high field effects; P- N junction diode modeling: Static model, Large signal model and SPICE models; BJT modeling: Ebers - Moll, Static, large-signal, small- signal models. Gummel - Poon model. Temperature and area effects. Power BJT model, SPICE models, Limitations of GP model; Advanced Bipolar models: VBIC, HICUM and MEXTARM;MOS Transistors: LEVEL 1, LEVEL 2 ,LEVEL 3, BSIM, HISIMVEKV Models, Threshold voltage modeling, Punchthrough, Carrier velocity modeling, Short channel effects, Channel-length modulation, Barrier lowering, Hot carrier effects, Mobility modeling, Model parameters; Analytical and Numerical modeling of BJT and MOS transistors; Types of models for Heterojunction Bipolar Transistors, Compact modeling concepts, Modeling of HBTs, HBT noise models, Measurement and parameter extraction.

Prerequisite: None

Text Books:

1. G. Massobrio, P. Antognetti, Semiconductor Device Modeling with SPICE, 2nd edition, McGraw-Hill, New York,1993.
2. M Rudolph, Introduction to Modeling HBTs, Artech House, Boston, 2006

Reference books:

1. S M Sze, K K Ng, Physics of Semiconductor Devices, 3rd edition, John Wiley, New Jersey, 2007.
2. G. A. Armstrong, C.K.Maiti, Technology Computer Aided Design for Si, SiGe and GaAs Integrated Circuits ,IET Series, London, 2007.

Course Code: EC6L021 **L-T-P: 3-0-0**	**Microwave Design and Measurement**

This course will be an introduction to microwave circuit design and analysis techniques, with particular emphasis on applications for modern microwave communication and sensing systems. Also, it will cover fundamental measurement techniques for device and circuit characterization at microwave frequencies The specific content of the course may be as follows:
Review of electromagnetics: Maxwell's equations, plane wave solutions.
Types of transmission lines and their properties: coaxial lines, rectangular waveguides, Microstrip.
Network analysis: scattering matrix, transmission matrix formulations.
Matching networks: lumped element designs and limitations, single and double-stub tuned designs, Quarter-wavelength transformers, multisection matching transformers.
Active microwave circuit design: characteristics of microwave transistors, mixers and detectors, Oscillators.
Amplifier design: LNA and Power amplifiers, gain and stability, design for noise figure. Single-stage amplifier design.
Noise in microwave circuits: dynamic range and noise sources, equivalent noise temperature, system noise figure considerations.

Prerequisite: None

Text Book:

1. David M. Pozar, *Microwave Engineering*, 3rd. ed., John Wiley & Sons, 2005.

Reference Books:

1. Guillermo Gonzalez, Microwave Transistor Amplifiers, 2nd. ed., Prentice-Hall, 1997.
2. Thomas H. Lee, Planar Microwave Engineering: A Practical Guide to Theory, Measurement, and Circuits, 1st Edition, Cambridge University Press, 2004.

Course Code: EC6L018 **L-T-P: 3-0-0**	**Satellite Communication**

Introduction, general overview, types of satellite communications systems, historical developments
Link budgets: antennas, propagation, noise, c0/n0, c/n calculation, transmitters, propagation and rain, receivers, lnas, figure of merit, total system performance.
Orbital mechanics: basic equations, special orbits, geometry and movement , constellations, real world effects
Rf and licensing issues : spectrum allocations, modulation, multiplexing, multiple access
Current and future trends
Spectrum sharing, additional noise issues, interference and coordination, telemetry and tracking, power limitations, reliability

Prerequisite: None

Text Books:

1. Principles of Communications Satellites, by G. Gordon and W. Morgan
2. Don I Dalgleish “An Introduction to Satellite Communications”: IET Publisher
3. Dennis Roddy, “Satellite Communication,” ,Tata McGraw-Hill Education

Course Code: EC6L019 **L-T-P: 3-0-0**	**Fibre Optic Sensors**

Optical fiber sensors and devices: overview of fibre optic sensors – advantages over conventional sensors, broadband classification, light sources, spatial light modulator, detection process in the fourier domain, system performance parameter
Introduction: intensity modulated optical fibre sensors, intensity modulation through light interruption shutter, multimode fibre optic sensors – reflective fibre optic sensors, evanescent wave fibre sensors, microbend optical fibre sensors, fibre optic refractometers, intensity modulated fibre optic thermometers, distributed sensing with fibre optics.
interferometric optical fibre sensors: introduction, basic principles of interferometric optical fibre sensors, components and applications of interferometric sensors.
Fibre optic sensor multiplexing: introduction, general topological configuration, and incoherent and coherent detection.
signal processing in monomode fibre optic sensor systems: introduction, transduction mechanisms, optical signal processing, electronic processing, industrial applications of fiber optic sensors, fiber optic smart structures and their applications.

