School of Electrical Sciences

Courses List

Course code	Course Title	Credit Structure			
		L	T	P	C
EE 601	Linear System Theory	3	0	0	3
EE 602	System Identification and Adaptive Control	3	0	0	3
EE 603	Power and Control Laboratory	0	0	3	2
EE 604	Applied Linear Algebra	3	0	0	3
EE 605	Optimization in Systems and Control	3	0	0	3
EE 606	Nonlinear Control	3	0	0	3
EE 607	Artificial Intelligence and Machine Learning	3	0	0	3
EE 608	Optimal and Robust Control	3	0	0	3
EE 610	Power Systems Dynamics and Control	3	0	0	3
EE 611	Modelling and Analysis of Electrical Machines	3	0	0	3
EE 612	Insulation in Power Apparatus and System	3	0	0	3
EE 613	Power Electronic Converters	3	0	0	3
EE 614	Power Electronics Laboratory	0	0	3	2
EE 615	Control of Electrical Drives	3	0	0	3
EE 616	Power Electronics for Renewable Energy Systems	3	0	0	3
EE 617	Wide Area Power System Control	3	0	0	3
EE 618	Smart Grid Technology	3	0	0	3
EE 619	FACTS and HVDC	3	0	0	3
EE 621	Advance Digital Signal Processing	3	0	0	3
EE 622	Electromagnetic Compatibility	3	0	0	3
EE 632	Analog Integrated Circuit Design	3	0	0	3
EE 631	Sensors and Actuators: Fabrication and Applications	3	0	0	3

EE 601 **Linear Systems Theory** **3-0-0-3**

Course Contents:

Maths Preliminaries: Vector Spaces, Change of Basis, Similarity Transforms, Introduction: Linearity, Differential equations, Transfer functions, State Space representations, Evolution of State trajectories Time Invariant and Time Variant Systems, Controller Canonical Form, Transformation to Controller Canonical, State Feedback Design, Discrete time systems representation, reachability and state feedback design, Observability: Grammian, Lyapunov Equation, Output Energy, Observabilty matrix Observer canonical form (SO, MO), Unobservable subspace, Leunberger Observer (SO, MO), State Feedback with Leunberger Observers, Minimum order observers, Stabilizability and Detectability, Output feedback and Output Stabilizability, Disturbance Decoupling Problem

Text Books:

1. M. Gopal, Digital Control and State Variable Methods, Tata McGraw-Hill

2. S. Lang, *Introduction to Linear Algebra*, Springer-Verlag, 2/e, 1997.
3. L. A. Zadeh and C. A. Desoer, *Linear System Theory: The State Space Approach*, Springer-Verlag, 2008.
4. C.T. Chen, *Linear System Theory and Design*, Oxford University Press, 3/e, 1999.
5. W. Rugh, *Linear System Theory*, Prentice Hall, 2/e, 1995.

Reference:

1. W. M. Wonham, *Linear Multivariable Control, A Geometric approach* , Springer-Verlag, 1985
2. B. Friedland, *Control System Design - An Introduction to State-Space Methods*, MacGraw-Hill

EE 602 System Identification and Adaptive Control 3-0-0-3

Introduction and overview of Systems Identification, Adaptive Control and applications. Parameter Estimation: Least Square, Generalized and Recursive Least Square, Estimator properties including error bounds and convergence, MES, ML and MAP estimators, Nonlinear Least Squares. Model Structures and Predictors. Recursive Identification of Linear dynamic systems: RLS, ELS, IV, RML, Stochastic Approximation, Extended Kalman Filter, generalized prediction error framework and its application to ARMA and state models, convergence analysis, Time varying parameters. Nonlinear System Identification. Adaptive schemes. Adaptive control theory. Applications. Situations when constant Gain feedback is insufficient. Robust control. The adaptive control problem. The model following problem. MRAS based on stability theory. Model following when the full state is measurable. Direct MRAS for general linear systems. Prior knowledge in MRAS. MRAS for partially known systems. Use of robust estimation methods in MRAS. The basic idea. Indirect self-tuning regulators. Direct Self-tuning regulators. Linear Quadratic STR. Adaptive Predictive control. Prior knowledge in STR. Linear-in-the-parameters model. Least squares estimation. Experimental conditions. Recursive estimators. Extended least squares. Robust estimation methods (dead zone, projection). Implementation issues. Nonlinear System Identification Techniques

