CURRICULUM AND SYLLABI

M.Tech.

in

INSTRUMENTATION AND CONTROL SYSTEMS

(With effect from Academic Year 2018-2019)

तमसो मा ज्योतिर्गमय

DEPARTMENT OF ELECTRICAL ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY CALICUT
CALICUT - 673601

DEPARTMENT OF ELECTRICAL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY CALICUT

Vision of the Department of Electrical Engineering

To be nationally and internationally recognized in providing electrical engineering education and training candidates to become well-qualified engineers who are capable of making valuable contributions to their profession and carrying out higher studies successfully.

Mission of the Department in pursuance of its vision

To offer high quality programs in the field of electrical engineering, to train students to be successful both in professional career as well as higher studies and to promote excellence in teaching, research, collaborative activities and contributions to the society.

The Programme Educational Objectives (PEOs) of M. Tech. Programme in INSTRUMENTATION AND CONTROL SYSTEMS

PEO1	To equip the engineering graduates with adequate knowledge and skills in the areas of Control Systems and Instrumentation so as to excel in advanced level jobs in modern industry and/ or teaching and/or higher education and/or research.
PEO2	To transform engineering graduates to expert engineers so that they could comprehend, analyze, design and create novel products and solutions to problems in the areas of Control Systems and Instrumentation that are technically sound, economically feasible and socially acceptable.
PEO3	To train engineering graduates to exhibit professionalism, keep up ethics in their profession and relate engineering issues to address the technical and social challenges.
PEO4	To improve the communication skills and willingness to work in groups and to develop multidisciplinary approach in problem solving.

The Programme Outcomes (POs) of M. Tech. Programme in INSTRUMENTATION AND CONTROL SYSTEMS

PO1	An ability to independently carry out research/investigation and development work to solve practical problems.
PO2	An ability to write and present a substantial technical report/document.
PO3	Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program.
PO4	Ability to utilize the acquired knowledge to take up administrative challenges including the management of projects related to Instrumentation and Control Systems having multidisciplinary nature with a perspective to maintain lifelong learning process.
PO5	Willingness and ability to upkeep professional ethics and social values while carrying out the responsibilities as an Instrumentation / Control Systems engineer/researcher in devising solutions to real life engineering problems in an independent manner.

Curriculum of M. Tech. Programme in Instrumentation and Control Systems

This Programme is offered in four semesters. The structure of the programme shall be the following:

Semester 1

Course Code	Course Title	L	T	P/S	C
MA6007D	Mathematical Methods in System Engineering	3	-	-	3
EE6101D	Systems Theory	3	-	-	3
EE6103D	Measurements and Instrumentation	3	-	-	3
EE6105D	Digital Control: Theory and Design	3	-	-	3
	Elective -1	3	-	-	3
EE6191D	Advanced Control Systems Lab	-	-	2	1
EE6193D	Seminar	-	-	2	1
Total credits		15	-	2	17

Semester 2

Course Code	Course Title	L	T	P/S	C
EE6102D	Optimal and Robust Control	3	-	-	3
EE6104D	Advanced Instrumentation	3	-	-	3
EE6106D	Stochastic Modelling and Identification of Dynamical Systems	3	-	-	3
EE6108D	Nonlinear Systems and Control	3	-	-	3
	Elective -2	3	-	-	3
	Elective -3	3	-	-	3
EE6192D	Instrumentation Systems Lab	-	-	2	1
Total credits		18	-		19

Semester 3

Course Code	Course Title	L	T	P/S	C
EE7191D	Project – Part 1	-	-	20	10
Total		-	-	20	10

Semester 4

Course Code	Course Title	L	T	P/S	C
EE7192D	Project –Part 2	-	-	28	14
Total		-	-	28	14

LIST OFELECTIVES

Sl. No	Code	Title	Credits
1	EE6121D	Data Acquisition and Signal Conditioning	3
2	EE6122D	Biomedical Instrumentation	3
3	EE6123D	Performance Modelling of Systems I	3
4	EE6124D	Performance Modelling of Systems II	3
5	EE6125D	Adaptive Control Theory	3
6	EE6126D	Advanced Topics in Control Systems	3
7	EE6127D	Optimal Estimation and Filtering	3
8	EE6128D	Variable Structure Control Systems	3
9	EE6129D	Large Scale Systems	3
10	EE6130D	Quantitative Feedback Theory	3
11	EE6131D	Multivariable Control Systems	3
12	EE6132D	Numerical Methods for Control System Design	3
13	EE6133D	Flight Control Systems	3
14	EE6134D	Networked Control and Multiagent Systems	3
15	EE6135D	Flexible Structures	3
16	EE6136D	Guidance, Navigation and Control	3
17	EE6138D	Selected Topics in Control	3
18	EE6140D	Advanced Soft Computing Techniques	3
19	EE6202D	Power System Dynamics and Control	3
20	EE6327D	Implementation of DSP Algorithms	3
21	EE6329D	Advanced Microprocessor Based Systems	3
22	EE6401D	Energy Auditing & Management	3
23	EE6402D	Process Control & Automation	3