Prerequisite: None

Text/Reference Books:

1. Optical Fiber Communications – Gerd Keiser, 4th Ed. McGraw Hill.
2. Fundamentals of Fibre Optics in Telecommunication and Sensor Systems – Bishnu P PAL Wiley Eastern Ltd. (1994).
3. David A. Krohn, "Fiber Optic Sensors: Fundamentals and Applications, Isa, 2000
4. Andreas Othonos, Kyriacos Kalli "Fiber Bragg gratings: fundamentals and applications in telecommunications and sensing", Artech House, 1999,
5. Francis T.S. Yu, Shizhuo Yin "Fiber Optic Sensors", Second Edition CRC Press, CRC Press, 2002
6. IEEE Sensors Journal

Course Code: EC6L023 **L-T-P: 3-0-0**	**Adaptive Signal Processing**

Introduction to adaptive filters, optimal estimation, linear estimation: normal equation, orthogonality principle, linear models. Constrained linear estimation: minimum variance unbiased estimation, steepest descent algorithms, stochastic gradient algorithms: LMS algorithm, normalized LMS algorithm, RLS algorithm. Steady-state performance of adaptive filters, transient performance of adaptive filters, block adaptive filters, the least-squares criterion, recursive least-squares, lattice filters

Prerequisite: None

Text Book:

1. *Fundamentals of adaptive filtering*, A. H. Sayed, Wiley, 2003
2. *Adaptive filter theory*, Simon Haykin, Fourth edition, Pearson, 2012
3. *Adaptive Signal Processing*, Widrow and Stearns, Pearson, 2007

Course Code: EC6L025 **L-T-P: 3-0-0**	**Multimedia Network**

Introduction: multimedia information representation – text, images, audio, video, digital coding techniques and standards, audio coding, image coding, video coding

Multimedia compression and resiliency, codecs, adaptive coding, error handling techniques, multimedia network services and applications.

Wireless broadband, broadcast tv and video streaming, qos, media transport protocols, session initiation protocol (sip), real-time streaming protocol (rtsp), real-time transport protocol (rtp), session description protocol (sdp), media transport - security issues/techniques and compression.

Firewalls, nats, ipsec and secure rtp, header compression, next-generation multimedia network architecture standards: multiservice switching forum architecture.

Prerequisite: Communication Network

Text Book:

1. Perkins, RTP: Audio and Video for the Internet, Addison-Wesley, 2003
2. Hwang, Multimedia Networking: From Theory to Practice, Cambridge
3. Fred Halsall, Multimedia Communications Applications, Networks, Protocols and Standards, Addison Wesley, 2001
4. K.R. Rao and Z.S. Bojkovic, Packet Video Communications over ATM Networks, Prentice Hall, 2000,
5. Mobile Communications, John B. Anderson, Series Editor
6. Chwan-Hwa Wu and J.D. Irwin "Emerging Multimedia Computer Communication Technologies," Prentice Hall, 1998
7. IEEE Journals

Course Code: EC6L024 **L-T-P: 3-0-0**	**Array Signal Processing**

Introduction: Array Processing and Applications.
Arrays and Spatial Filters: Uniform Linear Array, Array Steering, Array Performance, Linear Aperture
Synthesis of Linear Arrays and Apertures: Spectral Weighting, Array Polynomials, Minimum Beamwidth, Null Steering, Spatially Non-uniform Linear Arrays, Broadband Arrays
Planar Arrays and Apertures: Rectangular Arrays, Circular Arrays, Circular Apertures, Non-planar Arrays
Characterization of Space-time Processes: Snapshot Models, Space-time Random Process
Optimum Waveform Estimation: Optimum Beamformers, MVDR and MPDR Beamformers, LCMV and LCMP Beamformers, Eigenspace Beamformer, Beamspace Beamformer, Broadband Beamformer
Adaptive Beamformers: Parametric Estimation, RLS, LMS, Gradient Algorithms
Parameter Estimation and Direction of Arrival Estimation: Cramer-Rao Bounds, Maximum Likelihood Estimation, Capon methods, Subspace methods - MUSIC, Minimum-Norm and ESPRIT techniques.

Prerequisites: None

Text Book:

1. *Harry L. Van Trees, Optimum Array Processing (Part IV of Detection, Estimation, and Modulation Theory), Wiley-Interscience, 2002.*

Reference Books:

1. Dan E. Dugeon and Don H. Johnson. (1993). Array Signal Processing: Concepts and Techniques. Prentice Hall.
2. Petre Stoica and Randolph L. Moses. (2005, 1997) Spectral Analysis of Signals. Prentice Hall.

Course Code: EC6L022 **L-T-P: 3-0-0**	**Modern Radar System**

Introduction, Radar Basics, Radar Equation including its search and track forms, Displays, Receivers, Transmitters, Radar Antennas including Reflectors and Phased Array Antennas, Radar Cross Section, Statistical Models for Noise and Target RCS, General Characteristics of Clutter and Clutter Modelling, Clutter Reduction Techniques of Doppler and MTI, Pulse compression, Radar Measurements, Radar Tracking, Radar Detection and Target Classification, Constant False Alarm Rate Detectors, DPCA and STAP, Types of Radar and Emerging Trends.

Prerequisite: None

Text Book:

1. *M.A. Richards et al, Principles* of Modern Radar, Basic Principles Vol. 1, 1st edition, SciTech 2010

Reference Books:

1. Skolnik, Introduction to Radar Systems, 3rd edition, Tata McGraw Hill.
2. Hamish Meikle, Modern Radar Systems, 2nd Edition, ARTECH House, INC.

Course Code: EC6L026 **L-T-P: 3-0-0**	**Computer Networks**

Overview of OSI reference model. Topology design, Media Access Control Level, Services, Problems and protocols, Practical local area network design and implementation. IEEE LAN Standards, Logical Link Control protocols, HDLC, ALOHA, SLOTTED ALOHA, FDDI, Client Server model and related softwares. Network Layer level services, problems and protocols. WAN, MAN, interconnection networks related softwares, TCP/IP, Novel NetWare, Routers, Bridges and Gateways their Practical implementation aspects. X.25, Internet and related softwares NETSCAPE and MOSAIC.
Transport layer, services, problems and their protocol. Brief functioning of upper layers, E-mail and other application.

Prerequisites: None

Text Book:

1. Data Communications and Networking, Fourth Edition by Behrouza A. Forouzan, Tata McGraw-Hill Education.
2. Computer Networks, A.S.Tanenbaum,4th Edition,Pearson education.