Text Books/References:

1. K.J. Astrom and B. Wittenmark, *Adaptive Control*, Pearson
2. L. Ljung, *System Identification Theory for the user*, Prentice-Hall, 2007
3. K.S. Narendra and A.M. Annaswamy, *Stable Adaptive Systems,*, Prentice-Hall, 1989.
4. Miroslav Krsti, Ioannis Kanellakopoulos, and Petar V. Kokotovic, *Nonlinear and Adaptive Control Design*, Wiley-Interscience, 1995

EE 603 Power and Control Laboratory 0-0-3-2

Course Contents:

Computer aided analysis of Power systems, Simulation of FACTS devices, Control of Power electronic converters, Speed control of electrical drives, High-voltage engineering,Solar PV System Characteristics, MPPT Design.

DC motor driven closed loop position control system, Position Control System using Synchro, Identification of model of DC Motor, Compensator Design, Compensator Design for Power System Stabilizer, Position and Speed Control of a DC motor using PD and PID Controller via Ziegler-Nichols tuning method, Discrete-time version of the PID controller, Control of Magnetic Levitation System

Text/Reference Books

1. K. Ogata, *Modern Control Engineering,*, Pearson Higher Education, 2002
2. I.J. Nagrath, and M. Gopal, *Control System Engineering*, New Age, 2002
3. P. Kundur, Power System Stability and Control, McGraw Hill Inc, New York, 1995.

EE 604 Applied Linear Algebra 3-0-0-3

Course Contents:

Linear algebraic systems, Linear equations in matrix form, Elementary matrices, Matrix Inversion, Vector Spaces, Span & Linear independence, Basis & dimension, Fundamental Matrix Subspaces, Inner products Inequalities, Inner product space, Orthogonality, Orthogonal basis, QR decomposition, Orthogonal projections , Norms, Vector norms and inequalities, Matrix (Operator) norm and inequalities, Quadratic minimization, Linearity, Linear functions, Linear transformation, Affine transformation & Isometry, Eigen values and eigen vectors, Basic properties of Eigen value, Eigen vector basis, Invariant subspace, Coupled differential equations, Linear iterative system, Power matrix, Iterative solution to linear system of equation, Computing Eigen values & Eigen vectors, Convergence, Singular value decomposition, Pseudo inverse, Least square, Euclidean norm of a square matrix, Principal component Analysis and Data Compression.

Textbooks/ References

1. Strang, Gilbert (2016), *Introduction to Linear Algebra* (5th ed.), Wellesley-Cambridge Press, ISBN 978-09802327-7-6
2. Hoffman, Kenneth; Kunze, Ray (1971), *Linear algebra* (2nd ed.), Englewood Cliffs, N.J.: Prentice-Hall, Inc., MR 0276251
3. Meyer, Carl D. (February 15, 2001), *Matrix Analysis and Applied Linear Algebra*, Society for Industrial and Applied Mathematics (SIAM), ISBN 978-0-89871-454-8 (Free)
4. Olver, Peter J. ; Shakiban, Chehrzad (2018), *Applied Linear Algebra* (2nd ed.), Springer International Publishing, ISBN 978-3-319-91040-6

EE 605 Optimization in Systems and Control 3-0-0-3

Course Contents:

Concept of space, positive definite matrices, linearity, convex set, convex function Unconstrained optimizations for single and multi-variable problems, Newton step, backtracking line search method Constrained optimization techniques for linear and nonlinear problem, simplex method, active set methods concept of duality, Central path, penalty function, interior point methods Self-Concordant functions and Newton Method Complexity analysis Semidefinite programming, LMI, Evolutionary algorithms, Swarm optimization.

