Master of Technology

In

Electrical Engineering
(Signal Processing and Control)

Course Structure & Syllabus

Department of Electrical Engineering

National Institute of Technology Hamirpur

Hamirpur (HP) - 177005, India

Course Structure of M. Tech. in Electrical Engineering (Signal Processing and Control)

SEMESTER-I

Sr. No.	Course No.	Subject	Teaching Schedule			Hours/week	Credit
			L	T	P		
1	EE-631	Digital Signal Processing & Applications	4	0	0	4	4
2	EE-632	Probabilistic Methods of Signal and System Analysis	4	0	0	4	4
3	EE-633	Nonlinear Systems	4	0	0	4	4
4	EE-7MN	Programme Elective-I	4	0	0	4	4
5	EE-7MN	Programme Elective-II	4	0	0	4	4
6	EE-634	Control and Computation Lab	0	0	4	4	2
	Total		**20**	**0**	**4**	**24**	**22**

Programme Elective-I & II: List of Programme Electives is given in the Annexure

SEMESTER-II

Sr. No.	Course No.	Subject	Teaching Schedule			Hours/week	Credit
			L	T	P		
1	EE-641	Statistical Signal Analysis	4	0	0	4	4
2	EE-642	Adaptive Signal Processing	4	0	0	4	4
3	EE-643	Optimal Control Theory & Design	4	0	0	4	4
4	EE-7MN	Programme Elective-III	4	0	0	4	4
5	EE-70N	Institute Elective	4	0	0	4	4
6	EE-644	Signal Processing Lab	0	0	4	4	2
	Total		**20**	**0**	**4**	**24**	**22**

Programme Elective -III & Institute Elective: List of Programme Electives is given in the Annexure.

SEMESTER-III

Sr. No.	Course No.	Course Name	Hours/week	Credit
1	EE-798	M.Tech. Dissertation	--	18
	Total		**--**	**18**

SEMESTER-IV

Sr. No.	Course No.	Course Name	Hours/week	Credit
1	EE-799	M.Tech. Dissertation	--	18
	Total		**--**	**18**

Total Credit of the Programme = 80

Annexure

List of Programme Electives

Programme Elective-I:	**Common to all Streams of M. Tech**
EE-711	AI Techniques and Applications
EE-712	Optimization Techniques
EE-713	Genetic Algorithm and Evolutionary Programming
EE-714	PLC and SCADA Systems

Programme Elective-II:	**M. Tech in Electrical Engineering (Signal Processing and Control)**
EE-731	Digital Image Processing and Pattern Recognition
EE-732	Linear System Theory
EE-733	Speech Signal Processing
EE-734	Control system Design & Analysis

Programme Elective-III:	**M.Tech in Electrical Engineering (Signal Processing and Control)**
EE-751	Advanced Process Control
EE-752	Bio Medical Signal Processing
EE-753	Chaotic System Control & Synchronization
EE-754	Stochastic Systems
EE-755	Nonlinear Control Design
EE-756	Microprocessor Based System Design

List of Institute Electives

Course No.	Course Name
EE-701	Elements of Power Engineering
EE-702	Evolutionary Programming and Genetic Algorithms
EE-703	Distributed Generation Technology
EE-704	Optimization Techniques and Applications
EE-705	Electrical Vehicle Technologies
EE-706	Elements of Control Engineering

Semester-I

Course Name: **Digital Signal Processing and Applications**
Course Code: **EE-631**
Course Type: **Core**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To impart knowledge about the sampling/reconstruction of signals and their analysis in frequency domain.
- To introduce the fundamental concepts for filter designs, and multi-rate processing.
- To enable the students to understand the efficient algorithms and their use in real time implementation.

Course Content

Introduction: Discrete time signals, sequences, representation of signals on orthogonal basis, sampling and reconstruction of signals, Z-Transform, analysis of LTI systems, frequency analysis, Inverse systems, Discrete Fourier Transform (DFT), Fast Fourier Transform (FFT) algorithms, structures for realization of LTI systems, recursive and non-recursive realization of systems. Design of FIR Systems: Introduction to FIR, Fourier series method for the design of FIR filters, Design of FIR Filters using Window methods, Park McClellan's method. Design of IIR Systems: Design of IIR filters by approximation of derivatives, impulse invariant transformation, bilinear transformation, Butterworth, Chebyshev and Elliptic approximations, Low-pass, band-pass, band-stop and high pass filters. Multi-rate Systems: Fundamentals of multi-rate systems, basic multi-rate operations, interconnection of building blocks, poly phase representation, multi-stage implementation, applications of multi-rate systems, filter banks, Introduction to wavelet Transform, short-time Fourier Transform.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Understand the importance of discrete time signals.
CO2: Understand and use the Algorithms for efficiently computing the Fast Fourier Transform (FFT).
CO3: Design of FIR and IIR filter.
CO4: Understand the multi-rate signal processing and concept of decimators and interpolators.
CO5: Understand STFT and Wavelet transforms and their role in DSP.

Text Books

1. A.V. Oppenheim and Schafer, "Discrete Time Signal Processing," Prentice Hall.
2. John G. Proakis and D.G. Manolakis, "Digital Signal Processing: Principles, Algorithms and Applications," Prentice Hall.
3. L. R. Rabiner and B. Gold, "Theory and Application of Digital Signal Processing," Prentice Hall.
4. Ashok Ambardar, "Analog and Digital Signal Processing," CL Engineering; 2nd edition.

Reference Books

1. J.R. Johnson, "Introduction to Digital Signal Processing," Prentice Hall.
2. D.J. De Fatta, J.G. Lucas, and W.S. Hodgkiss, "Digital Signal Processing," J Wiley and Sons, Singapore.

Course Name: **Probabilistic Methods of Signal and System Analysis** Course Code: **EE-632** Course Type: **Core**	
Contact Hours/Week: **4L**	Course Credits: **04**

Course Objectives

- To learn the relative frequency approach and definition of axiomatic probability
- To emphasize importance of conditional probability and its use in computing the probability of unknown event using Bays rules
- To have knowledge of random variable along with the ideas of probability distribution and density functions, mean values, and other moments
- To extend the random variable concept to situations involving two or more random variables and introduce the concept of statistical independence and characteristic function.
- To develop the understanding of time and frequency domain analysis of the output signals obtained by exciting the linear systems with stochastic input signals

Course Content

Introduction to Probability Theory: Random experiments and events. Definition of probability, relative frequency approach. Elementary set theory. Axiomatic approach. Conditional probability. Probability of repeated trials and combined experiments. Random Variables: Concept of random variable, distribution, and density functions. Mean values and moments. Gaussian random variable. Functions of one random variable and their distribution, and density functions. Conditional distribution and density functions. Several Random Variables: Joint (bivariate) distributions, one function of two random variables, two function of two random variables, joint moments of two random variables, joint characteristic functions, conditional density, and statistical independence. Correlation between random variables. Characteristic functions. Random Processes and Response of linear systems to random inputs: General concepts and classifications correlation functions and their properties, spectral density, and its properties. White noise Analysis in the time domain, mean, mean-square value and correlation functions of system output for random input. Analysis in frequency domain system with stochastic inputs, power spectral and cross – spectral densities.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Understand basic concept of probability theory.
CO2: Model the real situation/uncertainties using concept of probability.
CO3: Understanding the random variables and processes.
CO4: Apply statistical methods for analyzing the random processes.
CO5: Use application of probability methods to analyze real world signals and systems.

Text Books

1. A. Papoulis, "Probability, Random Variables and Stochastic Processes," McGraw-Hill, 3rd Edition.
2. Hwei P. Hsu, "Probability, Random Variables and Stochastic Processes," Tata McGraw Hill Publishing company Ltd. New Delhi.
3. G. R. Cooper and C.D. McGillem, "Probabilistic Methods of Signal and System Analysis," 3rd Indian Edition, Oxford University Press, New Delhi.

Reference Books

1. Sheldon Ross, "A First Course in Probability," Pearson Education, 2002.
2. B. R. Bhatt, "Modern Probability Theory-An Introductory Text Book," New Age International Pvt. Ltd, New Delhi, 1999.
3. Kai Lai Chung, "A Course in Probability Theory," Academic Press, 2001.
4. Robert M. Gray, "Probability, Random Processes and Ergodic Properties," Springer-Verlag, NY.
5. W. Feller, "An Introduction to Probability Theory and its Applications," Vol. I, 3rd Edition, Wiley Eastern Limited, New Delhi.
6. K. S. Trivedi, "Probability and Statistics with Reliability and Queuing and Computer Science Applications," 2nd Indian Edition, John Wiley & Sons Inc. UK.

Course Name: **Nonlinear Systems**
Course Code: **EE-633**
Course Type: **Core**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To impart knowledge about developing state space models from differential/transfer function-based descriptions of linear systems.
- To enable the students to learn designing simple feedback controller for linear dynamical systems.
- To introduce the fundamental learning about typical behaviours of nonlinear systems and their stability analysis.
- To develop basic understanding about design of stabilization & tracking control of nonlinear systems.