Course Code: EC6LXXX **L-T-P: 3-0-0**	**Advanced Coding Theory**

Binary symmetric channels, erasure channel, introduction to linear codes and error correcting codes. Encoding and decoding of a linear code, dual codes, hard decision decoding, syndrome decoding. Gaussian channels, soft decision decoding, bitwise map decoder. Convolutional codes, Trellis representation, Viterbi decoder, recursive convolutional codes, Turbo Codes, Turbo Decoders, EXIT charts. Low Density Parity Check (LDPC) Codes, Definition and construction, degree distributions, regular and irregular ensembles, Hard and soft message-passing decoders, density evolution, Protograph LDPC Codes, Minsum iterative message passing decoder, Layered message passing decoder. Polar Codes, Definition and construction, Encoding of polar codes, Successive cancellation decoder, Upper bound on probability of error, List decoding, Capacity-approaching property of polar codes, Error exponent, finite length scaling, non-binary codes. Fountain Codes, Definition and construction of LT codes. and Raptor codes, systematic Raptor codes, Gaussian-elimination decoding, Belief-propagation decoding, inactivation decoding, standardized Raptor codes.

Text Books:

1. T. Richardson and R. Urbanke, "Modern Coding Theory", Cambridge University Press 2008, ISBN-13: 978-0-521-16576-1
2. S. Lin and D. J. Costello, "Error Control Coding," 2nd Ed., Pearson Prentice Hall, 200.¢, ISBN13: 978-0130426727.
3. R. Johannesen and K. Sh. Zigangirov, "Fundamentals of Convolutional Coding", Wiley-IEEE Press, 1999, Print ISBN: 9780780334830
4. E. Sasoglu, "Polarization and Polar codes", Foundations and Trends in Communications and Information Theory Vol:8, No:4, pp. 259-381, 2012, ISBN: 978-1-60198-596-5
5. W. Ryan and S. Lin, "Channel codes, Classical and Modern", Cambridge University Press 2009, ISBN-13 978-0-521-84868-8.
6. R.M. Roth, "Introduction to Coding Theory", Cambridge University Press, 2006, ISBN-13 978-0521-84868-8

Reference Books:

1. Robert G. Gallager "Low Density Parity-Check Codes", MIT Press, 2003, ISBN: 9780262571777.
2. E. Arikan, "Channel polarization: a method for constructing capacity-achieving codes for symmetric binary-input memoryless channels," IEEE Tr
3. F.J. MacWilliams and N.J.A. Sloane, "The Theory of Error-Correcting Codes", Elsevier/NorthHolland, 1977, Hardcover ISBN: 9780444851932.
4. Ian F. Blake, Ronald C. Mullin, "The Mathematical Theory of Coding", Academic Press Inc., 1975, ISBN: 01210355006.~
5. D. J. C. MacKay, "Fountain codes," in lEE Proceedings- Communications, vol. 152, no. 6, pp. 1062-1068,2005, doi: 10.1049/ip-com:20050237.
6. M. Luby, "LT codes," The 43rd Annual IEEE Symposium on Foundations of Computer Science, 2002. Proc., Vancouver, BC, 2002, pp. 271-280, doi: 10.1109/SFCS.2002.1181950.

Course Code: CS6L002 **L-T-P: 3-0-0**	**Networks and Systems Security**

Introduction: computer security concepts , the osi security architecture, security attacks, security services, security mechanisms, a model for network security Basic cryptography: historical background, transposition/substitution, caesar cipher, introduction to symmetric crypto primitives, asymmetric crypto primitives, and hash functions, block ciphers, message authentication, symmetric-key encryption, public-key encryption, digital signatures.

Secret key cryptography applications, data encryption standard (des), encrypting large messages (ecb, cbc, ofb, cfb, ctr), multiple encryption des (ede) Public key cryptography applications, theory: euclidean algorithm, euler theorem, fermat theorem, multiplicative and additive inverse, rsa, selection of public and private keys. Authentication: security handshake pitfalls, online vs. Offline password guessing, reflection attacks, per-session keys and authentication tickets, key distribution centers and certificate authorities.

Real-time communication security: introduction to tcp/ip protocol stack, implementation layers for security protocols and implications, Network security applications: key distribution and user authentication , symmetric key distribution using symmetric encryption, key distribution using asymmetric encryption, certificates, public-key infrastructure, federated identity management, transport-level security, web security considerations, secure socket layer and transport layer security, transport layer security, https, secure shell (ssh), wireless network security, ieee 802.11 wireless lan overview, ieee 802.11i wireless lan security, wireless application protocol overview, wireless transport layer security, wap end-to-end security, Electronic mail security: distribution lists, establishing keys, privacy, source authentication, message integrity, non-repudiation, proof of submission, proof of delivery, message flow confidentiality, anonymity, pretty good privacy (pgp), Firewalls and web security: packet filters, application level gateways, encrypted tunnels, cookies, web security problems

Prerequisite: None

Text Book:

1. William Stallings, "*Network Security Essentials Applications and Standards*" (5th Edition), Prentice Hall
2. Kaufman, Perlman and Speciner, "*Network Security: Private Communication in a Public World*" (2nd Edition) Prentice Hall, Publication Date: May 2, 2002.