24	EE6403D	Computer Controlled Systems	3
25	EE6404D	Industrial Instrumentation	3
26	EE6405D	Artificial Intelligence and Automation	3
27	EE6422D	Engineering Optimization and Algorithms	3
28	EE6424D	Robotic Systems and Applications	3
29	EE6428D	SCADA Systems and Applications	3
30	EE6429D	Wireless and Sensor Networks	3
31	EE6430D	Network and Data Security	3
32	EE6432D	Advanced Algorithms and data Structure Analysis	3
33	EE6434D	Internet of Things and Applications	3
34	EE6436D	Industrial load modelling & control	3
35	EC6302D	Communication Networks	4
36	EC6434D	Linear & Nonlinear Optimization	3
37	EC6413D	Pattern Recognition and Analysis	3
38	EC6421D	Digital Image Processing Techniques	3
39	EC6401D	Linear Algebra for Signal Processing	4
40	MA7165D	Statistical Digital Signal Processing	3
41	MA8154D	Wavelets Theory	3
42	MS9001D	Research Methodology	4
43	ME6313D	Industrial Automation and Robotics	3

Notes:

1. A minimum of **60** credits have to be earned for the award of M. Tech Degree in this Programme.
2. Communicative English and Audit courses are optional.
3. Industrial Training during summer is optional.
4. List of Electives offered in each semester will be announced by the Department.
5. Any other PG level course of NITC approved by senate offered in the Institute can also be credited as elective with the prior approval from the Programme Coordinator.

MA6007D MATHEMATICAL METHODS IN SYSTEM ENGINEERING

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1. Apply notions of vector spaces and linear transformations in engineering problems
CO2. Perform diagonalisation of linear operators and quadratic forms.
CO3. Solve problems involving random variables and functions of random variables
CO4: Analyze physical problems involving uncertainty using stochastic processes
CO5. Compute stationary/steady state probabilities for both discrete time and continuous time Markov chains.
CO6. Compute power spectral density functions for various second order processes.

Module 1: Linear Algebra (11 hours)

Vector spaces, subspaces, Linear dependence, Basis and Dimension, Inner product spaces, Gram-Schmidt Orthogonalization, Linear transformations, Kernels and Images, Matrix representation of linear transformation, Change of basis, Eigenvalues and Eigen vectors of linear operator, Quadratic form.

Module 2: Operations on Random Variables (10 hours)

Random Variables, Distributions and Density functions, Moments and Moment generating function, Multivariate distributions, Independent Random Variables, Marginal and Conditional distributions , Conditional Expectation, Transformation of Random Variables , Elements of stochastic processes, Classification of general stochastic processes.

Module 3: Random Processes (9 hours)

Markov Chains: Definition, Examples, Transition Probabilities, Classification of states and chains, Basic limit theorem, Limiting distribution of Markov chains.

Continuous Time Markov Chains: General pure Birth processes and Poisson processes, Birth and death processes, Finite state continuous time Markov chains

Module 4: Second Order Processes (9 hours)

Second Order Stochastic Processes, Stationary processes, Wide sense Stationary processes, Auto covariance and auto correlation function, Spectral density function, Low pass and band pass processes, White noise and white noise integrals, Linear Predictions andFiltering.

References:
1. Kenneth Hoffman and Ray Kunze, '*Linear Algebra'*, 2nd Edition, PHI,1992.
2. Erwin Kreyszig, '*Introductory Functional Analysis with Applications'*, John Wiley & Sons,2004.
3. Irwin Miller and Marylees Miller, '*John E. Freund's Mathematical Statistics'*, 6th Edition, PHI,2002.
4. S. Karlin& H.M Taylor, '*A First Course in Stochastic Processes'*, 2ndedition, Academic Press, New York, 2007
5. S. M. Ross, '*Introduction to Probability Models'*, Harcourt Asia Pvt. Ltd. and Academic Press,2004
6. J. Medhi, '*Stochastic Processes'*, New Age International, New Delhi,1994
7. A Papoulis, '*Probability, Random Variables and Stochastic Processes'*, 3rd Edition, McGraw Hill,2002
8. John B Thomas, '*An Introduction to Applied Probability and Random Processes'*, John Wiley & Sons, 2000.

EE6101D SYSTEMS THEORY

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Integrate the concepts of linear algebra to be applied in systems theory
CO2: Explain the various tools used for the analysis of both LTI and LTV systems
CO3: Apply various techniques for the analysis of system stability
CO4: Analyze and categorize systems with respect to various properties

Module 1: (8 hours)

Basics of linear algebra - Vector spaces, dimension, basis, subspaces, dual spaces, annihilators, direct sum, linear transformations, matrix representations, similarity, rank and nullity.

Module 2: (9 hours)

Linear Systems –State space models, explicit solutions to linear differential equations, solution to LTI and LTV systems, Solutions to homogeneous and non-homogeneous cases, Computation of matrix exponentials using Laplace transforms and Jordan Normal form, positive definite matrices, quadratic forms.

