Course Syllabi
Department of Electronics Engineering

ECL201 ELECTRONIC CIRCUITS (3-0-2-4)

Pre-requisite: NIL

Contents:

Semiconductor diodes V-I characteristics, modeling for various circuit applications, rectifier, Clipping and clamping circuits RC filters.

Introduction: Scope and applications of analog electronic circuits. Amplifier models: Voltage amplifier, current amplifier, trans-conductance amplifier and trans-resistance amplifier. Biasing schemes for BJT and FET amplifiers, bias stability, various configurations(such as CE/CS, CB/CG, CC/CD) and their features, small signal analysis, low frequency transistor models, estimation of volt-age gain, input resistance, output resistance etc., design procedure for particular specifications, low frequency analysis of multistage amplifiers.

High frequency transistor models, frequency response of single stage and multistage amplifiers, cascade amplifier. Various classes of operation (Class A, B, AB, C etc.), their power efficiency and linearity issues. Feedback topologies: Voltage series, current series, voltage shunt, current shunt, effect of feedback on gain, bandwidth etc., calculation with practical circuits, concept of stability, gain margin and phase margin.

Oscillators: Review of the basic concept, Barkhausen criterion, RC oscillators (phase shift, Wien bridge etc.), LC oscillators (Hartley, Collpits, Clapp etc.), non-sinusoidal oscillators.

Digital circuit families DTL, TTL RTL, MOS, CMOS circuits. Basic CMOS circuits.

Practical: Practicals as per course contents.

Text Books:

1. Sedra, A.S. and Smith, K.C., *Microelectronic Circuits: Theory and Applications*, 6th ed., Oxford University Press, 2013.
2. Boylestad, R.L. and Nashelsky, L., *Electronic Devices and Circuit Theory*, 10th ed., Pearson Education, 2013.

Additional Books:

1. Bell, D.A., *Electronic Devices and Circuits*, 5th ed., Oxford University Press, 2008.
2. Meade, R.L., *Foundations of Electronics Circuits and Devices*, 5th ed. Delmar Cengage Learning, 2006.
3. Horowitz, P. and Hill, W., *The Art of Electronics*, 3rd ed., Cambridge University Press, 2015.
4. Wait, J.V., Huelsman, L. P. and Korn, G.A., *Introduction to Operational Amplifier Theory and Applications*, 2nd ed., New York: McGraw Hill, 1992.
5. Millman, J., *Microelectronics*, 2nd ed., New Delhi: Tata McGraw-Hill, 2003.
6. Gray, P.R. *et. al*., *Analysis and Design of Analog Integrated Circuits*, 5th ed., John Wiley, 2009

ECL202 DIGITAL CIRCUITS (3-0-2-4)

Pre-requisite: NIL

Contents:

Motivation for digital systems, number system and codes, Set relations, partially ordered sets and lattices. Switching algebra: switching functions, isomorphic systems, electronic gate networks and Boolean algebra. Minimization of switching functions, K map, minimal functions and their properties, QM method, two level minimization. Introduction to synchronous sequential circuits and iterative networks, Sequential circuits – introductory example. The finite-state model – basic definitions, Memory elements and their excitation functions. Synthesis of synchronous sequential circuits, Iterative networks. Decoders, multiplexers, and code converters, adders: ripple and carry look ahead addition. Storage elements, flip-flops and latches: D, T, J/K flip-flops, shift register, counter. Asynchronous and synchronous design using state and excitation tables. FSM implementation. Overview of VLSI designs process. PAL, CPLD, FPGA, ASIC structure overview. Introduction to hardware description language for digital circuit implementation.

Lab based on 6th unit: VHDL and Verilog based examples of M. Mano

Practical: Practicals as per course contents.

Text Books:

1. Kohavi, Z. and Jha, N.K. *Switching and Finite Automata Theory*. 3rd ed. Cambridge: Cambridge University Press, 2013.
2. Mano, M.M. and Ciletti, M.D. *Digital Design: With an Introduction to the Verilog HDL*. 5th ed. Pearson Education, 2013.

Additional Books:

1. Palnitkar, S. *Verilog HDL: A guide to Digital Design and Synthesis*. 2nd ed. Pearson, 2013.
2. Brown, S.D. and Vranesic, Z.G. *Fundamentals of Digital Logic with Verilog Design*. 3rd ed. McGraw-Hill, 2013.
3. Bhaskar, J. *VHDL Primer*. 3rd ed. USA: Prentice Hall of India, 2011. Kohavi, Z. and Jha, N.K. *Switching and Finite Automata Theory*. 3rd ed. Cambridge University Press, 2013.
4. Kumar, A. Anand. *Fundamentals of Digital Circuits*. PHI Learning Pvt. Ltd., 2003.

ECL203 SIGNALS AND SYSTEMS (3-2-0-4)

Pre-requisite: NIL

Contents:

Introduction to Signals and Systems, Signal Properties, Convolution of Signals, System properties, Linear Shift Invariant Systems and their Properties and representation

Introduction to Transforms, Fourier series and Fourier Transform, Convergence of Fourier Transform, Properties of Fourier Transform.

Sampling theorem, Sampling/reconstruction of Signals, Realistic sampling, Aliasing. Introduction to Digital Signal Processing, Discrete Time Fourier Transform and Properties.

Introduction to Laplace Transform and Z-Transform, Region of Convergence, Properties of Laplace and Z-Transform, Inverse Laplace and Z-Transforms, Rational System Functions.

Part of tutorials will be based on MATLAB.

Text Books:

1. Oppenheim, A.V., Willsky, A.S., and Nawab, S.H. *Signals and Systems*. 2nd ed., PHI Learning Private Limited., 2012.
2. Haykin, S.S. and Veen, B.V. *Signals and Systems*. 2nd ed. Wiley, 2013.

Additional Books:

1. Phillips, C.L., Parr, J.M., and Riskin, E.A. *Signals, Systems and Transforms*. 5th ed., Pearson Education, 2014.
2. Carlson, G.E. *Signal and Linear System Analysis*. 2nd ed., Bombay: Allied Publishers Limited, 1993.

ECL204 ANALOG COMMUNICATION (3-0-2-4)

Pre-requisite: NIL

Contents:

Review of Signal analysis using Fourier transform, analysis of linear time in-variant systems and basic analog ideal filters. Transmission of signals through systems, criteria for distortion less transmission, distortions in practical systems, power and energy of signals. Review of random process and noise.

Amplitude modulation: Need of modulation, AM, DSB-SC, SSB-SC and vestigial side band modulation and demodulation, AM transmitter (broadcast and low power), FDM. Angle modulation: FM and PM, reactance FET modulator Armstrong method, Foster-Seely discriminator, PLL detector, Stereophonic FM, Spectrum of FM, narrow band and wide band FM, FM transmitter (broadcast and low power).

Radio receivers: TRF and super-heterodyne receiver, AGC, FM receiver, sensitivity, selectivity, communication receiver and its special features. Realization of communication systems. Noise in analog communication systems. SNR calculations for AM, FM systems. Analog pulse modulation: Sampling theorem, PAM, PWM, PPM, QAM generation & Detection of these pulse modulated signals, TDM.

Practical: Practicals as per course contents.

Text Books:

1. Haykin, S.S. and Moher, M., *Introduction to Analog and Digital Communications*, 2nd ed., Wiley, 2012.
2. Lathi, B.P. and Ding, Z., *Modern Digital and Analog Communication Systems*, 4th ed., Oxford University Press, 2012.

Additional Books:

1. Kennedy, G. and Davis, B., *Electronic Communication Systems*, 4th ed., Tata McGraw-Hill, 1999.
2. Schoenbeck, R.J., *Electronic Communications: Modulation and Transmission*, 2nd ed., New Jeresey, Prentice Hall, 1992.
3. Taub, H., Schilling, D.L. and Saha, G., *Principles of Communication Systems*, 2nd ed., Tata McGraw-Hill, 2008.

ECL205 ELECTROMAGNETIC WAVES (3-2-0-4)

Pre-requisite: NIL

Contents:

Review of Vector calculus. Review of basic laws of electrostatics: Coulomb's law, Electric field intensity, Field of 'n' point charges, Field of line and sheet of charge. Electric flux density, Gauss's law and its applications. Divergence and Divergence theorem. Definition of potential difference and potential, Potential of point charge and system of charges. Potential gradient, Energy density in electrostatic field. Poisson's and Laplace's equations. Current and current density, Continuity of current, Capacitance. Review of basic laws of magneto statics: Biot-Savart and Amperes circuital laws and their applications, Curl, Stoke's theorem. Magnetic flux density, Scalar and Vector magnetic potential. Maxwell's equations in steady electric and magnetic fields. Force on moving charge and differential current element, Force and torque on a closed circuit. Time varying fields and Maxwell's equations.

Uniform plane waves, wave motion in free space, perfect dielectric, lossy dielectric and good conductor, skin effect. Poynting vector and power

considerations. Reflection of uniform plane waves, Standing ratio, boundry conditions. Transmission lines: S-parameters, telegraphers model of transmission line. Various terminations. Transmission line equations and their solutions. Transmission line parameters, Characteristic impedances, Propagation constant, Attenuation constant, Phase constant, Waveform distortion, Distortion less transmission lines, loading of transmission lines, Reflection coefficient and VSWR. Equivalent circuits of transmission lines, Transmission lines at radio frequency. Open circuited and short circuited lines, Smith Chart, Stub matching.

Text Books:

1. Hayt, W.H. and Buck, J.A., *Engineering Electromagnetics*, 7th ed., Tata McGraw- Hill, 2013.
2. Sadiku, M.N.O., *Principles of Electromagnetics*, 4th ed., Oxford University Press, 2013.

Additional Books:

1. Jordan, E.C. and Balmain, K.G., *Electromagnetic Waves and Radiating Systems*, 2nd ed., Englewood Cliffs, NJ: Prentice Hall, 1968.
2. Rao, N.N., *Elements of Engineering Electromagnetics*, 6th ed., Pearson Education, 2006.
3. Elgerd, O.I., *Electric Energy Systems Theory: An Introduction*, 2nd ed., New York: McGraw-Hill, 1982.
4. Grainger, J.J., Stevenson, W.D., *Power System Analysis*. New York: McGraw Hill, 1994.
5. Saadat, H., Power *System Analysis, PSA Publishing*, 3rd ed., 2010.

ECL206 ELECTRONIC MATERIALS AND DEVICES (3-0-0-3)

Pre-requisite: NIL

Contents:

Introduction to SPICE Simulation, Analysis of complex electronic circuits, simulation and analysis using SPICE, AC/DC operation, DC sweep transfer function, frequency response, feedback control analysis, transient response, device models, simulation and analysis of electronic circuits and systems.

Review of semiconductor physics, pn junction, built-in voltage, Depletion width and junction capacitance, Diode current/voltage characteristic, Minority carrier charge storage MOS transistors, Threshold voltage and the body effect, Current/voltage characteristics, Sub threshold current, Short channel effect and narrow width effect, Drain induced barrier lowering Channel length modulation, Hot carrier effects, Effective mobility and velocity saturation, SPICE models, MOS inverter circuits Bipolar transistors, Current gain, Eber Molls model. Basic SPICE Models for electronic components Diode MOS and BJT. Small-signal, large-signal model, parameter extraction.

Text Books:

1. Streetman, B., and Banerjee, S. *Solid State Electronic Devices*. 7th ed., Upper Saddle River: Prentice Hall, 2014.
2. Roberts S. and Sedra A. *SPICE*. 2nd ed., Oxford Univ. Press, 1996.

Additional Books:

1. Hodges, D., Jackson, H., and Saleh, R. *Analysis and Design of Digital Integrated Circuits*. 3rd ed., McGraw-Hill, 2004.
2. Massobrio M., *Semiconductor Device Modeling with Spice*. 2nd ed., New Delhi: Tata McGraw-Hill, 2010.

ECL301 LINEAR INTEGRATED CIRCUITS (3-0-2-4)

Pre-requisite: ECL201 ELECTRONIC CIRCUITS

Contents:

Differential amplifier and Op-amp design, configurations (FET, BJT). DC & AC analysis, constant current bias, current mirror, cascaded differential amplifier stages, level translator. Op-amp, inverting, non-inverting, differential amplifier configurations, negative feedback, voltage gain, input & output impedance, Bandwidth. Input offset voltage, input bias and offset current, Thermal drift, CMRR, PSRR, Frequency response. Linear applications, DC, ac amplifiers, summing differential amplifier, instrumentation amplifier, V to I and I to V converters, Integrator, Differentiator. First/second order low/ high/ band pass, band reject active filters, All pass filter Phase shift oscillator, Wein bridge oscillator, Square wave and triangular waveform generators. Nonlinear applications, Comparators, Schmitt Trigger, Clipping and Clamping circuits, Absolute value circuits, Peak detectors, Sample and hold circuits, Log and antilog amplifiers. Sample Hold, R-2-R ladder DAC. Flash, successive approximation, dual slope ADC circuits. Introduction to sigma delta ADC. Special ICs for communications systems: 555 Timer, Voltage Regulator.

