



**COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY**  
**DEPARTMENT OF ELECTRONICS**  
COCHIN - 682 022

## **Syllabus**

**M.Tech. (Electronics & Communication Engineering)**

*Specialisations in*

**VLSI and Embedded Systems**  
**Microwave and Radar Engineering**  
**Robotics and Intelligent Systems**

**2018**

## Course structure

### Semester I

Course Code	Name of the Course	C/E	Credits
ELE 3101	Embedded Architecture and Interfacing	C	3
ELE 3102	Digital Communication	C	3
ELE 3103	Advanced Digital Signal Processing	C	3
ELE 3101L	Embedded Systems Laboratory	C	1
ELE 3102L	Communication Laboratory	C	1
	Elective-I (Specialization)	E	3
	Elective-II (General)	E	3
	Elective-Lab (Specialization)	E	1
Total credits			18

### Specialization Electives

#### VLSI and Embedded Systems

ELE 3104	VLSI Technology and Design	E	3
ELE 3104L	VLSI Laboratory	E	1

#### Microwave and Radar Engineering

ELE 3105	Microwave Devices and Circuits	E	3
ELE 3105L	Microwave Laboratory	E	1

#### Robotics and Intelligent Systems

ELE 3106	Robotics and Automation	E	3
ELE 3106L	Robotics Laboratory	E	1

#### General Electives

ELE 3107	Wireless Communications	E	3
ELE 3108	Neural Networks	E	3
ELE 3107L	Wireless Communications Laboratory	E	1
ELE 3108L	Neural Networks Laboratory	E	1

## Semester II

Course Code	Name of the Course	C/E	Credits
ELE 3201	Advanced Digital System Design	C	3
ELE 3202	Digital Image Processing	C	3
ELE 3203	Seminar	C	1
ELE 3202L	Signal and Image Processing Laboratory	C	1
	Elective-I (Specialization)	E	3
	Elective-II (Specialization)	E	3
	Elective -III (General)	E	3
	Elective-Lab (Specialization)	E	1
Total credits			18

### Specialization Electives

#### VLSI and Embedded Systems

ELE 3204	Hardware Software Codesign	E	3
ELE 3205	Real Time Operating Systems	E	3
ELE 3206	Analog Integrated Circuit Design	E	3
ELE 3204L	Hardware Software Codesign Lab	E	1
ELE 3205L	Real Time Operating Systems Lab	E	1
ELE 3206L	Analog Integrated Circuit Design Lab	E	1

#### Microwave and Radar Engineering

ELE 3207	Antenna Theory	E	3
ELE 3208	Radar Systems	E	3
ELE 3207L	Antenna Lab	E	1

#### Robotics and Intelligent Systems

ELE 3209	Machine Learning	E	3
ELE 3210	Mobile Robotics	E	3
ELE 3209L	Machine Learning Lab	E	1
ELE 3210L	Mobile Robotics Lab	E	1

### General Electives

ELE 3211	Broad Band Communication	E	3
ELE 3212	Spectrum Analysis	E	3
ELE 3213	Adaptive Signal Processing	E	3
ELE 3214	Spread Spectrum Communication	E	3
ELE 3215	RF MEMS	E	3
ELE 3216	Underwater Communication	E	3
ELE 3214L	Spread Spectrum Communication Lab	E	1
ELE 3215L	RF MEMS Lab	E	1

### Semester III

ELE 3301	Project Evaluation & Viva Voce	C	18
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### Semester IV

ELE 3401	Project Evaluation & Viva Voce	C	18
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**Total credits for the course = 18+18+18+18 = 72**

## ELE 3101 EMBEDDED ARCHITECTURE AND INTERFACING

**Course Description:** This course will teach the architectural optimizations of processors and embedded systems. Covers architectural optimizations and introduces new concepts such as cyber physical systems and internet of things. Low power embedded devices are reviewed and its interfacing with peripherals are discussed.

### Course Objectives

- Evolution of computer architecture and optimizations
- Review of commercial computing processors and development boards.
- Interfacing of embedded devices with peripherals

**1. Embedded Architecture:** Evolution of microprocessors and embedded systems. General purpose computers vs Embedded system. Performance and power consumption, Moore's law, Amdahl's law. **Embedded System Architecture:** Intel x86, IBM PowerPC, ARM. Classifications: RISC, CISC, Flynn's Classification, Big and little endian CPI. Computer Architecture: Pipelining stages, Superscalar processing, Throughput and latency.

**2. Optimizations in Architecture:** Pentium processor architecture, Out of order execution, micro ops and caching, branch prediction, register renaming. Pipeline conflicts and Hazards. Pipeline stalling, Delay Slot, Result forwarding, Speculative Execution. **Memory Organization:** Caches, multi-levels, placement and replacement policies, Cache hit and miss Cache performance and prediction. Address translation, base and bound registers, paging, virtual address, Translation Lookaside Buffer.

**3. ARM Architecture:** Evolution of ARM architecture, programming model, Cortex M3 Processor architecture, registers and flags, operation modes, memory map, Nested Vector Interrupt Controller, power management. **Graphics Processing:** Abstraction, multi-threaded programming, Hybrid processors, General Purpose-GPU, NVIDIA CUDA architecture.

**4. Low power Embedded Systems:** 16F87X series PIC processor organization, Instruction Set, Memory organization, Timing modes, Input-Output ports, Compare and Capture modes, Pulse Width Modulation, Interrupt Structure and handling, **Cyber Physical Systems and Internet of Things:** Client server model, Cloud computing, sensor network. Development and interfacing with evaluation boards: Arduino, Galileo, Raspberry Pi, etc.

**5. Interfacing of Embedded Systems:** Sensors and Transducers for interfacing. Bluetooth, Zigbee, HDMI. Interfacing standards: I<sup>2</sup>C, SPI, USB. Analog to Digital Convertors and properties: Parallel Comparator, Dual Slope and Successive Approximation methods. Interfacing of Real Time Clock, Pulse Width Modulation, Stepper motors, LCD.

### References

1. David Patterson and John L. Hennessy, "Computer Architecture: A quantitative approach", 5<sup>th</sup> Edition, Elsevier, 2012.
2. Microarchitecture of the Pentium 4 processor, Intel Technology Journal, 2001.
3. Joseph Yiu, "The definitive guide to ARM Cortex M3", Elsevier, 2<sup>nd</sup> Edition, 2010.
4. "NVIDIA® CUDA™ Architecture: Introduction and Overview", NVIDIA, 2009.
5. Microchip PIC - Microcontroller application notes / data sheets.
6. Mazidi et. al., "The PIC microcontroller and embedded systems", Pearson, 2008.
7. Wayne Wolf, Computers as Components: Principles of Embedded Computing System Design, Elsevier Publication 2000.
8. Barry B. Brey., "The Intel Microprocessors – Architecture, programming & Interfacing", Prentice Hall.

## ELE 3102 DIGITAL COMMUNICATION

**Course Description:** This course introduces students to the advanced concepts of digital communication. In particular, the course will review the concepts of probability and statistics and prepare a mathematical background for communication signal analysis.

### Course Objectives

- To understand and analyze the signal flow in a digital communication system.
- To analyze error performance of a digital communication system in presence of noise and other interferences especially AWGN.
- To understand the importance of the concept of orthogonality in Digital Communication.
- To understand Nyquist's sampling theorem and its practical implications.
- To learn Inter symbol interference (ISI) and design Nyquist filter for avoiding ISI and practical improvisation of ideal Nyquist filter.

**1. Review of Random variables.** Moment generating function, Chernoff bound, Markov's inequality, Chebyshev's inequality, Central limit Theorem, Chi square, Rayleigh and Rician distributions, Correlation, Covariance matrix- Stationary processes, wide sense stationary processes, ergodic process, cross correlation and autocorrelation functions- Gaussian process

**2. Characterization of Communication Signals and Systems-** Signal space representation- Connecting Linear Vector Space to Physical Waveform Space- Scalar and Vector Communication over Memory less Channels. Optimum waveform receiver in additive white Gaussian noise (AWGN) channels - Cross correlation receiver, Matched filter receiver and error probabilities.

**3. Optimum Receiver** Signals with random phase in AWGN Channels- Optimum receiver for Binary Signals- Optimum receiver for M-ary orthogonal signals- Probability of error for envelope detection of M- ary Orthogonal signals. Optimum waveform receiver for coloured Gaussian noise channels- KarhunenLoeve expansion approach, whitening.