Module 3: (10 hours)

Minimal realizations and co-prime fractions, canonical forms,Markovparameters,Hankelmatrices
Stability - Internal or Lyapunov stability, Lyapunov stability theorem, Eigen value conditions for Lyapunovstability,Input -Output stability: BIBOstability, Time domain conditions for BIBO stability. Frequency domain conditions for BIBOstability. BIBO versus Lyapunov stability

Module 4: (12 hours)

Controllability and Observability - Controllable and reachable subspaces, Physical examples and system interconnections, Reachability and controllability Gramians, Controllabilty matrix(LTI), Eigen vector test for controllability, Lyapunov test for controllability, Controllable decomposition and block diagram interpretation, Stabilizable system, Eigen vector test for stabilizability, Popov-Belevitch_Hautus (PBH) Test for stabilizability, Lyapunov test for stabilizability. Feedback stabilization based on Lyapunov test, Unobservable and unconstructable subspaces, Physical examples, observability and Constructability Gramians, Gramian based reconstruction, Duality (LTI), Observable decompositions, Kalman decomposition theorem, Detectability, detectability tests, State estimation, Eigen value assignment by output injection, Stabilization through output feedback

References:

1. Chi-Tsong Chen, *'Linear System Theory and Design',* Oxford University Press,1984
2. John S. Bay, *'Fundamentals of Linear State Space Systems',* Mc-Graw Hill, 1999
3. Thomas Kailath, *'Linear System',* Prentice Hall, 1990
4. Gillette, *'Computer Oriented Operation Research'*, Mc-Graw Hill Publications.
5. K. Hoffman and R. Kunze, *'Linear Algebra'*, Prentice-Hall (India), 1986.
6. F.M. Callier and C.A. Desoer, *'Linear System Theory'*, Springer Verlag, 1991
7. P. Halmos, *'Finite Dimensional Vector Spaces'*, Springer, 1984

EE6103D MEASUREMENTS AND INSTRUMENTATION

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Recognize about general units errors and significant digits in measurements.
CO2: Discuss about analog instruments and null balance methods for measurements.
CO3: Discuss digital measurement techniques.
CO4: Outline the applications of Data Acquisition Systems and virtual instrumentation.

Module 1: Units, significant digits and errors in measurements (8 Hours)

C.G.S electrostatic and electromagnetic systems of units- Practical and legal units and their relationship to the absolute units- Dimensions of electrical quantities- The M.K.S. system of units- International and absolute units and standards, significant digits.
Measurement and Error-Accuracy and precision- Types of errors- Systematic and random errors, propagation of errors.

Module 2: Analog instruments and null balance methods for measurements (13 hours)

Analog Indicating instruments- Moving iron instruments- Moving coil instruments- Permanent magnet and dynamometer type instruments- electrostatic instruments- thermal instruments- induction instruments-rectifier instruments
Null balance methods of measurement-potentiometer Principles-Bridge configuration-AC Bridges- Classification of AC bridge circuits- DC bridge analysis- Extension of instrument range-current transformer theory- voltage transformers.

Module 3: Digital Measurement techniques (11 hours)

Digital Measurement techniques- counters and timers. Time measurement- phase measurement- capacitance measurement- frequency measurement- ratio of two frequencies- high frequency- low frequency- peak frequency-Voltage measurement using digital techniques- ADC's Digital Multimeter.
Graphical measurement techniques- CRO-DSO

Module 4: Data acquisition systems and virtual instrumentation (7 hours)

Analog and digital data acquisition systems-Virtual instrumentation- concepts- virtual versus real instrumentation - physical quantities and analog interfaces, hardware and software- user interfaces- applications of virtual instrumentation.

References:

1. A.D. Helfrick, W.D. Cooper, '*Modern Electronic Instrumentation and Measurement Techniques'*, Prentice-Hall of India pvt ltd, 1994.
2. Golding and Widdis, *'Electrical measurements and measuring instruments'*,Reem publications, Newdelhi, 5thEdn, 2009
3. Ernest Frank, '*Electrical measurement analysis'*, Tata McGraw-hill publishing company ltd, Bombay,1959
4. G.W. Johnson, *'LabVIEW graphical programming practical application in Instrumentation and Control'*, McGraw Hill, New York, 1997.

EE6105D DIGITAL CONTROL: THEORY AND DESIGN

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Develop mathematical models of Digital Control Systems
CO2: Design and analyse digital control systems using classical techniques
CO3: Design and analyse SISO and MIMO digital control systems in the state space domain
CO4: Apply various techniques for the stability analysis of nonlinear digital control systems

Module 1: Introduction to digital control (9 hours)

Introduction -Discrete time system representation –Sample & Hold-Mathematical modeling of sampling process – Data reconstruction-Design of the hardware and software architecture - Software requirements- Selection of ADC and DAC- Choice of the sampling period –Prefilter/Antialiasing filters - Effects of quantization errors - Phase delay introduced by the ZOH-Sampling period switching- Dual-rate control
Modeling discrete-time systems by pulse transfer function -Revisiting Z-transform -Mapping of s-plane to z-plane -Pulse transfer function - Pulse transfer function of closed loop system - Sampled signal flow graph -Stability analysis of discrete time systems -Jury stability test - Stability analysis using bi-linear transformation

Module 2: Design of sampled data control systems (10 hours)