Textbooks/References

1. 1.S. Boyd and L. Vandenberghe, *Convex optimization*, Cambridge University Press , 2004
2. D. P. Bertsekas, *Nonlinear programming*, Athena Scientific , 2016
3. D. E. Goldberg, *Genetic Algorithms in search, Optimization and Machine Learning*, Pearson India, 2002
4. S. Boyd, L. El Ghaoui, E. Feron, V. Balakrishnan, *Linear Matrix Inequalities in System and Control Theory*, SIAM , 1994

EE 606 Nonlinear Control 3-0-0-3

Course Contents:

Introduction: state-space representation of dynamic al systems, phase-portraits of second order systems, types of equilibrium points: stable/unstable node, stable/unstable focus, saddle; Existence and uniqueness of solutions: Lipschitz continuity, Picard's iteration method, proof of existence and uniqueness theorem, continuous dependence of solutions on initial conditions; Features of nonlinear dynamical systems: multiple disjoint equilibrium points, limit cycles, Bendixson criterion, Poincare-Bendixson criterion; Linearization: linearization around an equilibrium point, validity of linearization: hyperbolic equilibrium points, linearization around a solution; Stability analysis: Lyapunov stability of autonomous systems, Lyapunov theorem of stability, converse theorems of Lyapunov theorem, construction of Lyapunov functions: Krasovskii method and variable gradient method, LaSalle invariance principle, region of attraction, input/output stability of non-autonomous systems, L-stability; Control of nonlinear systems: describing functions method, passivity theorem, small gain theorem, Kalman-Yakubovich-Popov lemma, Aizermann conjecture, circle/Popov criteria, methods of integral quadratic constraints and quadratic differential forms for designing stabilizing linear controllers, multiplier techniques.

Textbooks / References:

1. H. K. Khalil, *Nonlinear systems*, Prentice Hall, 3rd Edn., 2002.
2. M. Vidyasagar, *Nonlinear systems analysis*, 2nd Edn., Society of Industrial and Applied Mathematics, 2002.
3. H. Marquez, *Nonlinear Control Systems: Analysis and Design*, Wiley, 2003.
4. A. Isidori, *Nonlinear Control Systems*, Springer, 3rd Edn., 1995.
5. F. Verhulst, *Nonlinear Differential Equations and Dynamical Systems*, Springer, 1990.

EE 607 Artificial Intelligence and Machine Learning 3-0-0-3

Course Contents:

Module 1 (Concept Learning and General to specific ordering)

Concept Learning and General to specific ordering, Concept Learning as search, the inductive learning hypothesis, Decision Tree Learning, Hypothesis space search in decision tree learning.

Inferential Statistics: Learn Probability Distribution Functions, Random Variables, Sampling Methods, Central Limit Theorem and more to draw inferences

Linear Regression: Linear regression and predict continuous data values

Supervised Learning: Naive Bayes and Logistic Regression

Unsupervised Learning: Create segments based on similarities using K-Means and Hierarchical clustering

Support Vector Machines: Classification of data points using support vectors

Module 2 Artificial Neural Networks and Deep Learning

Neural Network representations, appropriate problems for neural network learning, perceptrons, representational power of perceptrons, perceptron training rule, Gradient Descent and Delta rule, Multilayer perceptron and backpropagation algorithm, Recurrent Neural Networks

Layer-by-layer training: Per-layer trained parameters, initialization of further training using contrastive divergence

Genetic Algorithms, Representing Hypothesis, Genetic operators, Population Evolution and schema search, Genetic programming , Models of Evolution and Learning, Parallelizing GAs

Module 3 Bayesian Learning and Reinforcement Learning

Bayesian Learning: Baye's Theorem and concept of learning, Brute-Force Bayes Concept of Learning, MAP hypothesis and consistent Learners, Maximum Likelihood and Least-squared Error Hypothesis, Bayes Optimal Classifier, GIBBS algorithm, Naïve Bayes classifier, Bayesian Belief Networks, EM algorithm, K Means Algorithm

Introduction to Reinforcement Learning (RL): Understand the basics of RL and its applications in AI. Q-learning: Write Q-learning algorithms to solve complex RL problems.