**4. Carrier Recovery and Symbol Synchronization in Signal Demodulation-** Carrier Phase Estimation- Effect of additive noise on the phase estimate- Maximum Likelihood phase estimation- Symbol Timing Estimation- Maximum Likelihood timing estimation- Receiver structure with phase and timing recovery-Joint Estimation of Carrier phase and Symbol Timing- Frequency offset estimation and tracking.

**5. Communication over band limited Channels-** Optimum pulse shaping- Nyquist criterion for zero ISI, partial response signaling- Equalization Techniques- Zero forcing linear Equalization- Decision feedback equalization- Adaptive Equalization.

### References

1. J.G. Proakis and MasoudSalehi, "Digital Communication", MGH 5TH edition, 2008..
2. Edward. A. Lee and David. G. Messerschmitt, "Digital Communication", Allied Publishers (second edition).
3. J.Marvin.K.Simon, Sami. M. Hinedi and William. C. Lindsey, "Digital Communication Techniques", PHI.
4. William Feller, "An introduction to Probability Theory and its applications", Vol 11, Wiley 2000.
5. Sheldon.M.Ross, "Introduction to Probability Models", Academic Press, 7th edition.
6. Ian A Glover and Peter M Grant "Digital Communication" 2nd edition Pearson education, 2008.

## ELE 3103 ADVANCED DIGITAL SIGNAL PROCESSING

**Course Description:** This course deals with the analysis & design of analog and digital DSP filters. It also gives an overview regarding multidimensional and multi rate signal processing. A basic understanding of DSP hardware chips.

### Course Objective

- To have a basic idea of z-transform
- To understand the basic steps involved in design of IIR & FIR filters
- To have an idea about 2D- signals, systems and transforms
- To have an insight into multirate signal processing techniques
- To have a thorough understanding of TMS 320 hardware

**1. Overview of Transforms :** Z – Transform, DFT, FFT, DCT, Hilbert Transform, Short-time Fourier Transform, Wavelet Transform.

**2. Filter Design –** LTI System as Frequency Selective Filters - FIR Filters - Characteristics of FIR Filters with Linear Phase - Fourier Series Method of FIR Filter Design – Windows - Design of FIR Filters by Frequency Sampling Technique - IIR Filters - Impulse Invariant Transformation, Bilinear Transformation - Design of Lowpass Digital Butterworth Filter, Design of Lowpass Digital Chebyshev Filter , Frequency Transformations.

**3. Multidimensional Signal Processing:** 2-D Signals and Systems, Multi-dimensional Sampling, Difference Equations, Convolution, Fourier representation, 2-D DFT, Multidimensional FFT, z – Transforms.

**4. Multi-rate Signal Processing:** Sampling and Sampling rate Conversion, Decimation and Interpolation, FIR & IIR Decimators and Interpolators.

**5. Hardware:** Finite word length affect in Signal Processing, Signal Processing Hardware – TMS 320 Series Chips. Real-time Implementation Considerations.

### References

1. Proakis, J.G., Manolakis, D.G. “Digital Signal Processing Principle Algorithms and Applications”. PHI 1996.
2. Dudgeon, D.E., Merseraus, R.M., “Multi Dimensional Digital Signal Processing”. Prentice-Hall, N.J., 1984.
3. Oppenheim, A.V., Schaffer, R.W. , “Discrete – Times Signal Processing”.PHI, 1992
4. Crochiere, R.E., Rabiner, L.R., “Multi rate Digital Signal Processing, Prentice-Hall, N.J. 1983
5. Haddad, Richard A., Parsons, Thomas W., “Digital Signal Processing: Theory Applications & Hardware”, Computer Science Press, 1991.
6. Ahmed, N., Natarajan, T.R., “Theory and Applications of Digital Signal Processing.” Reston Publishing Co., 1983.

## ELE 3104 VLSI TECHNOLOGY AND DESIGN

**Course Description:** This course deals with the analysis and design of MOS circuits and the various design rules associated with CMOS design process. It also discusses VLSI device fabrication techniques as well as high frequency VLSI devices.

### Course Objective:

- To have a basic idea regarding MOS and BiCMOS devices
- To understand the basic steps involved in MOS circuit design process
- To familiarise the propagation delay and scaling effects in MOSFETs
- To have an in-depth knowledge about MOS fabrication technology
- To have an overview of high frequency VLSI devices

**1. Basics of MOS, Bipolar and BiCMOS Device :** MOS transistors, nMOS / CMOS device technology, Basic electrical properties of MOS transistor, V-I relationship, Threshold Voltage, MOS device as a resistor, MOS device as a capacitor, Transconductance, Conduction mechanisms in MOS device, Latch up in CMOS, Bipolar transistor – structure and conduction, BiCMOS device, Latch up susceptibility in BiCMOS.

**2. MOS Circuit Design Processes and Subsystem Layout:** MOS Layers, Stick Diagrams, Design Rules and Layout, General observations on the Design rules, Layout Diagrams, Basic Circuit concepts, Inverters. Architectural issues, Gate logic, Combinational logic, structured design processes, Clock sequential circuits, General considerations for bus lines, power dissipation, current limitations.

**3. Propagation delays and Scaling in MOSFET :** Propagation Delays, Gate delay, Interconnect delay, Effects of sheet resistance and capacitances, Parasitics and interconnect impedances, Scaling factors for device parameters, Limitations of scaling, Constant field and constant voltage scaling, Effects on threshold voltage, Short channel effects.

**4. Basics of VLSI Device Fabrication :** Basics of wafer fab processing, FEOL processing, Basics of oxidation / implantation / lithography / PVDs and CVDs, BEOL process, Interconnects, Process integration and in-line tests.

**5. High Frequency VLSI Devices and Sub-Micron Trends:** Direct band gap semiconductors, Basics of GaAs material and structure for high frequency applications, GaAs based devices, MESFETs, RF-CMOS devices, FinFETS, Strained Si and Si-Ge Devices.

### References

1. Y Taur & T.H. Ning, Fundamentals of Modern VLSI Devices, Cambridge University Press, 2003.
2. D.S. Pucknell & K. Esharghian, Basic VLSI Design, Prentice Hall, 2000.
3. S. Wolf, Silicon Processing for VLSI Era, Lattice Press, 1990. (for Device Fabrication)
4. S. Oda & D. Ferry (eds), Silicon Nanoelectronics, Taylor & Francis, 2006 (for scaling in devices)
5. J. P. Colinge (ed), FinFETs and Other Multigate Transistors, Springer, 2008 (Chapters 1, 2,5)
6. R Doering & Y Nishi, Handbook of Semiconductor Manufacturing Technology, CRC Press, 2008.
7. Badih El-Kareh, Silicon Devices and Process Integration – Deep sub-micron and Nanoscale Technologies, Springer, 2009.
8. IEEE Transactions on Electron Devices (Reviews for trends in technology and device progression)

## ELE 3105 MICROWAVE DEVICES AND CIRCUITS

**Course Description:** This course helps to learn the RF semiconductor devices, amplifiers and fabrication techniques of microwave Integrated circuits.

### Course Objectives:

- To familiarize basic principles, characteristics and applications of commonly used microwave devices.
- To study about RF transistor amplifiers, RF oscillators and their matching networks.
- To provide the idea of RF IC design.

**1. Planar Transmission lines.** Review of Transmission lines, Smith Chart Microstrip Line, Strip line, Coplanar line. Basic theory and design of planar filters.

**2. Microwave Solid state devices:** BJT, IMPATT devices, Transferred Electron devices, Gunn diodes, MESFET, HEMT, control devices, Varactors, PIN diodes, switches, phase shifters, modulators and attenuators, Detectors.

**3. Transistor Amplifiers:** S Parameters of a network, stability consideration in active networks, Stability circles, stability criteria, matching networks, power gain concepts, unilateral transistor, gain circles, noise figure circles, bilateral design

**4. RF oscillators and Mixers:** Oscillation conditions, Two port and one port oscillators, Oscillator and stability conditions, tunable oscillators, mixers, mixer types, up convertors, down convertors, harmonic mixers, circuits design, conversion loss and noise figure, cascaded circuits, Inter modulation

**5. RF IC design:** Monolithic and hybrid MICs, Substrate and conductor materials, IC design, reproducibility and reliability issues, chip manufacturing aspects, RF MEMS

### References:

1. Kai Chang, "Microwave Solid state circuits and applications", John Wiley, 1994
2. Matthew M. Radmanesh, "Radio frequency and microwave electronics illustrated", Pearson Education Inc, 2001.
3. Samuel Liao, "Microwave Circuit Analysis and amplifier design", Prentice Hall, 1987
4. R Ludwig & Bretchko, "RF circuit design, Theory and applications", Pearson Education Inc, 2000.
5. J. Michael Golio, "Microwave MESFETs and HEMTs", Artech House, 1991.



