M. Tech. in VLSI Design (VL)

Suggested Plan of Study:

Sl. No.	Semester			
	I	II	III	IV
1	EC701	EC703	EC759	EC760
2	EC702	EC704		
3	EC791	EC792		
4	EC705	Elective 3		
5	Elective 1	EC757		
6	Elective 2	EC758		

Credit Requirements:

Category	Minimum Credits to be Earned
Program Core (PC)	26
Elective Courses (EL)	12
Mandatory Learning Courses (MLC)	04
Major Project (MP)	12
Total	**54**

Program Core (PC)

EC701	CMOS VLSI	(4-0-0) 4
EC702	Analog Integrated Circuit Design	(4-0-0) 4
EC703	VLSI Data Converters	(4-0-0) 4
EC704	VLSI Design Automation	(4-0-0) 4
EC705	IC Design Lab	(0-0-3) 2
EC791	Linear Algebra and Stochastic Processes	(4-0-0) 4
EC792	High Performance Computing Architectures	(4-0-0) 4

Electives (EL)
(At least ONE elective must be chosen from this list)

EC801	Logic Synthesis Techniques	(4-0-0) 4
EC802	Low Power VLSI Design	(4-0-0) 4
EC803	Microelectronic Devices	(4-0-0) 4
EC804	Digital VLSI Testing & Testability	(4-0-0) 4
EC805	Embedded Systems	(2-0-3) 4
EC806	Digital Design using FPGAs	(2-0-3) 4
EC807	Active Filter Design	(4-0-0) 4
EC808	CMOS RF Integrated Circuits	(4-0-0) 4
EC809	Heterogeneous and Parallel Programming	(3-0-2) 4
EC810	Selected Topics in VLSI Design	(4-0-0) 4
EC870	Architectures for Signal Processing and Machine Learning	(4-0-0) 4

Mandatory Learning Courses (MLC)

EC757	Seminar	2
EC758	Minor Project	2

Major Project (MP)

EC759	Major Project - I	4
EC760	Major Project - II	8

M. Tech. in Communication Engineering (CE)

Suggested Plan of Study:

Sl. No.	Semester			
	I	II	III	IV
1	EC731	EC732	EC759	EC760
2	EC733	EC734		
3	EC791	EC758		
4	EC793	Elective 2		
5	Elective 1	Elective 3		
6	EC757	EC736		

Credit Requirements:

Category	Minimum Credits to be Earned
Program Core (PC)	26
Elective Courses (EL)	12
Mandatory Learning Courses (MLC)	04
Major Project (MP)	12
Total	**54**

Program Core (PC)

EC731	Wireless Communication & Networks	(4-0-0) 4
EC732	Optical Networks and Switching	(4-0-0) 4
EC733	RF Circuit Design	(4-0-0) 4
EC734	Signal Detection and Estimation	(4-0-0) 4
EC736	Communication & Networking Lab	(0-0-3) 2
EC791	Linear Algebra and Stochastic Processes	(4-0-0) 4
EC793	Signal Analysis and Processing	(4-0-0) 4

Electives (EL)
(At least ONE elective must be chosen from this list)

EC831	Spread Spectrum Communication Systems	(4-0-0) 4
EC832	MIMO Communication Systems	(4-0-0) 4
EC833	Internet of Things	(4-0-0) 4
EC834	Error Control Coding	(4-0-0) 4
EC835	Algorithms for Parameter and State Estimation	(4-0-0) 4
EC836	Radar Signal Processing	(4-0-0) 4
EC837	Advanced Radiating Systems	(4-0-0) 4
EC838	Multi Target Tracking and Multi-Sensor Information Fusion	(4-0-0) 4
EC839	Nano-Photonics	(4-0-0) 4
EC840	Millimetre Wave Communications	(4-0-0) 4
EC841	Cryptography	(4-0-0) 4
EC842	Information Theory	(4-0-0) 4
EC843	Broadband Communications	(4-0-0) 4
EC844	Electromagnetic Interference and Compatibility	(4-0-0) 4
EC845	Principles of Communication Systems Simulation	(4-0-0) 4
EC 846	Computer Communication Networks	(4-0-0) 4
EC 847	Selected Topics in Communication Engineering	(4-0-0) 4

Mandatory Learning Courses (MLC)

EC757	Seminar	2
EC758	Minor Project	2

Major Project (MP)

EC759	Major Project - I	4
EC760	Major Project - II	8

M. Tech. in Signal Processing and Machine Learning (SPML)

Suggested Plan of Study:

Sl. No.	Semester			
	I	II	III	IV
1	EC791	EC792	EC759	EC760
2	EC793	EC762		
3	EC761	EC763		
4	EC764	Elective 3		
5	Elective 1	EC757		
6	Elective 2	EC758		

Credit Requirements:

Category	Minimum Credits to be Earned
Program Core (PC)	26
Elective Courses (EL)	12
Mandatory Learning Courses (MLC)	04
Major Project (MP)	12
Total	**54**

Program Core (PC)

EC791	Linear Algebra and Stochastic Processes	(4-0-0) 4
EC792	High Performance Computing Architectures	(4-0-0) 4
EC793	Signal Analysis and Processing	(4-0-0) 4
EC761	Information Processing and Compression	(4-0-0) 4
EC762	Pattern Recognition and Machine Learning	(4-0-0) 4
EC763	Optimization	(4-0-0) 4
EC764	Signal Processing Laboratory	(0-0-3) 2

Electives (EL)
(At least ONE elective must be chosen from this list)

EC861	Image Processing and Computer Vision	(4-0-0) 4
EC862	Time Series Analysis and Data Science	(4-0-0) 4
EC863	Statistical Signal Processing	(4-0-0) 4
EC864	Speech and Audio Processing	(4-0-0) 4
EC865	Multimedia Systems	(4-0-0) 4
EC866	Deep Learning and Applications	(3-0-2) 4
EC867	Fourier and Wavelet Analysis	(4-0-0) 4
EC868	Time Frequency Analysis	(4-0-0) 4
EC869	Medical Imaging and Biosignal Analysis	(4-0-0) 4
EC870	Architectures for Signal Processing and Machine Learning	(4-0-0) 4
EC871	Selected Topics in Signal Processing	(4-0-0) 4
EC734	Signal Detection and Estimation	(4-0-0) 4

Mandatory Learning Courses (MLC)

EC757	Seminar	2
EC758	Minor Project	2

Major Project (MP)

EC759	Major Project - I	4
EC760	Major Project - II	8

EC701 CMOS VLSI **(4-0-0) 4**

MOSFET - Review of current equation, regions of operation, MOSFET logic circuits. MOSFET logic gates. Interfacing CMOS and Bipolar logic families. Circuit characterization and performance estimation, Switching characteristics, Delay models, Power dissipation, Packaging, Scaling of MOS transistor dimensions, Yield and Reliability, CMOS subsystem design, Datapath operations, Addition, Multiplication, Counters, Shifters, Memory design. Interconnect design, Power-grid and clock design. Simulation exercises on MOSFET.

Jan M. Rabaey, Anantha Chandrakasan, and Borivoje Nikolic Digital Integrated Circuits – A design perspective, Pearson, 2003
S. M. Kang & Y. Leblebici, CMOS Digital Integrated Circuits, McGraw Hill, 1999.
David A Hodges, Horace G. Jackson and Resve Saleh, Analysis and Design of Digital Integrated Circuits, Mc GrawHill, 2003
Neil H. E. Weste, David Money Harris, Integrated Circuit Design, Fourth Edition, 2011
NPTEL Video Lectures

EC702 ANALOG INTEGRATED CIRCUIT DESIGN **(4-0-0) 4**

MOSFET - Review of current equation, regions of operation, small signal model. Current mirrors, Single-ended amplifiers, Differential amplifiers, Two-stage amplifiers – analysis, frequency response, stability, compensation; Band gap references, Constant–Gm biasing; Types of Noise, Introduction to switched capacitor circuits, switched capacitor amplifiers, noise analysis, Distortion, current and voltage references, Oscillators and PLL.