Text Books

1. Tom M Mitchell, *Machine Learning*, PHI learning pvt. Ltd.-New Delhi, 2015
2. Ethem Alpaydin, *Introduction to Machine Learning*, The MIT Press, 3rd Edition, 2015

Reference Books

1. R. Duda, P. Hart, and D. Stork. *Pattern Classification*, 2nd edition, Wiley Interscience, 2001.
2. C. M. Bishop. *Neural Networks for Pattern Recognition*, Oxford University Press, 1995.
3. T. Hastie, R. Tibshirani and J. Friedman, *Elements of Statistical Learning: Data Mining, Inference and Prediction*. Springer-Verlag, 2001.

EE 608 Optimal and Robust Control 3-0-0-3

Course Contents:

Mathematical preliminaries, Static optimization, Calculus of variations, Solution of general continuous time optimal control problem, Continuous time Linear Quadratic Regulator design - Riccati equation, Optimal tracking problem, Free final time problems, Minimum time problem, Constrained input control and Pontryagin’s maximum principle, Bang-Bang control, Principle of optimality, Dynamic Programming, Discrete LQR using Dynamic Programming, Continuous control and Hamilton-Bellman-Jacobi Equation.

Textbooks / References:

1. D. E. Kirk, *Optimal Control Theory: An Introduction*, Prentice-Hall, 2004.
2. B.D.O. Anderson and J.B. Moore, *Optimal Control: Linear Quadratic Methods*, Dover Publications, 2014.
3. F.L. Lewis, D. Vrabie and V.L. Syrmos, *Optimal Control*, 3rd edition, Wiley & Sons, 2012

EE 610 Power Systems Dynamics and Control 3-0-0-3

Course Contents:

Basic Concepts of dynamical systems and stability. Modelling of power system components for stability studies: generators, transmission lines, excitation and prime mover controllers, flexible AC transmission (FACTS) controllers.;Analysis of single machine and multi-machine systems. Small signal angle instability (low frequency oscillations): damping and synchronizing torque analysis, eigenvalue analysis;Mitigation using power system stabilizers and supplementary modulation control of FACTS devices. Small signal angle instability (sub-synchronous frequency oscillations): analysis and counter-measures. Transient Instability: Analysis using digital simulation and energy function method. Transient stability controllers. Introduction to voltage Instability. Analysis of voltage Instability.

Textbooks / References:

1. P. Kundur, *Power System Stability and Control*, McGraw Hill Inc, New York, 1995.
2. P. Sauer & M. A. Pai, *Power System Dynamics & Stability*, Prentice Hall, 1997.
3. K. R. Padiyar, *Power System Dynamics, Stability & Control*, Interline Publishers, Bangalore, 1996.

EE 611 Modelling and Analysis of Electrical Machines 3-0-0-3

Course Contents:

Reference Frame Theory – Equations of transformation, commonly used reference frames, variables observed from several frames of reference, transformation between reference frames. Symmetrical Induction Machines – Voltage and torque equations in machine variables, equations of transformation for rotor circuits, voltage and torque equation in arbitrary reference frame variables, commonly used references frames and analysis of steady-state operation. Permanent-Magnet AC Machines – Voltage and torque equations in machine variables, voltage and torque equations in rotor reference frame variables, analysis of steady-state operation and brushless dc motor. Introduction to design of Electrical Machinery – Machine geometry, stator windings, winding functions, flux linkage and inductances of various windings, lumped parameter magnetic equivalent network, design of radial and axial flux permanent magnet machines, induction motor design, introduction to switched and synchronous reluctance machines, flux reversal and flux switching machines, thermal and stress analysis of machines. Induction Motor and PMAC drives – Volts per Hertz Control, Field oriented control, direct torque control, slip power recovery, voltage source inverter fed PMAC drives and current regulated inverter fed PMAC drives.