Reference Books:

1. W. Richard Stevens, *"TCP/IP Illustrated, Vol. 1: The Protocols"* (Addison-Wesley Professional Computing Series) 1993, Edition: US ed.
2. ERIC Cole, *"Network Security Bible"*, Willey
3. Joseph Migga Kizza *"Computer Network Security"*

Course Code: EC6L052 **LTP: 3-1-0**	**Analog CMOS VLSI Design**

Introduction to analog VLSI and mixed signal issues in CMOS technologies; Recapitulation: I-V characteristic of MOS transistors, large signal and small signal models of MOS transistors, device parasitics, feedback configurations and stability theory; Basic MOS models, SPICE models, and frequency dependent parameters; Amplifiers: Basic amplifier topologies and their characteristics, cascode amplifiers, differential amplifier with active load; Biasing circuits: Simple and cascode current mirrors; Two-stage differential amplifier: Analysis for different performance parameters, pole-zero compensation and design, Operational amplifier design, OTA design; Current reference, voltage reference circuits; Comparator: Simple comparator, switch-based comparator, latch-based comparator; Device mismatch and noise analysis.

Prerequisites: Electronics/Introduction to Electronics

Text Books:

1. Behzad Razavi, Design of Analog CMOS Integrated Circuits, McGraw-Hill Education, Second Edition (2017).
2. Tony Chan Carusone David A. Johns Kenneth W. Martin, Analog Integrated Circuit Design, Wiley, Second Edition (2011)
3. CMOS Analog Circuit Design" by Phillip Allen and Douglas R. Holberg, OUP USA; Third Edition edition (1 September 2011)
4. Operation and Modeling of the MOS Transistor" by Yannis Tsividis, Oxford University, Press; 2 edition, June 26, 2003
5. "Microelectronic Circuits-Theory & Applications" by A.S. Sedra and K.C. Smith, Adapted by A.N. Chandorkar, 6th Edition, Oxford, 2013.

Course Code: EC6L039 **LTP: 3-0-0**	**IC Design for Wireless Communications**

Introduction to wireless/RF CMOS IC Design: Acronyms, Applications, RF viewpoints, definitions, and wireless specifications. System Architecture for Wireless Transceivers: Super-heterodyne, homodyne/direct-conversion, sliding-IF architectures, etc. Wireless Communication Standards: WLAN, IoT, LTE, 5G, 5G-NR, Bluetooth, I-IoT, NB-IoT, etc. Low-Noise Amplifiers: LNA Trade-offs, design requirements, different circuit topologies, matching, inductors design. Mixers: up-conversion and down-conversion mixers, mixer fundamentals and characterization, image rejection, up-conversion and down-conversion mixer circuit topologies, phase-shifters, sampling mixers, subsampling mixers. Introduction to Power Amplifiers: design requirement, approaches, circuit topologies, digital direct synthesis, examples. Clocking Circuits: Oscillators, phase-locked loops. Frequency Synthesizers- Introduction to Fractional-N and Integer-N frequency synthesizers. Study of few complete single-chip RF transceivers, system-to-circuit design examples for a reference wireless standard.

Prerequisites: Analog IC Design

Text Books:

1. B. Razavi, RF Microelectronics, 2e Paperback – 1 January 2013, Pearson Education India; 2nd edition (1 January 2013), ISBN-13: 978-9332518636.
2. Thomas H. Lee, The Design of CMOS Radio-Frequency Integrated Circuits, Cambridge University Press; 2nd edition (22 December 2003).

Reference Books:

1. Latest articles from the IEEE Journal of Solid-State Circuits, IEEE Transactions on Circuits and Systems-I and II, IEEE Transactions on Microwave Theory and Techniques.
2. Conference proceedings of IEEE ISSCC, ESSCIRC, RF IC Design, CICC etc.,
3. Gu, Qizheng, RF System Design of Transceivers for Wireless Communications, Springer, 2005, ISBN 978-0-387-24162-3
4. Gabriele Manganaro and Domine Leenaerts, Advances in Analog and RF IC Design for Wireless Communication Systems, 2013, Elsevier Inc., ISBN 978-0-12-398326-8

Course Code: EC6L053 **LTP: 3-1-0**	**Digital Integrated Circuit Design**

Integration Scales and Applications; Device Modeling for Digital ICs MOSFETs; Layout and fabrication related topics; The Inverter CMOS: DC and transient characteristics; Basic Logic Families; CMOS Logic Circuits; Combinational logic gates; Dynamic circuits and clocking; Digital Logic Units;
Sequential design and timing; Arithmetic logic circuits; Memories Cells and Arrays: SRAMs, DRAMs, Applications to Practical Design Problems; Examples from current literature including microprocessors, control systems, and signal processing

Prerequisites: None

Text /Reference Books:

1. Shih-Chii Liu, Jörg Kramer, Giacomo Indiveri, Tobias Delbrück, Rodney Douglas, Analog VLSI: circuits and principles, MIT press, 2002, ISBN 0262122553
2. Carver Mead, Analog VLSI and neural systems, Addison-Wesley, 1989, ISBN0201059924
3. Eric Kandel, James Schwartz, Thomas Jessell, Steven Siegelbaum, A.J. Hudspeth, Principles of neural science, McGraw Hill 2012, ISBN 0071390111
4. Dale Purves, Neuroscience, Sinauer, 2008, ISBN 0878936971

Course Code: EC6L056 **LTP: 3-0-0**	**Neuromorphic VLSI Hardware**

Introduction to Neuromorphic Engineering; Signalling and operation of Biological neurons, neuron models, signal encoding and statistics; Synapses and plasticity rules, biological neural circuits**;** Neuromorphic design principles; FETs - device physics and sub-threshold circuits; Analog and digital electronic neuron design; Non-volatile memristive semiconductor devices; Electronic synapse design; Interconnection Networks; Interconnection schemes for large non-spiking and spiking neural networks; Analysis of design, architecture and performance characteristics of demonstrated chips employing Analog neuromorphic VLSI, Digital neuromorphic VLSI, Electronic synapses and other neuromorphic systems. Neuromorphic Systems, Electronic Cochlea, Auditory Localization, Silicon Retinas: Voltage and Current Mode, Neuron Models, Address Event Communication and Motor Pattern Generation.