Course Content

State Variable Analysis: State variables and state model, state space representation of systems, block diagram for state equation, Transfer function decomposition, direct, parallel and cascade decomposition, solution of state equations, concept of controllability and observability, pole placement/state feedback design using feedback. Characteristic behaviour of Nonlinear Systems: Difference between linear and nonlinear systems, different nonlinearities, Common nonlinear system behaviours like multiple equilibrium points, limit cycle etc. Analysis of Nonlinear Systems: Phase plane method, singular points, construction of phase trajectories, phase plane analysis of linear and nonlinear systems, concepts of describing function method, stability analysis using describing function method. Lyapunov Stability Theory: Concept of stability, stability theorems, Lyapunov functions for nonlinear and linear systems, Krasovskii method, concept of stability non-autonomous systems, Lyapunov analysis of non-autonomous systems. Introduction to Nonlinear Control System Design: Nonlinear control problems, stabilization and tracking problems, specifying desired behaviour, issues in constructing nonlinear controllers, introduction to different nonlinear control design techniques like sliding mode, adaptive control, robust control etc. Feedback Linearization Based Control Design: Controller design based on feedback linearization, input-state linearization, input-output linearization, concept of relative degree and zero dynamics.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Develop state space models for linear and nonlinear systems.
CO2: Design simple control schemes for linear dynamical systems.
CO3: Analyse the stability of linear and nonlinear systems using different tools.
CO4: Apply feedback linearization to address stabilization and tracking problems.

Text-books

1. I.J. Nagrath and M. Gopal, "Control System Engineering," New Age International.
2. J.J.E. Slotine and W. Li, "Applied Nonlinear Control," Prentice Hall, Englewood Cliffs New Jersey.

Reference Books

1. Hassan K. Khalil, "Nonlinear Systems," Prentice Hall, Englewood Cliffs New Jersey.
2. M.Gopal, "Digital Control and State Variable Methods," Tata McGraw Hill, New Delhi.

Course Name: **Control & Computation Lab**
Course Code: **EE-634**

Contact Hours/Week**: 4P** Course Credits: **02**

Course Objectives

- To analyze the performance of basic control components experimentally.
- To study performance characteristics of LTI systems using basic control mechanisms i.e compensators and PID controllers.
- To learn about process control challenges and to execute control strategy to meet out desired performance.
- To study complex control mechanisms involving MIMO systems and coupled systems.

List of Experiments

1. Study of two-phase AC servo motor and draw its speed torque characteristics.
2. To study synchro transmitter–receiver pair and its operation as an error detector.
3. To study speed control and reversal of stepper motor using microprocessor.
4. To study magnetic amplifier and plot the control current versus load current characteristics in the series connection, Parallel connection and Self-saturation mode.
5. To study magnetic levitation system and to perform tracking control using PI Control.
6. To study magnetic levitation system and to perform tracking control using PID Control.
7. To study modeling and control of non-linear MIMO systems using Twin rotor helicopter model.
8. To study real time Cart-pendulum arrangement based Inverted pendulum stabilization with real time swing control using Digital Pendulum set up.
9. To study feedback control using rotary inverted pendulum module.
10. To study real-time control of a non-linear and unstable ball plate process set up and to analyze real-time PID control of ball position.
11. To study real-time control of a non-linear and unstable ball plate process set up and to analyze control of real-time trajectory tracking with ball.
12. To study simulation and real time model for single tank level control using coupled tank apparatus.
13. To study simulation and real time models for level control in parallel tanks using couple tank apparatus.
14. To study PI & PID based control of water level using Process Control Trainer.
15. To study voltage sensitive bridge and to analyze its sensitivity and linearity.
16. To design, implement and study the effects of different cascade compensation networks for a given system.
17. To study the Digital control system and to Implement digital PID control for a modeled Process.
18. To study relay as nonlinear element and effect of dead-zone and hysteresis on the controlled process
19. MATLAB based State Feedback (Pole Placement) controller design for a given LTI system.
20. MATLAB based State Observer design for a given LTI system.
21. MATLAB based implementation of Observer based control scheme for a given LTI system.
22. PID Control gain tuning for a given control system with desirable time domain performance attributes using MATLAB.

Note: The concerned Course Coordinator will prepare the actual list of experiments/problems at the start of semester based on above generic list.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Understand the characteristic behaviour of control components and their use in industrial applications.

CO2: Implement PID control strategy to achieve stabilization and tracking behaviour in linear and nonlinear systems.

CO3: Understand the nonlinear and unstable processes and the associated control challenges.

Course Name: **AI Techniques and Applications**
Course Code: **EE-711**
Course Type: **Programme Elective-I**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To impart knowledge about the application of artificial intelligence techniques in electrical engineering.
- To introduce the fundamental concepts relevant to fuzzy logic, artificial neural network, genetic algorithm, Evolutionary techniques, and Hybrid systems.
- This activity aims to get students thinking critically about what specialty makes humans intelligent, and how computer scientists are designing computers to act smartly or human like.

Course Content

Artificial Intelligence: Definition, problem solving methods, searching techniques, knowledge representation, reasoning methods, predicate logic, predicate calculus, multi-value logic. Fuzzy Logic: Concepts, fuzzy relations, membership functions, matrix representation, de-fuzzification methods. Learning Rules: Biological neuron, mathematical model, supervised and unsupervised learning, neuron learning rules, feed-forward and feedback neuron networks. Artificial Neural Networks: Introduction, multi-layer feed forward networks, back propagation algorithms, radial basis function and recurrent networks. Evolutionary Techniques: Introduction and concepts of genetic algorithms and evolutionary programming. Hybrid Systems: Introduction and Algorithms for Neuro-Fuzzy, Neuro-Genetic, Genetic-Fuzzy systems.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Identify different searching techniques, constraint satisfaction problem and example.

CO2: Able to apply these techniques in different field, which involve perception, reasoning, and learning.

CO3: Analyze and design a real-world problem for implementation and understand the dynamic behavior of a system.

CO4: Assess the results obtained by ANN, Genetic algorithm, and fuzzy systems.

Text Books

1. N. P. Padhy, “Artificial Intelligence and Intelligent Systems,” Oxford University Press.
2. S. Rajasekaran and G. A. V. Pai, “Neural Networks, Fuzzy Logic and Genetic Algorithm Synthesis and Applications,” PHI New Delhi.

Reference Books

1. C. Lin and G. Lee, “Neural Fuzzy Systems, Prentice Hall International Inc.
2. D. E. Goldberg, “Genetic Algorithms in Search Optimization & Machine Learning,” Addition Wesley Co., New York.
3. B. Kosko, “Neural Networks & Fuzzy Systems a Dynamical Systems Approach to Machine Intelligence,” Prentice Hall of India.

Course Name: **Optimization Techniques**
Course Code: **EE-712**
Course Type: **Programme Elective-I**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To impart knowledge about the principles of optimization techniques.
- To introduce the fundamental concepts relevant to classical optimization methods, linear programming, nonlinear programming, and dynamic programming.
- To enable the students to understand the factors that cause the different optimization methods to provide different solutions for the same mathematical problem.

Course Content

Introduction: Historical Development; Engineering applications of Optimization; Objective function; Constraints and Constraint surface; Classification of optimization problems based on nature of constraints, structure of the problem, deterministic nature of variables, separability of functions and number of objective functions. Linear Programming: Standard form of linear programming (LP) problem; Canonical form of LP problem; Assumptions in LP Models; Elementary operations; Graphical method for two variable optimization problem; Examples; Motivation of simplex method, Simplex algorithm, and construction of simplex tableau; Simplex criterion; Minimization versus maximization problems; simplex method with artificial variables; Classical Optimization: Stationary points - maxima, minima and saddle points; Functions of single and two variables; Global Optimum; Convexity and concavity of functions of one and two variables; Optimization of function of one variable and multiple variables; Gradient vectors; Examples; Optimization of function of multiple variables subject to equality constraints; Lagrangian function; Optimization of function of multiple variables subject to inequality constraints; Hessian matrix formulation; Eigen values; Kuhn-Tucker Conditions; Examples Unconstrained Minimization Methods: unimodal function, exhaustive search, dichotomous search, Fibonacci method, golden section method, multivariable unconstrained minimization, grid search method, univariate method, Hooke and Jeeves' method, Powell's method, steepest descent method, conjugate gradient method, newton's method, quasi-newton methods. Constrained Optimization Techniques: Sequential linear programming, Indirect methods, basic approach to the penalty function method, interior penalty function method, exterior penalty function method, augmented LaGrange multiplier method. Dynamic Programming: Sequential optimization; Representation of multistage decision process; Types of multistage decision problems; Concept of sub optimization and the principle of optimality; Recursive equations – Forward and backward recursions; Computational procedure in dynamic programming (DP); Discrete versus continuous dynamic programming; curse of dimensionality in DP, example.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Identify different types of optimization techniques and problems.