References:

1. *Analysis of Electric Machinery and Drive Systems*, by Paul Krause, Oleg Wasynczuk, Scott Sudhoff and Steven Pekarek, IEEE Press and Wiley Publications.
2. *The Induction Machine Handbook*, by Ion Boldea and Syed A. Nasar, CRC Press, Taylor and Francis Group.
3. *Brushless Permanent Magnet Motor Design*, by Duane C. Hanselman, Magna Physics Publishing.
4. *Permanent Magnet Motor Technology: Design and Applications*, by Jacek F. Gieras, CRC Press, Taylor and Francis Group.

EE 612 Insulation in Power Apparatus and System 3-0-0-3

Course Contents:

Introduction to HV engineering course and challenges & opportunities in electric power equipment industry; Insulation engineering: Insulation materials, Stresses on power apparatus insulation & insulation systems of various power apparatus; Fundamentals of Insulation Breakdown: Electrical breakdown in gases, liquid and solid dielectrics; Stress Control: Principles of stress control, Stress distribution in multiple dielectrics, Stress calculation; Generation of high voltages in laboratory: Generation of High voltage AC by cascading and series resonant system, High DC voltages, Multistage impulse generator circuits, Impulse current generator; Measurement of High Voltages : AC voltage, DC voltage, Impulse voltages; Non-Destructive Insulation Assessment: Schering bridge, Ampere turns bridge, Standard Capacitor, Partial discharge; Testing of Power apparatus: Non-destructive tests to check integrity of insulation of on various power apparatus, Impulse test of transformers.

Text Books:

1. Kuffel E., Zaengl W.S. and Kuffel J., *High Voltage Engineering Fundamentals*, Butterworth-Heineman press, Oxford, 2000.
2. M S Naidu & V Kamaraju, *High Voltage Engineering*, Tata McGraw Hill, 2004

References:

1. Naser E, *Fundamentals and Gaseous Ionization and Plasma Electronics*, John Wiley & Sons, Inc., New York, 1971.
2. A.von Hippel and A. S. Labounsky, *Dielectric Materials and Applications*, Artech House, Boston, 1995.
3. Alston L.L., *High Voltage Technology*, Oxford University Press, 1968.

EE 613 Power Electronic Converters 3-0-0-3

Course Contents:

Power semiconductor devices, Uncontrolled and controlled AC-DC converters, AC-AC converters, Non-isolated and isolated DC-DC converters, DC-AC converters, Modulation techniques, Harmonic Analysis, Resonant Converters, Multilevel converters, Design aspects of Power electronic converters, Gate drive circuits and Protection

Textbooks / References:

1. N. Mohan, T. M. Undeland, and W. P. Robbins, *Power Electronics: Converters, Applications, and Design*, John Wiley & Sons, 3rd ed., 2007.
2. M. H. Rashid, *Power Electronics: Circuits, Devices and Applications*, Pearson Education India, 4th ed., 2017
3. R. W. Erickson, D. Maksimovic, *Fundamentals of Power Electronics*, Kluwer Academic Publishers, 2nd ed., 2001.
4. G K Dubey, S R Doradla, A Joshi, and R M K Sinha, *Thyristorized Power Controllers*, New Age International, 2nd ed., 2012.
5. D. G. Holmes and T. A. Lipo, *Pulse Width Modulation for Power Converters: Principles and Practice*, John Wiley & Sons, 2003.

EE 614 **Power Electronics Laboratory** **0-0-3-3**

Course Contents:

Simulation of power electronic converters: thyristor rectifiers, buck and boost converters, DC-AC converters, PWM gate pulse generation in analog and digital modes, PCB design, Experimental verification of power electronic converters

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EE 615 **Control of Electrical Drives** **3-0-0-3**

Course Contents:

Mode ling of DC Machines, Phase Controlled DC Motor Drives, Chopper Controlled DC Motor Drives, Modeling of Polyphase Induction Machines, Phase Controlled Motor Drives, Frequency Controlled Induction Motor Drives, Vector Controlled Induction Motor Drives, Permanent Magnet Synchronous and Brushless DC Motor Drive Modeling and Control.