Design of PID controller-Filtering the derivative action- Integrator windup- Bumpless transfer between manual and automatic mode - Incremental form-Root locus method - Controller design using root locus - Root locus based controller design using MATLAB - Nyquist stability criteria - Bode plot - Lead compensator design using Bode plot - Lag compensator design using Bode plot - Lag-lead compensator design in frequency domain-Deadbeat response design -Design of digital control systems with deadbeat response - Practical issues with deadbeat response design - Sampled data control systems with deadbeat response

Module 3: Discrete state space model and state feedback design (9 hours)

Introduction to state variable model for SISO systems- Various canonical forms - Characteristic equation, state transition matrix - Solution to discrete state equation-Controllability, observability and stability of discrete state space models -Controllability and observability - Stability
Pole placement by state feedback - Set point tracking controller - Full order observer - Reduced order observer-Servo Design- State feedback with Integral Control-Deadbeat Control by state feedback and deadbeat observers -Output feedback design - Output feedback design: Theory - Output feedback design:Examples. Introduction to Multivariable & Multi-input Multi-output (MIMO) Digital Control Systems

Module 4: Nonlinear Digital control systems (11 hours)

Discretization of nonlinear systems - Extended linearization by input redefinition - - input and state redefinition - output differentiation - Extended linearization using matching conditions - Nonlinear difference equations - Logarithmic transformation- Equilibrium of nonlinear discrete-time systems - Lyapunov stability theory- Lyapunov functions - Stability theorems -Rate of convergence - Lyapunov stability of linear systems - Lyapunov's linearization method- Instability theorems - Estimation of the domain of attraction - Stability of analog systems with digital control-Hybrid Systems - State plane analysis - Discrete-tim.nonlinear controller design- Controller design using extended linearization-Controller design based on Lyapunov stability theory - Input-output stability and the small gain theorem-Absolute stability

References:

1. B.C Kuo , '*Digital Control Systems'* (second Edition),Oxford University Press, Inc., New York, 1992
2. G.F. Franklin, J.D. Powell, and M.L. Workman, '*Digital control of Dynamic Systems'*, Addison-Wesley Longman, Inc., Menlo Park, CA , 1998.
3. M. Gopal, '*Digital Control and State Variable Methods'*, Tata McGraw Hill Publishing Company, Third Edition, 2009.
4. John F. Walkerly, '*Microcomputer architecture and Programs'*, John Wiley and Sons Inc., New York, 1981.
5. K. Ogata, '*Discrete Time Control Systems'*, Addison-Wesley Longman Pte. Ltd., Indian Branch, Delhi, 1995.
6. C. H. Houpis and G.B. Lamont, '*Digital Control Systems'*, McGraw Hill Book Company, 1985.
7. C.L.Philips and H.T Nagle,Jr., '*Digital Control System Analysis and Design'*, Prentice Hall, Inc., Englewood Cliffs,N.J.,1984
8. M. Sami Fadali Antonio Visioli, '*Digital Control Engineering Analysis and Design'*, Academic Press,225 Wyman Street, Waltham, MA 02451, USA,Second Edition

EE6191D ADVANCED CONTROL SYSTEMS LAB

Pre-requisite: Nil

L	T	P	C
0	0	2	1

Total hours: 26

Course Outcomes:
CO1: Apply various software tools for control system design and hence its analysis
CO2: Analyze the simulation results, experimentally validate it and perform effective documentation.
CO3: Develop software solutions for linear and nonlinear control system problem.

List of Experiments

10 experiments will be offered in the lab, each experiment being of 2 hours duration. The experiments will be such as to understand the advanced topics in automatic control systems.
1. Transfer function of an amplidyne and load charateristics
2. The feedback MS150 modular servo system – Position Control
3. Experiments on Pendulum Control Sytem PCS 1
4. Twin Rotor MIMO system
5. Experiments on Level Process Control Station
6. Dynamic system simulation usin MATLAB
7. Real time control using dSPACE
8. MS 150A AC servo system: Familiarization and position control
9. State feedback controller for rotary flexible link module
10. Coupled Tank system: Charateristics of SISO, MIMO and interacting systems

References:
1. Gene F Franklin, J David Powell, Abbas EmamiNaeini, '*Feedback Control of Dynamic Systems'*, 4th Ed, Pearson Education Asia, 2002
2. Graham C Goodwin, Stefan F Graebe, Mario E Salgado, '*Control System Design'*, Prentice Hall, India, 2003.
3. John J D'Azzo, Constantine H Houpis, Stuart N. Sheldon, '*Linear Control System Analysis &Design with MATLAB'*, 5th Ed, Marcel Dekker, 2003
4. P. C. Sen, '*Principles of Electrical Machines & Power Electronics'*, John Wiley, 2003.
5. John E Gibson, Franz B. Tuteur, '*Control System Components'*, McGrawHill, 1958.
6. Ramesh S Gaonkar, '*Microprocessor architecture Programming and application with 8085/8080A* '2E, New Age Publications, 1995.
7. User's Manual for FEEDBACKR MS150 AC Modular Servo System
8. User's Manual for FEEDBACKR MS150 DC Modular Servo System
9. User's Manual for Bytronics Inverted Pendulum
10. User's Manual for TRMS

EE6193D SEMINAR

Pre-requisite: Nil

L	T	P	C
0	0	3	1

Total hours: 26

Course Outcomes:

CO1: Identify research papers for understanding emerging technologies in the field of Control and Instrumentation Systems, to summarize and to review them.
CO2: Interpret promising new directions of various cutting edge technologies.
CO3: Devise skills in preparing detailed report describing the reviewed topic.
CO4: Develop the ability to communicate by making an oral presentation before an evaluation committee.