Behzad Razavi, Design of Analog CMOS Integrated Circuits McGraw-Hill International Edition 2016
Behzad Razavi, Fundamentals of Microelectronics, Second edition, Wiley, 2013
Sedra and Smith, Microelectronics Circuits, Oxford Univ. Press, 2004
David A. Johns and Ken Martin, Analog Integrated Circuit Design, John Wiley, 2002
Phillip E. Allen and Douglas R. Holberg, CMOS Analog Circuit Design, Oxford University Press, 2003.
NPTEL Video Lectures

EC703 VLSI DATA CONVERTERS **(4-0-0) 4**

Sample and Hold Circuits: Basic S/H circuit, effect of charge injection, compensating for charge injection, bias dependency, bias independent S/H. D/A Converter – General considerations, Static non-idealities and Dynamic nonidealities; Current-steering DAC – Binary weighted DAC, Thermometer DAC, Design issues, Effect of Mismatches. A/D converter – General considerations, static and dynamic non-idealities. Flash ADC – Basic architecture, Design issues, Comparator and Latch, Effect of non-idealities, Interpolative and Folding architectures. Successive Approximation ADC; Pipeline ADC. Over sampling ADC – Noise shaping, Sigma-Delta modulator.

Behzad Razavi, Design of Analog CMOS Integrated Circuits McGraw-Hill International Edition 2016
David A. Johns and Ken Martin, Analog Integrated Circuit Design, John Wiley, 2002
Phillip E. Allen and Douglas R. Holberg, CMOS Analog Circuit Design, Oxford University Press, 2003.
Behzad Razavi, Principles of Data Conversion System Design, Wiley-IEEE Press, 1995
Rudy J. van de Plassche, CMOS Integrated Analog-to-Digital and Digital-to-Analog Converters, Springer, 2003
NPTEL Video Lectures

EC704 VLSI DESIGN AUTOMATION **(4-0-0) 4**

Introduction to VLSI design automation: VLSI design methodologies, use of VLSI EDA tools, Algorithmic Graph Theory, computational Complexity; Partitioning, Simulated Annealing. Floor planning and placement, Routing, High Level Synthesis, operation scheduling, Static Timing Analysis, Topological vs logical timing analysis, False paths, Arrival time, Required arrival Time, Slacks.Advanced VLSI Design Automation: Physical Synthesis, Optical Proximity correction, Interconnect issues.

Naveed Sherwani, Algorithms for VLSI Physical Design Automation, 3rd ed., Kluwer Academic Pub., 1999

Majid Sarrafzadeh and C. K. Wong, An Introduction to VLSI Physical Design, McGraw Hill, 1996.

Sabih H. Gerez, Algorithms for VLSI Design Automation, John Wiley, 1998

Sung Kyu Lim, Practical Problems in VLSI Physical Design Automation, Springer, 2008

Sadiq M. Sait & Habib Youssef, VLSI Physical Design Automation: Theory and Practice, World Scientific Publishing, 1999

NPTEL Video Lectures

EC705 IC DESIGN LAB **(0-0-3) 2**

Design, Simulation and layout of basic digital blocks, performance comparison, Design project Tools to be used: CADENCE, MAGIC, SPICE, ELECTRIC, Mentor Graphics

EC731 WIRELESS COMMUNICATION & NETWORKS **(4-0-0) 4**

Introduction to Wireless Communication Systems, Channel Modeling- Pathloss, large-scale fading, small-scale fading; Power budget of mobile links - Doppler spread and coherent time, delay spread and coherent bandwidth; flat fading and frequency selective fading. Digital Modulation and its various aspects, Channel Coding- forward error correction (FEC) coding, Network Architectures, Medium Access Schemes, Communication Protocol Layers, Routing Strategies, Network Reliability, Congestion Issues, Advanced Topics in Wireless Research-MANETs, Sensor Networks, Cellular Network Concepts, SDN, Existing Wireless Systems –GSM and its evolution.

A. Goldsmith, Wireless Communications, Cambridge University Press, 2005.

T. S. Rappaport, Wireless Communications Principles and Practice (2nd edition) Pearson, 2010.

Haykin & Moher, Modern Wireless Communications Indian Edition, Pearson, 2011.

James F.Kurose, Computer Networking: A Top own Approach, 5th Ed., Pearson, 2012

A. Kumar, D. Manjunath and Joy Kuri, Communication Networking: An Analytical Approach, Morgan Kauffmann, 2004.

EC732 OPTICAL NETWORKS AND SWITCHING **(4-0-0) 4**

Introduction to basic optical communications and devices. Optical multiplexing techniques. Optical Networks: Conventional optical networks, Multiple access optical networks, Optical amplification in all optical networks. All-optical subscriber access networks. Design issues. Optical switching: Motivation, Spatial light modulator, Relational and non-relational switching devices, Fundamental limits on optical switching elements, Switching architectures, Free-space optical switching. Wavelength routed networks and other special topics. Soliton based networks, Optical networks management issues.

Rajiv Ramaswami, Kumar Sivarajan, Galen Sasaki, Morgan Optical Networks: A Practical Perspective, Kauffman Publishers, ELSEVIER, 2010.

Hussein T. Mouftah, Jaafar M. H. Elmirghani, Photonic Switching Technology: Systems and Networks, Wiley, 1999.

Ray T. Chen, Joseph C. WDM and Photonic Switching Devices for Network Applications, Volume 4653, Chon SPIE, 2002 - Technology & Engineering

Martin Maier, Optical Switching Networks, Cambridge University Press, 2008.

A. Selvarajan, Subrat Kar, T. Srinivas, Optical Fibre Communication: principles and systems, TMH, 2002.

EC733 RF CIRCUIT DESIGN **(4-0-0) 4**

Review of Basic Transmission Line Theory, Planar Transmission Lines Microwave Network Analysis - Microwave network representation, Impedance Matching Techniques, Binomial and Chebyshev approximations, Basic Passive Components, Analysis and design of stripline/ microstrip components- Equivalent circuit and Characteristics, Basic series and shunt switches in microstrip; SPST and SPDT switches, Switched line, branch line coupled and loaded line phase shifters in microstrip. Applications in phased arrays. MIC Filters, Examples-Realization of lumped elements and filters in MMIC, Realization of planar transmission lines and filters in MEMS.

D.M. Pozar, Microwave Engineering, 2 Edition, John Wiley & Sons, 1998.
Michael Steer, "Microwave and RF Design: A Systems Approach", First Edition, Yes Dee Publishing 2012.
Peter Rizzi, Microwave Engineering-Passive Circuits, Pearson Education, 1988..
R. Ludwig and G. Bogdanov, "RF Circuit Design: Theory and Applications", 2nd Edition, Pearson Education India, 2009.
Behzad Razavi, "RF Microelectronics", Second Edition, Pearson Education India, 2012.

EC734 SIGNAL DETECTION AND ESTIMATION (4-0-0) 4

Hypothesis Testing, Neyman Pearson Lemma, UMP test, Decision Theoretic framework, Multiple-Decision Problem. Parameter Estimation - Unbiasedness, Consistency, asymptotic normality, sufficient statistics, minimax estimation, decision theoretic framework, Rao-Blackwell theorem, Cramer – Rao inequality. Estimation: Minimum mean square linear estimation, Wiener filter, Kalman filter, Levinson – Durbin and innovation algorithms.