Prerequisites: Basic Electronics/Introduction to Electronics

Text /Reference Books:

5. Shih-Chii Liu, Jörg Kramer, Giacomo Indiveri, Tobias Delbrück, Rodney Douglas, Analog VLSI: circuits and principles, MIT press, 2002, ISBN 0262122553
6. Carver Mead, Analog VLSI and neural systems, Addison-Wesley, 1989, ISBN0201059924
7. Eric Kandel, James Schwartz, Thomas Jessell, Steven Siegelbaum, A.J. Hudspeth, Principles of neural science, McGraw Hill 2012, ISBN 0071390111

8. Dale Purves, Neuroscience, Sinauer, 2008, ISBN 0878936971

Course Code: EC6L058 **LTP: 3-0-0**	**System-on-Chip Solutions & Architectures Design**

This course provides basics, current trends and challenges in the development of digital system-on-chip (SoC). We start with the main steps for building arbitrary CMOS-based combinatorial logic and sequential digital data processing and control circuitry (e.g. Finite State Machines) and explaining their role and significance in the scope of key system-on-chip components: microprocessors, memories and interconnects. The microarchitectural structure and building blocks of processor elements (RISC cores), on-/off-chip memory technology (SRAM, DRAM, Flash), bus and point-to-point interconnect standards (Processor Local Bus, Advanced Microcontroller Bus Architecture, FIFO) as well as the design of communications specific arithmetic blocks (adder, multipliers, shift and comparators) will be introduced and analyzed. Finally, we will introduce main implementation methods for SoCs, such as FPGA, standard cell and full custom design, and discuss methods for low power design, which is vital for the development of SoCs in embedded systems.

Prerequisites: Digital Electronics

Text /Reference Books:

1. J. Hennessy, "Computer Architecture. A Quantitative Approach", Elsevier
2. J. Rabaey, "Digital Integrated Circuits", Prentice Hall
3. N. Weste, K. Eshraghian, "Principles of CMOS VLSI Design", Addison Wesley

Course Code: EC6L057 **LTP: 3-0-0**	**Mixed Signal VLSI Design**

Sampling theory and discrete-time signals; sample-and-hold circuits; Switch design and switched capacitor circuits; Comparators; Basics of data converters; quantization, ADC and DAC metrics; Nyquist rate ADC's: SAR and pipelines ADC's; Nyquist rate DACS's; Architectures and design of Nyquist rate DAC's; High-resolution data converters (sigma-delta data converters); Mixed-signal layout design; Integrated power management units (Bulk Converter and LDO); Selected topics in mixed-signal VLSI circuits

Prerequisites: None

Text Books:

1. Data Conversion System Design, by B. Razavi, IEEE Press, 1995.
2. Tony Chan Carusone David A. Johns Kenneth W. Martin, Analog Integrated Circuit Design, Wiley, Second Edition (2011)

Reference Books:

3. Understanding Delta-Sigma Data Converters, by R. Schreier and G.C. Temes, IEEE Press/Wiley, 2004.
4. Data Converters, F. Maloberti, Springer 2007.
5. Analog-to-Digital Conversion, M. Pelgrom, second ed., Springer, 2013.
6. Journals and Conferences papers from IEEE SSCS, and IEEE CAS Societies.

Code: EC6L027 **LTP: 3-0-0**	**Pattern Recognition**

Introduction to pattern recognition; Bayesian decision theory : Classifiers, Discriminant functions, Decision surface, Normal density and discriminant functions, Parameter estimation methods: Maximum-Likelihood estimation, Gaussian mixture models, Expectation-maximization method, Bayesian estimation, Hidden Markov models: Discrete hidden Markov models, Continuous density hidden Markov models; Dimensionality reduction methods: Fisher discriminant analysis, Principal component analysis; Non-parametric techniques for density estimation: Parzen-window method, K-Nearest Neighbour method, Linear discriminant function based classifiers: Perceptron , Support vector machines, Non-metric methods for pattern classification: Non-numeric data or nominal data Decision trees, Unsupervised learning and clustering: Criterion functions for clustering Algorithms for clustering: K-means, Hierarchical and other methods, Cluster validation.

Pre-requisite(s): Digital signal processing, Probability and stochastic processes

Text Books:

1. R.O.Duda, P.E.Hart and D.G.Stork, “Pattern Classification,” John Wiley, 2001.
2. S.Theodoridis and K.Koutroumbas, “Pattern Recognition,” 4th Ed., Academic Press, 2009.
3. C.M.Bishop, “Pattern Recognition and Machine Learning,” Springer, 2006.

Code: EC6L030 **LTP: 3-0-0**	**Embedded Systems**

Embedded Processing Systems: Introduction, Components of Embedded Systems – Embedded Processor, Microcontrollers (PIC and ARM architectures), DSP and ASICs and SoC, Memory Devices: ROM and RAM family, Interfacing Memory, Simple I/O programming, Interrupts and their servicing, Timing Devices and Interfacing, Analog I/O Techniques, Introduction to HDL, Design of Embedded Processors and Components, Design Case Studies, Embedded Communication: Parallel Bus Standards, Serial Bus Standards, Networking Standards and Wireless Standards, Real Time Operating Systems (RTOS): Introduction, Memory Management, I/O Management and Device Drivers, Scheduling, Introduction to Software Design: Embedded System Life Cycle, Multicore and Heterogeneous Embedded Systems.