Individual students will be asked to choose a topic in any field of Instrumentation and Control Systems and/or relevant to industry or society, preferably from outside the M.Tech syllabusand give seminar on the topic for about thirty minutes. A committee consisting of at least three faculty members specialized on different fields of engineering will assess the presentation of the seminars and award the marks to the students. Each student will be asked to submit two copies of a write up of the seminar talk – one copy will be returned to the student after duly certifying by the Chairman of the assessing committee and the other copy will be kept in the departmental library.

EE6102D OPTIMAL AND ROBUST CONTROL

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Apply the various concepts in the mathematical area of 'calculus of variation' for solving optimal control problems.

CO2: Develop methods of problem formulation pertaining to optimal control and design of optimal controllers

CO3: Analyse robustness of systems and develop skills useful in controlling systems when accurate mathematical models are unavailable

CO4: Design and synthesis robust controllers for practical systems

Module 1: (10 hours)

Calculus of variations: Examples of variational problems, Basic calculus of variations problem, Weak and strong extrema, Variable end point problems, Hamiltonian formalism and mechanics: Hamilton's canonical equations.

From Calculus of variations to Optimal control :Necessary conditions for strong extrema, Calculus of variations versus optimal control, optimal control problem formulation and assumptions, Variational approach to the fixed time, free end point problem.

The Pontryagin's Minimum principle: Statement of Minimum principle for basic fixed endpoint and variable end point control problems, Proof of the minimum principle, Properties of the Hamiltonian, Time optimal control problems. Minimum energy problems.

Module 2: (10 hours)

Linear Quadratic Regulator: Finite horizon LQR problem-Candidate optimal feedback law, Ricatti differential equations (RDE), Global existence of solution for the RDE. Infinite horizon LQR problem-Existence and properties of the limit, solution, closed loop stability.LQR using output feedback: Output feedback LQR design equations, Closed loop stability, Solution of design equations .Numerical solution of Riccatti Equations-Linear Quadratic tracking control: Tracking a reference input with compensators of known structure, Tracking by regulator redesign, Command generator tracker, Explicit model following design. Linear Quadratic Guassian controller (LQG) and Kalman-Bucy Filter: LQG control equations, estimator in feedback loop, steady state filter gain, constraints and minimizing control, state estimation using Kalman-Bucy Filter, constraints and optimal control.

Module 3: (10 hours)

Robust Control - Control system representations, System stabilities, Co-prime factorization and stabilizing controllers, Signals and system norms, Modelling of uncertain systems - Unstructured Uncertainties-Additive, multiplicative and other forms. Parametric uncertainty, Interval Systems, Structured uncertainties, Linear fractional transformation Robust design specifications: Small gain theorem and robust stabilization, Performance considerations, Structured singular values. Design - Mixed sensitivity optimization, 2-Degree of freedom design, Sub-optimal solutions, H_2 /H_∞ Systems.

Module 4: (9 hours)

Loop-shaping design procedures: Robust stabilization against Normalized co-prime factor perturbation, Loop shaping design procedures, μ - Analysis and Synthesis - Consideration of robust performance, μ-synthesis: D – K iteration method, Schur Compliment & Linear Matrix Inequalities: Some standard LMI problems – eigen - value problems, generalized eigen - value problems; Algorithms to solve LMI problems – Ellipsoid algorithm, interior point methods.

References:

1. D. W.Gu, P. Hr.Petkov and M.M.Konstantinov, '*Robust Control esign with MATLAB'*, Springer, 2005.
2. Alok Sinha, *'Linear Systems-Optimal and Robust Controls',* CRC Press, 2007.
3. S. Skogestad and Ian Postlethwaite, *'Multivariable feedback control'*, John Wiley & Sons, Ltd, 2005.
4. G.E. Dullerud, F. Paganini, *'A course in Robust control theory-A convex approach'*, Springer, 2000.
5. Kemin Zhou with J.C. Doyle and K. Glover, *'Robust and Optimal control,'* Prentice Hall, 1996.
6. Kemin Zhou, John Comstock Doyle, Keith Glover, *'Robust and optimal control,'* PrenticeHall,1996.
7. Kemin Zhou, John Comstock Doyle, *Essentials of robust control*, Prentice Hall, 1998.
8. Stephen Boyd, Laurent El Ghaoul, Eric Feron, '*Linear Matrix Inequalities in System and ControlTheory',* SIAM, 1994.

EE6104D ADVANCED INSTRUMENTATION

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Summarize about the fundamental concepts of measurement systems.
CO2: Recognise the static and dynamic characteristics of measuring instruments.
CO3: Review the mathematical modelling and time response of first order and second order measurement systems.
CO4: Study and analysis of amplitude modulation of measurements and the design consideration of such amplitude modulated measurement systems.
CO5: Discuss the response of measurement systems to random inputs.
CO6: Outline the requirements to ensure accurate measurements

Module 1: Generalized measuring system (9 hours)

Generalized input output configuration of measuring system. Different methods of correction, General principles. Methods of inherent sensitivity, principle of filtering, method of opposing inputs.