H. L. Van Trees Detection, Estimation and Modulation Theory, Part I, John Wiley, 1968.
Srinath, Rajasekaran and Viswanathan, Introduction to Statistical Signal Processing with applications, PHI, 1995.
Steven M. Kay, Fundaments of Statistical Signal Processing, Vol. I:Estimation Theory, Vol. II: Detection Theory, Prentice Hall International, 1993
Papoulis A., Probability Random Variables and Stochastic Processes, McGraw Hill, 2002
H. Stark and J. W Woods, Probability and Random Processes with applications to signal processing, Pearson Education, 2002.

EC736 COMMUNICATION AND NETWORKING LAB (0-0-3) 2

Design experiments to reflect the contents of core courses in the curriculum. Exposure to hardware design of communication systems and simulation using tools such as MATLAB, ADS, HFSS, SystemVue, Network Simulator and GNU Radio etc.

EC761 INFORMATION PROCESSING AND COMPRESSION (4-0-0) 4

Introduction to Information theory, Entropy and Inference. Mathematical preliminaries for Lossless compression, Shannon's Source Coding Theorem Huffman coding, Arithmetic Coding, LZW coding. Mathematical preliminaries for lossy compression, quantization and the Lloyd-Max Algorithm, rate-distortion theory, Scalar and vector quantization, Transform coding, Subband coding.

Khalid Sayood, Introduction to Data Compression, Morgan Kaufman, 5th Ed. 2018.
David McKay, Information Theory, Inference and Learning Algorithms, Cambridge University Press, 2003.
David Solomon, Handbook of Data Compression, Springer, 2010.

EC762 PATTERN RECOGNITION AND MACHINE LEARNING (4-0-0) 4

Statistical foundations, Different Paradigms of Pattern Recognition, Probability estimation, Proximity measures, Feature extraction, Different approaches to Feature selection, Nearest Neighbor Classifier and variants, Bayes classification.

Linear models, regression, logistic regression, neural networks, objective function and learning, back propagation. Kernel based methods, support vector machines. Dimensionality reduction, principal component analysis, reconstruction, discriminant analysis. Clustering, K-means algorithm, distance measure, objective function, initialization. Anomaly detection, recommender systems. Scaling of algorithms.

R. O. Duda, P. E. Hart and D. G. Stork Pattern Classification, Wiley Publications, 2001.
D. McKay, Information Theory, Inference, and Learning Algorithms, Cambridge University Press 2003.
C. M. Bishop, Pattern Recognition and Machine Learning, Springer, 2006.

EC763 OPTIMIZATION (4-0-0) 4

Convex sets and Convex functions, Level sets and Gradients. Unconstrained Optimization: Search methods, Gradients Methods, Newton Method, Conjugate Direction Methods, Quasi-Newton Methods. Linear Programming: Standard Form Linear Programs, Simplex method, Duality and Non Simplex Methods. Nonlinear Constrained Optimization: Problems with equality constraints, Problems with Inequality Constraints, Convex Optimization Problems. Algorithms for Constrained Optimization: Projected Gradient Methods and Penalty Methods.

Lieven Vandenberghe and Stephen P. Boyd, Convex Optimization, Cambridge University Press, 2004.
Dimitris Bertsekas, John N. Tsitsiklis, Introduction to Linear Optimization, Athena Scientific Series, 1997.
Aharon Ben-Tal and Arkadi Nemirovski, Lectures on Modern Convex Optimization: Analysis, Algorithms, and Engineering Applications, SIAM, 2001.

EC764 SIGNAL PROCESSING LABORATORY (0-0-3) 2

Signals and spectral analysis, Transform domain analysis of systems, Sampling and Quantization effects, Digital Filter Design, Applications in Image and Speech – Compression Schemes, Denoising, Real Time DSP experiments.

D G Manolakis, V K Ingle, Applied Digital Signal Processing, Cambridge University Press, 2012
Donald Reay, Digital Signal Processing using ARM Cortex-M4, John-Wiley, 2015.

EC791 LINEAR ALGEBRA AND STOCHASTIC PROCESSES (3-1-0) 4

Vector Spaces, Subspaces, Linear Independence, Span, Basis, Dimension, Linear Transformations, Orthogonal Transformations, Orthogonal projections, Matrix subspaces and orientation, Eigen decomposition, SVD, Least Squares , Pseudo inverse.

Review of Probability theory and Random variables, Random vectors and moments, Stochastic Processes and Examples, stochastic processes and linear systems, Gaussian random process, spectral analysis of stationary processes, Power Spectral Densities, Stationarity and Ergodicity.

Gilbert Stran, Linear algebra and its applications, Thomson Brooks, 2006.
P Halmos, Finite Dimensional Vector Spaces, Springer, 1993.
Edgar G. Goodaire, Linear Algebra: Pure & Applied, World Scientific, 2014.
Dimitris P. Bertsekas, John N. Tsitsiklis, Introduction to Probability, 2nd Ed, Athena Scientific, 2008.
Alberto Leon-Garcia, Probability, Statistics, and Random Processes for Electrical Engineering, 3rd Ed, Addison-Wesley, 2008.

EC792 HIGH PERFORMANCE COMPUTING ARCHITECTURES (4-0-0) 4

Instruction Level Parallelism: Pipelining, Hazards, Instruction Level Parallelism, Branch prediction, Static and Dynamic Scheduling, Speculation, Limits of ILP. Multicore Memory Hierarchy: Cache trade-offs, Basic and Advanced optimizations, Virtual Memory, DRAM optimizations. Multiprocessors: Symmetric and Distributed architectures, Cache coherence protocols - Snoopy and Directory based, ISA support for Synchronization, Memory Consistency Models. Interconnection Networks: Architectures, Topologies, Performance, Routing, Flow control, Future of NoCs.

John Hennessy and David Patterson, Computer Architecture - A Quantitative Approach 6th Edition, Morgan Koufmann, 2017
John Hennessy and David Patterson, Computer Architecture - A Quantitative Approach 5th Edition, Morgan Koufmann, 2011

John Paul Shen and Mikko H. Lipasti, Modern Processor Design: Fundamentals of Superscalar Processors, Tata McGraw Hill, 2013
D. A. Patterson and J. Hennessy, Computer Organization and Design, Harcourt Asia, 1998.
Behrooz Parhami, Computer Arithmetic Algorithms and Hardware Design, Oxford, 2000.
NPTEL Video Lectures

EC793 SIGNAL ANALYSIS AND PROCESSING (4-0-0) 4

Review of Time domain analysis of discrete-time signals & systems, Transform domain analysis of discrete time signals & systems: Z transforms, application of Z transforms to discrete-time systems, Frequency domain analysis of discrete-time signals and systems, Sampling in time and frequency domain, linear convolution using DFT, Fast Fourier Transform algorithms.
Digital Filter Design: Filter Structures; FIR filter design, IIR Filter Design, Filter design using Butterworth, Chebyshev and elliptic approximations, Spectral transformation technique for HP, BP and BS filter design. Direct design of IIR filters, Introduction to multirate Signal Processing, Upsampling, Downsampling, Sample rate conversion.

D G Manolakis, V K Ingle, Applied Digital Signal Processing, Cambridge University Press, 2012
Oppenheim, Schaffer, Discrete Time Signal Processing, Prentice Hall,
Ashok Ambardar, Digital Signal Processing – A Modern Introduction, Thomson, 2007
Sanjit K. Mitra, Digital Signal Processing: A computer based Approach, TMH, 2006

EC801 LOGIC SYNTHESIS TECHNIQUES (4-0-0) 4

Introduction to Computer aided synthesis and optimization. Hardware Modeling. Advanced Boolean Algebra and Applications, Shannon co-factors, satisfiability and cover, Binary Decision Diagrams, Representing Boolean functions, ROBDD, ITE operator, Variable ordering- choice of variables, application of BDD to synthesize Boolean functions, Two level combinational logic optimization, Multiple level combinational optimization. Sequential logic optimization. Cell Library Binding. Algorithms for Technology mapping – Structural and Boolean matching, Simulation & Static Timing analysis - Event driven simulation – zero delay, unit delay and nominal delay simulation, Timing analysis at the logic level, Delay models, Delay graph, static sensitization, State of the art and future trends: System level synthesis and hardware software co-design.