CO2: Describe techniques like calculus based classical optimization, linear programming, nonlinear programming, dynamic programming.

CO3: Apply principles and techniques described in CO2 to solve sample mathematical and practical optimization problems.

CO4: Assess the results obtained by applying optimization techniques to solve mathematical programming problems.

Text Books

1. S. S. Rao, "Engineering Optimization: Theory and Practice," New Age International, New Delhi.
2. S. Chandera, Jaydeva, and A. Mehta, "Numerical Optimization with Applications," Narosa.

Reference Books

1. E. K. P. Chong, and S. H. Zak, "An Introduction to Optimization," John Wiley.
2. M. C. Joshi and K. M. Moudgalya, "Optimization Theory and Practice," Narosa.

Course Name: **Genetic Algorithms and Evolutionary Programming** Course Code: **EE-713** Course Type: **Programme Elective-I**	
Contact Hours/Week: **4L**	Course Credits: **04**

Course Objectives

- To impart knowledge about related with Genetic algorithm and Evolutionary programming.
- To introduce the fundamental concepts relevant to GA operators, creation of offspring etc.
- To enable the students to understand the factors related with application and fundamental of GA and EP.

Course Content

Introduction: Basic concepts and definitions, artificial intelligence, genetic algorithms (GAs), evolutionary programming (EP). Genetic algorithm: Coding, fitness function, Calculation of the number of bit required for a variable, GAs operators, crossover and mutation, roulette wheel method for selection process, cumulative probabilities, Basic flow chart, GAs for optimization detail steps, Similarities between GAs and traditional methods, Differences between GAs and traditional methods. Evolutionary programming: Initialization, Creation of offspring, Competition and selection, Gaussian random numbers, standard deviation, Difference between GAs and EP, basic algorithm, step by step procedure of evolutionary programming for optimization. Applications: Gas applications for economic power dispatch and optimal power flow, applications of EP for economic power dispatches and optimal powers flow.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Identify various concepts of Genetic algorithm and Evolutionary programming.
CO2: Describe important concepts related with optimization with GA and EP.
CO3: Apply principal to explain various problems related with problems described in CO2.
CO4: Assess the results obtained by solving above problems.

Text Books

1. M. Mitchell, "An Introduction to Genetic Algorithms," MIT Press, 1998.
2. A. E. Eiben, "Introduction to Evolutionary Computing," Springer-Verlag Berlin and Heidelberg.
3. N. P. Padhy, "Artificial Intelligence and Intelligent Systems," Oxford University Press.
4. Z. Michalewicz, "Genetic Algorithms, Data Structures and Evolution Programs," Berlin: Springer-Verlag.

References Books

1. M. Chis, "Evolutionary Computation and Optimization Algorithms in Software Engineering: Applications and Techniques," IGI Global publishers.
2. D. E. Goldberg, "Genetic Algorithms in Search-Optimization and Machine Learning," Addison-Wesley.

Course Name: **PLC and SCADA Systems**
Course Code: **EE-714**
Course Type: **Programme Elective-I**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- Understand the role and benefits of automation in industries.
- Master PLC systems, including their types, components, and programming languages.
- Grasp analog operations and PID control methods, including tuning and implementing closed-loop control systems.
- Explore SCADA systems, including architecture, communication methods, and applications in industrial control and monitoring.

Course Content

The role of automation in industries, benefits of automation, necessity of PLCs, history and evolution of PLCs, types of PLCs, overall PLC system, CPU architecture, memory organization, and power supply modules. Programming languages for PLCs, including ladder diagram, structured text, and function block diagram. Developing ladder logic for various industrial applications, analog PLC operation, PLC analog signal processing, PID principles, and typical continuous process control curves. Detailed study of simple closed-loop systems, closed-loop systems using Proportional, Integral, and Derivative (PID) control, PID modules, PID tuning methods, and motor controls including variable frequency drives (VFDs). Comprehensive coverage of PLC applications in manufacturing, and process control. Introduction to Supervisory Control and Data Acquisition (SCADA) systems, definitions, and history. SCADA system architecture, including Human-Machine Interfaces (HMI), Master Terminal Units (MTU), Remote Terminal Units (RTU), and communication means such as Ethernet, serial, and wireless. Desirable properties of SCADA systems, including reliability, scalability, and security. Advantages, disadvantages, and applications of SCADA in various industries such as power, water treatment, and oil and gas, functions and features of SCADA systems, and an overview of SCADA protocols.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Comprehend automation's impact and essential PLC functions and components.

CO2: Acquire skills in PLC programming and ladder diagram creation.

CO3: Implement control techniques like PID in PLC systems.

CO4: Understand SCADA systems' architecture, protocols, and applications in industrial monitoring and control.

Text books

1. Jon Stenerson, "Industrial Automation and Process Control", Prentice Hall, 2002.
2. Gary Dunning, "Introduction to Programmable Logic Controllers", Delmar Thomson Learning, 2001.
3. Frank D. Petruzella, "Programmable Logic Controllers", McGraw-Hill Education, 2010.
4. Ronald L. Kurtz, "Securing SCADA System", Wiley Publishing.
5. Stuart A Boyer, "SCADA supervisory control and data acquisition", 4th Revised edition, International Society of Automation.

Reference Books

1. Gordan Clark, Deem Reynders, "Practical Modern SCADA Protocols", Elesevier
2. Batten G. L., "Programmable Controllers", McGraw Hill Inc., Second Edition.

Course Name: **Digital Image Processing & Pattern Recognition**
Course Code: **EE-731**
Course Type: **Programme Elective-II**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To introduce the concepts of digital images, human visual system, EM spectrum, color models.
- To discuss transforms and principal mathematical tools required for processing of digital images.
- To develop background for filtering of digital images in spatial and transform domain.
- To introduce the Pattern recognition methods and their application for image processing.

Course Content

Introduction: Digital image representation, Fundamental steps in image processing, Elements of Digital Image processing systems, Elements of visual perception, Image model, Sampling and quantization, Relationship between pixels, imaging geometry. Image Enhancement & Restoration: Enhancement by point processing, Sample intensity transformation, Histogram processing, Image subtraction, Image averaging, Spatial filtering, Smoothing filters, Sharpening filters, Frequency domain: Low-Pass, High-Pass, Homomorphic filtering, Spatially dependent transform template and convolution, Window operations, 2-Dimensional geometric transformations, Colour Models, Colour Transforms. Wavelets and Multiresolution Processing: Image pyramids, Subband coding, Haar transform, Series expansion, Scaling functions, Wavelet functions, Discrete wavelet transforms in one dimension, Fast wavelet transform, Wavelet transforms in two dimensions Image Segmentation: Detection of discontinuities, Edge linking and boundary detection, Thresholding, Region oriented segmentation, Use of motion in segmentation, Spatial techniques, Frequency domain techniques. Image Segmentation Based on colour. Image Compression: Coding redundancy, Inter-pixel redundancy, fidelity criteria, Image compression models, Error-free compression, Variable length coding, Bit-plane coding, Loss-less predicative coding, Lossy compression, Image compression standards, Real-Time image transmission, JPEG and MPEG. Pattern Recognition: Classification and description, Structure of a pattern recognition system, feature extraction, Classifiers, Decision regions and boundaries, discriminant functions, Supervised and Unsupervised learning, PR-Approaches statistics, syntactic and neural.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Understand the principle of Digital image formation and concept of intensity & spatial resolution.

CO2: Enhance digital images using spatial and frequency domain approaches.

CO3: Understand the basic mathematics related to spatial and transform domain image compression approaches.

CO4: Implement basic feature extraction approaches and utilize them for Pattern recognition problems.

Text Books

1. R. Gonzalez and R. E. Woods, “Digital Image Processing,” Prentice Hall of India, 3rd Edition
2. M. Sonka, V. Hlavac, R. Boyle, “Image Processing, Analysis, and Machine Vision,” Cengage Learning, 3rd Edition
3. Andrian Low, “Introductory Computer Vision and Image Processing,” McGraw Hill Co.

Reference Books

1. W.K. Pratt, “Digital Image Processing,” McGraw Hill.
2. A.K. Jain, “Fundamentals of Image Processing,” Pearson Education.

Course Name: **Linear System Theory**
Course Code: **EE-732**
Course Type: **Programme Elective-II**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To impart knowledge about matrix algebra and linear algebra.
- To introduce the fundamental concepts relevant linear systems and their analysis.
- To enable the students to understand techniques for the analysis and stability of linear systems.