Module 2: Static and dynamic characteristics of measurement system (10 hours)

Static characteristics of measurement system. Computer aided calibration and measurement.Concept of development of software.Dynamic characteristics.Mathematical Models.Generalconcepts of transfer functions (with special reference to measuring system). Classification ofinstruments based on their order and their dynamic response and frequency response studies.

Module 3: Time domain analysis (10 hours)

Time Response of general form of first order and second order measurement systems to various input (a) periodic (b) transient.Characteristics of random signals.Measurement system response to random inputs.

Module 4: Signal Processing and Conditioning (10 hours)

Study and analysis of amplitude modulation of measurements and design consideration of suchamplitudes modulated measurement systems. Requirements on instrument transfer function toensure accurate measurements.

References:

1. Ernest O. Doebelin,*' Measurement system Application and Design'*, McGraw Hill International Editions, 1990
2. K. B. Klaasen, *'Electronic Measurement and Instrumentation'*, Cambridge University Press, 1996.
3. Bernard Oliver, John Cage, '*Electronic Measurements and Instrumentation'*, Tata McGraw-Hill Edition, 2008
4. A.D. Helfrick, W.D. Cooper,*'Modern Electronic Instrumentation and Measurement Techniques'*, Prentice-Hall of India pvt ltd, 1994

EE6106D STOCHASTIC MODELLING AND IDENTIFICATION OF DYNAMICAL SYSTEMS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Explain the advanced topics of statistics and stochastic processes
CO1: Explain the stochastic modelling of uncertain signals and dynamical systems
CO3: Apply stochastic modelling for control system analysis and design
CO4: Choose suitable methods for control system identification
CO5: Develop algorithms for analytical modelling & optimal control

Module 1: Random variables & Stochastic processes (9 hours)

Probability spaces, random variables and probability distributions, expectations, transforms and generating functions, convergence. Gaussian, Exponential, Poisson, Weibull, Cauchy, Laplace distributions, Time series models, AR, MA ARMA, ARMAX, Markov process. Non-parametric and parametric methods for modelling.Fuzzy and probability.

Module 2: Stochastic process and development of system models(10 hours)

Elements of the theory of stochastic processes, Gauss Markov sequence model, Gauss Markov Process model-Discrete and Continuous-time Markov Chains (MCs): Transition probability matrix, Chapman-Kolmogorov equations; n-step transition and limiting probabilities, ergodicity, stationarity, correlation-random walk Brownian motion: Wiener process as a limit of random walk, White noise-PRBS-optimal smoothing, filtering and prediction for continuous and discrete linear systems.

Module 3: Bayesian estimation and System identification (10 hours)

Maximum likelihood estimation, linear mean square estimation- Parameter estimation for Time series models, AR, MA ARMA, ARMAX-efficiency and bias of estimators- minimizing prediction errors-Instrumental variable method-consistency and identifiability-Recursive methods- Matrix inversion lemma-RLS Algorithm-Weighted RLS algorithm- -Modelling with orthogonal functions and transforms -feature extraction-introduction to big data analytics- system identification experiments- design of inputs for system identification-persistent excitation-open loop and closed loop system identification.

Module 4: System Identification &Kalman Filter (10 hours)

Wiener Filter- estimation problem-Wiener Hopf equation- realizability- stochastic state estimation problem- optimal filtering and prediction-derivation of Kalman filter-Extended Kalman Filter-Unscented Kalman Filter-Combined state and parameter estimation-System identification for control.

References:

1. Schoukens, Johan,RikPintelon,YvesRolain,*“Mastering System Identification in 100 Exercises”*, Wiley IEEE Press, 2012
2. LingfengWang,Kay Chen Tan, *“Modern Industrial Automation Software Design”* , Wiley IEEE Press, 2012
3. Ravindra V. Jategaonkar, *“Flight Vehicle System Identification: A Time-Domain Methodology”,* Second Edition, Aerospace Research Central, American Institute of Aeronautics & Astronautics, USA, 2015.
4. J S Meditch, *“Stochastic Optimal Linear Estimation and Control*”, McGraw Hill Book Company, 1969
5. Charles K Chui, Guanrong Chen, “*Kalman Filtering with Real time Applications*”, Springer, 2009.

EE6108D NONLINEAR SYSTEMS AND CONTROL

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Analyse nonlinear systems using classical techniques
CO2: Analyse stability of non linear systems using advanced techniques
CO3: Analyse nonlinear feedback systems using time and frequency domain techniques
CO4: Design controllers for nonlinear systems using advanced methods

Module 1: Introduction and classical techniques (10 hours)

Characteristics of nonlinear systems – examples of systems exhibiting nonlinear phenomena- second order nonlinear autonomous systems- vector field representation- classification of equilibrium points – qualitative behavior near equilibrium points- limit cycles – existence of periodic orbits- Poincare-Bendixon criterion- Poincare index of equilibrium points- stability of periodic solutions- analysis of systems with piecewise constant inputs using phase plane analysis-Jump response.