Textbooks/ References:

1. R. Krishnan, *Electric Motor Drives: Modeling, Analysis and Control*, Prentice Hall, 2002.
2. Mohamed El-Sharkawi, *Fundamentals of Electric Drive*, CL- Engineering, 1st Edition, 2000.

EE 616 **Power Electronics for Renewable Energy Systems** **3-0-0-3**

Course contents:

Photovoltaic inverter structures – Inverter structures from H-Bridge Topology (H5, HERIC, FB-ZVR), inverter structure from NPC Topology and Three phase PV inverters, international Regulations for EMC, interconnection of distributed generation, utility interface and anti-islanding requirements. Grid synchronization in single-phase power converters – using Phase-Locked Loop, Phase detection based on In-Quadrature signals, second-order adaptive filter based PLL, second-order generalized integrator based PLL. Grid synchronization in three-phase power converters – Synchronous reference frame PLL under unbalanced and distorted grid conditions and decoupled double synchronous reference frame PLL. Islanding detection – Non-detection zone, passive islanding detection methods and active islanding detection methods. Grid converter structures for wind turbine systems – WTS power configurations, single-cell converters, multi-cell (interleaved or cascaded) converters, generator-side control, doubly-fed induction generator and PM synchronous generator for wind turbines. Electric and Plug-In Hybrid EV – Electric, Hybrid Electric and Plug-In Hybrid EV topologies, power electronics for EV and PHEV charging, vehicle to grid and vehicle to home concepts and power electronics for more electric aircrafts.

References:

1. *Grid Converters for Photovoltaic and Wind Power Systems*, by Remus Teodorescu, Marco Liserre and Pedro Rodriguez, IEEE Press and Wiley Publications.
2. *Power Electronics for Renewable Energy Systems, Transportation and Industrial Applications*, by Haitham Abu-Rub, Mariusz Malinowski and Kamal Al-Haddad, IEEE Press and Wiley Publications.

EE 617 Wide Area Power System Control 3-0-0-3

Course Contents:

Introduction to Synchrophasor technology: basic architecture and communication requirement; Phasor and frequency estimation; Basic principles for Wide area monitoring and control in real-time; Dynamic modeling of synchronous generator; Transient stability monitoring and control; Small signal monitoring and control; Wide area power system stabilizers; Synchrophasor applications in power system protection and emergency control; Optimal placement of phasor measurement units; State estimation; Real-time monitoring and control of voltage stability.

Textbooks:

1. A. G. Phadke and J. S. Thorp, *Synchronized Phasor Measurements and their* Applications, Springer, 2008.
2. M. Shadidehpour and Y. Wang, *Communication and Control in Electric Power System*, Wiley, 2003.

References:

1. P. Kundur, *Power System Stability and Control*, McGraw-Hill, 1995.
2. P. M. Anderson and A. A. Fouad, *Power System Control and Stability*, 2nd Edition, Wiley, 2003.
3. Hsiao – Dong Chiang*, Direct Methods for Stability Analysis of Electric Power Systems: Theoretical Foundation, BCU Methodologies, and Applications*, Wiley, 2011.

EE 618 FACTS and HVDC 3-0-0-3

Course Contents:

FACTS: Concept, power flow and stability, basic theory of line compensation, Power Electronic Controllers: Review of PWM voltage source inverters used in FACTS, classifications of FACTS controllers. Static Compensators, Unified Power Flow Controller (UPFC), Stability Analysis: Modeling of FACTS devices, optimization of FACTS, transient and dynamic stability enhancement, Applications: Principle of control of FACTS in HVDC links, coordination of FACTS devices with HVDC links. Advanced FACTS devices, case studies and other applications of FACTS controllers.

Text books

1. Miller T. J. E., *Reactive Power Control in Electric Systems*, Wiley-Interscience.
2. Hingorani N. G. and Gyugyi L., *Understanding FACTS*, IEEE Press, Standard Publishers Distributors
3. Padiyar K. R., *FACTS Controller in Power Transmission and Distribution*, New Age International Private Limited.