## ELE 3106 ROBOTICS AND AUTOMATION

**Course Description:** This course introduces robot classifications, sensors and actuators. It also provides an overview into control, dynamics of robots and its use in automation.

### Course Objectives

- Discuss Robot classifications, sensors and actuators.
- Discuss kinematics, movement, joints of robots
- Discuss robot applications in automation.

- 1. Introduction:** Definition, Robot Classifications – Cartesian, Cylindrical, Spherical Work Envelope, Types of joints, Prismatic, Revolute, Ball and socket, Number of Axes, Degree of freedom, Joint variables, Grippers - Mechanical Grippers, Pneumatic and Hydraulic Grippers, Magnetic Grippers, Vacuum Grippers .
- 2. Sensors:** Measurement devices, Range, response time, Accuracy, Precision, Sensitivity, resolution, linearity, error, Dead band, Dead time, costs and uncertainty. Position and Odometry Sensors. Beacons and Range Sensors: Doppler Sensors, Haptic sensors. Touch Screen/ Touch Panel. **Actuators:** solenoids, DC motor, AC motor, Servomotors, Stepper motor, BLDC Motors, speed control, Pulse width modulation (PWM) frequency drive, vector drive, H-bridge. Pneumatics & Hydraulic Systems, directional & pressure control valves, Drive mechanisms: Lead screw, Ball screw, Chain linkage, belt drive and gear drives.
- 3. Kinematics:** World frame, joint frame, end-effectors frame, Rotation Matrix, composite rotation matrix, Homogeneous Matrix, Link Coordinate, Denavit-Hartenberg representation, Arm equation, Tool Configuration. **Robot Dynamics:** Velocity Kinematics, Jacobian, Singularities, Differential motion, Euler – LaGrange Equation, Expression of Kinetic and Potential Energy, Equations of Motion.
- 4. Robot Programming & Robot Controllers:** Teach-in, Teach-Through, High-Level languages –robot talk, Comparison of teaching and programming methods, Software speedup, Robot Controllers – essential components, joint actuation and Sensing, Overload, Over current and stall detection methods, Position, Speed, Direction Sensing.
- 5. Automation:** Introduction: Definition of automation, Types of production, Functions of Manufacturing, Organization and Information Processing in Manufacturing, Production concepts and Mathematical Models, Automation Strategies, Production Economics: Methods of Evaluating Investment Alternatives, Costs in Manufacturing, Break-Even Analysis, Unit cost of production, Cost of Manufacturing Lead time and Work-in-process.

### References:

1. Fu, K.S. et al "Robotics- Control, Sensing, Vision and Intelligence ", McGraw – Hill. Inc., Singapore, 1987.
2. H.R. Everett, "Sensors for Mobile Robots – Theory and Applications", A.K. Peteres Ltd. ISBN 1-56881-048-2, 1995.
3. Kurfess, Thomas R., ed. "Robotics and automation handbook". CRC press, 2004.
4. Selig J.M, "Introductory Robotics", PHY(UK), 1992.
5. Yorem Koren, "Robotics for Engineers", McGraw-Hill Book Co., 1992.
6. Groover M.P et al., "Industrial Robotics – Technology, Programming & Applications", McGraw-Hill. 1986.
7. Derby, Stephen J. "Design of Automatic Machinery". CRC Press, 2004.
8. Groover, Mikell P. "Automation, production systems, and computer-integrated manufacturing". Pearson Education India, 2016.
9. Siciliano, Bruno, and Oussama Khatib, eds. "Springer handbook of robotics". Springer, 2016

## ELE 3107 WIRELESS COMMUNICATION

**Course Description:** This course reviews the various communication standards in wireless domain. This course will provide students an understanding about the wireless standards, modes of communication and efficiency criteria.

### Course Objective

- Study the wireless channel characteristics and performance issues.
- Discuss cellular communication and modulation schemes.
- Review next generation cellular standards.

**1. Fading and Diversity:** Wireless Channel Models-pathlossandshadowingmodels-statisticalfadingmodels-Narrowband and wideband Fading models-Review of performance of digital modulation schemes over wireless channels- Diversity- Repetition coding and Time Diversity- Frequency and Space Diversity- Receive Diversity- Concept of diversity branches and signal paths-Combining methods-Selective diversity combining- Switched combining-maximal ratio combining-Equal gain combining-performance analysis for Rayleigh fading channels.

**2. Cellular Communication:** Cellular Networks-Multiple Access: FDM/TDM/FDMA/TDMA- Spatial reuse-Co-channel interference Analysis-Handover Analysis-Erlang Capacity Analysis-Spectral efficiency and Grade of Service- Improving capacity- Cell splitting and sectorization.

**3. Spread spectrum and CDMA:** Motivation -Direct sequence spread spectrum-Frequency Hopping systems-Time Hopping.-Anti-jamming- Pseudo Random(PN) sequence-Maximal length sequences-Gold sequences-Generation of PN sequences.- Diversity in DSSS systems-Rake Receiver-Performance analysis. Spread Spectrum Multiple Access- CDMA Systems-Interference Analysis for Broadcast and Multiple Access Channels-Capacity of cellular CDMA networks-Reverse link power control- Hardand Soft hand off strategies.

**4. Fading Channel Capacity:** Capacity of Wireless Channels-Capacity of flat and frequency selective fading channels-Multiple Input Multiple output(MIMO)systems-Narrowband multiple antenna system model-Parallel Decomposition of MIMO Channels-Capacity of MIMO Channels.

**5. Cellular Wireless Communication Standards:** Second generation cellular systems: GSM specifications and Air Interface-specifications, IS95 CDMA-3G systems: UMTS & CDMA2000 standards and specifications

### References :

1. Theodore S. Rappaport, "Wireless Communications: Principles & Practice", Second Edition, Prentice Hall of India Pvt. Ltd. (Low Priced Edition – Pearson Education Asia), 2002.
2. William C.Y. Lee, "Mobile Communication Engineering: Theory & Applications", Second Edition, McGraw Hill, 1998.
3. Gordon L. Stuber, "Principles of Mobile Communications", Kluwer Academic Press,1996.
4. John G. Proakis, "Digital Communications", Fourth Edition, McGraw Hill, 2001.
5. Jochan Schiller, "Mobile communications", Addison-Wesley (Low Priced Edition – Pearson Education Asia), 2002.
6. SimonHaykin andMichaelMoher, " Modern Wireless Communications", Pearson Education.
7. Andrea Goldsmith, "Wireless Communications",Cambridge Universitypress.
8. A.J.Viterbi,"CDMA- Principles of Spread Spectrum",AddisonWesley, 1995.

## ELE 3108 NEURAL NETWORKS

**Course Description:** This course provides a broad introduction to Neural Networks and its design approach.

### Course Objectives:

- To provide idea of neural networks
- To familiarize different architectures of Neural networks
- To understand various algorithms involved in modeling and problem solving
- To provide practical approach in various applications

**1. Introduction** - what is a neural network? Human Brain, Models of a Neuron, Neural networks viewed as Directed Graphs, Feedback, Network Architectures, Knowledge Representation. Learning Process–Supervised, Unsupervised and Reinforcement learning, Learning Tasks-Pattern Association, recognition, function approximation, control, beamforming

**2. Perceptron** –Perceptron convergence theorem, Relation between perceptron and Bayes classifier for a Gaussian Environment, **computer experiment**-pattern classification, batch perceptron algorithm. Model building through regression- linear regression model, maximum a posteriori estimation of the parameter vector. Relationship between regularized least-squares estimation and map estimation, **computer experiment:** pattern classification. Least-Mean-Square Algorithm

**3. Multilayer Perceptron** – Batch learning and Online learning, Back propagation algorithm, XOR problem, heuristics for making the back-propagation algorithm perform better, **computer experiment:** pattern classification.