Module 2: Lyapunov Stabilty (10 hours)

Existence and uniqueness of solutions of nonlinear state equations- stability of nonlinear systems - Lyapunov stability - local linearization and stability in the small – Centre manifold theorem- Direct method of Lyapunov - generation of Lyapunov function for linear and nonlinear systems- Variable gradient method- La Salle's Invariance theorem – Input to state stability - L stability - L stability of state models-Small gain theorem- Passivity- Positive real transfer functions-L_2 and Lyapunov stability-Passivity theorems- Loop transformation.

Module 3: Time domain analysis of feedback systems and perturbation techniques (7 hours)

Absolute stability of feedback interconnections of a linear part and nonlinear part- Circle criterion- Popov criterion- Frequency theorem- Harmonic linearization- filter hypothesis- Describing function of standard nonlinearities- amplitude and frequency of limit cycle using SIDF.Pertubation techniques- Regular perturbation- Singular perturbation-Reduced model- boundary- layer model- Tikhonov's theorem- slow and fast manifolds.

Module 4: Nonlinear system design tools (12 hours)

Control problems- stabilization via linearization - integral control via linearization- Gain scheduling-Feedback linearization-stabilization and tracking via state feedback control. Sliding mode control-Regulation via integral control- Lyapunov redesign- stabilization and nonlinear damping-Backstepping-Passivity based control- High gain observers. Linear Quadratic Regulators/Linear Quadratic Guassian Regulators-Numerical Solution for Riccatti Equations.

References:

1. Hassan K Khalil, *'Nonlinear Systems'*, Prentice - Hall International (UK) 1996
2. Slotine& W.LI, *'Applied Nonlinear Control'*, Prentice Hall, EngelwoodNewJersey 1991
3. AIsidori, *'Nonlinear Control systems'* Springer verlag New york 1995
4. S. Wiggins, *'Introduction to Applied Nonlinear Dynamical Systems and chaos'*, Springer Verlag New York 1990
5. H. Nijmeijer& A.J. Van Der schaft, *'Nonlinear Dynamic control Systems'*, Springer Verlag Berlin 1990.
6. Arther E Gelb & Vender Velde, *'Multiple input Describing function and Nonlinear System Design'*, MC Graw Hill 1968
7. Z Vukic, L Kuljaca, *'Nonlinear Control Systems',* Marcel Dekker, Inc., Newyork.

EE6192D INSTRUMENTATION SYSTEMS LAB

Pre-requisite: Nil

L	T	P	C
0	0	2	1

Total hours: 26

Course Outcomes:

CO1: Apply practical knowledge of the working of transducer based instrumentation systems and their application to engineering problems.

CO2: Develop solutions for different experimental instrumentation systems and document the results.

CO3: Integrate and apply the understanding into real time instrumentation problems.

List of Experiments

A total of 10 experiments will be offered in the lab, each being of 2 hours duration. The experiments have been designed so as to facilitate the understanding of various instrumentation systems. The lists of experiments are as follows:

1. Experiments on Sensors and Transducers with feedback instrumentation kit.
2. Real time measurement and analysis of physical parameters using Sensor Cassy.
3. Experiments on the operation of various types of hydraulic valves.
4. Experiments on the working of Single and Double Acting hydraulic cylinders.
5. Experiments on the working of Rolling Mill Conveyor.
6. Experiments on the working of various types of pneumatic valves.
7. Experiments on Speed Control of Single and Double Acting pneumatic cylinders.
8. Experiments on pneumatic logic gates.
9. Experiments on Programmable Logic Controllers (PLC).
10. Experiments on Air and Temperature Control System.

References:

1. Ernest O. Doebelin: '*Measurement Systems: Application and Design'*, McGraw Hill International Editions, 1990.
2. K. B. Klaasen: '*Electronic Measurement and Instrumentation*, Cambridge University Press, 1996.
3. Curtis D. Johnson: '*Process Control Instrumentation Technology'*, Pearson Education Limited, 2014.
4. Bela G. Liptak: '*Process Control Instrument Engineer's Handbook'*, Butterworth-Heinemann, 1995.
5. Roy Needham: '*Hydraulics, Tutor Notes & Workbook',* Mechatronics International Ltd, 2001.
6. Roy Needham: '*Pneumatics, Tutor Notes & Workboo'k*, Mechatronics International Ltd, 2001.
7. Manual for Transducers Kit, Feedback.
8. Manual for Air and Temperature Control System.

EE7191D PROJECT – PART 1

Pre-requisite: Nil

L	T	P	C
0	0	20	10

Total hours: 260

Course Outcomes:

CO1: Identify a research topic in the area of control and instrumentation system, conduct literature survey, formulate the problem and conduct its feasibility study

CO2: Design and implement control techniques and instrumentation systems for the selected process/problem

CO3: Apply new tools and techniques for development of cost effective and environmental friendly designs in the area of instrumentation and control systems.

CO4: Write technical project report and effectively communicate through oral presentation and demonstrate the work done to an audience and publish the work in reputed conferences/journals.