Pre-requisite(s): Digital Electronics and Microprocessor

Text Books:

1. W. Wolf, Computers as Components: Principles of Embedded Computing System Design, 2nd Ed., Burlington, 2008.
2. T Noergaard, Embedded Systems Architecture: A comprehensive Guide for Engineers and Programmers, Elsevier, Oxford, 2005.
3. Steve Heath, Embedded System Design, 2nd Edition, Newnes, Burlington, 2003.

Code: EC6L031 **LTP: 3-0-0**	**Computer Vision**

Introduction to computer vision, geometric camera models, light and shading, local image features: SIFT, HOG, texture and shape descriptors, active contour, segmentation, deformable models, RANSAC, image registration, learning and classification strategies, image classification, object detection and recognition, stereopsis, tracking, applications

Pre-requisite(s): Image & Video Processing

Text Books:

1. Forsyth and Ponce, “Computer vision: a modern approach,” 2nd Ed., Pearson, 2012.
2. Sonka, Hlavac and Boyle, “Digital image processing and computer vision,” Cengage learning, 2008.
3. Rick Szeliski, “Computer Vision: Algorithms and Applications,” Springer,2011.

Code: EE6L014 **LTP: 3-0-0**	**Smart Grid Technology**

Review of basic elements of electrical power systems, desirable traits of a modern grid, principal characteristics of the smart grid, key technology areas; Smart grid communication: Two way digital communication paradigm, network architectures, IP-based systems, Power line communications, advanced metering infrastructure; Renewable Generation: Renewable Resources: Wind and Solar, Microgrid Architecture, Tackling Intermittency, Distributed Storage and Reserves; Wide Area Measurement: Sensor Networks, Phasor Measurement Units, Communications Infrastructure, Fault Detection and Self-Healing Systems, Application and Challenges; Security and Privacy: Cyber Security Challenges in Smart Grid, Defense Mechanism, Privacy Challenges.

Pre-requisite(s): None

Text Books:

1. J. Momoh ‘Smart Grid: Fundamentals of Design and Analysis’ Wiley-IEEE Press, 2012.
2. P. F. Schewe ‘The Grid: A Journey through the Heart of our Electrified World’ Joseph Henry Press, 2006.

Course Code: EC6L007 **L-T-P: 3-0-0**	**VLSI Signal processing**

Introduction: Typical signal processing algorithms, overview of VLSI architectures, representations of DSP algorithms. General techniques: Iteration bound, pipelining, parallel processing, and computer arithmtic. Retiming techniques: Definitions, general methodology, retiming for critical path reduction. Unfolding and folding techniques: Unfolding algorithm, critical path, unfolding, and retiming, folding transformation, register minimization. Systolic Architectures: Overview, design methodology, matrix operations and 2D systolic array design. Mapping Algorithms onto Array Structures: Parallel algorithm expressions, canonical mapping methodology, generalized mapping.Programmable Signal Processors: Important features, FFT architectures, DSP processors for mobile and wireless communications, processors for multidimensional signal processing. Reconfigurable DSP Architectures: DSP design using VLIW architectures, PACT-XPP, Tightly-Coupled Processor Arrays, etc., advanced multimedia applications.

Texts/References Books:

1. Keshab K.Parhi, “VLSI Digital Signal Processing Systems, Design and Implementation”, John Wiley, Indian Reprint, 2007.
2. Architectures for Digital Signal Processing Paperback by Peter Pirsch, John Wiley, 2009.
3. U. Meyer-Baese, "Digital Signal Processing with Field Programmable Arrays", Springer, Second Edition, Indian Reprint, 2007.
4. VLSI array processors by Sun Yuan Kung. Prentice Hall, 1998.
5. VLSI Design Methodologies for Digital Signal Processing Architectures by Magdy A. Bayoumni, Springer 1994.
6. Lars Wanhammar, “DSP Integrated Circuits”, Academic Press, 1999
7. Sanjit K. Mitra, "Digital Signal Processing: A computer based Approach", TMH, 2006.
8. Invasive Tightly Coupled Processor Arrays by Vahid Lari, Springer 2016.

Code: EC6L028 **LTP: 3-0-0**	**Speech Signal Processing**

Introduction, Physiological and Mathematical Models, Categorization of Speech Sounds; Discrete time speech signals, Fourier transform and Z-transform, convolution, filter banks. Spectral estimation, Pole-zero modeling and linear prediction (LP) analysis. Homomorphic deconvolution, cepstral analysis; Feature extraction, Static and dynamic features, robustness, feature selection. Mel frequency cepstral coefficients (MFCC), linear prediction cepstral coefficients (LPCC), Perceptual LPCC; Distance measures: Log spectral distance, cepstral distances, weighted cepstral distances, distances for linear and warped scales, Dynamic Time Warping for Isolated Word Recognition; Statistical models for speech recognition: Vector quantization model, Gaussian mixture model, Discrete and Continuous Hidden Markov modeling.