Giovanni De Micheli, Synthesis and Optimization of Digital Circuits, McGraw Hill, 1994.
Srinivas Devadas, Abhijith Ghosh and Kurt Keutzer, Logic Synthesis", Kluwer Academic, 1998.
G. D. Hachtel and F. Somenzi, Logic Synthesis and Verification Algorithms, Kluwer Academic Publishers, 1996.
S. Hassoun and T. Sasao, (Editors), Logic Synthesis and Verification, Kluwer Academic publishers, 2002
NPTEL Video Lectures

EC802 LOW POWER VLSI DESIGN (4-0-0) 4

Introduction to Low Power VLSI. Modeling and Sources of Power consumption. Power estimation at different design levels. Power optimization for combinational circuits and sequential circuits Voltage scaling Approaches. Low energy computing using energy recovery techniques. Low Power SRAM architectures. Software design for low power. Computer Aided Design Tools. Case studies Recent trends in low-power design for mobile and embedded application.

Kaushik Roy, Sharat Prasad, Low-Power CMOS VLSI design, John Wiley, 2000.
K.-S. Yeo and K. Roy, Low-Voltage Low-Power Subsystems, McGraw Hill, 2004.
L. Benini and G. De Micheli, Dynamic Power Management Design Techniques and CAD Tools, Springer, 1998.
S. G. Narendra and A. Chandrakasan, Leakage in Nanometer CMOS Technologies, Springer, 2005.
Edgar Sánchez-Sinencio, Andreas G. Andreou, Low-Voltage/Low-Power Integrated Circuits and Systems: Low-Voltage Mixed-Signal Circuits IEEE Press Series on Microelectronic Systems 1999
NPTEL Video Lectures

EC803 MICROELECTRONIC DEVICES (4-0-0) 4

Review of basic device physics, Electronic structure of semiconductors, Diodes, MOS capacitor. Transistor theory. Scaling - Moore's law on technology scaling, MOS device scaling theory, Short channel effects, sub threshold leakage, Punch through, DIBL, High field mobility, Velocity saturation and overshoot. Reliability. Various definitions of channel length, Performance metric of digital technology, Transistor design trade-offs, Technology case studies, Silicon on Insulator (SOI) devices, Partially depleted and fully depleted SOI, Floating body effects, SOI for low power, Interconnects in sub-micron technology, Foundry technology, International Technology Roadmap for Semiconductors (ITRS)

J. A. del Alamo Integrated Microelectronic Devices: Physics and Modeling, Pearson, 2017
Yaun Taur, Tak H. Ning, Fundamentals of modern VLSI devices, Cambridge university press, 1998.
B. G. Streetman & S. Banerjee, Solid State Electronic Devices, Prentice Hall, 1999.
M. K. Achuthan and K. N. Bhat, Fundamentals of Semiconductor Devices, McGraw Hill, 2006
Nandita Dasgupta, Amitava Dasgupta, Semiconductor Devices: Modelling And Technology, Phi, 2009
A. K. Dutta, Semiconductor Devices and Circuits, Oxford Univ. Press, 2008.
ITRS Road map - http://public.itrs.net/
NPTEL Video Lectures

EC804 DIGITAL VLSI TESTING & TESTABILITY (4-0-0) 4

Overview of testing and verification, Defects and their modeling as faults at gate level and transistor level. Functional V/s. Structural approach to testing. Complexity of testing problem. Controllability and observability. Generating test for a signal stuck-at-fault in combinational logic. Algebraic algorithms. Test optimization and fault coverage. Logic Level Simulation – Delay Models, Event driven simulation, general fault simulation (serial, parallel, deductive and concurrent). Testing of sequential circuits. Observability through the addition of DFT hardware, Adhoc and structured approaches to DFT – various kinds of scan design. Fault models for PLAs, bridging and delay faults and their tests. Memory testing, testing with random patterns. LFSRs and their use in random test generation and response compression (including MISRs), Built-in self-test.

M. Abramovici, M. A. Breuer, and A. D. Friedman, Digital Systems Testing and Testable Design, IEEE Press, 1994.
M. L. Bushnel and V. D. Agarwal, Essentials of Testing for Digital, Memory and Mixed – Signal VLSI Circuits, Kluwer Academic Publishers, 2000.
Ajai Jain, Learning Module for the course - VLSI Testing and Testability, IIT, Kanpur, 2001.
NPTEL Video Lectures

EC805 EMBEDDED SYSTEMS (2-0-3) 4

Introduction: Overview of embedded systems, embedded system design challenges, common design metrics and optimizing. Survey of different embedded system design technologies & trade-offs. Embedded microcontroller cores, embedded memories, Examples of embedded systems. Architecture for embedded system, High performance processors – strong ARM processors, programming, interrupt structure, I/O architecture, Technological aspects of embedded systems: interfacing between analog and digital blocks, signal conditioning, Digital signal processing, Subsystem interfacing, interfacing with external systems. Software aspects of embedded systems: real time programming languages and operating systems for embedded systems – RTOS requirements, kernel types, scheduling, context switching, latency, inter-task communication and synchronization, Case studies.

Jack Ganssle, The Art of Designing Embedded Systems, Elsevier, 1999.
R. Gupta, Co-synthesis of Hardware and Software for Embedded Systems, Kluwer 1995.
Steve Furber, "ARM System Architecture", Edison Wesley Longman, 1996.
Andrew N. Sloss, Dominic Symes, Chris Wright, "ARM System Developer's Guide: Designing and Optimizing System Software", Elsevier, 2004.
NPTEL Video Lectures

EC806 DIGITAL DESIGN USING FPGAs (2-0-3) 4

Digital system design options and trade-offs, Design methodology and technology overview, High Level System

Architecture and Specification: Behavioral modeling and simulation, Overview of FPGA architectures and technologies, Logic block architecture, Input and Output cell characteristics, clock input, Timing, Power dissipation, Programmable interconnect, Applications, Embedded system design using FPGAs, Dynamic architecture using FPGAs, reconfigurable systems, application case studies, Simulation / implementation exercises of combinational, sequential and DSP kernels on Xilinx / Altera boards.

M.J.S. Smith, Application Specific Integrated Circuits, Pearson, 2000
Peter Ashenden, Digital Design using VHDL, Elsevier, 2007
Peter Ashenden, Digital Design using Verilog, Elsevier, 2007
Clive Maxfield, The Design Warriors's Guide to FPGAs, Elsevier, 2004
NPTEL Video Lectures

EC807 ACTIVE FILTER DESIGN (4-0-0) 4

Butterworth, Chebyshev & Inverse-Chebyshev filter response and pole locations; LC ladder filter – prototype & synthesis; Frequency transformation of lowpass filter. Impedance converters; Gm-C filters – Gm-C biquad, Q enhancement, Automatic Tuning; Active-RC filters – Comparison with Gm-C filter, Issues in realizing high frequency active-RC filters; Characterization of on-chip integrated continuous time filters.