Course Content

Finite Dimensional Vector Spaces: Definition and examples of vector spaces, subspaces of a vector space, and the quotient space; linear dependence and independence of a set of vectors, linear span; basis and dimension of a vector space; isomorphic vector spaces' transformations on vector space and their examples; algebra of linear transformations on a vector space, matrix representation of a linear transformation, kernel and range of a linear transformation; inverse of linear transformation, orthogonality. Response of a Linear System: State equation representation, Gronwall-Bellman inequality, existence and uniqueness of solutions, state equation solution, Peano-Baker series, complete solution, transition matrix, properties of transition matrices, transition matrices for time-invariant and periodic cases. Stability of Linear System: Internal stability, uniform stability, uniform exponential stability, uniform asymptotic stability, Lyapunov transformations, Lyapunov stability criteria, instability. Controllability, Observability, and Realization Theory: Reachability and controllability, observability and constructibility, dual systems, standard forms for uncontrollable and unobservable systems, eigenvalue/eigenvector tests for controllability and observability, controller and observer forms. Internal and External Descriptions and Realization: Relations between state-space and input-output descriptions, relations between Lyapunov and input-output stability, relations between poles, zeros, and eigenvalues, polynomial matrix and matrix fractional descriptions of systems, state-space realizations of external descriptions, existence and minimality of realizations, realization algorithms, polynomial matrix realizations. Feedback Control Systems: Linear state feedback, linear quadratic regulator, linear state observers, full-order observers, reduced-order observers, optimal state estimation, observer-based dynamic controllers, feedback control systems using polynomial matrix and matrix fractional descriptions.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Demonstrate comprehensive knowledge of vector spaces and linear transformations relevant to engineering problems.
CO2: Analyze and solve state equations to understand and predict the behaviour of linear systems.
CO3: Assess system stability using theoretical methods, ensuring robust system design.
CO4: Evaluate and implement control solutions based on system controllability and observability properties.

Text Books

1. Antsaklis and Michael, "A Linear Systems Primer," Birkhauser, 2007
2. Rugh, "Linear Systems ," Pearson (2nd Edition), 1995.
3. Paul Halmos, "Finite-dimensional vector spaces," Springer, 2000

Reference Books

1. I.J. Nagrath, M. Gopal, "Control System Engineering," Wiley Eastern Limited.
2. T. Kailath, "Linear Systems", Pearson, 2016.
3. B.C. Kuo, Farid Golnaraghi, "Automatic Control Systems," 9th ed., Wiley, 2014.

Course Name: **Speech Signal processing**
Course Code: **EE-733**
Course Type: **Programme Elective-II**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To familiarize the student with the mechanism of speech production, physics of sound and modeling of speechsignal.
- To explain the algorithms for speech analysis and speech synthesis.
- To describe techniques related to speech coding.
- To discuss applications like speaker recognition, speech recognition etc.

Course Content

Introduction: Principle Characteristics of Speech: Linguistic information, Speech and Hearing, Speech production mechanism, Acoustic characteristic of speech Statistical Characteristics of speech. Speech production models, Linear Separable equivalent circuit model, Vocal Tract and Vocal Cord Model. Speech Analysis and Synthesis Systems: Digitization, Sampling, Quantization and coding, Spectral Analysis, Spectral structure of speech, Autocorrelation and Short Time Fourier transform, Window function, Sound Spectrogram, Mel frequency Cepstral Coefficients, Filter bank and Zero Crossing Analysis, Analysis–by-Synthesis, Pitch Extraction. Linear Predictive Coding Analysis: Principle of LPC analysis, Maximum likelihood spectral estimation, Source parameter estimation from residual signals, LPC Encoder and Decoder, PARCOR analysis and Synthesis, Line Spectral Pairs, LSP analysis and Synthesis. Speech Coding: Reversible coding, Irreversible coding and Information rate distortion theory, Coding in time domain: PCM, ADPCM, Adaptive Predictive coding, Coding in Frequency domain: Sub band coding, Adaptive transform coding, Vector Quantization, Code Excited Linear Predictive Coding (CELP). Speech Recognition: Principles of speech recognition, Speech period detection, Spectral distance measure, Structure of word recognition system, Dynamic Time Warping (DTW), Theory and implementation of Hidden Markov Model (HMM). Speaker recognition: Human and Computer speaker recognition Principles Text dependent and Text Independent speaker recognition systems. Applications of speech Processing.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Derive the expression for the digital models related to speech production.

CO2: Understand the algorithms and techniques used for speech analysis and synthesis.

CO3: Extract time and frequency domain features from given speech signal

CO4: Comprehend the utility of different algorithms for applications like speaker and speech recognition.

Text Books:

1. L.R. Rabiner & R.W Schafer., "Digital Processing of Speech Signals," Prentice Hall Inc.
2. D. O'Shaughnessy, "Speech Communication, Human and Machine," Addison-Wesley.

Reference Books

1. Thomas F. Quatieri, "Discrete-Time Speech Signal Processing: Principles and Practice Prentice Hall," SignalProcessing Series.
2. J. Deller, J. Proakis, and J. Hansen, "Discrete-Time Processing of Speech Signals," Macmillan, New York, 1993.

Course Name: **Control System Design and Analysis**
Course Code: **EE-734**
Course Type: **Programme Elective-II**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To provide a comprehensive understanding of both time and frequency domain analysis techniques, focusing on stability analysis and controller configurations for control systems.
- To introduce and explore various industrial controllers, including ON/OFF, PID, and advanced compensator designs, with a focus on practical tuning and application.
- To develop proficiency in state space design and Lyapunov stability analysis for designing robust control systems using modern control theory techniques.

Course Content

Introduction: Review of time and frequency domain analysis techniques for control systems, stability analysis, introduction to controller configurations and design. Industrial Controllers: Introduction, industrial automatic controllers, ON/OFF controller, P, PI, PD, PID controllers, tuning rules for PID controllers, one degree of freedom and two degrees of freedom control, various design considerations. Root Locus Design: Cascade compensator design for improving steady-state response and transient response, lag, lead, and lag-lead compensator design. Frequency domain design of control Systems: Introduction, lead, lag, lead-lag compensation, comparison of different compensation techniques, rate feedback compensation design. State Space Design of Systems: Analysis of control systems in state space, solution of the state equation, controllability and observability, pole placement method, state feedback matrix, state observers, minimum order observers, Observer-based controller. Lyapunov Stability Analysis: LTI System analysis using the Lyapunov method, Model Reference Control, and Quadratic optimal control.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Apply the concepts of system response (including transients and steady-state) and of system stability.
CO2: Apply the principles of feedback control in engineering systems, to design control systems for steady-state tracking of reference inputs.
CO3: Use graphical design techniques (e.g., root locus, Nyquist plots, Bode plots) to control systems design.
CO4: Understand the fundamental concept of state space representation of dynamical systems, Lyapunov stability analysis.

Text Books

1. K. Ogata, “Modern Control Engineering,” Prentice Hall of India Pvt. Ltd., New Delhi, India.
2. A. Tewari, “Modern Control Design,” John Wiley and Sons Ltd., England.

Reference Books

1. I.J. Nagrath, M. Gopal, “Control System Engineering,” Wiley Eastern Limited.
2. B.C. Kuo, Farid Golnaraghi, “Automatic Control Systems,” 9th ed., Wiley, 2014.

Semester-II

Course Name: **Statistical Signal Analysis**
Course Code: **EE-641**
Course Type: **Core**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To develop ability to process discrete random signals.
- To study the algorithms for modeling of stochastic signals.
- To study the basic classical and Bayesian estimation techniques.
- To familiarize with non-parametric and parametric spectrum estimation techniques.

Course Content

Introduction: Signal Processing methods, Review of Probability Theory, Random Variables and Stochastic Processes. Random Signal Analysis: Discrete random signals, Spectral representation of discrete random signals, filtering random processes, Random signal models AR, MA and ARMA. Power spectrum and phase of the signal generating system, Least squares method, Pade approximation, Prony's method, finite data records, stochastic models, Levinson-Durbin recursion; Schur recursion; Levinson recursion. Spectrum Estimation: Nonparametric methods, minimum-variance spectrum estimation, maximum entropy method, parametric methods, frequency estimation, principal components spectrum estimation Estimation Theory: Estimation of moments, classical and Bayesian estimation. MAP, ML, MMSE, and MAVE estimators for model parameters and signal. Cramer-Rao Bound on the minimum estimator variance. Introduction to Hidden Markov Models, Noise and Distortion.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Apply the principles of random processes for analysis of linear systems.

CO2: Model random signals and appreciate its utility in signal interpolation, signal prediction and signal compression.

CO3: Implement estimation techniques on signal processing problems and acquire ability to estimate parameters using them.

CO4: Understand the non-parametric and parametric spectrum estimation techniques.

Textbooks

1. Saeed V.Vaseghi, “Advanced Digital Signal Processing and Noise Reduction,” John Wiley & Sons, Ltd, Singapore, 2nd Edition.
2. Peter M. Clarkson, “Optimal and Adaptive Signal Processing,” CRC Press London.
3. Monson H. Hayes, “ Statistical Digital Signal Processing and Modeling,” John Wiley & Sons, 2009.