Pre-requisite(s): Digital Signal Processing

Text Books:

1. Thomas F. Quatieri, "Discrete-Time Speech Signal Processing: Principles and Practice," Prentice-Hall, 2001.
2. L. Rabiner and B. Juang, "Fundamentals of Speech Recognition," Prentice-Hall, 1993.
3. B. Gold and B. Morgan, "Speech and Audio

Code: EC6L054 **LTP: 3-0-0**	**CAD for VLSI Design**

Introduction to Semiconductors and Design Flow, Representation of digital circuits by Boolean functions, Optimization of combinatorial two-level digital circuits: Quine-McCluyskey; Karnaugh diagram; cube graph; resolution method; combinatorial optimization (cofactor, Boole's expansion); BDDs. Optimization of multi-level, multi-output, incompletely specified Boolean functions: Sharing of logic; finding common cubes; utilizing "don't cares"; functional decomposition. Optimization of sequential circuits: Representation of sequential circuits by FSMs; optimization of FSMs; binary coding of FSMs. Fundamental introduction to digital simulation concepts and Verilog. Testing of digital circuits: Introduction to testing; Fault tables; Boolean difference; structure-oriented computation of Boolean difference; fault simulation; fault trees; D-Algorithm; testing of sequential circuits; Design for testability. Mixed Integer Linear Programming (MILP) Modeling: properties of modeling method, mathematical modeling techniques (constraint linearization, OR-relation transformation, propositional logic modeling, absolute value modeling), modeling common EDA problems including grid routing, gridless routing, escape routing on printed circuit board (PCB), area routing on PCB, non-overlapping placement, area minimization, network flow, etc.

Pre-requisite(s): Digital Electronics

Text Books:

1. Algorithms for VLSI Design Automation; Sabih H. Gerez; John Wiley & Sons,1999
2. Synthesis and Optimization of Digital Circuits; De Micheli, Giovanni; McGraw-Hill ,1994
3. VLSI Physical Design Automation; S. Sait, H. Youssef; McGraw-Hill, 1995
4. Applied Mathematical Programming; Bradley, Hax, and Magnanti; Addison-Wesley, 1977

Code: EC6L055 **LTP: 3-0-0**	**VLSI Testing**

Physical faults and their modeling. Fault equivalence and dominance; fault collapsing. Fault simulation: parallel, deductive and concurrent techniques; critical path tracing.Test generation for combinational circuits: Boolean difference, D-algorithm, PODEM, etc. Exhaustive, random and weighted test pattern generation; aliasing and its effect on fault coverage.

Pre-requisite(s): None

Text Books:

1. M.L. Bushnell and V.D. Agrawal, “Essentials of Electronic Testing”, Kluwer Academic Publishers, 2000
2. N.K. Jha and S. Gupta, “Testing of Digital Systems”, Cambridge University Press 2004
3. M. Abramovici, M.A. Breuer and A.D. Friedman, “Digital Systems Testing and Testable Design”, Wiley-IEEE Press,1993
4. P.H. Bardell, W.H. McAnney and J. Savir, “Built-in Test for VLSI: Pseudorandom Techniques”, Wiley Interscience, 1987
5. L-T. Wang, C-W. Wu and X. Wen, “VLSI Test Principles and Architectures”, Morgan Kaufman Publishers, 2006
6. P.K. Lala, “Fault Tolerant and Fault Testable Hardware Design”, Prentice-Hall Intl 1985

Code: EC6L059 **LTP: 3-0-0**	**VLSI Physical Design**

Introduction to physical design automation. Partitioning, Floorplanning and Placement. Grid Routing and Global Routing, Detailed Routing and Clock Design. Clock Routing and Power/Ground. Static Timing Analysis and Timing Closure. Physical Synthesis and Performance Driven Design Flow: Interconnect Modeling and Layout Compaction. Introduction to Testing, Fault Modeling and Simulation. Test Pattern Generation, DFT and BIST. Low Power Design Techniques.

Pre-requisite(s): None

Text Books:

1. Andrew B. Kahng, Jens Lienig, Igor L. Markov and Jin Hu “VLSI Physical Design: From Graph Partitioning to Timing Closure”. 2011
2. Naveed A. Sherwani “Algorithm for VLSI Physical Design Automation”, 3rd Edition, Springer, 1998
3. Sung Kyu Lim, Practical Problems in VLSI Physical Design Automation, Springer, 2008

Code: EC6L060 **LTP: 3-0-0**	**Parallel Systems**

Theory of parallelism (parallel computer models, parallel specification forms and languages, performance models and calculation). Classification of parallel and scalable computer architectures (multiprocessors and multicomputers, vector computers, data flow machines, VLSI computing fields) Programmable System-on-Chip (SoC) architectures Programming of parallel computers (languages and models, design methods and compilers, optimization) Massive Parallelism: From Algorithm to Circuit Theoretical and practical exercises with computer-aided tools deepen the knowledge.

Pre-requisite(s): None

Text Books:

1. Kai Hwang, "Advanced Computer Architecture: Parallelism, Scalability, Programmability"
2. Michael Wolfe, "High Performance Compilers for Parallel Computing"
3. Alain Darte, Yves P. Robert, Frederic Vivien, "Scheduling and Automatic Parallelization"
4. Utpal Banerjee, "Loop Parallelization (VLSI, Computer Architecture and Digital Signal Processing)"
5. S. Y Kung, "VLSI Array Processors"

Course Code: EC6L061 **LTP: 3-0-0**	**Architectural Design of VLSI Systems**

VLSI Design flow, general design methodologies; Mapping algorithms into Architectures: Signal flow graph, data dependences, datapath synthesis, control structures, critical path and worst case timing analysis, concept of hierarchical system design; Datapath elementa: Datapath design philosophies, fast adder, multiplier, driver etc., datapath optimization, application specific combinatorial and sequential circuit design, CORDIC unit; Pipeline and parallel architectures: Architecture for real time systems, latency and throughput related issues, clocking strategy, power conscious structures, array architectures; Control strategies: Hardware implementation of various control structures, microprogrammed control techniques, VLIW architecture; Testable architecture: Controllability and observability, boundary scan and other such techniques, identifying fault locations, self reconfigurable fault tolerant structures; Treadeoff issues: Optimization with regard to speed, area and power, asynchronous and low power system design, ASIC (application specific integrated circuits) and ASISP (application specific instruction set processors) design;