**4. Back Propagation** - back propagation and differentiation, Hessian matrix, optimal annealing and adaptive control of the learning rate, Approximations of function, Generalization, Cross validation, Network pruning Techniques, Virtues and limitations of back propagation learning, Convolutional Networks

**5. Kernel Methods and Radial-Basis Function networks** – cover’s theorem on the separability of patterns, the interpolation problem, radial-basis-function networks, k-means clustering, recursive least-squares estimation of the weight vector, hybrid learning procedure for RBF networks, **computer experiment:** pattern classification, interpretations of the Gaussian hidden units, kernel regression and its relation to RBF networks

### REFERENCES:

1. Simon Haykin, “Neural Networks and Learning Machines”, Pearson Education; 3<sup>rd</sup> edition 2016
2. Martin T Hagan, Howard B Demuth, Mark H Beale, Orlando De Jesús, "Neural Network Design", Cengage Learning, 2<sup>nd</sup> Edition, 2014
3. S. Haykin, “*Neural Networks: A Comprehensive Foundation*”, 2<sup>nd</sup> edition, (Prentice Hall, 1999)
4. Philip D. Wasserman, “Neural Computing: Theory and Practice”, Coriolis Group, 1989.
5. B.Vegnanarayana, “Artificial neural networks”, Prentice Hall of India, 2005
6. James. A.Freeman and David.M.Skapura, "Neural Networks Algorithms, Applications and. Programming Techniques ", Pearson Education, 2002

## ELE 3201 ADVANCED DIGITAL SYSTEM DESIGN

**Course Description:** This course aims to provide students with knowledge about designing digital circuits and realizing them using hardware description languages.

### Course Objective

- Review digital logic design fundamentals, design of sequential circuits.
- Learn VHDL programming to realize digital systems.
- Discuss the design and test of digital systems.

**1. Combinational Logic Modules and Logic Families:** Definition and specification; Truth table; Basic logic operation and logic gates, Decoders, encoders, multiplexers, demultiplexers and their applications; Parity circuits and comparators; Arithmetic modules-adders, subtractors, Propagation Delay. Basic postulates and fundamental theorems of Boolean algebra; Standard representation of logic functions - SOP and POS forms; Simplification of switching functions - K-map. Introduction to different logic families; Operational characteristics of BJT in saturation and cut-off regions; Operational characteristics of MOSFET as switch; TTL inverter - circuit description and operation; CMOS inverter - circuit description and operation; Structure and operations of TTL and CMOS gates; Electrical characteristics of logic gates – logic levels and noise margins, fan-out, propagation delay

**2. Sequential Circuits:** Definition of state machines, state machine as a sequential controller; Basic sequential circuits- latches and flip-flops: SR-latch, D-latch, D flip-flop, JK flip-flop, T flip-flop; Timing hazards and races; Analysis of state machines using D flip-flops and JK flip-flops; Design of state machines - state table, state assignment, transition/excitation table, excitation maps and equations, logic realization Sequential circuits and timing - Setup and hold times, Basics of static timing analysis, Setup and Hold time analysis.

**3. System Design with VHDL :**Introduction, Behavioral, Data flow, Structural Models, Process. Concurrent Statements, Sequential Statements, Loops. Sequential Circuits, FSM Coding. Library, Packages, Functions, Procedures.Test bench, Realization of combinational and sequential circuits using HDL – Registers –counters – sequential machine

**4. Logic Design with Programmable Devices:** Designing with Programmable Devices, Designing with Programmable Logic Devices. Read Only Memories, Programmable Array Logic PALs, Programmable Logic Arrays PLAs PLA minimization and PLA folding, Other Sequential PLDs, Design of combinational and sequential circuits using PLD's. MUX based digital design. Design using ROM, Programmable Logic Arrays (PLA) and Programmable Array Logic (PAL), Sequential circuit design - design of Moore and Mealy circuits , Design of a pattern sequence detector using MUX, ROM and PAL FPGA Simulation, Synthesis, Place and Route.

### 5. Fault Diagnosis and Testability

Testing combinational and sequential logic , Boundary scan testing, and Built-in self test . Test Generation, DFT Schemes.

### References

1. Charles H.Roth Jr “Fundamentals of Logic Design” Thomson Learning 2004
2. Nripendra N Biswas “Logic Design Theory” Prentice Hall of India, 2001
3. Parag K.Lala “Fault Tolerant and Fault Testable Hardware Design” B S Publications, 2002
4. Parag K.Lala “Digital system Design using PLD” B S Publications, 2003
5. Charles H Roth Jr.”Digital System Design using VHDL” Thomson learning, 2004
6. Douglas L.Perry “VHDL programming by Example” Tata McGraw.Hill - 2006

## ELE 3202 DIGITAL IMAGE PROCESSING

**Course Description:** This course deals with digital images and processing of digital images for various applications like Image Representation, Image Enhancement, Image Restoration, Image Compression, Image Segmentation, Morphological Image Processing, Image Recognition & Interpretation

### Course Objective

- To understand the basic algorithms of image processing
- To get familiarize with 2D Systems & Transforms
- To familiarise with the image compression techniques
- To understand an overall idea regarding image segmentation, image representation and description.
- To understand the basics of pattern recognition and supervised/unsupervised learning

**1. Fundamentals of Digital Image Processing:** Image enhancement – Enhancement by Point Processing, Spatial Filtering, Frequency Domain Filtering, Colour Image Processing, Wavelet Transforms - 1D and 2D- fundamentals.

**2. Image Restoration:** Degradation Models, Algebraic approach to Restoration, Inverse Filtering, Wiener Filter, Constrained Least Squares and Interactive Restoration, Restoration in Spatial Domain, Geometric Transformation.

**3. Image Compression:** Error-Free Compression, Lossy Compression - Lossy Predictive Coding, Transform Coding, Wavelet Coding. Lossless Compression - Variable Length Coding, Arithmetic Coding, Lossless Predictive Coding. Image Compression Standards.

**4. Image Segmentation, Representation and Description:** Detection of Discontinuities and Boundary, Region Oriented Segmentation, Use of Motion in Segmentation. Representation Schemes; Boundary, Regional and Relational Descriptors. Morphological Operations.

**5. Recognition and Interpretation :** Pattern Classes, Decision-Theoretic Methods, Structural Methods; Interpretation - Knowledge types, Logical Systems, Semantic Networks, Production Systems, Statistical Pattern, Recognition, Supervised/Unsupervised learning etc.

### Reference:

1. Gonzalez, Rafael.C. & Woods, Richard.E.,“Digital Image Processing” - Pearson Education Asia, 1992, 2002
2. Anil K. Jain, “ Fundamentals of Digital Image Processing”, PHI, 1995.
3. B.Chanda&D.DuttaMajumder, “Digital Image Processing & Analysis” , Prentice Hall of India, 2001
4. S. Jayaraman, S. Esakkirajan & T. Veerakumar,” Digital Image Processing”, Mcgraw Hill, 2009.

## ELE 3204: HARDWARE SOFTWARE CODESIGN

**Course Description:** This course provides an understanding of interaction between hardware and software in electronic system design. It covers modeling of hardware and software at various levels of abstraction and interfacing between hardware and software components.

### Course Objectives

- Transform software programs into cycle-based hardware descriptions.
- Partition and implement software programs into hardware and software components and design interfaces to communicate between them.
- Explain the control-flow and data-flow of a software program and cycle accurate hardware components.

**1. Introduction to Hardware Software Codesign:** Levels of Abstraction, Driving factors in codesign. Data flow modeling and implementation, Synchronous Data Flow Graphs, Scheduling of Data Flow, dynamic and static schedule. Pipelining, multi-rate expansion.

**2. Transformation of software into hardware:** Data and control flow of programs, construction of control flow graph. Design of data path and controller. Finite State Machine with Data path, FSMD modeling and implementation, Simulation and Synthesis of FSMD.

**3. Design of Custom Architectures:** Programming in Gezel. FSMD examples in Gezel, Verilog, VHDL. Limitations of Finite state machines, Microprogrammed architecture: control, encoding, datapath. Microprogrammed Interpreters and pipelining. Picoblaze: A contemporary microprogram controller. Embedded Cores for Codesign: Processors, RISC pipeline, Control, data and structural hazards.

**4. Program organization:** data types, memory hierarchy, program layout, object code, compiled code. System On Chip: Design principles of SoC architecture. Data processing, Communications, Storage and Control of Heterogeneous and Distributed systems. Interfacing for Hardware Software Codesign: on-chip bus systems, bus transfers, bus priority and locking.