Practical: Practicals as per course contents.

Text Books:

1. Graeme, J.G., Tobey, G.E., and Huelsman, L.P. *Operational Amplifiers*: *Design and Applications*. New York: McGraw Hill, 1971.
2. R.A. Gayakwad. *Op-amps and Linear Integrated Circuits*. 4th ed., New Delhi: Prentice Hall of India, 2004.

Additional Books:

1. Franco, S. *Design with Operational Amplifiers and Analog Integrated Circuits*. 3rd ed., McGraw Hill Education, 2002.
2. Fiore, J.M. *Op amps and Linear Integrated Circuits: Theory and Application*. New York: Delmar Thomson Learning, 2001.
3. Choudhury. Roy D. *Linear integrated Circuits*. 2nd ed. New Delhi: New Age International Publications, 2003.

ECL302 DIGITAL COMMUNICATION (3-0-2-4)

Pre-requisite: NIL

Contents:

Comparison of analog and digital communication. Advantages and disadvantages of digital communication. Source Coding of Analog Sources: PCM-TDM, Delta modulation, Adaptive DM, DPCM, ADPCM. Source coding of digital sources: Information, entropy, Shannon's source coding theorem, Huffman algorithm, prefix codes .General digital transmitter and receiver, signal constellation and geometric interpretation of signals, performance of matched filter receiver and correlator receiver in the presence of white noise. Threshold setting and error probability. Baseband transmission: Line coding fundamentals, transmission formats, spectral requirements, error probabilities, types of noise and other impairments. Inter-symbol interference, Nyquist's results for ISI, Eye pattern and adaptive equalization. Pass-band transmission methods: Binary ASK, PSK and FSK, Quadrature multiplexing, QPSK and QAM methods, MSK and GMSK. Basic detection algorithms, error probability and spectral requirements. Constellations and their applications in study of communication channels. Error control coding: Shannon's channel capacity theorem, significance of the theorem. Linear block codes generation and decoding, hamming distance considerations, cyclic codes and their applications, convolutional codes and viterbi decoding algorithm. Basics of TDMA, FDMA, OFDM.

Practical: Practicals as per course contents.

Text Books:

1. Haykin, S.S. and Moher, M., *Communication Systems*, 5th ed., John Wiley and Sons, 2012.
2. Lathi, B.P. and Ding, Z., *Modern Digital and Analog Communication Systems*, 4th ed., Oxford University Press, 2009.

Additional Books:

1. Proakis, J.G. and Salehi, M., *Digital Communications*, 5th ed., New York: McGraw Hill, 2010.
2. Taub, H., Schilling, D.L. and Saha, G., *Principles of Communication Systems*, 3rd ed., New York: Tata McGraw-Hill, 2008.

ECL303 MICROWAVE AND ANTENNAS (3-0-2-4)

Pre-requisite: ECL205 ELECTROMAGNETIC WAVES

Contents:

Rectangular Wave Guide: Field Components, TE, TM Modes, Dominant, TE10 mode, Field Distribution, Power, Attenuation. Circular Waveguides: TE, TM modes, Wave Velocities.

Field due to a current element, power radiated and radiation resistance for field due to a dipole, power radiated and radiated resistance. Reciprocity theorem applied to antennas. Antenna terminology: Gain, Aperture, Radiation intensity, Directivity, Directive gain, Beam width, Radiation patterns, FBR, Antenna band-width etc. Concept of antenna arrays, Two element arrays and their directional characteristics, Linear array analysis, Broadside and end fire arrays, Principles of pattern multiplication and their application. Polynomial representation, Binomial arrays, Design of broadcast array for a specific pattern, Chebyshev array synthesis. Analysis of power patterns of various antennas like parabolic reflectors, Lens antenna, folded dipole, Turnstile antenna, Yagi antenna, Log-periodic antenna, Horn antenna and feeding.

Practical: Practicals as per course contents.

Text Books:

1. Jordan, E.C. and Balmain, K.G., *Electromagnetic Waves and Radiating Systems*, 2nd ed., Prentice Hall of India, 2013.
2. Kraus, J.D., Marhfeka, R. and Khan, A.S., *Antennas and Wave Propagation*, 4th ed., Tata McGraw-Hill, 2006.

Additional Books:

1. Prasad, K.D., *Antennas and Wave Propagation*. New Delhi: Satya Prakashan, 1983.
2. Raju, G.S.N., *Antennas and Wave Propagation.* Pearson Education, New Delhi: 2006.
3. Shevgaonkar, R.K., *Electromagnetic Waves.* 1st ed., Tata McGraw-Hill, 2005.

ECL304 DIGITAL SIGNAL PROCESSING (3-0-2-4)

Pre-requisite: ECL203 SIGNALS AND SYSTEMS

Contents:

Discrete time signals and systems, Sampling process, Classification of LTI, Discrete time systems, Linear convolution, Inverse systems, Discrete Time Fourier Transform (DTFT), Discrete Fourier Transform (DFT), theorems, DFT symmetry relations, Circular convolution, Linear convolution using DFT, overlap addmethod, overlap save method. Fast Fourier Transform (FFT) algorithms, decimation in time and frequency domain and algorithms, Goertzel algorithms

Signal flow graph representation, parallel and cascade form. Design of FIR digital filter using window method, Park-McClellans method. Design of IIR digital filter, Butterworth and Chebyshev with bilinear transformation and impulse in-variant method.
Group delay, phase delay and effect of finite word length in FIR filter design. Digital Signal Processors.
Lab experiments based on MATLAB and DSP processor kits.
Practical: Practicals as per course contents.

Text Books:

1. Oppenheim, A.V. and Schafer, R.W., *Discrete-Time Signal Processing*, 3rd ed., Pearson, 2010.
2. Mitra S. K., *Digital Signal Processing: a Computer based Approach*, 4th ed., TataMcGraw-Hill, 2013.

Additional Books:

1. Proakis, J.G. and Manolakis, D.G., *Digital Signal Processing: Principles, Algorithms and Applications*, 4th ed., Pearson, 2011.
2. Chen, C-T, *Digital Signal Processing: Spectral Computation and Filter Design*, Oxford University Press, 2001
3. Salivahanan, S. and Gnanapriya, C., *Digital Signal Processing*, 2nd ed., New Delhi: TataMcGraw Hill, 2008.

ECL305 MICROCONTROLLER AND INTERFACING (3-0-2-4)

Pre-requisite: ECL202 DIGITAL CIRCUITS

Contents:

Tuning machine, von Neumann and Harvard architecture. Overview of microcomputer systems and their building blocks, memory interfacing, concepts of interrupts and Direct Memory Access, instruction sets of microprocessors (with examples of 8085 and C51 architecture); Interfacing with peripherals - timer, serial I/O, parallel I/O, A/D and D/A converters; Arithmetic Coprocessors; System level interfacing design; Bus architectures- Concepts of virtual memory, Cache memory. Microprocessor v/s Microcontroller, overview of various microcontrollers. Architecture and hardware description of signals of 8051/PIC. Instruction set and timing diagrams. Assembly language programming of 8051. Developing an application using 8051. Introduction to ARM microcontroller architecture and organization. Lab experiments will be based on 8085 and C51 architecture.
Practical: Practicals as per course contents.

Text Books:

1. Gaonkar, R. *Microprocessor Architecture, Programming and Applications with the 8085*. 6th ed. Mumbai: Penram International Publishing, 2011.
2. Mazidi, M.A. *The 8051 Microcontroller and Embedded Systems using Assembly and C*. 2nd ed., New York: Pearson Education, 2013.

Additional Books:

1. Predko, M. *Programming and Customizing the 8051 Microcontroller*. New York: McGraw-Hill, 1998.
2. Hall, D.V. *Microprocessors & Interfacing*. 3rd ed., Singapore: Tata McGraw-Hill, 1992.

ECL402 FINITE AUTOMATA (3-2-0-4)

Pre-requisite: ECL202 DIGITAL CIRCUITS

Contents:

Review of combinational circuit design and optimization, functional decomposition and symmetric functions, identification of symmetric functions. Threshold logic, synthesis of threshold networks. Fault detection in combinational circuits, Boolean differences and Path sensitization. Synchronous sequential circuits and iterative networks, memory elements and their excitation functions, synthesis of synchronous sequential circuits, Moore and Mealy machines, Applications to controller design, finite state machine flow charts, tables, ASM charts. Machine minimization, Asynchronous Sequential circuits, synthesis, state assignment, minimization.

Text Book:

1. Kohavi, Z. and Jha, N.K., *Switching and Finite Automata Theory*, 3rd ed. Cambridge University Press, 2013.

Additional Books:

1. Kohavi, Z., *Switching and Finite Automata Theory*, 2nd ed., McGraw Hill, 1978.
2. Taub, H., *Digital Circuits and Microprocessors*, McGraw Hill, 1982.
3. Mano, M.M., *Digital Logic and Computer Design*, 5th ed., Upper Saddle River, NJ: Pearson, 2013.
4. Lee, S.C., *Modern Switching Theory and Digital Design*, Englewood Cliffs, NJ: Prentice-Hall, 1978.

ECL403 HARDWARE DESCRIPTION LANGUAGE (3-0-2-4)

Pre-requisite: ECL202 DIGITAL CIRCUITS

Contents:

Modeling digital systems, Hardware design environment, Design Flow, Hard ware description languages, various design styles. Introduction to Verilog, elements of Verilog, basic concepts in Verilog, simulation, synthesis. Dataflow modeling, Concurrent signal assignment, delays, Behavioral modeling, processes. Design organization, Structural specification of hardware, parameterization, hierarchy, abstraction, configurations, utilities. Subprogram, packages, libraries, Basic I/O, Programming mechanics Synthesis, RTL description, constraints attributes, FPGA, CPLD structure, technology libraries. Introduction to VHDL Programming
Practical: Practicals as per course contents.

Text Book:

1. Palnitkar, S. Verilog HDL: *A guide to Digital Design and Synthesis*. 2nd ed. Pearson, 2013.

Additional Books:

1. Bhasker, J. *A System Verilog Primer*. 1st Indian ed. B.S. Publication, 2008.
2. Navabi, Z. VHDL: *Analysis and Modeling of Digital Systems*. 2nd ed., New York: McGraw Hill, 2000.
3. Weste, N.H.E., Harris, D., and Banerjee, A. *CMOS VLSI Design: Circuits and Systems Perspective*, 4th ed. Pearson Education, 2012.
4. Pucknell, D.A. and Eshraghian, K. *Basic VLSI Design*. 3rd ed. PHI Learning Private Limited, 2013.
5. Brown, S.D. and Vranesic, Z.G. *Fundamentals of Digital Logic with VHDL/Verilog Design*. 3rd ed., McGraw-Hill, 2009.

ECL404 INDUSTRIAL ELECTRONICS (3-0-0-3)

Pre-requisite: NIL

Contents:

Review of switching regulators and switch mode power supplies-Uninterrupted power supplies- solid state circuit breakers–programmable logic controllers Analog Controllers-Proportional controllers, Proportional–Integral controllers, PID controllers, Feed forward control. Signal conditioners-Instrumentation amplifiers–voltage to current, current to voltage, voltage to frequency, frequency to voltage converters, Isolation circuits– cabling; magnetic and electro static shielding and grounding. Opto-Electronic devices and control, Applications of opto isolation, interrupter modules and photo sensors. Fibre optics- barcode equipment, application of barcode in industry. Stepper motors and servo motors-control and applications. Servo motors– servo motor controllers– servo amplifiers– selection of servo motor– applications of servo motors.
Practical: Practicals as per course contents.

Text Book:

1. Kissell, T.E. *Industrial Electronics: Applications for Programmable Controllers Instrumentation*. 3rd ed. New York: Prentice Hall, 2012.

Additional Book:

1. Maas, J.W. *Industrial Electronics*. 1st ed., London: Prentice Hall International, 1995,

ECL405 ADAPTIVE SIGNAL PROCESSING (3-2-0-4)

Pre-requisite: ECL304 DIGITAL SIGNAL PROCESSING

Contents:

Vectors, Matrices and Eigen Analysis. Application to adaptive signal processing. Stochastic Processes, Ensemble average, mean, average power, auto and cross correlation functions, stationarity and white noise, Auto-regressive process. Optimal FIR (Wiener) filter, Method of steepest descent, extension to complex valued signals.
Least Squares and LMS algorithms, Normal equations, properties. Eigen System decomposition. Gradient search technique, convergence properties of LMS. Normalized LMS algorithm. Recursive solution techniques, RLS algorithm. Application to noise cancellation, modeling of physical processes, communications.