EE 619 Smart Grid Technology 3-0-0-3

Course Contents:

Smart grids key characteristics, demand side management, load characteristics, hybrid electric vehicles, energy markets, deregulation, wide area monitoring, protection and control, smart metering, adaptive relaying, power line carrier communication and networking, architectures and standards, renewable energy, distributed generation, smart grids policies.

Text books /References

1. Keyhani, *Smart Power Grid Renewable Energy Systems*, Wiley 2011
2. William H. Kersting, *Distribution System Modeling and Analysis*, CRC Press, Second Edition, 2004
3. M. A. El-Sharkawi, *Electric Energy: An Introduction*, CRC Press, 2005

EE 621 Advance Digital Signal Processing 3-0-0-3

Course Contents:

Discrete-Time Signals and Systems, Linear Time-Invariant Systems, Representation of sequences by Fourier transforms, The z-Transform, z-Transform properties and ROC, z-Transform Inversion and LTI system, Transform Analysis of Linear Time-Invariant Systems, The Frequency Response of LTI Systems, Minimum-Phase and All-Pass Decomposition, Linear Systems with Generalized Linear Phase, Structures for Discrete-Time System, Block Diagram Representation, Signal Flow Graph Representation, Basic Structures for IIR Systems, Basic Structures for FIR Systems, Finite-Precision Numerical Effects, Sampling of Continuous-Time Signals, Periodic Sampling, Reconstruction of A Bandlimited Signal from Its Samples, Discrete-Time Processing of Continuous-Time Signals, Changing the Sampling Rate Using Discrete-Time Processing, Multirate Signal Processing, Digital Processing of Analog Signals, Oversampling and Noise Shaping In A/D And D/A Conversion, Filter Design Techniques, Design of Discrete-Time IIR Filters from Continuous-Time Filters, Discrete-Time Butterworth, Chebyshev And Elliptic Filters, Frequency Transformations of Lowpass IIR Filters, Design of FIR Filters by Windowing, Optimum Approximations of Fir Filters, The Discrete Fourier Transform, The Discrete Fourier Series (DFS), Properties of the DFS, Sampling the Fourier Transform, Properties of the DFT, Computing Linear Convolution Using the DFT, The Discrete Cosine Transform (DCT), Computation of the Discrete Fourier Transform, Direct Computation of The Discrete Fourier Transform, Decimation-In-Time FFT Algorithms, Decimation-In-Frequency FFT Algorithms, Effects of Finite Register Length, Fourier Analysis of Signals Using the Discrete Fourier Transform, DFT Analysis of Sinusoidal Signals, The Time-Dependent Fourier Transform, Examples of Fourier Analysis of Nonstationary Signals.

Textbooks/References:

1. A.V. Oppenheim and Schafer, *Discrete Time Signal Processing*, Prentice Hall, 2014.
2. John G. Proakis and D.G. Manolakis, *Digital Signal Processing: Principles, Algorithms and Applications*, Prentice Hall, 2014.
3. L.R. Rabiner and B. Gold, *Theory and Application of Digital Signal Processing*, Prentice Hall, 1992.
4. J.R. Johnson, *Introduction to Digital Signal Processing*, Prentice Hall, 1992.

EE 622 **Electromagnetic Compatibility** **3-0-0-3**

Course Contents:

General introduction and the basic concepts, EMC requirements for electronic systems, Governmental Requirements, Additional Product Requirements, Design Constraints for Products, Advantages of EMC Design, Transmission Lines and Signal Integrity, The Transmission-Line Equations, The Per-Unit-Length Parameters, High-Speed Digital Interconnects and Signal Integrity, Sinusoidal Excitation of the Line and the Phasor Solution, Lumped-Circuit Approximate Models, Non-ideal Behavior of Components, Wires, Printed Circuit Board (PCB), Effect of Component Leads, Resistor, Capacitor, Inductor, Electromechanical Devices, Digital Circuit Devices, Mechanical Switches, Conducted Emissions and Susceptibility, Measurement of Conducted Emissions, Power Supply Filters, Power Supplies, Power Supply and Filter Placement, Conducted Susceptibility, Radiated Emissions and Susceptibility, Simple Emission Models for Wires and PCB Lands, Simple Susceptibility Models for Wires and PCB Lands, Shielding, Shielding Effectiveness, Shielding Effectiveness: Far-Field Sources, Shielding Effectiveness: Near-Field Sources, Low-Frequency, Magnetic Field Shielding, Effect of Apertures, System Design for EMC and ESD, Ground, Printed circuit board , System Configuration and Design, Noise Reduction techniques in electronic systems.