**5. Synchronization schemes:** semaphore, handshake, blocking and non-blocking data transfer. Memory-Mapped Interfaces: Register, Mailbox, FIFO, Shared memory. Coprocessor Interfacing: tight and loose coupling, Fast Simplex Link, Custom instruction interfaces, ASIP Design flow. Coprocessor design for Advanced Encryption Standard (AES): functions of coprocessor, Data and Control design, Programmers model, software design.

### References

1. Patrick Schaumont, "A Practical Introduction to Hardware/Software Codesign", Springer, 2<sup>nd</sup> Edition, 2012.
2. D. D. Gajski, S. Abdi, A. Gerstlauer, G. Schirner, "Embedded System Design: Modeling, Synthesis and Verification", Springer, 2009.
3. P. Marwedel, "Embedded System Design: Embedded systems foundations of Cyber-Physical Systems", Springer, 2011.
4. Frank Vahid, Tony Givargis, "Embedded System Design: A Unified Hardware/Software Introduction", John Wiley & Sons, 2002.
5. G. De Micheli, R. Ernst, W. Wolf, "Readings in Hardware/Software Codesign", Morgan Kaufman, 2002.
6. J. Staunstrup and Wayne Wolf, "Hardware/Software Co-design: Principles and practice", Springer, 1997.
7. Wayne Wolf, Computers as Components: Principles of Embedded Computing System Design, Elsevier Publication, 2<sup>nd</sup> Edition, 2008.

## ELE 3205 REAL TIME OPERATING SYSTEMS

**Course Description:** This course provides an understanding on the various aspects of real time operating systems. It covers methodologies in task scheduling and resource management.

### Course Objectives

- Provide an understanding of the factors influencing embedded software.
- Discuss the various scheduling algorithms in a real time operating system
- Study the software development tools and review commercial RTOS.

1. Factors influencing Embedded system design: CPU and memory types, Direct memory access, Interrupt basics, interrupt latency, disabling and masking interrupts, Shared data problems, atomicity, critical section, multi-threaded programming, data race, IEEE POSIX standard for programming, POSIX Threads.

2. Software Architectures for RTOS: Embedded Architecture Types: Round Robin approach, Round-Robin with interrupts, Real Time Operating Systems. Soft and hard real time OS, tasks and task states, scheduler, reentrancy, semaphores, signaling, semaphore problems, POSIX semaphores, mutex locks.

3. Tasks Scheduling: Modeling of real time systems, Event triggered and Time triggered approach, interrupt driven systems, Worst case execution time, pre-emptive priority systems, hybrid systems, task control block model. The scheduling problem, schedulability test, Process scheduling, Fixed priority scheduling – Rate Monotonic approach, Dynamic priority Scheduling- Earliest Deadline First.

4. Communication and resource management: Message queue, mailbox, pipes. Inter-task communication, Blocking and non-blocking task synchronization. Nested interrupts, resource management, deadlock, starvation, pre-emption, priority inversion, priority inheritance, priority ceiling protocol.

5. Embedded software development tools: Host and target machines, cross compilers, Linker, locator, emulators, in-circuit emulators, monitors. Review of free and commercial Real Time Operating Systems- VxWorks, RTlinux, uCOS.

### References

1. David E. Simon, An Embedded Software Primer - Pearson Education, 2000.
2. Abraham Silberschatz, Operating Systems Concepts, John Wiley & Sons, 2004.
3. Herman Kopetz, Real-Time systems, Design principles for distributed embedded applications, Springer 2011.
4. Philip A. Laplante, Real- Time Systems Design and Analysis, John Wiley & Sons, 2004.
5. Frank Vahid and Tony Givargis, Embedded System Design: A Unified Hardware/ Software Introduction, John Wiley & Sons, 1999.
6. Wayne Wolf, Computers as Components: Principles of Embedded Computing System Design, Elsevier 2000.
7. VxWorks, <https://www.windriver.com/products/vxworks/>
8. Micrium uCOS, <https://www.micrium.com/rtos/kernels/>.
9. Real Time Linux [https://rt.wiki.kernel.org/index.php/Main\\_Page](https://rt.wiki.kernel.org/index.php/Main_Page)

## ELE 3206: DESIGN OF ANALOG INTEGRATED CIRCUITS

**Course Description:** This course deals with the small signal and large signal modeling of MOS and BiCMOS circuits with a basic understanding of analog integrated circuit technology. This course also emphasise on the working, analysis and design of various analog MOS circuits.

### Course Objectives

- To model and analyse analog MOS circuits.
- To have a basic idea regarding MOS and BiCMOS integrated circuit technology
- To understand the working of current mirrors, active load, voltage and current references.
- To get an insight into nonlinear analog circuits like multipliers, PLL, Function Synthesis etc.

**1. Analog MOS Models for Integrated Circuit:** Large-Signal Behavior of Metal-Oxide-Semiconductor Field-Effect Transistors, Small-Signal Models of MOS Transistors, Advanced MOS modeling, SPICE modeling parameters, MOS diodes, Active resistors, basics of single stage CMOS amplifiers -common Source, gate and source follower stages-frequency response

**2. MOS and BiCMOS Integrated-Circuit Technology:** Basic Processes in Integrated-Circuit Fabrication - Electrical Resistivity of Silicon, Solid-State Diffusion, Electrical Properties of Diffused Layers, Epitaxial Growth, Local Oxidation, Polysilicon Deposition, Passive Components in MOS Technology – Resistors and Capacitors in MOS Technology, BiCMOS Technology, Heterojunction Bipolar Transistors, Interconnect Delay, Economics of Integrated Circuit Fabrication - Yield Considerations in Integrated-Circuit Fabrication, Cost Considerations in Integrated-Circuit Fabrication

**3. Current Mirrors, Active Loads, and References - Current Mirrors** - General Properties, Simple Current Mirror, Simple Current Mirror with Beta Helper, Simple Current Mirror with Degeneration, Cascode Current Mirror, Wilson Current Mirror, **Active Loads** - Common-Emitter–Common-Source Amplifier with Complementary Load, Common-Emitter–Common-Source Amplifier with Depletion Load, Common-Emitter–Common-Source Amplifier with Diode-Connected Load, Differential Pair with Current-Mirror Load, **Voltage and Current References** - Low-Current Biasing, Supply-Insensitive Biasing, Temperature-Insensitive Biasing

**4. Differential Amplifiers:** Single Ended and Differential Operation, Basic Differential Pair, Common-Mode Response, **Frequency Response of Amplifiers:** General Considerations, Common Source Stage, Source Followers, Common Gate Stage, Cascode Stage, Differential Pair. **Noise:** Types of Noise, Representation of Noise in circuits, Noise in single stage amplifiers, Noise in Differential Pairs.

**5. Nonlinear Analog Circuits** - Analog Multipliers Employing the Bipolar Transistor, The Emitter-Coupled Pair as a Simple Multiplier, The dc Analysis of the Gilbert Multiplier Cell, The Gilbert Cell as an Analog Multiplier, A Complete Analog Multiplier, The Gilbert Multiplier Cell as a Balanced Modulator and Phase Detector, Phase-Locked Loops (PLL), PLL Concepts, The PLL in the Locked Condition, Integrated-Circuit PLL, Nonlinear Function Synthesis.

### References

1. Behzad Razavi, “Design of Analog CMOS Integrated Circuits”, Tata McGraw Hill, 2<sup>nd</sup> Edition, 2016.
2. Behzad Razavi, “Fundamentals of Microelectronics”, Wiley, 2013.
3. R. Jacob Baker, “CMOS Circuit Design, Layout, and Simulation”, Wiley, 3<sup>rd</sup> Edition, 2010.
4. Paul. R. Gray, Paul J. Hurst, Stephen H. Lewis, Robert G. Meyer, “Analysis and Design of Analog Integrated Circuits” Wiley, Fifth Edition, 2009.
5. Philip Allen & Douglas Holberg, “CMOS Analog Circuit Design”, Oxford University Press, 2002.
6. D. A. John and K. Martin, “Analog Integrated Circuit Design”, John Wiley, 1997.



## ELE 3207 ANTENNA THEORY

**Course Description:** This is a course on the design and analysis of antenna. This course provides a comprehensive coverage of a wide variety of antennas and propagation topics related to numerous communication systems. This course presents fundamental theory together with techniques for the practical design, measurement and application of antennas over the RF (radio-frequency) to milli-meter wave frequency range.