Text Book:

1. Haykin, S., *Adaptive Filter Theory*, 4th ed., Canada: Pearson Education, 2012.

Additional Books:

1. Treichler, J.R., *Theory and Design of Adaptive Filters*, Prentice Hall of India, 2010.
2. Widrow B., Stearns S.D., *Adaptive Signal processing*, Englewood Cliffs, NJ: Prentice Hall 1985.

ECL406 WIRELESS DIGITAL COMMUNICATION (3-0-2-4)

Pre-requisite: ECL302 DIGITAL COMMUNICATION

Contents:

Cellular engineering concepts; frequency reuse, frequency management and channel assignment, handoff and handoff strategies, trunking theory, coverage and capacity improvements, medium access techniques, FDMA, TDMA, CDMA, SDMA.
Wireless Mobile Communication channel characterization: large scale path loss, free space propagation model, propagation effects such as reflection, diffraction, scattering etc. Outdoor and indoor propagation models, ray tracing and coverage prediction. Small scale fading effects: time-variant impulse response model, channel correlation functions and spectral densities, coherence time, coherence bandwidth, channel models for Rayleigh, Ricean and Nakagami fading.

Spread Spectrum methods: basics; generation and properties of PN se quences, DS-SS system analysis; slow and fast FH-SS system; performance analysis.
Interference measurement and reduction, co-channel and other interference, Diversity methods for Mobile Wireless Radio Systems, concepts of diversity branch and signal paths, combining and switching methods, C/N and C/I ratio improvements, average error probability improvements.
Review, and discussion on fundamental design issues of 2/3G systems: GSM, GPRS, CDMA2000, UMTS, LTE.
IEEE 802.11 Wireless LAN's system and protocol architecture, physical layer and MAC, options like 802.11b, a g etc. and their purpose. Bluetooth: User scenarios, layered architecture, link management, L2CAP, SDP, IEEE 802.15
Practical: Practicals as per course contents.

Text Book:

1. Rappaport, T.S., *Wireless Communication: Principles and Practices*, 2nd ed., Pearson Education, 2013.

Additional Books:

1. Feher, K., *Wireless Digital Communication*, New Delhi: Prentice Hall of India, 2000.
2. Proakis, J.G. and Salehi, M., *Digital Communications*, 5th ed., McGraw Hill, 2007.
3. Haykin, S., *Digital Communication*, Wiley India, 2012.
4. Haykin, S., *Communication Systems*, 5th ed., John Wiley & Sons, 2009.
5. Schiller, J., *Mobile Communication*, 2nd ed., Berlin: Pearson Education, 2004.

ECL408 RADIO FREQUENCY AND MICROWAVE ENGINEERING (3-2-0-4)

Pre-requisite: ECL205 ELECTROMAGNETIC WAVES

Contents:

Two port RF networks-circuit representation, Low frequency parameters-impedance, admittance, hybrid and ABCD. High frequency parameters-Formulation of S parameters, properties of S parameters. Reciprocal and lossless net-works, transmission matrix, Introduction to component basics, wire, resistor, capacitor and inductor.
RF transistor amplifier design and matching networks, Amplifier power relation, stability considerations, gain considerations noise figure, impedance match-ing networks, frequency response, T and Π matching networks, micro strapline matching networks, significance of microwave frequency range -applications of microwaves. Scattering matrix- Concept of N port scattering matrix representation. Microwave junctions, Tee junctions, Magic Tee, Rat race, Corners, bends and twists, Directional couplers, two hole directional coupler, Ferrites micro-wave properties and applications, Termination, Gyrator, Isolator, Circulator, Attenuator, Phase changer, S Matrix for microwave components, Cylindrical cavity resonators.
Microwave semiconductor devices, operation, characteristics and application of BJTs and FETs -Principles of tunnel diodes-Varactor, Step recovery diodes, Gunn diode-Avalanche Transit time devices-IMPATT and TRAPATT devices. Parametric devices-Principles of operation- applications of parametric amplifier. Microwave monolithic integrated circuit (MMIC) - Materials and fabrication techniques Microwave tubes and measurements, Microwave tubes- High frequency limitations - Principle of operation of Multi cavity Klystron, Reflex Klystron, Traveling Wave Tube, and Magnetron. Measurement of power, wavelength, impedance, SWR, attenuation, Q and Phase shift.

Text Books:

1. Liao, S.Y., *Microwave Devices and Circuit*, 3rd ed., Pearson Education, 2012.
2. Ludwig, R. and Bogdanov, G., *RF Circuit Design: Theory and Applications*, 2nd ed., Pearson Education, 2009.

Additional Books:

1. Collin, R.E., *Foundation of Microwave Engineering*, 2nd ed., Wiley India, 2000.
2. Das, A. and Das, S.K., *Microwave Engineering*, 2nd ed., Tata McGraw- Hill Education Private Limited, 2012.
3. Radmanesh, M.M., *Radio Frequency and Microwave Electronics Illustrated*, California: Prentice-Hall, 2001.
4. Pozar, D.M., *Microwave Engineering*, 4th ed., Wiley India, 2011.

ECL409 RADIO FREQUENCY CIRCUIT (3-2-0-4)

Pre-requisite: ECL205 ELECTROMAGNETIC WAVES

Contents:

Review of Passive RLC networks. Transmission lines. Two-port network modeling. S-parameter model. The Smith Chart and its applications in design of matching networks. Challenges in RF transceiver design. Transceiver architectures. Translation of communication specifications to circuit specifications. Active devices for RF circuits: HBT and MESFET, SiGe HBT and MOSFET, GaAs pHEMT,. PIN diode. Device parameters and their impact on circuit performance, intrinsic and extrinsic models RF Amplifier design issues: noise types and their characterization, two port network noise analysis, noise figure and its applications, noise models of passive and active devices, large scale and linearity issues, voltage references and biasing. Low Noise Amplifier design: LNA topologies, power match vs noise match. Linearity and large-signal performance. LNA design case studies. RF Power amplifiers: General properties. Class A, AB and C PAs. Class D, E and F amplifiers. Modulation of power amplifiers. Performance parameters and de-sign issues. PA design case studies. IF amplifiers. Analog communication circuits: Mixers, phase-locked loops, oscillators and synthesizers.
Design and performance characterization. Spurious frequencies, phase noise.

Text Books:

1. Lee, T.H., *The Design of CMOS Radio Frequency Integrated Circuits*, 2nd ed., New York: Cambridge University Press, 2004.
2. Ludwig, R. and Bogdanov, G., *RF Circuit Design*: *Theory and Applications*, 2nd ed., Pearson Education, 2009.

Additional Books:

1. Radmanesh, M.M., *Radio Frequency and Microwave Electronics Illustrated*, Prentice-Hall, 2001.
2. Leung, B., *VLSI for Wireless Communication, 2nd ed., Springer, 2011.*

ECL410 IMAGE PROCESSING (3-2-0-4)

Pre-requisite: NIL

Contents:

Image representation, gray scale and colour images, image sampling and quantization. Two dimensional orthogonal transforms-DFT, FFT, WHT, Haar transform, KLT, DCT. Image enhancement-filters in spatial and frequency domains, histogram-based processing, homomorphic filtering. Edge detection-non parametric and model based approaches, LOG filters, localisation problem. Image Restoration-PSF, circulant and block circulant matrices, deconvolution, restoration using inverse filtering, Wiener filtering and maximum entropy-based methods. Mathematical morphology, binary morphology, dilation, erosion, opening and closing, duality relations, gray scale morphology, applications such as hit-and-miss transform, thinning and shape decomposition. Computer tomography parallel beam projection, Radon transform, and its inverse, Back-projection operator, Fourier-slice theorem, CBP and FBP methods, ART, Fan beam projection. Image communication, JPEG, MPEGs and H.26x standards, packet video, error concealment.
Image texture analysis, co-occurrence matrix, measures of textures, statistical models for textures. Hough Transform, boundary detection, chain coding, and segmentation, thresholding methods.

Text Books:

1. Jain, A. K., *Fundamentals of Digital Image Processing, Prentice Hall of India*, 2012.
2. Gonzalez, R.C. and Woods, R.E., *Digital Image Processing*, 3rd ed., Pearson Education, 2007.

Additional Books:

1. Haralick, R.M. and Shapiro, L.G., *Computer and Robot Vision*, Boston, USA: Addison Wesley Longman Publishing Co., 1992.
2. Jain, R., Kasturi, R. and Schunck, B.G., *Machine Vision*, McGraw-Hill, 1995.
3. Pratt, W. K., *Digital Image Processing*, 4th ed., Los Altos, California: John Wiley and Sons, 2007.

ECL412 VLSI TECHNOLOGY (3-0-2-4)

Pre-requisite: NIL

Contents:

Environment for VLSI Technology: Clean room and safety requirements. Wafer cleaning processes and wet chemical etching techniques. Impurity incorporation: Solid State diffusion modelling and technology, Ion Implantation modeling, technology and damage annealing; characterization of impurity profiles. Oxidation: kinetics of silicon dioxide growth both for thick, thin and ultrathin films. Oxidation technologies in VLSI and ULSI. Characterization of oxide films, high k and low k dielectrics for ULSI.
Lithography: Photolithography, E-beam lithography and newer lithography techniques for VLSI/ULSI, mask generation. Chemical Vapour Deposition techniques: CVD techniques for deposition of polysilicon, silicon dioxide, silicon nitride and metal films. Epitaxial growth of silicon, modeling and technology.
Metal film deposition: Evaporation and sputtering techniques. Failure mechanisms in metal interconnects; Multi-level metallization schemes Plasma and Rapid Thermal Processing: PECVD, Plasma etching and RIE techniques; RTP techniques for annealing, growth and deposition of various films for use in ULSI. Process integration for NMOS, CMOS and Bipolar circuits; Advanced MOS technologies.
Practical: Practicals as per course contents.

Text Book:

1. Sze, S.M., *VLSI Technology*, 2nd ed., Tata McGraw-Hill, 2003.

Additional Book:

1. Ghandhi, S.K., *VLSI Fabrication Principles*, 2nd ed., Wiley India, 2001.

ECL413 MICRO-ELECTROMECHANICAL SYSTEMS (3-0-2-8)

Pre-requisite: NIL

Contents:
Introduction to MEMS, MEMs devices overview. Fabrication, Mechanical Properties, Electrometrical properties and modeling, Interfacing circuits. MEMS Application Areas: All-mechanical miniature devices, 3-D electromagnetic actuators and sensors, RF/Electronics devices, Optical/Photonic devices, Medical devices e.g. DNA-chip, micro-arrays.
Practical: Practicals as per course contents.

Text Book:
1. Ananthasuresh, G.K. *et. al. Micro and Smart Systems*, John Wiley & Sons, Inc., 2012.

Additional Books:
1. Bao, M.-H., *Micro Mechanical Transducers: Pressure Sensors, Accelerometers and Gyroscopes*, 1st ed., Elsevier, 2000.
2. Kovacs, G.T.A., *Micromachined Transducers Sourcebook*, McGraw-Hill Higher Education, 1998.
3. Senturia, S.D., *Microsystem Design*, 1st ed., USA: Springer, 2001.

ECL414 ELECTRONIC SYSTEM DESIGN (3-0-2-4)
Pre-requisite: NIL

Contents:
Design of Power supply systems: Unregulated PS with rectifiers and filters, design of linear regulators, series regulators, overload and foldback protection. Design of SMPS: stepup and stepdown.Electrostatic Discharge, ESD reduction techniques. Noise reduction in electronic systems.Project based with circuit design, fabrication and characterization.
Practical: Practicals as per course contents.

Text Books:
1. *Regulated Power Supply Handbook Texas Instruments*.
2. Khetan, R.K. and Goyal, N.C., *A Monograph on Electronic Design Principles, Khanna Publisher*, 2002.

Additional Books:
1. Boxleitner, W., *Electrostatic Discharge and Electronic Equipment: Practical Guide for Designing to Prevent ESD Problems*, Wiley-IEEE, 1999.
2. Ott, H.W., *Noise Reduction Techniques in Electronic Systems*, 2nd ed., John Wiley and Sons, 1989.