R. Schaumann and M.E. Van Valkenburg, Design of Analog Filters, Oxford University Press, 2003.
P. V. Ananda Mohan, Current-Mode VLSI Analog Filters - Design and Applications, Birkhauser, 2003
NPTEL Video Lectures

EC808 CMOS RF INTEGRATED CIRCUITS (4-0-0) 4

Basic concepts in RF Design – harmonics, gain compression, desensitization, blocking, cross modulation, intermodulation, inter symbol interference, noise figure, Friis formula, sensitivity and dynamic range; Receiver architectures – heterodyne receivers, homodyne receivers, image-reject receivers, digital-IF receivers and subsampling receivers; Transmitter architectures – direct-conversion transmitters, two-step transmitters; Low noise amplifier (LNA) – general considerations, input matching, CMOS LNAs; Down conversion mixers – general considerations, spur-chart, CMOS mixers; Oscillators – Basic topologies, VCO, phase noise, CMOS LC oscillators; PLLs – Basic concepts, phase noise in PLLs, different architectures.

Behzad Razavi, RF Microelectronics, Prentice Hall PTR, 1997
Thomas H. Lee, The design of CMOS radio-frequency integrated circuit, Cambridge University Press, 2006
Chris Bowick, RF Circuit Design, Newnes, 2007
NPTEL Video Lectures

EC809 HETEROGENEOUS AND PARALLEL PROGRAMMING (3-0-2) 4

Heterogeneous platform and GPU architecture. Introduction to OpenCL. OpenCL device architecture. Concurrency and execution model. Programming examples like vector addition, convolution and matrix multiplication. Application case studies.

Benedict R. Gaster, Lee Howes, David R. Kaeli, Perhaad Mistry, Dana Schaa, "Heterogeneous Computing with OpenCL" - Revised OpenCL 1.2 Edition, Morgan Kaufmann, 2013.
Aaftab Munshi, Benedict R. Gaster, Timothy G. Mattson, James Fung, Dan Ginsburg, "OpenCL Programming Guide", Addison-Wesley, 2012.
David B. Kirk and Wen-mei W. Hwu, "Programming Massively Parallel Processors - A Hands-on Approach", Second Edition, Morgan Kaufmann, 2013.
AMD Accelerated Parallel Processing OpenCL User Guide, AMD, 2014.
NPTEL Video Lectures

EC810 SELECTED TOPICS IN VLSI DESIGN (4-0-0) 4

Current advances in VLSI Design as defined by the instructor.

Current literature from IEEE and other quality journals and recent books in the field.

EC831 SPREAD SPECTRUM COMMUNICATION SYSTEMS (4-0-0) 4

Direct sequence spread spectrum, Frequency hop spread spectrum, Hybrid direct sequence/frequency hop spread spectrum, Complex envelope representation of spread spectrum systems. Binary Shift Register Sequences for Spread Spectrum Systems: Maximum length sequences, Gold Codes, Synchronization of Spread Spectrum Signals: Acquisition, Tracking, Code tracking loops for frequency hop systems, Synchronization using matched filter, Performance of Spread Spectrum Systems in Jamming Environments, CDMA System Design Concepts, Direct Sequence Ultra-wideband Communications, Ultra Low Power, Short Range system optimization and trade-offs.

Roger L.Peterson, Rodger E.Ziemer, David E.Borth, "Introduction to Spread Spectrum Communications", Prentice Hall, 1995.
Gordon Stuber, "Principles of Mobile Communication", Fourth Edition, Springer, 2017.
Don Torrieri, "Principles of Spread Spectrum Communications", Springer, Third Edition, 2015.
Marvin Simon, Jim Omura, Robert Scholtz, Barry Levitt "Spread Spectrum Communication Handbook", McGraw - Hill Inc., 2002.
Jack K. Holmes, "Spread Spectrum Systems for GNSS and Wireless Communications", First Edition, Artech House, 2007.

EC832 MIMO COMMUNICATION SYSTEMS (4-0-0) 4

Overview of MIMO communications: Introduction to MIMO, Introduction to Spatial Diversity and Spatial Multiplexing, MIMO capacity formula, MIMO System Model. Application of MIMO Capacity, Phenomenology of multipath channels, Power law propagation, Impulse response of a multipath channel, Intrinsic multipath channel parameters, Classes of multipath channels, Statistics of small-scale fading, MIMO channels in LOS geometry, Antenna spacing and scattering angle,. Alamouti Coding and Space-time Coding: Maximal ratio receive combining (MRRC), Maximum likelihood decoding in MRRC and Alamouti receivers, Performance results, Space-time coding. Spatial Multiplexing: Overview of spatial multiplexing, BLAST architecture, Broadband MIMO, Narrowband and Broadband MIMO channel estimation,

Jerry R. Hampton, "Introduction to MIMO Communications", Cambridge University Press, 2014.
Bliss and S. Govindasamy, "Adaptive Wireless Communications: MIMO Channels and Networks", Cambridge University Press, 2013.
Simon Haykin, Michael Moher, "Modern Wireless Communications", First Edition, Pearson, 2004.
Andrea Goldsmith, "Wireless Communication", Cambridge University Press 2005.
Jafarkhani, "Space-Time Coding: Theory and Practice", Cambridge University Press, 2005.

EC833 INTERNET OF THINGS (4-0-0) 4

The IoT Networking Core , Technologies involved in IoT Development, Overview of IoT supported Hardware, Network Fundamentals: Overview and working principle of Wired Networking equipment, Linux Network configuration Concepts, IoT Architecture, Applications, Back end Application, Case Study & advanced IoT Applications, IoT applications in home, infrastructures, buildings, security, Industries, Home appliances, other IoT electronic equipment. Use of Big Data and Visualization in IoT, Industry 4.0 concepts. Sensors and sensor Node and interfacing.

Ovidiu Vermesan, Peter Friess, Internet of Things: Converging Technologies for Smart Environments and Integrated Ecosystems, River Publishers, 2013.
Jean-Philippe Vasseur, Adam Dunkels, Interconnecting Smart Objects with IP: The Next Internet, Morgan Kuffmann, 2010.
Lu Yan, Yan Zhang, Laurence T. Yang, Huansheng Ning, The Internet of Things: From RFID to the Next Generation Pervasive Networked, Auerbach Publications, 2008.
Arshdeep Bahga, Vijay Madisetti, Internet of Things (A Hands on Approach), VPT, 2014.
Adrian McEwen, Hakim Cassimally, Designing the Internet of Things, Wiley, 2013.

EC834 ERROR CONTROL CODING (4-0-0) 4

Coding for reliable digital transmission and storage. Groups, Rings, Vector Spaces, Galois Fields, Polynomial rings, Channel models, Linear Block codes, Cyclic codes, BCH codes, Reed Solomon Codes, Berlekamp-Massey and Euclid decoding algorithm, Applications of Reed-Solomon codes, Convolutional codes, Decoding algorithms for Convolutional codes, Viterbi, Trellis coded modulation, Turbo Codes, LDPC codes.

Shu Lin and Daniel J. Costello Jr., Error Control Coding: Fundamentals and Applications, Prentice Hall, 2003.
S. B Wicker, Error Control Systems for Digital Communication and Storage, Prentice Hall International, 1995.

Blahut R.E., Algebraic codes for Data transmission, Cambridge University Press, 2003.

EC835 ALGORITHMS FOR PARAMETER AND STATE ESTIMATION (4-0-0) 4

Maximum likelihood (ML) estimation, Maximum a posteriori (MAP) estimation, Least squares (LS) estimation, Minimum mean square error (MMSE) estimation, Linear MMSE (LMMSE) estimation. LS estimation for linear and nonlinear systems, modeling stochastic dynamic systems, the Kalman filter for discrete time linear dynamic systems with Gaussian noise. Steady state filters for noisy dynamic systems, adaptive multiple model estimation techniques. Nonlinear estimation techniques, computational aspects of discrete time estimation.