### Course Objectives

- Understand important and fundamental antenna engineering parameters and terminology,
- Learn the basic concepts of electromagnetic wave radiation and reception,
- Develop the basic skills necessary for designing a wide variety of practical antennas and antenna arrays.

**1. Overview of Antennas:** Types of Antennas and antenna parameters, Diploes, Horn antennas – Sectoral horns – pyramidal horns, – Helical Antennas – Yagi – Uda antenna – Reflector Antennas, Plane reflector – Corner reflector – Parabolic reflector Parabolic cylinder – Cassegrain antennas, Corrugated horn, Reflect array, Frequency independent antennas, Patch antenna.

**2. Antenna arrays** – Broadside array – end fire array – Array factor, directivity of the array, Non uniform arrays – Binomial array – Chebyscheff array – Planar array -- Design procedure

**3. Computational Electromagnetics:** Different methods; Integral Equation and Moment Method, Point matching method, Basic functions, Application of point matching, Weighing function, Moment method; Finite Difference Time Domain Analysis; Numerical examples

**4. Antenna Synthesis:**Synthesis principles, Continuous sources, Schelkunoff Polynomial method, Fourier transform method – Woodward method – Taylor Line source method – Triangular, Cosine and Cosine squared amplitude distribution – Line source phase distribution – Continuous aperture sources.

**5. Microstrip Antennas and Smart Antennas:** Basic characteristics – Feeding techniques – Rectangular and circular patch antennas – Smart Antenna analogy – Cellular radio system evolution – Signal propagation – Antenna beamforming – Mobile Adhoc Networks (MANETs), System design.

### References:

1. Constantine A Balanis, Antenna Theory – Analysis and design, Third Edition, John Wiley and Sons, 2005
2. John D Kraus – Antennas, Fourth Edition, Tata McGraw Hill, 2010
3. John L Volakis, Antenna Engineering Hand Book – Fourth Edition, Tata McGraw Hill Companies, 2007

## ELE 3208 RADAR SYSTEMS

**Course Description:** The main objective of this course is to introduce the students to the basic concepts in the field of Radar communication. The students will gain knowledge on the different types of Radar Systems, different types of navigational aids used and the basic design of radar transmitter and receiver.

### Course Objectives

- Learn about fundamentals of Radar
- Understand different types of radar and their working
- Study of Radar signal detection techniques
- Study of Radar navigation techniques

**1. Radar fundamentals and operation:** Introduction, principles, types of radar, transmitter functions, wave form spectra, receiver functions, signal processing, Radar equation, Radar cross section.

**2. Radar Systems:** Pulse, CW, FM-CW, MTI, Doppler Radar, Tracking Radar: Tracking system parameters, Conical Scan, amplitude comparison and phase comparison monopulse, Range and velocity tracking, Tracking accuracy.

**3. Detection of Radar Signals and information extraction and estimation:** Detection introduction, threshold detection, Signal integration, Binary integrators, CFAR, Theoretical accuracy of radar measurements, ambiguity function and radar waveform design, correlation detection and matched filter receiver.

**4. Radar signal processing:** Signal integration, spectrum analysis, windows and resolution, MTI principles and methods, De staggering and processing, Moving Radars and moving clutter, Doppler processing.

**5. Radar Applications:** Direction finders, instrument landing systems, Radar beacons, Electronic Warfare, ECM and ECCM, high resolution radar, range and Doppler resolution, Pulse compression (analog and digital), Synthetic aperture radar.

### References:

1. Skolnik M.M., "Introduction to Radar systems", McGraw Hill, (Second Edition) 1981.
2. Byron Edde. "Radar: principles, technology and applications", Pearson Education Inc., 1995.
3. D.CurtisScheleher, "Introduction to Electronic Warfare", Artech House Inc., 1986.
4. Wheeler G.J., "Radar Fundamentals", Prentice Hall Inc. NJ 1967.
5. LavanonNadav, "Radar Principles" John Wiley & Sons, 1988.

## ELE 3209 MACHINE LEARNING

**Course Description:** This course provides a broad introduction to machine learning and how to apply learning algorithms.

### Course Objectives

- To understand the basics of machine learning
- To familiarize with regression, classification and optimization problems
- To provide an idea about the NN Learning and SVM
- To familiarize with factors to keep in mind while systems design

**1. Introduction:** Introduction to learning, Supervised Learning, Unsupervised Learning, Reinforcement Learning. Linear Regression with One Variable - idea of cost function, and gradient descent method for learning, Linear Regression with Multiple Variables- Multiple Features, Gradient Descent for Multiple Variables, Feature Scaling, Learning Rate, Normal Equation Noninvertibility, Features and Polynomial Regression, Logistic Regression-classification, hypothesis representation, decision boundary, cost function, optimization, multiclass classification.

**2. Neural Network learning and SVM:** Non-linear hypotheses, model representation, multiclass classification. Learning-cost function, back propagation algorithm, unrolling parameters, gradient checking, random initialization. **SVM:** introduction, optimization objective, large margin classification, kernels

**3. Unsupervised Learning:** Introduction, k-means algorithm, optimization, random initialization, clustering. **Dimensionality Reduction:** Data compression, visualization, principal component analysis algorithm, reconstruction from compressed representation.

**4. Anomaly Detection and Recommender Systems:** Gaussian distribution, algorithm for anomaly detection, feature choosing, multivariate Gaussian distribution, Anomaly Detection using the Multivariate Gaussian Distribution. **Recommender Systems:** content based recommendations, collaborative filtering algorithm, vectorization and normalizations.

**5. Large Scale ML and ML System Design:** Learning with large datasets, stochastic gradient descent, mini-batch gradient descent, stochastic gradient descent convergence, online learning, map reduce and data parallelism. **System Design:** performance of a machine learning system, prioritizing, error analysis, error matrix for skewed classes, trading off precision and recall, data for machine learning. Evaluating a Hypothesis, Model Selection and Train/Validation/Test Sets, Diagnosing Bias vs. Variance, Regularization and Bias/Variance, Learning Curves.

### REFERENCES:

1. Stuart J. Russell, "Artificial Intelligence 3e: A Modern Approach", Pearson Education India; 3rd edition 2015
2. Shai Shalev Shwartz, Shai Ben David, "Understanding Machine Learning: From Theory to Algorithms", Cambridge University Press, 2014
3. Ethem Alpaydin, "Introduction to Machine Learning", Second Edition, MIT Press, 2010
4. Tom Mitchell, "Machine Learning", McGraw-Hill 1997
5. R.S.Michalski, J.G.Carbonell, T.M.Mitchell, "An Artificial Intelligence Approach", Springer-Verlag, 1984
6. Mehryar Mohri, Afshin Rostamizadeh and Ameet Talwarkar, "Foundations of Machine Learning", MIT Press, 2012
7. Kevin Murphy, "Machine learning: a Probabilistic Perspective", MIT Press, 2012.

## ELE 3210 MOBILE ROBOTICS

**Course Description:** This course discusses robots who are mobile and communicate real time sensor data. It will discuss how these robots will make decisions for navigation using input from surroundings.

### Course Objectives

- Movement and communication of mobile robots.
- Localization, navigation and control of mobile robots.

**1. Mobile Robots:** Introduction to Wheeled Robots, Classification of wheels, Fixed wheel, Centered Oriented Wheel, Off-centered oriented wheel, Swedish wheel, Mobile robot locomotion, Differential Wheel, Tricycle, Synchronous drive, Omni-directional, Ackerman Steering, Kinematics models of WMR.

**2. Mobile Robot Kinematics:** Kinematic Models and Constraints: Representing robot position, Forward kinematic models, Wheel kinematic constraints, Robot kinematic constraints. Mobile Robot Maneuverability: Degree of mobility, Degree of steerability, Robot maneuverability. Mobile Robot Workspace: Degrees of freedom, Holonomic robots, Path and trajectory considerations, Beyond Basic Kinematics, Motion Control (Kinematic Control): Open loop control (trajectory-following), Feedback control.

**3. Perception:** Sensors for Mobile Robots: Sensor classification, Characterizing sensor performance, Wheel/motor sensors, Heading sensors, Ground-based beacons, Active ranging, Motion/speed sensors, Vision-based sensors. Representing Uncertainty: Statistical representation, Error propagation: combining uncertain measurements, Feature Extraction: Feature extraction based on range data (laser, ultrasonic, vision-based ranging), Visual appearance based feature extraction.