Reference Books

1. Dimitris G. Manolakis, Vinay K. Ingle and Stephen M. Kogan, “Statistical and Adaptive Signal Processing,” McGraw Hill, 2005.
2. Louis L Scharf, “Statistical Signal Processing, Detection, Estimation and Time Series Analysis,” Pearson Education Inc. 1991.
3. Steven M. Kay, “Fundamentals of Statistical Signal Processing, Volume I: Estimation Theory,” Prentice Hall, USA, 1998.

Course Name: **Adaptive Signal Processing**
Course Code: **EE-642**
Course Type: **Core**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To learn the basics of adaptive filtering.
- To understand the derivation of optimal solution based on given objective function and use of state space model in Kalman filtering.
- To learn the techniques for deriving various gradient search based adaptive algorithms for different objective functions, their performance comparison and implementation issues
- To understand various linear predictors, their advantages, and different structures
- To learn application of adaptive filtering in the communication systems

Course Content

Introduction to Adaptive Signal Processing: General properties Filtering, prediction and smoothing. Applications in Communications: Equalization Echo cancellation Noise cancellation, switched communication systems. Optimal Signal Processing: Principles of orthogonality, minimum square error, Wiener Hopf equations, state space model, innovations process, Kalman filter equations. Gradient Search Algorithms: Steepest descent adaptation algorithms, effect of eigen-value spread on stability and rate of convergence, stochastic gradient descent using Least Mean Squares (LMS) algorithms, transient and steady state properties including convergence rate and mis-adjustment, least square estimation, normal equations, Recursive Least Squares (RLS) algorithms, relationship between RLS and Kalman filters. Linear Prediction: Forward Linear Prediction, Backward Linear Prediction, Lattice structure for the realization of Linear Predictor. Conversion of direct form filters to lattice form structure and vice versa. Levinson-Durbin Algorithm, Properties of the Prediction Error Filter, Joint Process Estimator, Adaptive Lattice Filter. Applications in Communications: Introduction to Fast Recursive Algorithms for Equalization Adaptive linear prediction, lattice filtering for RLS. Other Applications Echo cancellation in two-wire systems, Noise cancellation

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Understand basic concept of adaptive filter theory.

CO2: Describe the basic components/specifications of adaptive filter.

CO3: Derive and implement of various gradient search adaptive algorithms.

CO4: Carry out performance comparison of different adaptive algorithms.

CO5: Apply adaptive filtering in linear prediction, channel equalization, echo cancellation and noise cancellation in communication system.

Text Books

1. Simon Haykin, “Adaptive Filter Theory,” Pearson Education Inc, 4th Edition.
2. Tamal K Bose, “Digital Signal and Image Processing,” John Wiley & Sons Inc, USA.
3. Paulo S R Diniz, “Adaptive Filtering Algorithms and Practical Implementation,” Kluwer Academic Publisher, 2nd Edition.

Reference Books

1. Peter M Clarkson, “Optimal and Adaptive Signal Processing,” CRC Press London.
2. Bernard Widrow and Sumuel D Sterns, “Adaptive Signal Processing,” Addison Wesley Pvt Ltd Delhi.
3. Saeed V Vaseghi, “Advanced Digital Signal Processing and Noise Reduction,” John Wiley & Sons, 2nd Edition.
4. D G Manloakis, V K Ingle and S M Kogan, “Statistical and Adaptive Signal Processing,” McGraw Hill, 2005.

Course Name: **Optimal Control Theory & Design** Course Code: **EE-643** Course Type: **Core**	
Contact Hours/Week: **4L**	Course Credits: **04**

Course Objectives

- To develop basic understanding about various optimal control problems existing in practice
- To enable the students to formulate optimal control problems for continuous systems with and without constraints
- To introduce the calculus of variation-based approach to address continuous-time and discrete-time optimization problems
- To impart basic knowledge about designing state observers and optimal observers
- To develop basic understanding about design of stabilization & tracking control of nonlinear systems

Course Content

Introduction: Basic introduction and classification of optimal control problems, different optimal control problems, Performance indices for optimal control. Calculus of variation Approach to Optimal Control: Concept of differential and variation, optimization without constraints, Euler-Lagrange equation for different two-point boundary value problems (TPBVP), Hamiltonian Formalism, Pontryagin function and Minimum Principle. Linear Quadratic Optimal Control: Introduction, finite and infinite horizon problems for continuous time systems, formulation of regulator and tracking problem, regulation problem with prescribed degree of stability, output regulator and tracking problem.
Optimal Control Problems in Discrete-Time: Discrete time formulation of optimal control problem, Calculus of Variation results for problems with general performance index, formulation of LQR problem for discrete time systems. Dynamic Programming: Multistage decision process in continuous time, Principle of optimality, dynamic programming-based control problem formulation for discrete systems, Dynamic Programming based formulation for continuous time case, Hamilton-Jacobi-Bellman (HJB) Equation. Optimal observers and Controllers: Introduction to continuous and digital Observers, Full order and reduced order observers, separation principle, optimal observers, Kalman-Bucy Filter for continuous time case, LQR/LQG controllers, State observer-state feedback configuration, disturbance rejection, tracking performance.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Identify different optimal control problems in real practice.
CO2: Develop analytical solutions for optimal control problems with and without constraints in CT and DT case.
CO3: Analyse the class of optimal control problems with quadratic objective function.
CO4: Develop mathematical structure for observers/estimators for linear systems.

Text Books

1. D.S. Naidu, “Optimal Control Systems,” New CRC Press, USA.
2. M. Gopal, “Modern Control System Theory,” New Age International.

Reference Books

1. A.P. Sage & C.C White, “Optimum Systems Control,” Englewood Cliff New Jersey, Prentice Hall.
2. D.E Kirk, “Optimal Control Theory,” Englewood Cliff New Jersey, Prentice Hall.
3. Frank L. Lewis, Dragunal.Vrabie & Vassilis L. Syrmos, “Optimal Control”, John Wiley & Sons, INC

Course Name: **Signal Processing Lab**
Course Code: **EE-644**

Contact Hours/Week**: 4P** Course Credits: **02**

Course Objectives

- To develop programming skills for conducting research in the field of signal processing.
- To develop an ability to work with some practical signals like speech, ECG etc.
- To implement the concepts of Adaptive filters studied in theory course.
- To illustrate effects of basic image enhancement and edge detection techniques on Images.

List of Experiments

1. To generate elementary discrete time sequence of following signals:
   a Impulse
   b. Step
   c. Ramp
   d. Parabolic
   e. Sinusoidal signal
2. To design FIR Digital filter using
   a. Window method
   b. Frequency sampling method
3. To design IIR Digital filter using analog filter design
   a. Chebyshev filter
   b. Butterworth filter
4. To detect the characteristics points of an ECG signal.
5. To implement LMS algorithm and its variants for system identification.
6. To estimate pitch of voice signal.
7. To implement RLS algorithm and its variants for system identification.
8. To implement a Speech coding algorithm.
9. To implement image enhancement techniques.
10. To implement edge detection approaches.

Note: *The concerned Course Coordinator will prepare the actual list of experiments/problems at the start ofsemester based on above generic list.*

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Design FIR & IIR filters for a given specification.
CO2: Develop basic application using speech signals.
CO3: Collect an ECG signal from a subject using ECG setup/machine and process it using basic filters.
CO4: Improve the quality of images and extract features from them.

Course Name: **Advanced Process Control**
Course Code: **EE-751**
Course Type: **Programme Elective-III**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To impart knowledge about the different process dynamics in Process industries and different control schemes generally used to get best output.
- To introduce the fundamental concepts of controller design in various loops and also optimization of their parameters.
- It also makes students aware of various analysis and design methods for multivariable systems.
- In addition, the subject also introduces about discrete state process control and advanced control schemes such as Internal Model Control (IMC) and Model Predictive Control for industrial process.

Course Content

Introduction to process control: Review of general concepts of system simulation and modeling, Process dynamicsof fluid flow, heat transfer systems and chemical processes, dynamical behavior of simple and complicated processes with time delay. Development of process models: Development of process models from empirical data, fitting first and second order models, development of discrete dynamical models. Different control strategies: Ratio control and feed forward controllers, PID controller design, tuning and troubleshooting, Enhanced single loop control strategies, cascade control, time delay compensation and inferential control, Digital PID controllers and their tuning, Multi-loop and multivariable control: Multi-loop and multivariable control, Pairing of controlled and manipulated variables, tuning of multi-loop PID controller, formulation and solution of real time optimization problem, unconstrained and constrained optimization, Internal Model Control (IMC). Model Predictive Control (MPC): Model Predictive Control (MPC): Prediction of MIMO models, MPC calculations and implementation. Applications: Some typical applications of process modeling and control. Introduction of PLC.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Handle any kind of process by framing it in block diagram, mathematical modeland different process variables.
CO2: Handle different types of controller like PID, IMC and MPC.
CO3: Implement different control schemes to various processes.
CO4: Understand various industrial processes and their control.