Y. Bar-Shalom, X. Rong Li and T. Kirubarajan, Estimation with Applications to Tracking and Navigation, John Wiley & Sons, 2001.
F. L. Lewis, Optimal Estimation, John Wiley & Sons, 1986.
R. G. Brown and P. Y. C. Hwang, Introduction to Random Signals and Applied Kalman Filtering, John Wiley & Sons, 1992.

EC836 RADAR SIGNAL PROCESSING (4-0-0) 4

Radar and its composite environment, Review of Radar range performance computations, Detection Processes, Sequential and adaptive processes, Atmospheric effects, Sea and land Back scatter, Signal Processing concepts and waveform designs MTI & CW radars, phase coding techniques, FM pulse compression waveforms, Mateorogical radar and system performance analysis.

R.J Sullivan, Radar Foundations for imaging and Advanced Concepts, PMI, 2004.
F.E Nathanson, Radar Design Principles, Signal Processing and the Environment, PMI, 2004.
J.C. Toomay, Principles of radar, PMI, 2004.

EC837 ADVANCED RADIATING SYSTEMS (4-0-0) 4

Planar Antennas - Microstrip rectangular and circular patch antennas- Analysis and design, Feeding methods; circularly polarized microstrip antennas, Broadband techniques. Array Theory, Planar array- Array factor, beamwidth, directivity. Electronic scanning,. Broadband Antennas, Yagi array of linear elements and printed version, Log-periodic dipole array. Frequency Independent Antennas Aperture Antennas- Field equivalence principle, Babinet's principle, Antennas for mobile communication - Active and smart microstrip antennas, Design and analysis of microstrip antenna arrays.

C. A. Balanis, Antenna Theory and Design, John Wiley & Sons, 1997.
J.D. Kraus, Antennas, McGraw-Hill, 1988.
R.A. Sainati, CAD of Microstrip Antennas for Wireless Applications, Artech House, 1996.
R. Garg, P. Bharhia, I. Bahl, and A. Ittipiboo, Microstrip Antenna design Handbook, Artech House.
J. R. James, P.S. Hall and C.Wood, Microstrip Antennas: Theory & Design, Peter Peregrinns , UK.

EC838 MULTI TARGET TRACKING AND MULTI-SENSOR INFORMATION FUSION (4-0-0) 4

Target tracking, performance evaluation techniques, data association. Tracking with multiple sensors, out - of - sequence measurement, track initialization, track management. Probabilistic Data Association Filter (PDAF), adaptive gating for PDAF. Maximum Likelihood - PDA (ML - PDA). Joint Probabilistic Data Association Filter (JPDA). Multiple Hypothesis Tracking (MHT). Performance prediction, sensor management, track - to - track fusion. Nonlinear filters.

Y. Bar-Shalom, X. Rong Li, Multi Target Multi Sensor Tracking-Principles and Techniques, YBS Publishers, 1995.
Y.Barshalom, P K Willet and X Tin, Tracking and Data Fusion: A Hand book of algorithms, Yaakov Bar-Shalom, 2011.
Y.Barshalom, Multitarget-Multisensor Tracking: Applications and Advances v.2, Yaakov Bar-Shalom, 2000.
Y.Barshalom, Multitarget-Multisensor Tracking: Applications and Advances v.3, Artech House, 2000.
S.Blackman and R.Popoli, Design and Analysis of Modern Tracking systems published by Artech house, 1999.

EC839 NANO-PHOTONICS (4-0-0) 4

Fundamentals, Maxwell's equations, light-matter interaction, dispersion, EM properties of nanostructures, etc. Photonic crystals and photonic crystal fibers, Photonic and plasmonic nanocircuits, Metal optics Manipulating light with plasmonic nanostructures, Plasmonic nano-sensors, Near-field optics, Metamaterials: artificial magnetism and negative refractive index, Metamaterials: superlens and hyperlens, Transformation optics and cloaking, Metasurfaces, Nanolasers, Tunable and active plasmonic materials, Refractory plasmonics, Plasmonics for energy conversion, data storage and biomed applications, Silicon photonics, Diamond photonics, Graphene photonics, Intro to quantum photonics.

W. Cai and V. Shalaev, Optical Metamaterials: Fundamentals and Applications, Springer, 2009.
Surface plasmons on smooth and rough surfaces and on gratings," Raether (Springer-Verlag, New York, 1986)
Principles of Nano-Optics," Lukas Novotny and Bert Hecht, Cambridge, 2006.
S. Maier, Plasmonics: Fundamentals and Applications, Springer (2007). Photonic Crystals: Molding the Flow of Light ," J. D. Joannopoulos, R. D. Meade, J. N. Winn (Princeton University Press, 1995).

EC840 MILLIMETER WAVE COMMUNICATIONS (4-0-0) 4

Millimeter wave characteristics, Radio wave propagation for mm wave, emerging applications of millimeter wave communications. Millimeter wave generation and amplification, Analog mm wave components, Consumption factor theory, Modulation for millimeter wave communications, Millimeter wave link budget, Transceiver architecture, Millimeter wave calibration, Millimeter wave design considerations. Massive MIMO Communications, Noise coupling in MIMO system, Dynamic spatial, frequency and modulation allocation. Antenna beam width, polarization, advanced beam steering and beam forming, mm wave design consideration, Implementation for mm wave in adaptive antenna arrays, Device to Device communications over 5G systems.

K.C. Huang, Z. Wang, "Millimeter Wave Communication Systems", Wiley-IEEE Press, March 2011.
Robert W. Heath, Robert C. Daniel, James N. Theodore S. Rappaport, Murdock, "Millimeter Wave Wireless Communication", Prentice Hall, 2014.
Jonathan Wells, "Multi-Gigabit Microwave and Millimeter-Wave Wireless Communications", Artech House, 2010.
Xiang, W; Zheng, K; Shen, X.S; "5G Mobile Communications: Springer, 2016.

EC841 CRYPTOGRAPHY (4-0-0) 4

Elementary Number Theory, Finite series, Arithmetic and Algebraic Algorithms, Secrete key and Public key Cryptography, Pseudo Random bit generators, Block and Stream Ciphers, Hash functions and Message digests, Public key encryption, Authentication, Digital Signatures, Zero Knowledge Interactive Protocols, Elliptic curve cryptosystems, formal verification, Crypt analysis, Hard Problems.

Koblitz N., A Course on Number Theory and Cryptography, Springer Verlag, 1986.
Menezes A. et. all, Handbook of Applied Cryptography, CRC Press, 1996.

EC842 INFORMATION THEORY (4-0-0) 4

Communication systems and Information Theory, Measures of Information, Coding for Discrete sources, Discrete memory-less channels and capacity, Noisy channel coding theorem, Techniques for coding and decoding, Waveform channels, Source coding with Fidelity criterion, Network Information Theory.

Thomas M Cover & Joy A Thomas, Elements of Information Theory, Second Edition, John Wiley,2006.
R.G.Gallagher, Information Theory and Reliable Communication, Addison Wesley, 1987.
A.J.Viterbi & J.K. Omura, Principles of Digital Communications and Coding, McGraw Hill, 1979.

EC843 BROADBAND COMMUNICATIONS (4-0-0) 4

Introduction, Internet-based Networks, Networking Technologies, Multiple Access Techniques, Timing Synchronization, Delay Lock Loop, ISDN Physical Layer, ISDN Data Link Layer, Signaling System Number 7, BISDN and SONET, ATM Switch and Protocols, UWB, specialized video (DBS) and wireless networks; CATV architecture; and the role of the Internet in the broadband environment, Access Networks, Cable Modem Systems, PONs, Personal Communication Systems, VPNs, VSATs, CLOS Network Switch, OFDM Concept, OFDMA System, Multi-Carrier CDMA, WiMAX.