**4. Mobile Robot Localization:** Introduction, Localization: Noise, Aliasing, Localization-Based Navigation, Programmed Solutions, Belief Representation, Map Representation: Continuous representations, Decomposition strategies, Challenges in map representation. Probabilistic Map-Based Localization: Markov localization, Kalman filter localization, Landmark-based navigation, Positioning beacon systems, Route-based localization, Autonomous Map Building, The stochastic map technique.

**5. Planning and Navigation:** Introduction, Competences for Navigation: Planning and Reacting: Path planning, Obstacle avoidance, Navigation Architectures: Modularity for code reuse and sharing, Control localization, Techniques for decomposition, Introduction to IoT. Case studies: ESP32 based Mobile Robot.

### References

1. Siegwart, Roland, Illah Reza Nourbakhsh, and Davide Scaramuzza. "Introduction to autonomous mobile robots", MIT press, 2011.
2. H.R. Everett, "Sensors for Mobile Robots – Theory and Applications", A.K. Peteres Ltd. ISBN 1-56881-048-2. 1995.
3. Siegwart, Roland, Illah Reza Nourbakhsh, and Davide Scaramuzza. "Introduction to autonomous mobile robots". MIT press, 2011.
4. Kurfess, Thomas R., ed. "Robotics and automation handbook". CRC press, 2004.
5. David Poole, Alan Mackworth "Artificial Intelligence: Foundations of Computational Agents", Cambridge University Press, 2010.
6. "Where am I? Sensors and Methods for Mobile Robot Positioning", J. Borenstein, et al., The University of Michigan, 1996.
7. Janakiraman P.A, "Robotics and Image Processing", Tata McGraw-Hill, 1995.
8. Siciliano, Bruno, and Oussama Khatib, eds. "Springer handbook of robotics". Springer, 2016.

## ELE 3211 BROADBAND COMMUNICATION

**Course Description:** This course introduces cutting-edge technologies for broadband communication systems and to understand how ATM will interoperate with existing protocols and technologies to make networked multimedia a reality.

### Course Objectives

- Discuss existing network architectures
- Discuss broadband over different technologies
- Discuss cable TV network architecture

**1. Introduction:** Network Architectures – Telephone Network – Internet and Intranets – Limitations of today's Network Infrastructure. Classification of Applications. Traffic Requirements and QoS Requirements.

**2. Principle of ATM Network:** Switched Point to Point Architecture, Packet Switching, Fast Packet Switching, Advantages of BISDN Technical & Strategic. Overview of BISDN – Basic Elements of BISDN Networks, Network Operations, Virtual Channel and Virtual Path. Traffic Management:

**3. Residential Broadband Services:** Connectivity and Functional Requirements. Residential Broadband Service Architecture – Residential Access Networks, CO and Headend Networks, Broadband Internet Access, In-Home Network and End-to-end Protocol/model.

**4. Broadband Over xDSL:** Network Architecture – Subscriber Loop Architecture, xDSL characteristics, xDSL Technologies, HDSL, ADSL, SDSL and VDSL. ADSL based broadband service architecture – ADSL based ATM-to-the-Home Architecture – DSLAM and Broadband Internet.

**5. Hybrid Fibre/ Coax Network Architecture:** Legacy Cable Network Architecture – Hybrid Fibre Coax Network Architecture – Fibre Nodes – Residential Broadband Architecture – end-to-end Protocol Architecture.

### References:

1. Kswok, Timothy, “ATM – The Paradigm for Internet, Intranet & Residential Broadband Services & Applications”, Prentice Hall PTR, New Jersey (1998)
2. Sumit Kasera and Pankaj Sethi, “ATM Networks: Concepts and Protocols” Tata McGraw – Hill Publishing Company Limited, New Delhi (2001)
3. Introduction to Broadband Communication systems, Cajetan M. Akujuobi, Matthew N.O. Sadiku, CRC press, 2007.
4. Leon Gracia and Widjaja, “Communication Networks”, Tata McGraw Hill, 2008.
5. Jean Warland and Pravin Varaiya, “High Performance Communication Networks”, 2nd Edition, Harcourt and Morgan Kanffman Publishers, London, 2008

## **ELE 3212 SPECTRUM ANALYSIS**

**Course Description:** This course introduces cutting-edge technologies for broadband communication systems and to understand how ATM will interoperate with existing protocols and technologies to make networked multimedia a reality.

### **Course Objectives**

- Discuss spectral density and its properties.
- Study of algorithms used in spectrum analysis.
- Study the filtering techniques for spectrum analysis.

**1. Power Spectral Density:** Energy spectral density of deterministic signals, Power spectral density of random signals, Properties of PSD

**2. PSD Estimation -Non-parametric methods.** Estimation of PSD from finite data, Non-parametric methods: Periodogram properties, bias and variance analysis, Blackman-Tukey method, Window design considerations, time-bandwidth product and resolution-variance trade-offs in window design, Refined periodogram methods :Bartlet method, Welch method.

**3. Parametric method for rational spectra:-** Covariance structure of ARMA process, AR signals, Yule- Walker method, Least square method, Levinson-Durbin Algorithm, MA signals, Modified Yule-Walker method, Two-stage least square method, Burg method for AR parameter estimation.

**4. Parametric method for line spectra:-** Models of sinusoidal signals in noise, Non-linear least squares method, Higher order Yule-Walker method, MUSIC and Pisayenko methods, Min-norm method, ESPRIT method.

**5. Filter bank methods:** Filter bank interpretation of periodogram, Slepia base-band filters, refined filter bank method for higher resolution spectral analysis, Capon method, Introduction to higher order spectra.

### **References**

1. Steven M. Kay, "Modern Spectral Estimation Theory & Application", Prentice-Hall Publishers, Englewood Cliffs, New Jersey USA, (1999).
2. Julius S. Bendat and Allan G. Piersol, "Engineering Application of Correlation and Spectral Analysis", John Wiley & Sons, Inc., New York (1993)
3. William A. Gardner, "Statistical Spectral Analysis", Prentice Hall Inc., New Jersey(1988)
4. Steven M. Kay and Stanley Lawrence Marple Jr., "Spectrum Analysis – A Modern Perspective", Proceedings of the IEEE, 69(11), pp.1380-1419,(1981)

## ELE 3213 ADAPTIVE SIGNAL PROCESSING

**Course Description:** A beginner course in adaptive signal processing intended to be taught to intermediate degree qualified students. The course is aimed at providing a basic idea of adaptation that is employed in numerous adaptive systems across various domains.

### Course Objective

- To introduce the practical aspect of Adaptive Signal Processing in different adaptive systems.
- Adaptive systems in the fields of communications, radar, sonar, seismology, navigation systems and biomedical engineering explored in brief.
- This course will present the basic principles of adaptation in system perspective.
- The course will cover various adaptive signal processing algorithms (e.g., the LMS algorithm) and many applications, such as adaptive noise cancellation, interference canceling, system identification, etc.

**1. Introduction :** Adaptive Systems - Definition and Characteristics - Open-and Closed-Loop Adaptation - Adaptive Linear Combiner - Input Signal and Weight Vectors - Desired Response and Error - Performance Function

**2. Theory of Adaptation** - Properties of the Quadratic Performance Surface - Normal Form of the Input Correlation Matrix - Eigenvalues and Eigenvectors of the Input - Correlation Matrix - Geometrical Significance of Eigenvectors and Eigenvalues

**3. Performance Surface** - Methods of Searching the Performance Surface - Basic Ideas of Gradient Search Methods - simple Gradient Search Algorithm - Gradient Estimation and its Effects on Adaptation - Gradient Component Estimation by Derivative Measurement - Derivative Measurement and Performance Penalties with Multiple Weights

**4. Adaptive Algorithms** - The LMS Algorithm - Derivation of the LMS Algorithm - Convergence of the Weight Vector - An Example of Convergence - Learning Curve Noise in the weight-Vector Solution.