ECL415 BIOMEDICAL INSTRUMENTATION (3-0-0-3)
Pre-requisite: NIL

Contents:
Human body, physiology and sub system, Biochemistry Measurement of electrical activities in human body, Electrocardiography, Electroencephalography, Electromyography and interpretation of records. Measurement of non-electrical quantity in human body, Measurement of blood flow respiration rate and depth heart rate, blood pressure, temperature, pH impedance of various CSR. Biotelemetry X Ray and Radio isotrope instruments, A scan, B scan, fital monitoring, X ray component Tomography.
Cardiac pacemaker. Defibrillator, Neuropath physiology of the Nervous System, Detection and treatment of nervous system disorder. Detection & treatment of nerway system disorders. Prosynthesis for hearing, visual, limb impairments students design & test a nueroprosthesis. Non inveasive diagnosis instrumentation. Blood pump Respiration controller. Latest trends in Biomedical Instrumentation. Electrical safety & Laser-Tissue interaction (Optical)

Text Books:
1. Cromwell, L., Weibell, F.J. and Pfeiffer, E.A., *Biomedical Instrumentation and Measurements*, 2nd ed., Prentice Hall of India, 2010.
2. Khandpur, R.S., *Handbook of Biomedical Instrumentation*, 3rd ed., Tata McGraw- Hill, 2014.

Additional Books:
1. Plonsay, R., *Biomedical Phenomenon*, McGraw Hill.
2. Singh, M., *Introduction to Biomedical Instrumentation*, 1st ed., PHI Learning Private Limited, 2010.
3. Ganong, W.F. *et. al.*, *Review of Medical Physiology*, 24th ed., McGraw Hill, 2012.
4. Webster, J.G., *Medical Instrumentation: Application and Design*, 4th ed., John Wiley and Sons, 2009.
5. Cook, A.M. and Webster, J.G., *Therapeutic Medical Devices, Application and Design*, 1st ed., Prentice-Hall, 1982.

ECL416 ANALOG INTEGRATED CIRCUITS (3-0-2-4)
Pre-requisite: ECL206 ELECTRONIC MATERIAL AND DEVICES, EEL202 BASIC ELECTRICAL CIRCUITS

Contents:
Analog Integrated Circuits: Basics to Analog Design, MOS Device physics, single-stage amplifiers, Differential Amplifiers, Current Mirrors: Basic current mirrors, cascode current mirrors, Frequency Response of Amplifiers, Feedback, Operational Amplifiers- 1stage, 2 stage, Stability and Frequency Compensation, Noise- Noise in RC circuits, Noise in single stage amplifiers, Bandgap Voltage Reference.
Practical: Practicals as per course contents.

Text Book:
1. Razavi, Behzad. *Design of Analog CMOS Integrated Circuits*. 2nd ed. McGraw Hill Education, 2016.

Additional Books:
1. Allen, Phillip E., and Holberg, Douglas R. *CMOS Analog Circuit Design*. Oxford University Press, 2011.
2. Carusone, Tony C., Johns, David A., and Martin, Kenneth W. *Analog Integrated Circuit Design.* 2nd ed., John Wiley and Sons, 2013.
3. Gray, Paul, and Meyer, Robert. *Analysis and Design of Analog Integrated Circuits*. 5th ed., John Wiley and Sons, 2009.
4. R. Jacob Baker. *CMOS Circuit Design, Layout, and Simulation*. 3rd ed. Wiley-IEEE Press, 2010.
5. Gray, P.R., Hodges, D.A., R.W. Brodersen, Eds. *Analog MOS integrated Circuits*. New Jersey: IEEE press Wiley, 1980.

ECL417 RF AND MICROWAVE MEASUREMENT SYSTEM TECHNIQUES (3-0-0-3)
Pre-requisite: NIL

Contents:
Review of measurement and instrumentation basics, Principles and applications of various sensors used in characterization of RF materials, devices, circuits and system: acoustic, ultrasonic, magnetic, electrical, thermal, optical, radiation and smart sensors, Mechanical and thermal engineering issues for RF modules/ instruments. Instrumentation concepts and measurement techniques in: Oscilloscopes, Spectrum analyzers, Network analyzer, Lock-in-amplifiers, Waveform generators, Bit-error rate measurement, S/N measurement telemetry, Data recording and display, Recent advances in RF and Microwave measurement Techniques.

Text Book:
1. Basu, Ananjan. *An Introduction to Microwave Measurements*. CRC Press, 2014.

Additional Book:
1. Teppati, Valeria, Ferrero, Andrea, and Sayed, M. *Modern RF and Microwave Measurement Techniques*. Cambridge University Press, June 2013.

ECL418 RF RECEIVER DESIGN FOR WIRELESS APPLICATIONS (3-0-0-3)
Prerequisite: NIL

Contents:
Introduction to Wireless Systems: Classification of wireless systems; Design and performance issues: Choice of operating frequency, multiple access and duplexing, circuit switching versus packet switching, propagation, radiated power and safety; Cellular telephone systems and standards. Noise and Distortion in Microwave Systems: Basic threshold detection, noise temperature and noise figure, noise figure of a lossy transmission line; Noise figure of cascade systems: Noise figure of passive networks, two-port networks, mismatched transmission lines and Wilkinson power dividers; Dynamic range and inter-modulation distortion.
Microwave Amplifier Design: Two-port power gains; Stability of transistor amplifier circuits; Amplifier design using S-parameters: Design for maximum gain, maximum stable gain, design for specified gain, low-noise amplifier design, and design of class-A power amplifiers. Mixers: Mixer characteristics: Image frequency, conversion loss, noise figure; Devices for mixers: p-n junctions, Schottky barrier diode, FETs; Diode mixers: Small-signal characteristics of diode, single-ended mixer, large-signal model, switching model; FET Mixers: Single-ended mixer, other FET mixers; Balanced mixers; Image reject mixers. Switches; Devices for microwave switches; Device models; Types of switches; Switch configurations; Basic theory of switches; Multi-port, broad-band and isolation switches. Oscillators and Frequency Synthesizers: General analysis of RF oscillators, transistor oscillators, voltage-controlled oscillators, dielectric resonator oscillators, frequency synthesis methods, analysis of first and second order phase-locked loop, oscillator noise and its effect on receiver performance.

Text Book:
1. Pozar, D.M. *Microwave and RF Design of Wireless Systems*. Wiley India Pvt. Ltd., 2000.

Additional Books:

1. Bahl, I., and Bhartia, P. *Microwave Solid State Circuit Design*. 2nd ed., John Wiley & Sons, 2003.
2. Chang, K., Bahl, I., and Nair, V. *RF and Microwave Circuit and Component Design for Wireless Systems*. Wiley Inter Science, 2002.
3. Rohde, U.L., and Newkirk, D.P. *RF/Microwave Circuit Design for Wireless Applications*. 2nd ed., John Wiley & Sons, 2012.
4. Larson, L.E. *RF and Microwave Circuit Design for Wireless Applications*. Artech House, 1996.
5. Egan, W. F. *Practical RF Circuit Design*. John Wiley & Sons, 1998.
6. Gonzalez, G. *Microwave Transistor Amplifiers: Analysis and Design*. 2nd ed., Prentice-Hall, 1996.

ECL419 CAD OF RF AND MICROWAVE CIRCUITS (3-0-2-4)

Pre-requisite: NIL

Contents:

Review of basic microwave theory: Transmission Lines-Concepts of characteristic impedance, reflection coefficient, standing and propagating waves, Equivalent Circuits.

Network analysis: S, Z, ABCD, Y, T multi-port parameters, impedance matching Techniques.

Planar transmission lines: Stripline, Microstrip line and suspended stripline,

Filters: Low pass, band pass, high pass, band stop filters using lumped element as well as distributed element realization.

Direction Couplers: Hybrid Branch line, rat race and parallel coupled type, even and odd mode analysis.

Power divider, Power combiner.

Practicals: Design of filters, direction coupler, power divider using simulator.

Practical: Practicals as per course contents.

Text Book:

1. Pozar, D. M. *Microwave Engineering*. 4th ed., Wiley India Pvt. Ltd., 2011.

Additional Books:

1. Collin, R.E. *Foundation for Microwave Engineering*. 2nd ed. Wiley India Pvt. Ltd., 2007
2. Edwards, T., and Steer, *M.B. Foundations for Microstrip Circuits Design*. 3rd ed., John Wiley & Sons, 2000.
3. Bhat, B., and Koul, S. K. *Stripline like transmission lines for Microwave Integrated Circuits*. New Delhi: New Age Publishers, 2007.

ECL420 HUMAN AND MACHINE SPEECH COMMUNICATION (3-0-2-4)

Pre-requisite: ECL203 SIGNALS AND SYSTEMS

Contents:

Introduction: Human-machine speech communications aspects; digital representations of speech; intensity level of sound.

Speech production: Anatomy and physiology of speech organs; articulatory phonetics; acoustic phonetics; phonetics transcription, Physiological and Mathematical Model.

Speech signal analysis: Time domain methods; Frequency domain methods; Pitch estimation spectrogram analysis; Spectrum analysis, MFCC.

Linear prediction coding: Least squares autocorrelation and covariance methods; Line spectral frequencies.

Psychoacoustics and auditory perception: Hearing; critical bands; phenomena of masking; Mel scale.

Speech signal coding: Speech coder attributes; Coding rates; PCM; ADPCM; CELP; Coding standards.

Assessment of speech quality: Objective and subjective quality evaluation measures.

Automatic Speech recognition: Pattern recognition approach; Dynamic time warping; Feature extraction; HMM; Language models.

Practical: Practicals as per course contents.

Text Book:

1. Rabiner, L. R., and Schafer, R. W. *Digital Processing of Speech Signals.* 4th ed., New Delhi: Pearson Education, 2009.

Additional Books:

1. Quatieri, Thomas F., Cloth. *Discrete-Time Speech Signal Processing: Principles and Practice.* Pearson Prentice Hall, 2001.
2. Young, S., and Bloothooft, G. *Corpus-Based Methods in Language and Speech Processing. Berlin: Springer Science and Business Media*, 2013.
3. Deller, J, R., Proakis, J. G., and Hansen J. H. *Discrete Time Processing of Speech Signals.* Wiley-IEEE Press, 1999.
4. Gold, B., and Morgan, N. *Speech and Audio Signal Processing: Processing and perception of speech and music*. 2nd ed., Wiley India Pvt. Ltd., 2011.
5. Huang, X. D., Ariki, Y., and Jack, M.A. *Hidden Markov Models for Speech Recognition*. Edinburgh: University Press, 1990.
6. Rabiner, L., and Juang, B. *Fundamentals of Speech Recognition*. 1st ed., Prentice-Hall, 1993.

ECL421 OPTICAL COMMUNICATION SYSTEM (3-0-0-3)

Pre-requisite: NIL

Contents:

Optical Fibers: Structure, Waveguiding. Step-index and graded index optical fibers. Modal analysis. Classification of modes. Single Mode Fibers. Pulse dispersion. Material and waveguide dispersion. Polarization Mode Dispersion. Absorption, scattering and bending losses. Dispersion Shifted Fibers, Dispersion Compensating Fibers.

Optical Power Launching and Coupling: Lensing schemes for coupling improvement. Fiber-to-fiber joints. Splicing Techniques. Optical fiber connectors.

Optical sources and detectors: Laser fundamentals. Semiconductor Laser basics. LEDs. PIN and Avalanche photodiodes.

Design considerations of fiber optic systems: Analog and digital modulation. Noise in detection process. Bit error rate. Optical receiver operation.

Power Budget and Rise time Budget. WDM. GPON, FTTH

Text Book:

1. Senior, John M. *Optical Fiber Communication*, 3rd ed. Pearson Education India, 2009.

Additional Books:

1. Keiser, G. *Optical Fiber Communications*. 4th ed., New Delhi: McGraw Hill Education, 2007.
2. Agrawal, G. P. *Fiber Optic Communication Systems*. 4th ed., New Delhi: Wiley, 2010
3. Ramaswami R., Sivarajan K. N. *Optical Networks*: *A Practical Perspective*. 3rd ed., Elsevier, 2010.

ECL422 RF MEMS (3-0-0-3)

Pre-requisite: NIL

Contents:

Introduction to RF MEMS technologies: need for RF MEMS components in wireless communications. Review of micromachining techniques and MEMS fabrication approaches, Actuation methods in MEMS, RF MEMS design and modeling. Examples of RF MEMS components from industry and academia. Case studies: micro switches, tunable capacitors, inductors, resonators, filters, and oscillators.