Text Books

1. Donald Dale E. Seborg, Thomas F. Edgar, Duncan A. Mellichamp, Francis J.Doyle, "Process Systems Analysis & Control," John Wiley & Sons.
2. Donald R. Coughanowr., "Process Dynamics & Control," Mc Graw – Hill International.

Reference Books

1. Stefani, Savant, Shahian, Hostetter, "Design of feedback Control System," Oxford University Press.
2. Gopal M., "Modern Control System Theory," Wiley Eastern limited.

Course Name: **Biomedical Signal Processing**
Course Code: **EE-752**
Course Type: **Programme Elective-III**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To study the origin and process of acquisition of principal bioelectric signals like ECG, EEG, EMG etc.
- To understand the background material required for processing of the biomedical signals.
- To understand the utility of biomedical signals for disease diagnosis like ECG for Cardiovascular diseases andEEG for sleep disorders.
- To explore the utility of bioelectrical signals for developing other application.

Course Content

Introduction: Genesis and significance of bioelectric potentials, ECG, EEG, EMG and their monitoring and measurement, spectral analysis, digital and analog filtering, correlation, and estimation techniques, AR/ARMA models, adaptive filters. ECG: Pre-processing, measurements of amplitude and time intervals, classification, QRS detection, ST segment analysis, baseline wander removal, waveform recognition, morphological studies and rhythm analysis, automated diagnosis based on decision theory ECT compression, evoked potential estimation. EEG: Evoked responses, epilepsy detection, spike detection, averaging techniques, removal of artifacts by averaging and adaptive algorithms, pattern recognition of alpha, beta, theta and delta waves in EEG waves, sleep stages. EMG: Wave pattern studies, biofeedback, zero crossing, integrated EMG, time frequency methods, and wavelets in biomedical signal processing.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Understand the acquisition methods for collecting ECG, EEG and EMG signals.

CO2: Develop mathematical models for analysis of biomedical signals.

CO3: Identify the characteristic points in an ECG waveform and understand their relevance.

CO4: Understand the EEG and EMG signal analysis and apply them to develop practical applications like BCI, prosthetic limbs.

Text Books

1. R.M. Rangayyan, "Biomedical Signal Analysis," Wiley.
2. D.C. Reddy, "Biomedical Signal Processing: Principles and techniques," Tata McGraw Hill, New Delhi.

References Books

1. Willis J Tompkins, "Biomedical Signal Processing," Prentice Hall.
2. L. Sornmo, "Bioelectrical Signal Processing in Cardiac & Neurological Application," Elsevier.

Course Name: **Chaotic System Control & Synchronization**
Course Code: **EE-753**
Course Type: **Programme Elective-III**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To impart knowledge about dynamical systems, especially, chaotic systems.
- To introduce the fundamental concepts relevant to nonlinear systems and their control strategies.
- To enable the students to understand the concept of synchronization of chaotic systems.

Course Content

Introduction: Chaos control-in a broader sense, need of chaos control, some distinct features nonlinear dynamical systems including chaotic systems, limit sets and attractors, Poincare maps, centre manifold theory. Chaos in Nonlinear Systems: Routes to chaotic behaviour, bifurcations, paradigms of chaos symmetry, self-similarity and stabilities, Parameter-Dependent approaches to Chaos Control, Periodic parametric forcing, parametrically forced oscillators, Microscopic parametric variation, controlling chaos to higher-periodic orbits, controlling transient chaos, some applications of parameter control. Chaos Control: Chaos control via external forcing, entrainment and migration controls, engineering feedback control, chaos in feedback control systems, feedback control of chaos, controlling chaos via Lyapunov methods. Chaos Synchronization: Concept of synchronization, synchronization based on system decomposition, stability analysis for chaos synchronization, chaos synchronization via feedback, synchronization of identical subsystems, adaptive synchronization, chaos synchronization with observer, generalized synchronization, phase synchronization, synchronization via the OLC methods, synchronization by contraction mappings, communication based on chaos synchronization, robustness of chaos synchronization, dead-beat synchronization for communication, implementation of chaos synchronization based communication.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Differentiate chaotic systems from common nonlinear systems.

CO2: To apply the concepts of state space analysis for the description of chaotic systems.

CO3: Apply Lyapunov stability analysis to stabilize and synchronize chaotic systems.

Text Books:

1. Guanrong Chen & Xiaoning Dong, “From Chaos to Order,” World Scientific.
2. Ricardo Femat & Gualberto Solis-Perales, “Robust Synchronization of Chaotic Systems via Feedback,” Springer.

Reference Books:

1. J M González-Miranda, “Synchronization and Control of Chaos: An Introduction for Scientists and Engineers,” Imperial College Press.
2. Victor Powell, “Chaotic Systems: Dynamics, Algorithms and Synchronization,” Nova Publications.
3. Jean-Jacques E. Slotine, “Applied Nonlinear Control,” Prentice Hall.

Course Name: **Stochastic Systems**
Course Code: **EE-754**
Course Type: **Programme Elective-III**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To impart knowledge about the random phenomena.
- To introduce the concepts of statistical estimators.
- To enable the students to understand convergence theorem and markov processes

Course Content

Review of Probability: random variables, random processes, Analysis in the time domain, mean, mean-square value and correlation functions of system output for random input. Analysis in frequency domain system with stochastic inputs, power spectral and cross –spectral densities. Estimation and Detection with Random Sequences: BAYES, MMSE, MAP, ML Schemes, Linear stochastic dynamical Systems. Martingale Convergence Theorem: Ergodic Theory, Measure preserving transformations, stationary processes, mixing conditions, ergodic Theorems, Shannon – Millan- Breiman Theorem. Markov Chains: Continuous time processes, separability, continuity, measurability, stochastic integral.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Understand basic concept of stochastic systems.
CO2: Describe the various approaches for statistical estimation.
CO3: Derive various convergence theorems and implementation of statistical estimation methods.
CO4: Carry out performance comparison of different statistical estimation methods.
CO5: Model the practical problems using the concept of the statistical theory.

Text Books

1. Athanasios Papoulis, "Probability, Random Variables and Stochastic Processes," McGraw-Hill. 3rd Edition.
2. Peter M Clarkson, "Optimal and Adaptive Signal Processing," CRC Press London.
3. George R. Cooper and C.D. McGillem, "Probabilistic Methods of Signal and System Analysis," 3rd Indian Edition, Oxford University Press, New Delhi.

Reference Books

1. Sheldon Ross, "A First Course in Probability," Pearson Education, 2002.
2. J. E. Meditch, "Stochastic Optimal Linear Estimation and control," McGraw Hill, New York.
3. C. W. Helstorm, "Probability and Stochastic processes for Engineers," McMillan, New York.
4. Saeed V Vaseghi, "Advanced Digital Signal Processing and Noise Reduction," John Wiley & Son.
5. V K Ingle, S M Kogan, and D G Manloakis, "Statistical and Adaptive Signal Processing," McGraw Hill.

Course Name: **Nonlinear Control Design**
Course Code: **EE-755**
Course Type: **Programme Elective-III**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To develop an understanding of nonlinear system dynamics, including stability and feedback linearization.
- To learn the principles and applications of sliding mode control for robust performance.
- To explore advanced back stepping control techniques for complex systems.
- To master adaptive control strategies that accommodate system uncertainties.
- To apply safety-critical control methodologies using Barrier Lyapunov functions in constrained settings.

Course Content

Review of Nonlinear System: Nonlinear Systems, Stability, Feedback Linearization, Lie Derivative, Lie Bracket, Diffeomorphism, Distributions, Input-State Linearization, Input-Output Linearization, Zero Dynamics. Sliding Mode Control (SMC): Sliding Surface, Graphical Interpretation, Filippov Theory, Reaching Laws, Finite-Time Stability, Equivalent Control Method, SMC Based on Reaching Law, Robust SMC Based on Reaching Law, SMC Based on Input-Output Feedback Linearization. Backstepping Control: Integrator Backstepping, Strict Feedback Systems, Recursive Applications of Backstepping, Backstepping with Zero Dynamics, Backstepping Control of Multi-Input Systems. Adaptive Control: Model Reference Adaptive Control, Self-Tuning Control, Parameter Adaptive Control, Certainty Equivalence Technique, Non-Certainty Equivalence Technique, Projection in Adaptive Control, Robustness Modification, Adaptive Backstepping Control, Adaptive Sliding Mode Control. Safety-critical control of Nonlinear Systems: Maintain consistency in term capitalization and descriptions. Example correction: "Barrier Functions, Lyapunov-Like Barrier Functions, Control Barrier Functions, Control Lyapunov Functions, Constrained Nonlinear Control Problem, High-Order Control Barrier Functions.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Understand and analyze the behaviour of nonlinear systems, applying stability analysis and feedback linearization effectively.