**5. Applications:** Adaptive Modeling and System Identification - Adaptive Modeling of a Multipath Communication Channel. Inverse Adaptive Modeling Deconvolution and Equalization - General Description of Inverse Modeling- Adaptive Equalization of Telephone Channels - The Concept of Adaptive Noise Canceling - Stationary Noise-Canceling Solutions, Filtered-X LMS Algorithm - Adaptive Arrays - Sidelobe Cancellation - Beam forming with a Pilot Signal- Spatial Configurations, Adaptive Algorithms

### References:

1. Bernad, Widrow, Stearns, .S.D, “Adaptive Signal Processing”. Prentice Hall, 2009.
2. TülayAdali, Simon Haykin, “Adaptive Signal Processing: Next Generation Solutions”, John Wiley & Sons, 2010
3. Ali H. Sayed, “Fundamentals of Adaptive Filtering”, John Wiley & Sons, 2003
4. John R. Treichler, C. Richard Johnson, Michael G. Larimore, “Theory and design of adaptive filters”, Wiley, 1987
5. Dimitris G. Manolakis, Vinay K. Ingle, Stephen M. Kogon, “Statistical and adaptive signal processing: spectral estimation, signal modeling, adaptive filtering, and array processing” McGraw-Hill, 2000
6. Jacob Benesty, Yiteng Huang, “Adaptive Signal Processing: Applications to Real-World Problems” Springer.

## ELE 3214 SPREAD SPECTRUM COMMUNICATION

**Course Description:** This course introduces students to the basic concepts of spread spectrum communications, its major applications and techniques for analyzing these systems. In particular, the course will review these concepts and emphasize the various trade-offs in the design of such systems. Students will learn to simulate spread spectrum systems in order to understand the principles upon which they are based.

### Course Objectives

- To learn the principles of spread spectrum systems, including CDMA systems.
- To learn principles of finite fields, orthogonal codes & pseudorandom noise sequences.
- To understand and use generator functions to generate pseudorandom codes
- Analyze the performance and design of spread-spectrum communication systems.
- To understand the concepts of code synchronization and interference suppression.
- Examine the use of code-division multiple access in digital cellular systems.

**1. Fundamentals of Spread Spectrum :** Introduction to spread spectrum communication, pulse noise jamming, low probability of detection, direct sequence spread spectrum, frequency-hopping and time-hopping spread spectrum systems, correlation functions, spreading sequences-maximal-length sequences, gold codes, Walsh orthogonal codes-properties and generation of sequences , Synchronization and Tracking: delay lock and tau-dither loops, coarse synchronization- principles of serial search and match filter techniques.

**2. Performance Analysis of SS system :** Performance of spread spectrum system under AWGN, multi-user Interference, jamming and narrowband interferences, Low probability of intercept methods, optimum intercept receiver for direct sequence spread spectrum, Error probability of DS-CDMA system under AWGN and fading channels, RAKE receiver

**3. Capacity, Coverage and Control of Spread Spectrum Multiple Access Networks .** Basics of spread spectrum multiple access in cellular environments, reverse Link power control, multiple cell pilot tracking, soft and hard handoffs, cell coverage issues with hard and soft hand off, spread spectrum multiple access outage, outage with imperfect power control, Erlang capacity off or ward and reverse links.

**4. Multi-user Detection-**MF detector, decorrelating detector, MMSE detector. Interference Cancellation: successive, Parallel Interference Cancellation, performance analysis of multiuser detectors and interference cancellers.

**5. CDMA Systems** General aspects of CDMA cellular systems, IS-95 standard, Downlink and uplink, Evolution to Third Generation systems, WCDMA and CDMA-2000 standards, Principles of Multicarrier communication, MC- CDMA and MC-DS-CDMA.

### References

1. R.L.Peterson,R.Ziemer and D.Borth,“Introduction to Spread Spectrum Communications,” Prentice Hall, 1995.
2. A.J. Viterbi,“CDMA- Principles of Spread Spectrum Communications,” Addison-Wesley, 1997.
3. Vijay K. Garg, Kenneth Smolik, Joseph E. Wilkes, Applications of CDMA Wireless/ Personal Communications, Prentice Hall, 1995
4. S.Verdu, “Multiuser Detection” , Cambridge University Press-1998
5. M.K.Simon, J.K. Omura, R.A. Scholtz and B.K.Levitt,“Spread Spectrum Communications Handbook”, McGraw- Hill, Newyork-1994
6. Cooper and McGillem, “Modern Communications and Spread Spectrum” TMH 1985
7. J. G. Proakis, “Digital Communications,” McGrawHill, 4th edition.
8. S.Glisic and B.Vucetic, “Spread Spectrum CDMA Systems for Wireless Communications,” Artech House, 1997.



## ELE 3215 RF MEMS

**Course Description:** A beginner course in RF MEMS intended to be taught to intermediate degree qualified students. The course is designed to familiarize the student with the functions and applications of RF MEMS along with various design of different RF MEMS structures.

### Course Objectives

- The course is designed to familiarize the student with the functions and applications of RF MEMS and other associated devices
- To familiarize with the application of RF MEMS in different fields
- To Understand the basic and complex design issues involved in RF MEMS
- Familiarize with the different type of structures used in RF MEMS such as beams, mirrors, cantilevers, comb drives, patches, coplanar waveguide etc.
- Basically, understand the concept of micromachining

**1. RF MEMS relays and switches.** Switch parameters. Actuation mechanisms. Bistable relays and micro actuators. Dynamics of switching operation.

**2. MEMS inductors and capacitors.** Micromachined inductor. Effect of inductor layout. Modeling and design issues of planar inductor. Gap tuning and area tuning capacitors. Dielectric tunable capacitors.

**3. Micromachined RF filters.** Modeling of mechanical filters. Electrostatic comb drive. Micromechanical filters using comb drives. Electrostatic coupled beam structures.

**4. MEMS phase shifters.** Types. Limitations. Switched delay lines. Micromachined transmission lines. Coplanar lines. Micromachined directional coupler and mixer.

**5. Micromachined antennas.** Microstrip antennas – design parameters. Micromachining to improve performance. Reconfigurable antennas.

### References

1. H.J.D.Santos, RF MEMS Circuit Design for Wireless Communications, Artech House, 2002.
2. G.M.Rebeiz, RF MEMS Theory, Design and Technology, Wiley, 2003.
3. Stephen D Senturia, "Microsystem Design", Kluwer Academic Publishers, 2001.
4. Marc Madou, "Fundamentals of Microfabrication", CRC Press, 1997.
5. V.K.Varadan, K.J Vinoy & K.A. Jose, RF MEMS and their Applications, Wiley, 2003.
6. Gregory Kovacs, "Micromechanised Transducers Source Book", WCB McGraw Hill, Boston, 1998.
7. M H Bao, "Micromechanical Transducers, Pressure Sensors, Accelerometers and Gyroscopes" Elsevier, Newyork, 2000.

## ELE 3216 UNDERWATER COMMUNICATION

**Course Description:** This course provides an outline about sonar systems, its types and their applications. The course will provide overview of signal processing and filtering options for output received from sonar systems and acoustic modems. It will discuss acoustic modems and underwater sensor networks.

### Course Objectives

- Discuss the transducers and array systems used for sonar.
- Classification of sonar systems and modern versions.
- Signal processing, filtering and noise impact on sonar systems.

**1. Types of sonar systems :** active and passive - sonar equations - propagation characteristics of the medium - transmission loss and spreading effects - beam forming and steering - detection threshold - square law detector - cross-correlation detector. **Ambient noise :** sources of ambient noise - shallow water ambient noise - effect of depth- directional characteristics of deep water ambient noise - electrical noise, machinery noise, flow noise, propeller noise, self-noise and radiated noise.

**2. Correlation receivers and matched filters:** Advanced Sonar Signal Processing functions – adaptive beam forming - synthetic aperture arrays - automated decision making.

**3. Orthogonal Frequency division multiplexing:** Key features, characteristics and principle of operation of OFDM, Channel coding and interleaving System model, Enhancement of spectral efficiencies, Transmission/ Reception of OFDM - OFDM Simulations.

**4. Acoustic Modem:** Underwater Wireless Modem- Sweep spread carrier signal-transmission characteristics in shallow water channel-separation of time varying multipath arrivals-Typical acoustics modems-characteristics and specifications- Applications, Acoustic Releases-Real time wireless current monitoring system.

**5. Underwater Sensor Network:** Underwater Networking- Ocean Sampling Networks, Pollution Monitoring, Environmental Monitoring and Tactical surveillance systems, Major challenges in design of Underwater Sensor Networks, Factors that affect the UWSN- Sensor Node Architecture- GIBS, VRAP, DABSRAPT. etc.

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