Text Book:

1. Vardan, V.K., Vinoy, K.J., and Jose, K.A. *RF MEMS and Their Applications.* New Delhi: Wiley India Pvt. Ltd, 2011.

Additional Books:

1. Liu, Chang. *Foundation of MEMS*. 2nd ed., Prentice Hall, 2011
2. Senturia, Stephen D. *Microsystem design*. Springer, 2001.
3. Madou, Marc J. *Fundamentals of Microfabrication: The Science of Miniaturization*. 2nd ed., CRC Press, 2002.
4. Brodie, I., and Murray, Julius J. *The Physics of Micro/Nano fabrication.* Springer Science & Business Media, 2013.
5. Adams, Thomas M., and Richard A L. *Introductory MEMS: Fabrication and Applications.* Springer, 2010.
6. Kubby, J.A., *A guide to Hands-on MEMS Design and Prototyping*. Cambridge University Press, 2011.

ECL423 RADAR SYSTEMS (3-0-0-3)

Pre-requisite: ECL204 ANALOG COMMUNICATION

Contents:

Principles of communication, Introduction to radar systems. Basic radar functions, classifications.

Free space radar range equation, maximum unambiguous range, Pulse radar System, Radar Receivers- General Principles/salient features. Radar Displays: A-scope, B-scope, E-scope, F-scope and pulse position indicator.

Resolution, Spatial frequency, Fourier transforms, sampling theorem and spectrum replication, Signal conditioning and Interference Suppression, Imaging.

Target Detection, Scanning and tracking with radars, Doppler Effect, CW Doppler radar, Moving Target Indicator, blind Speeds, Frequency Modulation CW Radar,

Signal Models: Amplitude Model, Frequency Model, Clutter, noise model and SNR, Jamming.

Text Book:

1. Skolnik, M.I. *Introduction to Radar Systems*. 2nd ed., New Delhi: Tata McGraw-Hill Education, 2006.

Additional Books:

1. Raemer, Harold R. *Radar Systems Principles*. CRC Press, 1996.
2. Lynn, Paul A. *Radar Systems.* Berlin: Springer Science & Business Media. 1987.

ECL424 SATELLITE COMMUNICATION SYSTEMS (3-0-0-3)

Pre-requisite: ECL204 ANALOG COMMUNICATION

Contents:

Basic Principles: General features, frequency allocation for satellite services, properties of satellite communication systems.
Satellite Orbits: Introduction, Kepler's laws, orbital dynamics, orbital characteristics, satellite spacing and orbital capacity, angle of elevation, eclipses, launching and positioning, satellite drift and station keeping.
Satellite Construction (Space Segment): Introduction; attitude and orbit control system; telemetry, tracking and command; power systems, communication subsystems, antenna subsystem, equipment reliability and space qualification.
Satellite Links: Introduction, general link design equation, system noise temperature, uplink design, downlink design, complete link design, effects of rain.
Earth Station: Introduction, earth station subsystem, different types of earth stations.
Satellite system: GPS, remote sensing etc.

Text Book:

1. Roddy, D. *Satellite Communications*. 4th ed., New Delhi: Tata McGraw-Hill, 2008.

Additional Books:

1. Pritchard, W. L., Sciulli, J. A. *Satellite Communication Systems Engineering*. 2nd ed., Prentice-Hall Inc., 1993
2. Kolawole, M. O. *Satellite Communication Engineering.* Marcel Dekker Inc., 2002.
3. Pratt, T., Charles, W. B. *Satellite Communications*. 2nd ed., John Wiley & Sons, 2002.

ECL425 SOLID STATE DEVICES (3-0-0-3)

Pre-requisite: ECL201 ELECTRONIC CIRCUITS

Contents:

Introduction: Evolution and uniqueness of Semiconductor Technology, Equilibrium carrier concentration, Thermal Equilibrium and wave particle duality, intrinsic semiconductor – Bond and band models, Extrinsic semiconductor – Bond and band models .
Carrier transport: Random motion Drift and diffusion.
Excess carriers: Injection level, Lifetime, Direct and indirect semiconductors
Procedure for analysing semiconductor devices, Basic equations and approximations.
P-N Junction: Device structure and fabrication, Equilibrium picture, DC forward and reverse characteristics, Small-signal equivalent circuit, Switching characteristics, Solar cell.
Bipolar Junction Transistor: Device structures and fabrication, Transistor action and amplification, Common emitter DC characteristics
MOS Junction: C-V characteristics, threshold voltage, body effect.
Metal Oxide Field Effect Transistor: Device structures and fabrication, Common source DC Characteristics, Small-signal equivalent circuit, Differences between a MOSFET and a BJT.
JunctionFET and MESFET, Recent Developments, Heterojunction FET, Heterojunction bipolar transistor.

Text Books:

1. Millman, J., and Halkias, Christos C. *Integrated Electronics*. 2nd ed., New Delhi: McGraw Hill Education, 2009.
2. Streetman, B.G., and Banerjee, S.K. *Solid state Electronics devices*. 7th ed., Pearson Education, 2014.

Additional Books:

1. Bell, David A. *Electronics Devices and Circuits*. 5th ed., Oxford Publication, 2008.
2. Sedra, A. S., and Smith, K.C. *Microelectronics Circuits*. 7th ed., Oxford University Press, 2015.

ECL426 DIGITAL INTEGRATED CIRCUITS (3-0-2-4)

Pre-requisite: ECL202 DIGITAL CIRCUITS

Contents:

Issues in Digital Integrated Circuit Design, MOS Transistor basics– Static and Dynamic Behavior, Secondary effects.
CMOS Inverter Static and Dynamic Behaviour, Noise Margin, Power Consumption and Power Delay Product, Latch up, Technology Scaling.
Logic gates- Static CMOS Design: Complementary CMOS, Ratioed Logic, Pass Transistor Logic. Dynamic CMOS Design: basic principles, performance of dynamic logic, Noise consideration, Power consumption in CMOS gates – switching activity, Glitches.
Sequential Circuits: Bistability, CMOS static flip-flop, Pseudo static latch, Dynamic two-phase flip-flop, C^2MOS latch, NORA (no race)-CMOS logic design style, Schmitt Trigger, Astable and monostable circuits.
Arithmetic Building blocks: Adder, Multiplier and Shifters, ALU Timing Issues in synchronous design Interconnect Parasitics.
Memories and array structures: ROM and RAM cells design, SRAM cell and arrays, memory peripheral circuits.
BiCMOS Logic Circuits: Introduction, Basic BiCMOS Circuit behavior, Switching delay in BiCMOS logic circuits.
Practical: Practicals as per course contents.

Text Book:

1. Rabaey, J. M. *Digital Integrated Circuits - A Design perspective*. 2nd ed. Pearson Education, 2002.

Additional Books:

1. Martin, K. *Digital integrated circuit design*. Oxford University Press, 2003.
2. Kuo, J., and Lou, J. *Low voltage CMOS VLSI circuits*. John Wiley, 1999.
3. Weste, N., and Eshraghian, K. *Principles of CMOS VLSI Design - A Systems perspective*. 2nd ed., Pearson, 1993

ECL427 INTRODUCTION TO PROBABILISTIC GRAPHICAL MODELS: PRINCIPLES AND TECHNIQUES (3-0-0-3)

Pre-requisite: SCL203 SIGNALS AND SYSTEMS

Contents:

Introduction and overview: Motivation, Structured Probabilistic Models, Probability Theory, Graphs.
Representation: Bayesian Network Representation: Exploiting Independence Properties, Bayesian Networks, Independencies in Graphs, From Distributions to Graphs. Undirected Graphical Models: Parameterization, Markov Network Independencies, Bayesian Networks and Markov Networks, Partially Directed Models. Local Probabilistic Models: Tabular CPDs, Deterministic CPDs, Context-Specific CPDs, Independence of Causal Influence, Continuous Variables, Conditional Bayesian Networks. Template-Based Representations: Introduction, Temporal Models, Template Variables and Template Factors, Undirected Representation, Structural Uncertainty.
Inference: Variable Elimination: Complexity and Graph Structure. MAP Inference: Variable Elimination for (Marginal) MAP, Max-Product in Clique Trees. Inference in Temporal Models: Exact Inference, Approximate Inference, Hybrid DBNs
Learning: Introduction. Learning Graphical Models: Motivation Goals of Learning, Density Estimation, Learning Tasks, Knowledge Discovery. Parameter Estimation: Maximum Likelihood Estimation.

Text Book:

1. Koller, D., and Friedman, N. *Probabilistic Graphical Models: Principles and Techniques*. Massachusetts: MIT Press, 2009.

Additional Books:

1. Darwiche, A. *Modeling and Reasoning with Bayesian networks*. Cambridge University Press, 2009.
2. Bishop, C. *Pattern Recognition and Machine Learning.* Springer US, 2009.
3. Murphy, Kevin P. *Machine Learning: a Probabilistic Perspective.* Massachusetts: MIT Press, 2012.
4. Mackay, David J. C. *Information Theory, Inference, and Learning Algorithms*. Cambridge University Press, 2004.
5. Barber D. *Bayesian Reasoning and Machine Learning*. Cambridge University Press, 2012.
6. Wainwright, Martin J., and Jordan, Michael I. *Graphical models, exponential families and variational inference*. Now Publishers Inc, 2008.

ECL428 LOW NOISE OSCILLATOR FOR WIRELESS APPLICATIONS (3-0-0-3)

Pre-requisite: ECL205 ELECTROMAGNETIC WAVES

Contents:

Course will be project-oriented and involve a combination of analytical derivations and simulation in EM simulator.
Overview of Oscillators, Transistor Models, Large signal S parameter, Resonator choices, General Theory of Oscillators, Noise Modeling in Oscillators, Noise Figure, Impact of Oscillator Nonlinearities, Calculation and optimization of Phase Noise in Oscillators, Validation Circuits, Low Noise Oscillators, Voltage Controlled Oscillators, Noise in Voltage Controlled Oscillators, Integer-N Frequency Synthesizers, Noise in Integer-N Frequency Synthesizers, Advanced Frequency Synthesizers, Design and Simulation of Synthesizers, Measurement of Low phase noise.
Project 1 will be focused on the design and simulation of a low noise oscillator for phase-locked loop applications. Project 2 will be focused on the analytical derivations of project 1.

Text Book:

1. Rohde, Ulrich L., Poddar, Ajay K., and Böck, Georg. *The design of modern microwave oscillators for wireless applications: theory and optimization*. John Wiley & Sons, 2005.

Additional Books:

1. Lee, Thomas H. *The Design of CMOS Radio-Frequency Integrated Circuits.* 2nd ed., Cambridge University Press, 2003.
2. Razavi, Behzad. *RF Microelectronics.* 2nd ed., Pearson Education India, 2013.
3. Gonzalez, Guillermo. *Foundations of Oscillator Circuit Design*. Artech House, 2007.

ECL429 ADVANCED WIRELESS MOBILE COMMUNICATIONS (3-0-0-3)

Pre-requisite: ECL302 DIGITAL COMMUNICATION

Contents:

Wireless Communications and Diversity: Fast Fading Wireless Channel Modelling Rayleigh/Ricean Fading Channels, BER Performance in Fading Channels, Diversity modelling for Wireless Communications, BER Performance Improvement with diversity, Types of Diversity – Frequency, Time, Space.

Broadband Wireless Channel Modelling: WSSUS Channel Modelling, RMS Delay Spread, Doppler Fading, Jakes Model, Autocorrelation, Jakes Spectrum, Impact of Doppler Fading

OFDM and MIMO: Introduction to OFDM, Multicarrier Modulation and Cyclic Prefix Channel model and SNR performance, OFDM Issues – PAPR, Frequency and Timing Offset Issues, Introduction to MIMO, MIMO Channel Capacity, SVD and Eigen-modes of the MIMO Channel, MIMO Spatial Multiplexing & Diversity MIMO - OFDM

UWB (Ultra-Wide Band): UWB Definition and Features, UWB Wireless Channels, UWB Data Modulation, Uniform Pulse Train, Bit-Error Rate Performance of UWB

3G and 4G Wireless Standards: GSM, GPRS, WCDMA, UMTS, LTE, WiMAX, 5G technology.

Text Book:

1. Tse, D., and Viswanath, P. *Fundamentals of Wireless Communications.* Cambridge University Press, 2005

Additional Books:

1. Rappaport, Theodore S. *Wireless Communications: Principles and Practice*. 2nd ed., Prentice Hall, 2002.
2. Biglieri, Ezio. *MIMO Wireless Communications*. Cambridge University Press, 2010.
3. Haykin, S., and Moher, M. *Modern Wireless Communications.* Pearson Education, 2005.
4. Goldsmith, A. *Wireless Communications*. Cambridge University Press, 2005.

ECL430 THEORY OF ESTIMATION AND DETECTION (3-0-0-3)

Pre-requisites: SCL203 PROBABILITY & NUMERICAL METHODS, ECL304 DIGITAL SIGNAL PROCESSING

Contents:

Introduction: Classification of Estimation Approaches, Formulation of the Detection Problems, Hierarchy of Detection Problems.