CO2: Design and implement sliding mode control systems that ensure robust performance under model uncertainties.

CO3: Apply backstepping control techniques to a range of nonlinear systems, enhancing their stability and performance.

CO4: Develop adaptive control schemes that adjust to parameter variations and maintain system robustness.

CO5: Design safety-critical control systems that meet specified performance criteria while ensuring compliance with safety regulations.

Text Books

1. Y. Shtessel, C. Edwards, L. Fridman, and A. Levan, “Sliding mode control and observation,” Springer, 2014.
2. Horacio J. Marquez, “Nonlinear Control Systems: Analysis and Design,” Wiley, 2003.
3. P. Ioannou and J. Sun, “Robust Adaptive Control,” Upper Saddle River, NJ: Prentice Hall 1996.
4. W. Xiao, C. G. Cassandras, C. Belta, “Safe Autonomy with Control Barrier Functions,” Springer, 2023.

Reference Books

1. J. J. E. Slotine & W. Li, “Applied Nonlinear Control,” Prentice Hall, 1991.
2. K. S. Narendra and A. M. Annaswamy, “Stable Adaptive Systems,” Dover Publications,” 2005.
3. Hassan K. Khalil, “Nonlinear Systems,” 3rd Edition, Prentice Hall, 2002.

Course Name: **Microprocessor Based System Design**
Course Code: **EE-756**
Course Type: **Programme Elective-III**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To impart knowledge about the fundamentals for microprocessor-based instrumentation systems.
- To introduce the basic concepts relevant to identify signal conditioning circuits for microprocessor-based instrumentation systems.
- To enable the students to understand the interfacing of various peripheral devices and signal conditioning issues for a given problem/application.

Course Content

Introduction: Overview of Microcontroller/Microprocessor, Basic differences and similarities between Microprocessor and Microcontroller. Introduction to various Microcontrollers, Difference between 8-bit /16-bit/32-bit, RISC/CISC processors, Concept of pipelining, Introduction to FPGA. Intel 8051 Microcontroller: Intel 8051 history, Pin diagram of 8051, 8051- architecture, Registers, Timers Counters, Flags, Special Function Registers, DPTR, PC, PSW, SP etc., Addressing Modes, Data types and Directives, Additional features in 8052, Intel 8096, PIC16F877. Instructions in Microcontrollers: Jump, Loop and Call instructions Arithmetic instructions, and their simple programming applications, Jump, Loop, Call, Arithmetic instructions, Introduction to development of a Microcontroller based system, Simple programming applications, Concept of PLC, Features, and parts in a PLC unit. System Design Using Microcontroller/Microprocessor: Interfacing with LEDs, Seven Segment, LCD, Sensors, ADC, DAC, Stepper Motor, Relays, Optocoupler etc., Case studies based on Microcontroller/ microprocessor, Case studies on Microprocessor/Microcontroller based systems, an 8086 based process control system, developing the prototype of a microcomputer-based instrument, digital filters.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Understand the basic instrumentation systems and microprocessor-based systems and signal conditioning circuits.
CO2: Develop an idea about the evolution of microprocessors/microcontrollers.
CO3: Understand various types of signal conditioning circuits.
CO4: Understand the interfacing of ADC, DAC, S/H, and sensors, transducers to microprocessor, microcontroller using peripheral devices.

Text Books

1. Douglas V. Hall, "Microprocessors and Interfacing: Programming and Hardware," McGraw-Hill, 1986.
2. B. Ram, "Fundamentals of Microprocessors and Microcomputers," Dhanpat Rai Publication, 2008.
3. A.K. Mukhopadhyay, "Microprocessor, Microcomputer and their Applications," Narosa Publishing House, 2006.

Reference Books

1. S.I. Ahsan, "Microprocessors with Applications in Process Control," TMH India, 1991.
2. Naresh Grover, "Microprocessors: Comprehensive Studies," Dhanpat Rai & Co., 2004.

Institute Electives

Course Name: **Elements of Power Engineering** Course Code: **EE-701** Course Type: **Institute Elective**
Contact Hours/Week: **4L** Course Credits: **04**
Course Objectives • Learn modelling, analysis, and operation of power systems. • Instills a practical knowledge of large-scale power system analysis. • Explore modern power system trends like smart grids distributed generation and microgrids.
Course Content
Basics of Power System: Basic structure and concepts of power system, significance of Electrical Energy, single-line diagram of a power supply network, working and applications of power transformer, distribution transformer and alternator. Introduction to load characteristics, various factors and power factor improvement. Power Generation and Distribution Systems: Sources of electric energy: wind, solar, hydro, thermal nuclear, battery energy storage systems, cogeneration, distributed Generation. General aspects, Kelvin's Law, AC and DC distribution systems, Calculation of feeder currents and voltages, distribution loss. Power Transmission system: Long length transmission line model, ABCD Parameters and T and π model representation, calculation of efficiency and voltage regulation, Ferranti effect, series and shunt compensation, surge impedance loading (SIL), introduction to underground cables and grading. Protective Relays: Basics of different types of relays, over current relay, IDMT relay, differential protection, distance protection of transmission lines through impedance, reactance and mho relay, comparison between distance relays, static relays. Power System Economics: Characteristics of generating units, Incremental Cost, Economic dispatch with and without losses using λ- Iteration Method. Modern power systems: Deregulated power systems, Smart grids, demand side management, microgrids - types of microgrids.
Course Outcomes Upon successful completion of the course, the students will be able to CO1: Provide a solid understanding of the theoretical aspects of power systems. CO2: Understand different types of power generation systems. CO3: Understand the operation of power systems and various protection relays. CO4: Adapt to modern power system trends for industry relevance.
Text Books 1. C. L. Wadhwa, "Electric Power Systems," New Age International, New Delhi. 2. D. P. Kothari and I. J. Nagrath, "Power System Engineering," Tata McGraw Hill, New Delhi. **Reference Books** 1. S. S. Rao, B. Ravindernath, and M. Chander, "Switchgear and Protection," Khanna Publishers. 2. J. J. Grainger and W. D. Stevenson, "Power System Analysis," McGraw-Hill Education. 3. S. Borlase, "Smart Grids: Infrastructure, Technology, and Solutions," David J. Hill, CRC Press

Course Name: **Evolutionary Programming and Genetic Algorithms**
Course Code: **EE-702**
Course Type: **Institute Elective**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To impart knowledge about related with Genetic algorithm and Evolutionary programming.
- To introduce the fundamental concepts relevant to GA operators, creation of offspring etc.
- To enable the students to understand the factors related with application and fundamental of GA and EP.

Course Content

Introduction: Basic concepts and definitions, artificial intelligence, genetic algorithms (GAs), evolutionary programming (EP). Evolutionary Programming: Initialization, Creation of offspring, Competition and selection, Gaussian random numbers, standard deviation, Difference between GAs and EP, basic algorithm, step by step procedure of evolutionary programming for optimization Genetic Algorithm: Coding, fitness function, Calculation of the number of bit required for a variable, GAs operators, crossover and mutation, roulette wheel method for selection process, cumulative probabilities, Basic flow chart, GAs for optimization detail steps, Similarities between GAs and traditional methods, Differences between GAs and traditional methods. Applications: GAs applications for economic power dispatch and optimal power flow, applications of EP for economic power dispatches and optimal powers flow.

Course Outcomes

CO1: Identify various concepts of Genetic algorithm and Evolutionary programming.
CO2: Describe important concepts related with optimization with GA and EP.
CO3: Apply principal to explain various problems related with problems described in CO2.
CO4: Assess the results obtained by solving above problems.

Text Books

1. M. Mitchell, "An Introduction to Genetic Algorithms," MIT Press, 1998.
2. N. P. Padhy, "Artificial Intelligence and Intelligent Systems," Oxford University Press.
3. A. E. Eiben, "Introduction to Evolutionary Computing," Springer-Verlag Berlin and Heidelberg.
4. Z. Michalewicz, "Genetic Algorithms, Data Structures and Evolution Programs," Berlin: Springer-Verlag.

References Books

1. M. Chis, "Evolutionary Computation and Optimization Algorithms in Software Engineering: Applications and Techniques," IGI Global publishers.
2. D. E. Goldberg, "Genetic Algorithms in Search Optimization and Machine Learning," Addison-Wesley.

Course Name: **Distributed Generation Technology**
Course Code: **EE-703**
Course Type: **Institute Elective**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To impart knowledge about the distributed generation technology
- To introduce the modern power system, solar photovoltaic system, wind power system, and energy storage system.
- To enable the students to understand how the solar photovoltaic, wind power, and energy storage system works.