Introduction to Broadband Communication Systems, Cajetan M. Akujuobi, Matthew N.O. Sadiku, Scitech Publishing Inc, CRC Press, 2007.
Balaji Kumar, Broadband Communications, McGraw-Hill, 1998.
Robert Newman, Broadband Communications, Prentice Hall, 2002.

EC844 ELECTROMAGNETIC INTERFERENCE AND COMPATIBILITY (4-0-0)4

Introduction to EMI/EMC to circuit designer, Biological effects of EMI. Sources of EMI/EMC-noise paths Measurement of RE/CE interference. EMI in analog and digital circuits, power circuit case studies, Grounding, Shielding-cut-off frequency, effectiveness calculation, common mode choke design, radiation emission reduction. Power distribution issues in PCB using different converters, filtering techniques. Reflection and cross talk in PCB for high-speed circuits. Signal integrity-propagation on multi-conductor lines and cross talk, PCB design for signal integrity, EMI/EMC standards.

Ott. H.W. Noise reduction techniques in Electronic system, 2nd edition, John Wiley Interscience, New York (1988).
Clayton R.Paul, Introduction to electromagnetic compatibility, John Wiley and Sons, Inc. 1991.
Dr.V.P.Kodali, "Engineering EMC", IEEE Publications, S. Chand., New Delhi, 2000.

EC845 PRINCIPLES OF COMMUNICATION SYSTEMS SIMULATION (4-0-0)4

The role of simulation and simulation methodology. Sampling and Quantization. Low pass Simulation models for Band pass Signals and systems, Complex envelope representation of band pass signals, multi carrier signals, nonlinear and time variant systems. Filter Models and Simulation Techniques, Phase Locked Loops and Differential Equation Methods, Generating and Processing random Signals, Stationary and ergodic processes, PN sequence generation and processing. Monte Carlo Simulation of Communication Systems: Fundamental concepts, AWGN channel, Fading channel, examples, Semi analytic techniques.

Tranter, Sam Shanmugan, Rappaport and Kosbar, "Principles of Communication Systems Simulation with Wireless Applications", First edition, Prentice Hall, 2004.
Jeruchim, "Simulation of Communication Systems", Second Edition, Springer, 2011.
Won Y Yang, "MATLAB/Simulink for Digital Communication", Second Edition, YesDee Publishers, 2014.

EC846 COMPUTER COMMUNICATION NETWORKS (4-0-0)4

Introduction to common networks such as the Internet, WiFi, Cellular networks, Ad hoc and Sensor networks; Introduction to ISO/OSI Layers; Deterministic and Stochastic Network Calculus, Introduction to Network Simulators, Medium Access Control Layer, ARQ protocols; Random access, Backoff algorithms; WFQ implementations, Introduction to Queueing theory, Routing Layer and algorithms, Buffer management; Transport Layer, Cross-layer Design; Network Monitoring; Performance Measures.

Communication Networking: An Analytical Approach, Anurag Kumar, D Manjunath and Joy Kuri, Morgan Kauffmann, 2004.
Data Networks, 2nd Edition, Dimitri P Bertsekas and R Gallager, Pearson, 1992.
Wireless Networking, Anurag Kumar, D Manjunath and Joy Kuri, Morgan Kauffmann, 2004.
Resource Allocation and Cross-Layer Control in Wireless Networks, Leonidas Georgiadis, Michael J. Neely and Leandros Tassiulas, NOW Publishers, 2006.
Computer Networking: A top-down approach, James F Kurose, Pearson Education, 5th Edition, 2012.
Various research publications

EC847 SELECTED TOPICS IN COMMUNICATION ENGINEERING (4-0-0) 4

Current advances in Communication Engineering as defined by the instructor

Current literature from IEEE and other quality journals and recent books in the field.

EC861 IMAGE PROCESSING AND COMPUTER VISION (4-0-0) 4

Overview of image processing systems, image formation and perception, continuous and digital image representation, image quantization, image contrast enhancement, histogram equalization, 2D signals and systems, 2D sampling, linear convolution in 2D, continuous and Discrete Fourier transform in 2D, image

filtering in the DFT domain, color representation and display; true and pseudo color image processing, image compression, imaging geometry, model of image degradation/restoration process, texture analysis, motion analysis, geometric camera models, stereopsis, structure from motion, tracking, robot vision, object identification.

Anil K. Jain, Fundamentals of digital image processing, Prentice Hall, 1989.
Rafael C. Gonzalez, Richard E. Woods, Digital Image Processing, 2nd Ed, Prentice Hall, 2002.
Forsth D. A. and Ponce J., Computer Vision: A Modern Approach, Prentice Hall, 2003.
Richard Szeliski, Computer Vision: Algorithms and Applications, Springer, 2010.
Hartley and Zisserman, Multiple Geometry in Computer Vision, Cambridge University Press, 2004.

EC862 TIME SERIES ANALYSIS AND DATA SCIENCE (4-0-0) 4

Identifying patterns in time series data, inference, estimation, prediction, general properties of time series models, systematic pattern and random noise, trend and seasonality analysis, time domain and frequency domain analysis, data visualization, linear and mixed models, AR models, ARMA models, ARIMA models, identification and parameter estimation, model estimation and forecasting, Akaike information criterion, mixed models, single spectrum and cross spectrum analysis, higher order statistics, state space models, Kalman filter, non-Gaussian linear models, Generalized autoregressive conditional hetereoskedastic (GARCH) models, stochastic volatility models, extreme value theory, nonlinear time series models, applications in data science.

Peter J. Brockwell, Richard A. Davis, Introduction to Time Series and Forecasting, Springer, 2001.
George E. P. Box, Gwilym M. Jenkins, Gregory C. Reinsel, Time Series Analysis: Forecasting and Control 4th Ed, Wiley, 2008.
Andrew C. Harvey, Forecasting, Structural Time Series Models and the Kalman Filter, Reprint Ed, 2001.
Box-Steffensmeier, Janet M., John R. Freeman, Matthew P. Hitt, Jon C. W. Pevehouse, Time Series Analysis for the Social Sciences, Cambridge University Press. 2014.
James Fahl, Data Analytics, Paperback, 2017.

EC863 STATISTICAL SIGNAL PROCESSING (4-0-0) 4

Introduction to Adaptive Filters: General properties, filtering, prediction and smoothing, Applications in Communications, Optimal Signal Processing, Principles of orthogonality, minimum square error, Wiener Hopf equations, state space model, innovations process, Kalman filter equations. Linear Adaptive Equalisation, Gradient search and steepest descent adaptation algorithms, Transient and Steady state properties including convergence rate and mis-adjustment, least square estimation, Recursive Least Squares (RLS) algorithms, Introduction to Fast Recursive Algorithms for Equalization, lattice filtering for RLS. Tracking time-varying systems.

S.J. Orfanidis, Optimum Signal Processing, McGraw Hill, 1989.
S. Haykin, Adaptive FilterTheory, Pearson, 1996.
Mayson H. Hayes, Statistical Digital Signal Processing and Modeling, Wiley, 1996.

EC864 SPEECH AND AUDIO PROCESSING (4-0-0) 4

Speech Production–human speech production mechanism, digital models for speech production, Speech perception, Speech Analysis–Time and frequency domain analysis of speech, Linear prediction, Speech compression, Audio processing–characteristics of audio signals, sampling, Audio compression techniques, Standards for audio compression in multimedia applications, MPEG audio encoding and decoding, audio databases and applications. Speech synthesis–text to speech synthesis, letter to sound rules, syntactic analysis, timing and pitch segmental analysis. Speech recognition.