Classical Unbiased Estimation and Bounds: Minimum variance unbiased estimator (MVUE), Cramer-Rao lower bound (CRLB) on unbiased estimators, Fisher information and its relation to CRLB, Computation of CRLB in general cases Linear model of data and its generalization. General MVU Estimation: Sufficient statistics, Determination of MVUE using a sufficient statistics, Best linear unbiased estimation (BLUE).

Maximum Likelihood Estimation (MLE): Basic Procedure of MLE, MLE for Transformed Parameters, MLE for General Linear Model, Asymptotic Property of MLE.

Least Squares Estimator: Basic Procedure of LSE, Linear Least Squares, Geometrical Interpretations of LS Approach, Constrained Least Squares.

Estimation of Signals: Linear Minimum Mean Square Error (LMMSE) Estimator, Bayesian Gauss-Markov Theorem, Wiener Filtering and Prediction.

Detection Theory: Simple hypothesis testing, Neyman-Pearson criterion, Bayes criterion, Minimax criterion, Composite hypothesis testing, Bayesian criterion Generalized likelihood ratio tests.

Text Book:

1. Kay, S. M. *Fundamentals of Statistical Signal Processing: Estimation Theory*. Vol I, Prentice-Hall, 1993.

Additional Books:

1. Poor, H. V. *An Introduction to Signal Detection and Estimation*. 2nd ed., Springer, 2010.
2. Helstrom, Carl W. *Elements of Signal Detection & Estimation*. Prentice Hall, 1994.
3. Srinath, M. D., Rajasekaran, P. K., and Visawanath, R. *Introduction to Statistical Signal Processing with Applications*. Prentice Hall, 1995.

ECL431 MIMO SYSTEM (3-0-0-3)

Pre-requisite: ECL301 DIGITAL COMMUNICATION

Contents:

Spatio-Temporal Propagation Modeling: Introduction, Directional Channel Modeling, Gaussian Wide Sense Stationary Uncorrelated Scattering, Gaussian Scatter Density Model.

Theory of MIMO Wireless Communication: Shannon's Capacity Formula, Extended Capacity Formula for MIMO Channels, Remarks on the Extended Shannon Capacity Formula, Capacity of SIMO — MISO Channels, Stochastic Channels, MIMO Capacity with Rice and Rayleigh Channels.

Information Theory and Electromagnetism: The Laws of Electromagnetism, Spatial Capacity and Correlation, Spatial Sampling and MIMO Capacity, MIMO Capacity of Waveguide Channels, Spatial Capacity of Waveguide Channels.

Introduction to Space–Time Coding: MIMO System and Space–Time Coding, Alamouti's Transmit Technique, Space–Time Block Codes, Orthogonal Space–Time Block Codes, Space–Time Trellis Codes.

Feedback Techniques for MIMO Channels: Limited Feedback MIMO, Quantized Signal Adaptation Algorithms.

Antenna Selection in MIMO Systems: Spatial Multiplexing, Implementing Antenna Selection: Criteria and Algorithms.

Performance of Multi-User Spatial Multiplexing: Multiple-User MIMO Channel, Multi-User MIMO Transmission Schemes.

Text Book:

1. Tsoulos, G. *MIMO System Technology for Wireless Communications*. CRC Press, 2006

Additional Books:

1. Tse, D., and Viswanath, P. *Fundamentals of Wireless Communication*. Cambridge University Press, 2005.
2. Paulraj, Nabar, R., and Gore, D. *Introduction to Space-time Communications*. Cambridge University Press, 2003.

ECL432 PROBABILITY, STOCHASTIC PROCESS AND NUMERICAL METHODS (3-0-0-3)

Pre-requisite: NIL

Contents:

Probability spaces. Random variables and random vectors. Distributions and densities-Conditional distributions and densities. Independent random variables. Transformation of random variables.

Expectations. Indicator. Moment generating function. Characteristic function. Multiple random variable. Gaussian random vector. Co-variance matrix. Complex random variables. Sequence of random variable-Central limit theorem.

Strictly stationary random process. Wide sense stationary random process. Complex random process. Jointly strictly and wide sense stationary of two random processes. Correlation matrix obtained from random process. Ergodic process. Independent random process. Uncorrelated random process. Random process as the input and output of the system. Power spectral density.

Application to communication systems, White random process. Gaussian random process. Cyclo-stationary

random process. Wide sense cyclo stationary random process. Sampling and reconstruction of random process. Band pass random process.

Solution of Ordinary differential equations – One-step and multistep methods – Boundary value and Eigen value Problems. Partial Differential Equation, Introduction to Finite Element Methods and Finite Difference Methods.

Text Books:

1. Papoulis, A., Pillai, S. U. Probability, *Random variables and Stochastic Processes*. 4th ed., New York: Tata-McGraw Hill, 2001.
2. Chapra, Steven, and Canale, R. *Numerical Methods for Engineer*. 6th ed., New York: Tata McGraw -Hill, 2005.

Additional Books:

1. Stark, H., and Woods, J. W. *Probability and Random Processes with Applications to Signal Processing*. 4th ed., Upper Saddle River: Prentice Hall, 2012
2. Ash, R. B., and Dade, C. D. *Probability and Measure Theory*. 2nd ed. Harcourt Academic Press California 2005

ECL433 MOS DEVICE MODELING (3-0-0-3)

Pre-requisite: NIL

Contents:

Review of MOS basics, Modeling Techniques, Numerical, analytical and empirical approaches.

MOSFET DC models: Pao-Sah model, charge sheet model, piece-wise linear model, models for depletion devices, carrier mobility models in deep-submicron and nanoscale dimensions, short geometry models, source/drain resistance evaluation. Dynamic models: Intrinsic charges and capacitance, Meyer's model, quasi-static and non-quasi-static model, low frequency modeling of MOS transistors, high frequency modeling of MOS transistors. SPICE MOSFET models: Level 1, 2, 3 and 4 models and their comparison. Statistical modeling: Model sensitivity, principal factor method, principal component analysis, regression models

Text Book:

1. Arora, N. *MOSFET Modeling for VLSI Circuit Simulation*. Singapore: World Scientific, 2007.

Additional Book:

1. Tsividis, Y. *Operation and Modeling of the MOS Transistor*. New York Oxford University Press, 2011.

ECL434 LOW POWER VLSI DESIGN (3-0-0-3)

Pre-requisite: ECL425 SOLID STATE DEVICES, ECL426 DIGITAL INTEGRATED CIRCUITS

Contents:

Introduction: Need for low power VLSI chips, Sources of power dissipation in Digital Integrated circuits. Emerging low power approaches. Physics of power dissipation in CMOS devices.
Device and Technology Impact on Low Power: Dynamic dissipation in CMOS, Transistor sizing and gate oxide thickness, Impact of technology Scaling, Technology and Device innovation.
Power Estimation: Simulation Power analysis- SPICE circuit simulators, Gate level logic simulation, Capacitive power estimation, Static state power, Gate level capacitance estimation, Architecture level analysis, Data correlation analysis. Monte Carlo simulation.
Low Power Design: Circuit level- Power consumption in circuits, Flip Flops and Latches design, High capacitance nodes, Low power digital cells library Logic level- Gate reorganization. Low Power Clock Distribution.
Low Power Architecture and Systems: Power and performance management, Switching activity reduction, Parallel architecture with voltage reduction, Flow graph transformation, Low power arithmetic components, Low power memory design.
Algorithm and Architectural Level Methodologies: Introduction, design flow, algorithmic level analysis and optimization, architectural level estimation & synthesis.

Text Book:

1. Roy, K., Prasad, S. *Low-Power CMOS VLSI Circuit Design*. New Delhi: Wiley, 2000.

Additional Books:

1. Yeap, Gary K. *Practical Low Power Digital VLSI Design*. Massachusetts: Springer, 2002.
2. Rabaey, J.M., and Pedram, M. *Low power design methodologies*. Boston: Kluwer Academic, 1997.

ECL435 VLSI TESTING (3-0-0-3)

Prerequisite: NIL

Contents:

Motivation for Testing: Design for testability, the problems of digital and analog testing, Design for test, Software testing.
Faults in Digital Circuits: General introduction, Controllability and Observability, Fault models – stuck-at faults, Bridging faults, Intermittent faults.
Digital Test Pattern Generation: Test pattern generation for combinational logic circuits, Manual test pattern generation, Automatic test pattern generation – Roth's D-algorithm, Developments following Roth's Dalgorithm, Pseudorandom test pattern generation, Test pattern generation for sequential circuits, Exhaustive, Delay fault testing .
Signatures and Self-Test: Input compression output compression arithmetic, Reed-Muller and spectral coefficients, Arithmetic and Reed-Muller coefficients, Spectral coefficients, Coefficient test signatures, Signature analysis and online self-test .
Testability Techniques: Partitioning and ad-hoc methods and scan-path testing, Boundary scan, Offline built in Self-Test (BIST), Hardware description languages and test.
Testing of Analog and Digital circuits: Testing techniques for Filters, A/D Converters, RAM, Programmable logic devices and DSP, Test generation algorithms for combinational logic circuits – fault table, Boolean difference, Path sensitilization, D-algorithm, Podem, Fault simulation techniques – serial single fault propagation, Deductive, Parallel and concurrent simulation, Test generation for a sequential logic, Design for testability – adhoc and structured methods, Scan design, Partial scan, Boundary scan, Pseudo-random techniques for test vector generation and response compression, Built–in-Self test, PLA test and DFT.

Text Book:

1. Bushnell, M.L., and Agrawal, V. D. *Essentials of Electronics Testing: for Digital Memory and mixed signal VLSI circuits*. New York: Springer.

Additional Books:

1. Abramovici, M., Breuer, M. A., and Friendman, A.D. *Digital systems and Testing and Testable Design*. New Jersey: Wiley, 1994.
2. Hurst, Stanley L. *VLSI Testing: digital and mixed analogue digital techniques*. IET, 1998.

ECL436 NANOSCALE DEVICES (3-0-0-3)

Pre-requisite: ECL425 SOLID STATE DEVICES

Contents:

CMOS scaling challenges in nanoscale regimes: Moore and Koomey's law, Leakage current mechanisms in nanoscale CMOS, leakage control and reduction techniques, process variations in devices and interconnects.
Device and technologies for sub 100nm CMOS: Silicidation and Cu-low k interconnects, strain silicon – biaxial stain and process induced strain; Metal-high k gate; Emerging CMOS technologies at 32nm scale and beyond – FINFETs, surround gate nanowire MOSFETs, heterostructure (III-V) and Si-Ge MOSFETs.
Device scaling and ballistic MOSFET: Two dimensional scaling theory of single and multigate MOSFETs, generalized scale length, quantum confinement and tunnelling in MOSFTEs, velocity saturation, carrier back scattering and injection velocity effects, scattering theory of MOSFETs.
SOI MOSFET: FDSOI and PDSOI, 1D Electrostatics of FDSOI MOS, VT definitions, Back gate coupling and body effect parameter, IV characteristics of FDSOI-FET, FDSOI-sub-threshold slope, Floating body effect.
Emerging nanoscale devices: Si and hetero-structure nanowire MOSFETs, carbon nanotube MOSFETs, Tunnel FET, quantum wells, quantum wires and quantum dots; Single electron transistors, resonant tunnelling devices.
Non-classical CMOS: CMOS circuit design using non-classical devices – FINFETs, nanowire, carbon nanotubes and tunnel devices.

Text Book:

1. Lundstrom, M. *Nanoscale Transport: Device Physics, Modeling, and Simulation*. Massachusetts: Springer, 2005.

Additional Books:

1. Maiti, C.K., Chattopadhyay, S. and Bera, L.K. *Strained-Si and Hetrostructure Field Effect Devices.* Milton Park, Abingdon: Taylor and Francis 2007.
2. Hanson, G.W. *Fundamentals of Nanoelectronics*. New Delhi: Pearson India, 2009.
3. Wong, B.P., Mittal, A., Cao, Y., and Starr, G. *Nano-CMOS Circuit and Physical Design*. New Jersey: Wiley, 2004
4. Kundu, S. and Sreedhar, A. *Nanoscale CMOS VLSI Circuits: Design for Manufacturability*. New York: McGraw Hill, 2010.