Text books

1. Clayton R. Paul, *Introduction to electromagnetic compatibility*, John Wiley and Sons, Inc. 1991.
2. Ott. H.W. *Noise reduction techniques in Electronic system*, 2nd edition, John Wiley Interscience, New York (1988)
3. Laszlo Tihanyi, *Electromagnetic Compatibility in Power Electronics*, IEEE Press.

EE631 Sensors and Actuators: Fabrication and Applications 3-0-0-3

Level: PhD/PG/UG Elective

Physical Micro-sensors: Classification of physical sensors- Active and Passive sensors

Sensor Fabrication:

Oxidation/Diffusion, Thin Film Deposition Techniques: Chemical Vapor Deposition, Physical Vapor Deposition (Thermal Deposition, E-beam Evaporation, Sputtering, Pulsed Laser Deposition), Basics understanding of Photolithography for pattering layer. Micromachining.

Sensor Applications:

Various gas sensors: Optical gas sensor, Metal oxide semiconductor gas sensor, Field effect transistor gas sensor, Piezoelectric gas sensor, Polymer gas sensor, Nano-structured based gas sensors

Micro-sensors: Force Sensors, Pressure Sensors, Strain gauges and practical applications

Actuator and its applications:

Working principles of Actuators: Piezoelectric and Piezoresistive actuators; microvalve and micropumps with practical applications

Microfluidic device design and pattern transfer techniques (PDMS moulding and device bonding techniques).

Tutorial:

Design, Simulation, Optimization and characterization of various sensors using CoventorWare and COMSOL Multiphysics software

References:

1. Fundamentals of Microfabrication. Marc Madou, CRC Press, 1997.

2. Sensors and Signal Conditioning Wiley-Blackwell, 2008 Jacob Fraden, Handbook of modern sensors, Springer, Stefan Johann Rupitsch.

3. Piezoelectric Sensors and Actuators: Fundamentals and Applications, Springer, 2018 Senturia S. D.

4. Microsystem Design, Kluwer Academic Publisher, 2001 J.D. Plummer, M.D. Deal, P.G. Griffin

5. Silicon VLSI Technology, Pearson Education, 2001 S.M. Sze (Ed)

6. VLSI Technology, 2 Edition, McGraw Hill, 1988

7. Reputed International Journal papers

EE632 **Analog Integrated Circuit Design** **3-0-0-3**

Level: PhD/PG/UG Elective

Objective:

- Introduce the learners to the world of CMOS analog integrated circuits
- Expose the students to the end to end design flow of analog custom integrated circuits

Syllabus:

Introduction to CMOS analog integrated circuit design. MOS transistor as the basic design unit: device structure, I-V characteristics, second order effects, SPICE models. Basic amplifier topologies: CS, CG, CD, cascode amplifiers. Differential amplifiers: single ended and differential operation, small signal analysis. Current mirrors: passive and active topologies. Performance parameters of analog circuits: frequency response, noise. Feedback in analog integrated circuits: types of feedback, stability and frequency compensation. Operational amplifiers: topologies, performance parameters. Layout of analog integrated circuits.

Texts/References:

- Phillip E. Allen and Douglas R. Holberg, "CMOS Analog Circuit Design," Oxford University Press
- Behzad Razavi, "Design Of Analog Cmos Integrated Circuit," Tata McGraw Hill
- R. Jacob Baker, Harry W. Li, and David E. Boyce, "CMOS Circuit Design, Layout, and Simulation", PHI
- Paul R. Gray, Paul J. Hurst, Stephen H. Lewis, and Robert G. Meyer, "Analysis and Design of Analog Integrated Circuits", Wiley India