Course Content

Modern Power System: Generation, Transmission, Distribution, Loads, Introduction to distributed generation, Technologies of distributed generation, IEEE-1547. Solar Photovoltaic: Solar cell overview, Photon absorption at the junction, Solar cell construction, Types and adaptations of photovoltaics, Photovoltaic circuit properties, Applications, and systems. Wind Power: Overview about wind power, Turbine types and terms, Linear momentum and basic theory, Dynamic matching, Blade element theory, Electricity generation. Energy Storage System: Importance of energy storage, Chemical storage, Heat storage, Batteries, Fuel cells, Ultracapacitors, and Mechanical storage.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Understand the distributed generation technology

CO2: familiarise with modern power system, solar photovoltaic system, wind power system, and energy storage system

CO3: Realize the technology, design methodologies and operation of distributed generation technology

Text Books

1. N. Jenkins, J.B. Ekanayake and G. Strbac, “Distributed Generation,” IET.
2. J. Twidell and T. Weir, “Renewable Energy Resources,” Taylor & Francis.

Reference Books

1. A. Khaligh and O. C. Oner, “Energy Harvesting – Solar, Wind, and Ocean Energy Conversion Systems,” CRC Press.
2. C. S. Solanki, “Solar Photovoltaics: Fundamentals, Technologies, and Applications,” PHI.

Course Name: **Optimization Techniques and Applications**
Course Code: **EE-704**
Course Type: **Institute Elective**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To impart knowledge about the principles of optimization techniques.
- To introduce the fundamental concepts relevant to classical optimization methods, linear programming, nonlinear programming, and dynamic programming.
- To enable the students to understand the factors that cause the different optimization methods to provide different solutions for the same mathematical problem.

Course Content

Introduction: Historical Development; Engineering applications of Optimization; Design Vector, Design Constraints, Constraint Surface, Objective Function, Objective function Surfaces. Linear Programming: Standard form of linear programming (LP) problem; Canonical form of LP problem; Assumptions in LP Models; Elementary operations; Graphical method for two variable optimization problem; Examples; Motivation of simplex method, Simplex algorithm, and construction of simplex tableau; Simplex criterion; Minimization versus maximization problems; simplex method with artificial variables. Classical Optimization: Stationary points, saddle points; Convexity and concavity of functions; multiple variables optimization, necessary and sufficient conditions, concept of hessian matrix, Newton Raphson method, optimization subject to equality constraints, optimization subject to inequality constraints; Kraush-Kuhn-Tucker Conditions, examples. Non-Linear Programming: Unconstrained algorithms, Direct search method, gradient method, constrained algorithms, separable programming, quadratic programming, augmented LaGrange multiplier method. Kuhn Tucker conditions, examples. Metaheuristic Algorithms: Introduction to Tabu search algorithm, simulated annealing algorithm, genetic algorithm. Dynamic Programming: Sequential optimization; Representation of multistage decision process; Types of multistage decision problems; Concept of sub optimization and the principle of optimality; Recursive equations - Forward and backward recursions; curse of dimensionality, application.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Identify different types of optimization techniques and problems.
CO2: Describe techniques like calculus based classical optimization, linear programming, nonlinear programming, dynamic programming.
CO3: Apply principles and techniques described in CO2 to solve sample mathematical and practical optimization problems.
CO4: Assess the results obtained by applying optimization techniques to solve mathematical programming problems.
CO5: Identify the pre-requisite measures required to carry out state space design of the system.

Text Books

1. S. S. Rao, "Engineering Optimization: Theory and Practice," New Age International (P) Ltd., New Delhi, 2000.

Reference Books

1. S. Chandera, Jaydeva, and A. Mehta, "Numerical Optimization with Applications," Narosa.
2. H. A. Taha, "Operations Research an Introduction," Publisher: Pearson.

Course Name: **Electrical Vehicle Technologies**
Course Code: **EE-705**
Course Type: **Institute Elective**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To impart knowledge about the recent electric vehicle technologies
- To introduce the fundamental concepts of electric energy source and storage device, battery management system, traction machines, power electronic essentials, and regulations and standards
- To enable the students to understand how the electric energy system, traction machines, various power electronic essentials, and various regulations and standards works in electric vehicle

Course Content

Fundamentals of Electric Vehicles: Overview of electric vehicle, Layout of an electric vehicle, History of electric vehicle, Challenges of electric vehicle, Types of electric vehicle. Review of Power Electronics Devices: V-I characteristics and comparison study of different Power electronic devices, Basics, output waveforms, working of different converters used in EVs. Energy Storage Device: Types of energy source, Classification of energy storage technologies, electric batteries, Fuel-cell, Ultracapacitors, Selection of electric battery, and Modelling based on equivalent electric circuits. Charging Infrastructure and Battery Management System: Battery Chargers: Forward/Flyback Converters, Half-Bridge DC–DC Converter, Full-Bridge DC–DC Converter, Power Factor Correction Stage, Bidirectional Battery Chargers, Other Charger Topologies, Inductive Charging, Wireless Charging, Buck Converter and Rectifiers used in EVs, non-isolated and isolated Bidirectional DC–DC Converter. Traction Systems: Structure, principle, and characteristics of DC machine, induction machine, permanent magnet brushless machine, and switched reluctance machine used in electric vehicle. Regulations and Standards: Electric batteries standards, Grid interface standards, and Charging infrastructure standards.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Understand the power electronic devices, electric energy devices

CO2: Realize the technology, design methodologies and control strategy of electric vehicles

CO3: Apply energy management techniques for electric vehicles

CO4: to apply the knowledge in the charging infrastructure, traction system

Text Books

1. S. Singh, S. Gairola, and S. Dwivedi, "Electric Vehicle Components and Charging Technologies: Design, Modeling, Simulation and Control, IET.
2. M. Ehsani, Y. Gao, S. E. Gay, and A. Emadi, "Modern Electric, Hybrid Electric, and Fuel Cell Vehicles: Fundamentals, Theory, and Design, CRC Press.

Reference Books

1. K. T. Chau, "Electric Vehicle Machines and Drives - Design, Analysis and Application," Wiley.
2. S. Leitman, and B. Brant, "Build Your Own Electric Vehicle," McGraw Hills.

Course Name: **Elements of Control Engineering**
Course Code: **EE-706**
Course Type: **Institute Elective**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To study and analyses the various control system components.
- To understand the basic control design methods to meet out desired performance/ specifications.
- To explain the parameters to be taken into consideration while designing a compensator.
- To study the state space modelling and optimal design using state space approach.

Course Content

Introduction: Review of open loop and close loop systems, degenerative and regenerative feedback, transfer function-based models of different systems, study of control system components, sensors and actuators, servo control systems. Control System Analysis: Time domain and frequency domain specifications, concept of stability, asymptotic stability, BIBO stability, Routh-Hurwitz's stability criterion for transfer function models, Nyquist Stability criterion- Stability using Root Locus and Bode plots, absolute stability and relative stability, stability margins. Design of Controllers: Various control schemes, on-off controllers, regulator, tracking control, classical methods for design of control systems, design of compensators-lead, lag, lead lag design using Bode plots, Proportional Integral, and Derivative control strategies and use of their combinations, design of PID Controllers, PID Tuning methods in process control, control of systems with time delay or dead time, feed forward and feedback controllers. State Space Models and Design: State Space models for continuous time linear, single input single output systems, concept of state and state space, linear systems in state space, state models from transfer functions, introduction to multi input multi output systems, transfer function from state space models, controllable and uncontrollable modes, testing for controllability and observability, pole placement design for state feedback systems, Ackerman formula, introduction to observers, full order and reduced order observers.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Identify different physical systems and classify them as open loop and close loop control systems.

CO2: Apply different time domain and frequency domain tools to analyze the absolute and relative stability of LTI systems.

CO3: Assess the performance of LTI systems to different inputs and to design basic controllers to meet out desired performance.

CO4: Identify the pre-requisite measures required to carry out state space design of the system.

Text Books

1. G. F. Franklin, J. D. Powell, and A. E. Nacini, "Feedback Control of Dynamic Systems," 4th Ed, Pearson Education Asia, 2002.
2. M. Gopal, L. J. Nagrath, "Control Systems Engineering," Wiley Eastern, 1978.
3. D. R. Choudhary, "Modern Control Engineering," Prentice Hall India, 2005.
4. R. C. Dorf and R. H. Bishop, "Modern Contral Systems," 8th Ed., Addison Wesley.

Reference Books

1. B. C. Kuo, "Automatic Control Systems," 7th Ed, Prentice Hall India, 1995.
2. E. U. Eronini, "System Dynamics and Control," Thomson Brooks/Cole, 1999.
3. N. S. Nise, "Control Systems Engineering," 4 Ed., John Wiley, 2004.
4. G. C. Goodwin, S. F. Graebe, and M. E. Salgado, "Control System Design, Prentice Hall India, 2003.