Douglas O'Shaugnessy, Speech Communication–Human and Machine, IEEE Press, 2000
L R Rabiner, Digital Processing of Speech Signals, Pearson,1978.
T.F Quatieri , Discrete-time speech signal processing: Principles and Practise Pearson,2002.
Zi Nian Li, Fundamentals of Multimedia, Pearson Education, 2003.

EC865 MULTIMEDIA SYSTEMS (4-0-0) 4

Computer information representation through text, graphics, images, sound, audio, animation, video, processing, storage, generation, manipulation, rendition, transmission of multimedia information, psycho acoustic models, synthesis and recognition, color models for video, television, video formats, text in multimedia and internet, image compression, video indexing and content based image/video retrieval, audio coding, storage, retrieval and presentation of media, multimedia annotation and indexing, multimedia recommendation and summarization, multimodal translation between language and vision, DLT for audio, multimedia synchronization, multimedia databases, multimedia communications, network applications, distributed multimedia systems, multimedia system integration.

Ze-Nian Li, Mark S. Drew, Fundamentals of Multimedia. Prentice-Hall/Pearson Education, 2004.
P. K. Andleigh, Kiran Thakrar, Multimedia Systems Design, 1/e, Prentice Hall, 1995.
R. Steinmetz, K. Nahrstedt, Multimedia Fundamentals, Volume 1: Media Coding and Content Processing, Prentice Hall, 2002.
F. Kuo, J. J. Garcia Luna-Aceves, W. Effelsberg, Multimedia Communications: Protocols and Applications, 1/e 1998.
Milovanovic, Zoran S. Bojkovic, Dragorad A. Milovanovic, Kamisetty Ramamohan Rao: Multimedia Communication Systems: Techniques, Standards, and Networks, Prentice Hall, 2002.

EC866 DEEP LEARNING AND APPLICATIONS (3-0-2) 4

Linear Regression , Logistic regression, Basic neuron structure, Perceptron, error functions, optimization – gradient descent, Multilayer perceptron, transfer function, nonlinearities, learning, backpropagation, function approximations, overfitting, underfitting, Deep networks, challenges, regularization techniques – Norm penalties, early stopping, drop outs, dataset augmentation, bagging and ensemble methods, Convolutional Networks – Convolution, pooling, variants, transfer learning, Sequence Modeling – Recurrent neural networks, Bidirectional RNNs, architectures, LSTM, Application examples – Computer Vision, Speech recognition, NLP.

Simon S. Haykin, Neural Networks and Learning Machines, 3rd Ed, Pearson, 2009.
José C. Principe, Neil R. Euliano, W. Curt Lefebvre, Neural and Adaptive Systems: Fundamentals through Simulations, John Wiley and Sons, 2000.
Ian Goodfellow, Yoshua Bengio, Aaron Courville, Deep Learning, MIT Press, 2016.

EC867 FOURIER AND WAVELET ANALYSIS (4-0-0) 4

Hilbert Spaces, Review of sequences and discrete time systems, functions, DTFT, convergence, multi rate systems, polyphase representation, stochastic processes and systems. Continuous time systems, Fourier transform, definition, existence, spectral decay, Fourier series. Sampling and Interpolation–finite dimensional vectors, sequences, functions, periodic functions, approximation and compression polynomial and spline approximation. Localization and uncertainity, Filter banks–Localization, two channel orthogonal filter banks, design, biorthogonal filter banks, design, Local fourier bases–N channel filter banks, exponentially modulation filter banks, cosine modulated filter banks. Wavelet bases on sequences, Tree structured filter banks, orthogonal, biorthogonal bases, wavelet packets, frames. Wavelet bases on functions–local Fourier transforms.

Martin Vetterli Jelena Kovacevic & Vivek K. Goyal, Foundations of Signal Processing, Cambridge University Press, 2015.
J. Kovacevic, V. K. Goyal and Martin Vetterli, Fourier and Wavelet Signal Processing, Cambridge University Press, 2013.

EC868 TIME FREQUENCY ANALYSIS (4-0-0) 4

The need for Time-frequency analysis: introduction, Time and Frequency Description of Signals, Instantaneous Frequency and the Complex Signal, Densities and Characteristic functions: one and two dimensional density functions and their characteristic functions, Fundamentals of Time-Frequency Distribution (TFD), Different Types of TFD, Generation of TFD Using Kernel Methods. Kernel design for reduced interference in TFD. Positive Distributions Satisfying the Marginals. Applications of TFD in the fields of Radar, Speech, Sonar Signal Processing.

Leon Cohen, Time-Frequency Analysis, Prentice-Hall PTR, Upper Saddle River, 1995.
S. Mallat, A wavelet tour of signal processing - The sparse way, Elsevier, Third Edition, 2009.
D. Gabor, Theory of communication, Proceedings of IEE, pp. 429-457, 1946.

EC869 MEDICAL IMAGING AND BIOSIGNAL ANALYSIS (4-0-0) 4

Bio-electromagnetism, bioelectric sources and conductor modeling, image formation in modern medical imaging modalities, radiography, fluoroscopy, and computed tomography, magnetic resonance imaging, ultrasound, acoustic and photoacoustic imaging, X-Ray tomography, radiation measurements, safety issues, and physiological signals and responses, Bioelectrical signals, Evoked potentials, Electromyogram, respiration and heart rate variability, mathematical modeling and techniques for image and bio-signal analysis and diagnostic decision-making, detection, segmentation and classification techniques, Computational Bio-imaging, data interpolation, registration, acquisition and compression.

Jaakko Malmivuo, Bioelectromagnetism - Principles and Applications of Bioelectric and Biomagnetic Fields, Oxford University Press, 1995.

John L. Semmlow, Benjamin Griffel, Biosignal and Medical Image Processing, 3rd Ed, CRC Press, 2014.

E. Russell Ritenour and William Hendee, Medical Imaging Physics, 4th Ed, 2002.

Rangaraj M. Rangayyan, Biomedical image analysis, CRC Press, 2004.

B.H Brown, R.H Smallwood, D.C. Barber, P.V Lawford, D.R Hose, Medical Physics and Biomedical Engineering, CRC Press, 1998.

EC870 ARCHITECTURES FOR SIGNAL PROCESSING AND MACHINE LEARNING (4-0-0) 4

Representation of digital signal processing systems: block diagrams, signal flow graphs, data-flow graphs, dependence graphs; pipelining and parallel processing for high-speed and low power realizations; iteration bound, algorithms to compute iteration bound, retiming of data-flow graphs; unfolding transformation of data-flow graphs; systolic architecture design, architectures for real and complex fast Fourier transforms; stochastic logic based computing, computing digital filters, arithmetic functions and machine learning functions using stochastic computing; Neural Network architectures.

K.K. Parhi, VLSI Digital signal processing systems: Design and implementation, John Wiley, 1999.

Lars Wanhammar, DSP Integrated Circuits, Academic Press, 1999.

Sen M. Kuo Bob H. LeeWenshun Tian, Real-Time Digital Signal Processing: Implementations and Applications, John Wiley & Sons, Ltd, 2006.

Roger Woods, John McAllister, Gaye Lightbody, Ying Yi, FPGA Based Implementation of Signal Processing Systems, John Wile, 2017.

U. Meyer-Baese, Digital Signal Processing with Field Programmable Gate Arrays, 4th Ed. Springer, 2014.

Recent literature

EC871 SELECTED TOPICS IN SIGNAL PROCESSING (4-0-0) 4

Current advances in Signal Processing as defined by the instructor.

Current literature from IEEE and other quality journals and recent books in the field.

EC757	**SEMINAR**	**2**
EC758	**MINOR PROJECT**	**2**
EC759	**MAJOR PROJECT – I**	**4**
EC760	**MAJOR PROJECT – II**	**8**