ECL437 CAD FOR VLSI (3-0-2-4)

Prerequisite: NIL

Contents:

Introduction to Hierarchical and Structured Design: Role of CAD Tools in the VLSI design process, Modeling techniques: Types of CAD tools, introduction to logic simulation and synthesis. CAD Algorithms for switch level and circuit simulation, Circuit extraction and Testing.
SPICE: Introduction to SPICE, AC, DC, Transient, Noise, Temperature extra analysis. MOSFET process/device simulation and parameter extraction, Layout design rules, MOS device layout: Transistor layout, Inverter layout, CMOS digital circuits layout & simulation, Circuit Compaction; Circuit extraction and post-layout simulation.
Technology Oriented CAD (TCAD): Introduction, Process and Device CAD, Process Simulation Techniques, Interfaces in process and Device CAD, Semiconductor Device Analysis, meshing concepts, MOS Device Design by Simulation, Monte-carlo simulation.
Practical: Practicals as per course contents.

Text Books:

1. Massobrio. *Semiconductor Device Modeling with Spice*. 2nd ed., New York: Tata McGraw-Hill, 2010.
2. Sarkar, Chandan K. *Technology Computer Aided Design: Simulation for VLSI MOSFET*. Massachusetts: CRC Press, 2016.

Additional Book:

1. Williams, Spencer E. *A New TCAD-based Statistical Methodology for the Optimization and Sensitivity Analysis of Semiconductor Technologies*. Louisiana: Louisiana Tech University, 1999.

ECL438 VLSI INTERCONNECTS (3-0-0-3)

Prerequisite: NIL

Contents:

Interconnects: Interconnect Parameters: Resistance, Inductance, and Capacitance, Interconnect RC Delays: Elmore Delay Calculation. Interconnect Models: The lumped RC Model, the distributed RC
Model, the transmission line model. SPICE Wire Models, Scaling issues in interconnects, Gate and Interconnect Delay
Parasitic extraction: Parasitic resistance, effect of surface/interface scattering and diffusion barrier on resistance, Capacitance: parallel-plate capacitance, fringing capacitance, coupling capacitance, methods of capacitance extraction, self-inductance, mutual inductance, methods of inductance extraction, high frequency losses, frequency dependent parasitic, skin effect, dispersion effect.
CMOS Repeater: The Static Behavior- Switching Threshold, Noise Margins, The Dynamic Behavior- Computing the capacitances, Propagation Delay: First order Analysis, Propagation Delay from a Design perspective, Power, energy and Energy-Delay- Dynamic Power Consumption, Static Consumption, Analyzing Power Consumption using SPICE, Repeater Design, Transient Analysis of an RC loaded CMOS repeater, Delay Analysis, Analytical power expressions: Dynamic power, Short circuit Power, Resistive Power Dissipation, CMOS Repeater insertion.
Crosstalk, Contribution of driver and interconnect to dissipated energy, Crosstalk effects in logic VLSI circuits. Introduction to Future VLSI Interconnects.

Text Book:

1. Moll, F., Roca, M. *Interconnection Noise in VLSI Circuits*. Berlin: Springer Science & Business Media, 2007.

Additional Books:

1. Rabaey, Jan M. *Analysis and Design of Digital Integrated Circuits– A design Perspective*. 2nd ed., TMH, 2003.
2. Uymera, J.P., *Introduction to VLSI Circuits and Systems*. New Jersey: Wiley, 2002.

3. Goel, A.K. *High-Speed VLSI Interconnects*. 2nd ed., New Jersey, Canada: John Wiley & Sons, 2007.
4. Diamand, Y.S. *Advanced Nanoscale ULSI Interconnects: Fundamentals and Applications.* Massachusetts: Springer, 2009.
5. Wong, Philip H.S., and Akinwande, D. *Carbon nanotube and Graphene Device Physics*. New York: Cambridge University Press, 2011.

ECL439 VLSI PHYSICAL DESIGN (3-0-0-3)

Prerequisite: NIL

Contents:

Introduction: Layout and design rules, materials for VLSI fabrication, basic algorithmic concepts for physical design, physical design processes and complexities.

Partition: Kernigham-Lin's algorithm, Fiduccia Mattheyes algorithm, Krishnamurty extension, hMETIS algorithm, multilevel partition techniques.

Floor-Planning: Hierarchical design, wirelength estimation, slicing and nonslicing floorplan, polar graph representation, operator concept, Stockmeyer algorithm for floorplanning, mixed integer linear program.

Placement: Design types: ASICs, SoC, microprocessor RLM; Placement techniques: Simulated annealing, partition-based, analytical, and Hall's quadratic; Timing and congestion considerations.

Routing: Detailed, global and specialized routing, channel ordering, channel routing problems and constraint graphs, routing algorithms, Yoshimura and Kuh's method, zone scanning and net merging, boundary terminal problem, minimum density spanning forest problem, topological routing, cluster graph representation.

Sequential Logic Optimization and Cell Binding: State based optimization, state minimization, algorithms; Library binding and its algorithms, concurrent binding.

Text Book:

1. Sarrafzadeh, M. and Wong, C.K. *An Introduction to VLSI Physical Design.* 4th ed., New York: McGraw-Hill, 1996.

Additional Books:

1. Sherwani, N.A. *Algorithm for VLSI Physical Design Automation*. 2nd ed. Berlin: Kluwer, 1999.
2. Wolf, W. *Modern VLSI Design System on Silicon*. 2nd ed., New York: Pearson Education, 2000.
3. Sait, S.M. and Youssef, H. *VLSI Physical Design Automation: Theory and Practice*. Singapore: World Scientific, 1999.
4. Dreschler, R. *Evolutionary Algorithms for VLSI CAD*. 3rd ed. Massachusetts: Springer, 2002.
5. Lim, S.K. *Practical Problems in VLSI Physical Design Automation*. Massachusetts: Springer, 2008

ECL440 OPTOELECTRONIC DEVICES (3-0-0-3)

Pre-requisite: NIL

Contents:

Optical processes in semiconductors, EHP formation and recombination, absorption and radiation in semiconductor, deep level transitions, Auger recombination, luminescence and time resolved photoluminescence, optical properties of photonic band-gap materials

Junction photodiode: PIN, heterojunction and avalanche photodiode; Comparisons of various photodetectors, measurement techniques for output pulse.

Photovoltaic effect, V-I characteristics and spectral response of solar cells, heterojunction and cascaded solar cells, Schottky barrier and thin film solar cells, design of solar cell, Modulated barrier, MS and MSM photodiodes; Wavelength selective detection, coherent detection; Microcavity photodiode.

Dynamic effects of MOS capacitor, basic structure and frequency response of charge coupled devices, buried channel charge coupled devices. Electroluminescent process, choice of light emitting diode (LED) material, device configuration and efficiency; LED: Principle of operation, LED structure, frequency response, defects, and reliability.

Semiconductor laser diode, Einstein relations and population inversion, lasing condition and gain, junction lasers, heterojunction laser, multi quantum well lasers, beam quantization and modulation.

Text Book:

1. Bhattacharya, P. *Semiconductor Optoelectronic Devices*. 2nd ed. Upper Saddle River: Pearson Education Inc., 1994.

Additional Books:

1. Yariv, A., and Yeh, P. *Photonics – Optical Electronics in Modern Communications.* New York: Oxford University Press, 2007.
2. Deen, M. J., and Basu, P.K. *Silicon Photonics – Fundamentals and Devices.* UK: John Wiley & Sons Ltd., 2012.

ECL441 FIBER OPTIC COMMUNICATION SYSTEMS & TECHNOLOGY (3-0-0-3)

Pre-requisite: NIL

Contents:

Introduction to Optical Communication and Fiber Characteristics: Evolution of Light wave systems, System components, Optical fibers - Step Index & Graded index – Mode theory, Fiber modes – Dispersion in fibers, Limitations due to dispersion - Dispersion shifted and dispersion flattened fibers - Fiber Losses - Non-linear effects

Optical Transmitters: Basic concepts - LED's structures - Spectral Distribution - Semiconductor lasers - Structures – Threshold conditions - SLM and STM operation - Transmitter design.

Optical Detectors and Amplifiers: Basic Concepts - PIN and APD diodes structures, Photo detector Noise, Receiver design. Amplifiers: Basic concepts - Semiconductor optical amplifiers; Raman - and Brillouin amplifiers - Erbium-doped fiber amplifiers, pumping requirements, cascaded in-line amplifiers.

Coherent Lightwave Systems: Homodyne and heterodyne detectors - Modulation formats - Demodulation schemes - BER in synchronous receivers - Sensitivity degradation – Post - and pre compensation techniques

Optical Components for Communication & Networking: Couplers, Isolators and Circulators, Multiplexers, Bragg Gratings, Fabry-Perot Filters, Mach Zender Interferometers, Arrayed Waveguide Grating, Tunable Filters,

Link Design and Power Budget: System Model, Power Penalty in Transmitter and Receiver, Optical Amplifiers, Crosstalk and Reduction of Crosstalk, Cascaded Filters, Dispersion Limitations and Compensation Techniques.

Text Book:

1. Keiser, Gerd. *Optical Fiber Communications*. 5th ed., New Delhi: Tata McGraw- Hill, 2013

Additional Books:

1. Yariv, A., and Yeh, P. *Photonics – Optical Electronics in Modern Communications*. New York: Oxford University Press, 1997.
2. Deen, M. J., and Basu, P.K. *Silicon Photonics – Fundamentals and Devices*. UK: John Wiley & Sons Ltd., 2012.
3. Ramaswami, R., and Sivarajan, K.N. *Optical Networks, A Practical Perspective.* 3rd ed. London: Elsevier, 2010.
4. Agrawal, Govind. P. *Fiber Optic Communication Systems*. 4th ed., New Delhi: Wiley, 2010.

ECL442 MICROWAVE AND MILLIMETRE WAVE ENGINEERING (3-0-0-3)

Pre-requisite: NIL

Contents:

Review of microwave & millimetre wave theory: Basic difference of RF circuits, digital circuits, High frequency digital circuits and ultra-high frequency circuits.

Transmission Lines: Analysis of Transmission line and waveguide, consideration of distributed and lumped components. Interconnect, Transient Analysis, Concepts of characteristic impedance. Analysis of different transmission lines: Stripline, Microstrip line, coplanar wave guide, suspended strip line.

Antenna and Propagation: Basic reviews of antennas and propagation, Antenna parameters, Antenna for ground base system, airborne system and satellite borne system. Microwave & millimetre wave planner antennas.

Noise and Distortion in Microwave: Review of Random Process, Noise distributions, Noise in linear system, Basic Threshold detection, Noise Temperature and Noise Figure, Noise Figure of Passive Networks, Dynamic Range, Link Analysis.

Passive Microwave Devices: Filter, Direction Couplers, Power divider, Power combiner, Magic TEE, Attenuator, and Resonator.

Microwave & millimetre wave Measurements: Power Meter, Spectrum Analyser, and Vector Network analyser. Microwave System: Radar System, Cellular Phone, Satellite Communication, RFID, GPS.

Modern Trends in Microwave & Millimetre wave Engineering: Effect of Microwave on Human body, Medical and civil application of microwave, Electromagnetic Interference/Electromagnetic Compatibility (EMI/EMC), Monolithic Microwave IC Fabrication, RF MEMS for Microwave components, Microwave Imaging.

Text Book:

1. Pozar, D. M. *Microwave Engineering*. 3rd ed. New Jersey USA: John Wiley & Sons, 2009.

Additional Books:

1. Ramo, S., Whinnery, J.R., and Duzer, T.V. *Fields and Waves in Communication Electronics.* 3rd ed., New Jersey: Wiley India, 2008.
2. Pozar, D. *Microwave and RF Design of Wireless Systems*. New Jersey USA: John Wiley & Son, 2000.
3. Collin, R.E. *Foundation for Microwave Engineering*. New York: John-Wiley & Sons.

ECL443 2D SIGNALS AND IMAGE PROCESSING (3-0-2-4)

Pre-requisite: NIL

Contents:

2D Signals and system: 2D filtering, FIR, IIR.

Digital Image fundamentals: image representation, image sampling and quantization.

Spatial filtering and Filtering in frequency domain: Histogram processing, smoothening and sharpening filters, Edge detection-non parametric and model based approaches, LOG filters, localization problem.
Two dimensional orthogonal transforms: DFT, FFT, WHT, Haar transform, KLT, DCT.
Image Restoration: PSF, circulant and block-circulant matrices, deconvolution, restoration using inverse filtering, Wiener filtering and maximum entropy-based methods.
Morphological processing: Mathematical morphology, binary morphology, dilation, erosion, opening and closing, duality relations. Gray scale morphology, applications such as hit-and-miss transform, thinning and shape decomposition.
Image compression: JPEG, H.26x standards.
Image texture analysis: co-occurrence matrix, measures of textures, statistical models for textures. Hough Transform, boundary detection, chain coding, and segmentation, thresholding methods.
Pattern Recognition and its introduction.
Practical: Practicals as per course contents.