Pre-requisite(s): None

Text Books:

1. Computer Arithmetic: Algorithms and Hardware Designs by B. Parhami, 2000
2. Digital Arithmetic (M. D. Ercegovac and T. Lang), 2004
3. Advanced Arithmetic for the Digital Computer (K. Ulrich), 2002

Course Code: MA7L002 **LTP: 3-0-0**	**Advanced Techniques in Operation Research**

One variable unconstrained optimization, multivariable unconstrained optimisation, Karush-Kuhn-Tucker (KKT) conditions for constrained optimization, quadratic programming, separable programming, convex and non convex programming, steepest and Quasi-Newton method. Dynamic Programming: Characteristics of dynamic problems, deterministic dynamic programming and probabilitistic dynamic programming, Network analysis, Shortest path problems, minimum spanning tree problem, maximum flow problem, minimum cost flow problem, network simplex, interior point methods, stochastic programming, Nonlinear goal programming applications, Geometric Programming. Multi-objective Optimization Problems: Linear and non linear programming problems, Weighting and Epsilon method, P-norm methods, Gradient Projection Method, STEM method, Convex Optimization.

Pre-requisite(s): None

Text Book:

1. S.S. Rao, Engineering Optimization Theory and Practices, John Wiley and Sons, 2009

Reference Books:

1. M. Ehrgott, Multi-criteria Optimization, Springer 2006
2. K.M, Miettien, Non-linear multi-objective optimization, Kluwers International Series, 2004
3. K. Deb, Multi-Objective Optimization using Evolutionary Algorithms, John Wiley & Sons, 2001.

Course Code: ID6L004 **LTP: 3-0-0**	**Machine Learning and Data Analytics-I**

Introduction: Prediction, Classification, Forecasting, Filtering, Regression, Clustering. Review of Linear Algebra, Probability and Statistics. Data Exploration and Pre-processing: Data Objects and Attributes; Statistical Measures, Visualization, Data Cleaning and Integration. Dimensionality Reduction: Linear Discriminant Analysis; Principal Component Analysis; Transform Domain and Statistical Feature Extraction and Reduction. Regression: Least Mean Square Regression; Ridge Regression and LASSO regression; Support Vector Regression. Clustering: K-Means, Hierarchical, and Density-based Clustering, Spectral Clustering. Classification: K-nearest-neighbor, Bayesian and Naïve Bayes Classifier, Decision Tree Induction including Attribute Selection, and Tree Pruning, Random Forests, Logistic Regression; Support Vector Machine; Ensemble Classification including Adaboost. Artificial Neural Networks: Single Layer Neural Network, Multilayer Perceptron, Back Propagation Learning, Functional Link Artificial Neural Network, and Radial Basis Function Network, Recurrent Neural Networks, Deep Learning, Convolutional Neural Networks.

Pre-requisite(s): None

Text Book:

1. Bishop, C., “Pattern Recognition and Machine Learning”, Springer, 2006.
2. Mitchell, T. “Machine Learning”, 1997 (freely available online)
3. Duda, Hart, Stork. “Pattern Classification”. Wiley
4. Daumé, H. III, “A Course in Machine Learning”, 2015 (freely available online).
5. Haykin S., “Neural Networks and Learning Machines”, Third Edition, Prentice Hall, 2008.
6. Goodfellow I.,Bengio Y. and Courville A.; “Deep Learning”, MIT Press, 2016

Reference Books:

1. Hastie, T., R. Tibshirani, J. Friedman, “The Elements of Statistical Learning”, Springer 2009 (freely available online).
2. Shai Shalev-Shwartz and Shai Ben-David. “Understanding Machine Learning: From Theory to Algorithms”, Cambridge University Press, 2014

Course Code: ID6L005 **LTP: 3-0-0**	**Machine Learning and Data Analytics-II**

Probability-based Machine Learning: Review of statistics; Parameter Estimation by Maximum-Likelihood and Bayesian approach; Probabilistic classification and PCA; Random Projections. Generative Models: Bayesian and Markov Networks; Hidden Markov Model; Markov Random Fields; EM Algorithm; Probabilistic inference – Metropolis-Hastings Algorithm, Gibbs Sampling. Topic Models: PLSI, Latent Dirichlet Allocation, HMM-LDA, modern variants. Introduction to Bayesian Nonparametrics: Chinese Restaurant Process and variants, Indian Buffet Process, Dirichlet Process, Gaussian Process. Online Algorithms: Online Clustering, online learning, Frequent Itemset mining on streaming data. Reinforcement Learning: Markov Decision Processes, and Q-Learning. Learning Theory: PAC Learning, Sample Complexity and VC Dimension, and Structural Risk Minimization. Spectral Methods. Applications to Vision, text, climate, finance domains.

Pre-requisite(s): Machine Learning and Data Analytics-I

Text Book:

1. Bishop, C., “Pattern Recognition and Machine Learning”, Springer, 2006.
2. Murphy, K., “Machine Learning: A Probabilistic Perspective”, MIT Press, 2012.
3. Koller D. and Friedman N.: “Probabilistic Graphical Models: Principles and Techniques”, MIT Press, 2009

Reference Books:

1. Montgomery, D. C., and G. C. Runger, “Applied Statistics and Probability for Engineers”. John Wiley & Sons, Sixth Edition, 2013.
2. Shai Shalev-Shwartz and Shai Ben-David. “Understanding Machine Learning: From Theory to Algorithms”, Cambridge University Press, 2014