Text Book:

1. Gonzalez, R. C., and Woods, R. E. *Digital image processing*. 3rd ed., New York: Pearson, 2008.

Additional Books:

1. Lim, J. S. *Two dimensional signal and image processing*. New Jersey: Prentice Hall, 1990.
2. Pratt, W. K. *Digital image processing*. 3rd ed. Vol I. New Jersey: Wiley, 2001.
3. New Jersey Prentice Hall India, 1989.

ECL446 FINITE AUTOMATA (3-0-0-3)

Pre-requisite: ECL202 DIGITAL CIRCUITS

Contents:

Review of combinational circuit design and optimization, functional decomposition and symmetric functions, identification of symmetric functions. Threshold logic, synthesis of threshold networks. Fault detection in combinational circuits, Boolean differences and Path sensitization. Synchronous sequential circuits and iterative networks, memory elements and their excitation functions, synthesis of synchronous sequential circuits, Moore and Mealy machines, Applications to controller design, finite state machine flow charts, tables, ASM charts. Machine minimization, Asynchronous Sequential circuits, synthesis, state assignment, minimization, logic families.

Text Book:

1. Kohavi, Z. and Jha, N. K. *Switching and Finite Automata Theory*, 3rd ed.New YorkCambridge University Press, 2013.

Additional Books:

1. Kohavi, Z. Switching and Finite Automata Theory, 2nd ed., Tata McGraw Hill, 1978.
2. Taub, H. *Digital Circuits and Microprocessors*. McGraw Hill, 1986.
3. Mano, M.M. *Digital Logic and Computer Design*. Pearson, 2011.
4. Lee, S.C. *Modern Switching Theory and Digital Design*. Prentice-Hall, 1978.

ECL447 ADAPTIVE SIGNAL PROCESSING (3-0-0-3)

Pre-requisite: ECL304 DIGITAL SIGNAL PROCESSING

Contents:

Vectors, Matrices and Eigen Analysis. Application to adaptive signal processing. Stochastic Processes, Ensemble average, mean, average power, auto and cross correlation functions, stationarity and white noise, Auto-regressive process. Optimal FIR (Wiener) filter, Method of steepest descent, extension to complex valued signals.
Least Squares and LMS algorithms, Normal equations, properties, Eigen System decomposition, Gradient search technique, convergence properties of LMS. Normalized LMS algorithm. Recursive solution techniques, RLS algorithm. Application to noise cancellation, modeling of physical processes, communications.
Frequency domain block LMS Algorithm. Kalman Filter as the basic of RLS filter. Forward and backward linear prediction.

Text Book:

1. Haykin, S. Adaptive Filter Theory. 4th ed. Pearson Education, 2012.

Additional Books:

1. Treichler, J.R. *Theory and Design of Adaptive Filters*. Prentice Hall of India, 2010.
2. Widrow, B., and Stearns, S.D. *Adaptive Signal processing*. Prentice Hall 1985.

ECL448 RADIO FREQUENCY AND MICROWAVE ENGINEERING (3-0-0-3)

Pre-requisite: ECL205 ELECTROMAGNETIC WAVES

Contents:

Two port RF networks-circuit representation, Reciprocal and lossless networks, transmission matrix, Introduction to component basics, wire, resistor, capacitor and inductor.
Scattering matrix-Concept of N port scattering matrix representation. Microwave junctions, Tee junctions, Magic Tee, Rat race, Corners, bends and twists, Directional couplers, two hole directional coupler, Ferrites microwave properties and applications, Termination, Gyrator, Isolator, Circulator, Attenuator, Phase changer, S Matrix for microwave components, Cylindrical cavity resonators.
Microwave semiconductor devices, operation, characteristics and application of BJTs and FETs -Principles of tunnel diodes-Varactor, Step recovery diodes, Gunn diode-Avalanche Transit time devices-IMPATT and TRAPATT devices. Parametric devices-Principles of operation- applications of parametric amplifier. Microwave monolithic integrated circuit (MMIC) - Materials and fabrication techniques
Microwave tubes and measurements, Microwave tubes- High frequency limitations - Principle of operation of Multi cavity Klystron, Reflex Klystron, Traveling Wave Tube, and Magnetron. Measurement of power, wavelength, impedance, SWR, attenuation, Q and Phase shift.

Text Books:

1. Liao, S.Y. *Microwave Devices and Circuit*. 3rd ed., Pearson Education, 2012.
2. Ludwig, R., and Bogdanov, G. *RF Circuit Design: Theory and Applications*. 2nd ed., Pearson Education, 2013.

Additional Books:

1. Collin, R.E. *Foundation of Microwave Engineering*. 2nd ed. Wiley India, 2012.
2. Das, A. and Das, S.K. *Microwave Engineering*. 2nd ed. Tata McGraw- Hill Education Private Limited, 2012.

ECL449 VLSI TECHNOLOGY (3-0-0-3)

Prerequisite: NIL

Contents:

Environment for VLSI Technology: Clean room and safety requirements. Wafer cleaning processes and wet chemical etching techniques. Impurity incorporation: Solid State diffusion modeling and technology, Ion Implantation modeling, technology and damage annealing; characterization of impurity profiles.
Wafer preparation and Crystal growth of Si and GaAs (Bridgeman, CZ and Liquid encapsulation method), Process flow of Novel MOS based devices.
Oxidation: kinetics of silicon dioxide growth both for thick, thin and ultrathin films. Oxidation technologies in VLSI and ULSI. Characterization of oxide films, high k and low k dielectrics for ULSI.
Lithography: Photolithography, E-beam lithography and newer lithography techniques for VLSI/ULSI, mask generation. Chemical Vapour Deposition techniques: CVD techniques for deposition of polysilicon, silicon dioxide, silicon nitride and metal films. Epitaxial growth of silicon, modeling and technology.
Metal film deposition: Evaporation and sputtering techniques. Failure mechanisms in metal interconnects; Multi-level metallization schemes Plasma and Rapid Thermal Processing: PECVD, Plasma etching and RIE techniques; RTP techniques for annealing, growth and deposition of various films for use in ULSI. Process integration for NMOS, CMOS and Bipolar circuits; Advanced MOS technologies.

Text Book:

1. Sze, S.M. *VLSI Technology*. 2nd ed., New Delhi: Tata McGraw-Hill, 2011.

Additional Books:

1. Ghandhi, S.K. *VLSI Fabrication Principles*. 2nd ed., New Delhi: Wiley India, 2010.
2. Plummer, James D. *Silicon VLSI Technology Fundamentals: Practice and Modeling*. Upper Saddle River, Pearson Education, 2009.
3. Campbell, Stephen A. *The Science & Engineering of Microelectronics Fabrication*. 2nd ed., New York: Oxford University Press, 2001.

ECL452 MICRO ELECTROMECHANICAL SYSTEMS (3-0-0-3)

Prerequisite: NIL

Contents:

Introduction to MEMS, MEMs devices overview. Fabrication, Mechanical Properties, Electromechanically properties and modeling, Interfacing circuits. MEMS Application Areas: All-mechanical miniature devices, 3-D electromagnetic actuators and sensors, RF/Electronics devices, Optical/Photonic devices, Medical devices e.g. DNA-chip, micro-arrays.

Text Book:

1. Ananthasuresh, G. K. *Micro and Smart Systems*. Wiley India, 2014.

Additional Books:

1. Bao, M.-H. *Micro Mechanical Transducers: Pressure Sensors, Accelerometers and Gyroscopes*. 1st ed., Elsevier, 2004.
2. Kovacs, G.T.A. *Micromachined Transducers Sourcebook*. Tata McGraw-Hill, 1998.
3. Senturia, S.D. *Microsystem Design*. Kluwer Academic Publishers, 2005.
4. Ananthasuresh, G. K. *Micro and Smart Systems*. Wiley India, 2014.

ECL453 ADVANCED DIGITAL COMMUNICATION (3-0-0-3)

Pre-requisite: ECL302 DIGITAL COMMUNICATION

Contents:

Introduction: Elements of digital communication system – Communication channels and their characteristics– Mathematical models for channels. Representation of digitally modulated signals – Performance of memory less modulation methods – signaling schemes with memory – CPFSK – CPM. Optimum Receivers for AWGN Channels: Waveform and vector channel models. Detection of signals in Gaussian noise. Optimum detection and error probability for band limited signaling and power limited signaling – Non coherent detection – Comparison of digital signaling methods – Lattices and constellations based on lattices –Detection of signaling schemes with memory – Optimum receiver for CPM – Performance analysis for wireline and radio communication systems. Introduction to partially coherent, double differentially coherent communication systems. Channel Coding: Introduction to linear block codes, Convolution coding –Tree, Trellis and State diagrams – Systematic, Non-recursive and recursive convolutional codes – The inverse of a convolutional Encoder and Catastrophic codes – Decoding of convolutional codes - Maximum likelihood decoding, Viterbi algorithm and other decoding algorithms – Distance properties – Punctured convolutional codes, Dual-k codes, Concatenated codes – MAP and BCJR algorithms – Turbo coding and Iterative decoding – Factor graphs and sum-product algorithms – LDPC codes – Trellis coded modulation - Performance comparison.

Pulse Shaping and Equalization: Pulse shaping: Characterization of Band limited channels – ISI – Nyquist criterion – Controlled ISI – Channels with ISI and AWGN – Pulse shaping for optimum transmissions and reception. Equalization: MLSE – Linear equalization – Decision feedback equalization – ML detectors – Iterative equalization – Turbo equalization. Adaptive linear equalizer – Adaptive decision feedback equalization – Blind equalization. Synchronization: Signal parameter Estimation-Carrier phase Estimation–Symbol timing Estimation – Joint estimation of carrier phase and symbol timing – Performance characteristics of ML Estimators.

Text Book:

1. Proakis, John G., and Salehi, Masoud. *Digital Communications*. 5th ed. New Delhi: Tata McGraw Hill, 2008.

Reference Books:

1. Glover, Ian A., and Grant, Peter M. *Digital Communications*. 2nd ed. New York: Pearson education, 2008.
2. Goldsmith, Andrea. *Wireless Communications*. Cambridge: Cambridge University Press, 2005
3. Simon, Marvin, K., Hinedi, Sami, M., and Lindsey, William C. *Digital Communication Techniques: Signal Design and Detection*. New Delhi: Prentice Hall of India, 2009.
4. Sklar, Bernard. *Digital Communications: Fundamentals and Applications.* 2nd ed. Upper Saddle River: Pearson Education, 2002.
5. Theodoridis, S., and Koutroumbas, K. *Pattern Recognition*. 4th ed. Massachusetts: Academic Press, 2009.

ECL501 MIXED SIGNAL VLSI DESIGN (3-0-0-3)

Pre-requisites: ECL416 ANALOG INTEGRATED CIRCUITS, ECL426 DIGITAL INTEGRATED CIRCUITS

Contents:

Signals, Filters and Tools: Sinusoidal signal, Comb filters and representation of signals Sampling and Aliasing: Impulse Sampling, Decimation, K-Path Sampling Sample-and-Hold, Track-and-Hold, Implementation of S/H, Discrete Analog Integrator Analog Filters: Integrator building blocks, MOSFET-C Integrator gm-C Integrators, Discrete time Integrators, Filtering topologies, Bilinear and Biquadratic Transfer function Digital Filters: SPICE Models for DACs and ADCs, Sinc Shaped digital filters, Bandpass and Highpass sinc Filters, Filtering topologies, FIR Filter, Concept of stability and Overflow Data Convertor SNR: Quantization noise, Signal-to-Noise Ratio (SNR), Concept of Spectral Density, Clock Jitter reduction techniques, Improving SNR using Averaging and Feedback, Basics of Data Convertor Design: (ADC and DAC), Mix signal layout, Voltage mode signaling and data transmission, current mode signaling and data transmission Passive mixed signal layout Noise shaping, Improving SNR and Linearity, Improving Linearity using Active circuits, Noise Shaping Data Converters: First Order Noise Shaping, Second order noise shaping, noise shaping topologies, Cascaded Modulators, Bandpass Data Converters: Continuos Time bandpass noise shaping, Active and Passive component bandpass modulators, switched capacitor bandpass modulator, Digital I/Q Extraction to bandpass High Speed Data Converters: Topologies, path settling time, implementation, generation of clock signals and comparators, Clocked comparators, ADC.

Text Book:

1. Baker, Jacob R. *CMOS Mixed signal Circuit Design*. 2nd ed. Wiley IEEE Press, 2009.

Additional Books:

1. Baker, Jacob R. *CMOS circuit design, layout and simulation*. 3rd ed., Wiley-IEEE Press, 2010.
2. Razavi, Behzad. *Design of analog CMOS integrated circuits*. 2nd ed., New Delhi: Tata McGraw-Hill, 2016.