Main Project will be done by the individual students normally in two semesters. Students are exposed to various topics in Instrumentation and Control Systems and allied areas and the recent developments through the class seminars so as to inculcate interest in these topics. Faculty members propose projects/broad area of work and student will be asked to meet the faculty member who is offering the project of interest for guidance. Student can also select the topic for the interdisciplinary project too after discussions with guide. Students can carry out their projects in R&D organizations/ industries which have facility in the proposed area with an officer from there as external guide and with internal guide from Department.

Students are required to undertake detailed technical work in the chosen area using one or more of the following: (i) Analytical models (ii) Computer simulations (iii) Hardware implementation. The assessment of the project will be done at the end of the semester by a committee consisting of three or four faculty members specialized in various fields of Electrical Engineering. The students will present their project work before the committee. The complete project report is not expected at the end this semester. However, a 30-40 page typed report based on the work done will have to be submitted by the students to the assessing committee. The Department level evaluation shall have 50% weight in the final grading-50% weight will be given to the assessment by the individual guide. Marks will be reported based on 100 as maximum. Result shall be finalized at the Department level.

EE7192D PROJECT – PART 2

Pre-requisite: EE7191D PROJECT – PART 1

L	T	P	C
0	0	28	14

Total hours: 364

Course Outcomes:

CO1: Develop comprehensive solution to issues identified in previous semester work and meet the requirements as stated in project proposal

CO2: Compile the results of the detailed analytical studies conducted and interpret the results for application to the instrumentation and control systems.

CO3: Summarise the results and effectively communicate the research contribution and publish in reputed Journals /Conferences.

EE7192D PROJECT – PART 2 is a continuation of EE7191D PROJECT – PART 1 in the third semester. Students should complete the work planned in the third semester, attaining all the objectives, and should prepare the project report of the complete work done in the two semesters. They are expected to communicate their research contributions in reputed conferences and/or journals. The project evaluation committee of the M. Tech programme shall assess the project work during the fourth semester in two stages. Two internal evaluations shall be conducted in the department level followed by final viva-voce examination by the committee including an external examiner. The mode of presentation, submission of the report, method of evaluation, award of grades etc will be decided by the project evaluation committee. The students shall submit both soft and hard copies (required number of copies) of project report in the prescribed format to the department and library after incorporating all the corrections and changes suggested by the project evaluation committee.

EE6121D DATA ACQUISITION AND SIGNAL CONDITIONING

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: **39**

Course Outcomes:

CO1: Explain characteristics of transducers and various signal conditioning techniques.

CO2: Design filters for signal conditioning.

CO3: Explain signal conversion (analog to digital and digital to analog) as well as transmission techniques

CO4: Describe various interfacing techniques and standards for communication between instruments

Module 1: Transducers & Signal Conditioning (10 hours)

Data Acquisition Systems (DAS)- Introduction . Objectives of DAS. Block Diagram Description of DAS-General configurations - Single and multichannel DAS-Transducers for the measurement of motion, force, pressure, flow, level, dc and ac voltages and currents (CTs, PTs for supply frequency as well as high frequency, Hall Effect Current Sensors, High Voltage Sensors , Opto-sensors, Rogowski Coil, Ampflex Sensors etc.) - Signal Conditioning: Requirements - Instrumentation amplifiers: Basic characteristics . Chopped and Modulated DC Amplifiers-Isolation amplifiers - Opto couplers - Buffer amplifiers .Noise Reduction Techniques in Signal Conditioning- Transmitters .Optical Fiber Based Signal Transmission-Piezoelectric Couplers- Intelligent transmitters.

Module 2: Filtering and Sampling (10 hours)

Review of Nyquist.s Sampling Theorem- Aliasing. Need for Prefiltering-First and second order filters - classification and types of filters - Low -pass, High-pass, Band-pass and Band-rejection and All Pass: Butterworth, Bessel, Chebyshev and Elliptic filters. Op-amp RC Circuits for Second Order Sections-Design of Higher Order Filters using second order sections using Butterworth Approximation-Narrow Bandpass and Notch Filters and their application in DAS. Sample and Hold Amplifiers

Module 3: Signal Conversion and Transmission (10 hours)

Analog-to-Digital Converters(ADC) -Multiplexers and demultiplexers - Digital multiplexer . A/D Conversion . Conversion Processes , Speed, Quantization Errors . Successive Approximation ADC . Dual Slope ADC . Flash ADC . Digital-to-Analog Conversion (DAC) . Techniques, Speed, Conversion Errors, Post Filtering- Weighted Resistor, R-2R, Weighted Current type of DACs- Multiplying Type DAC-Bipolar DACs- Data transmission systems-Schmitt Trigger-Pulse code formats- Modulation techniques and systems-Telemetry systems.

Module 4: Digital Signal Transmission And Interfacing (9 hours)

DAS Boards- Introduction. Study of a representative DAS Board-Interfacing Issues with DAS Boards, I/O vs Memory Addressing, Software Drivers, Virtual Instruments, Modular Programming Techniques for Robust Systems, Bus standard for communication between instruments - GPIB (IEEE-488bus) - RS-232C-USB-4-to-20mA current loop serial communication systems.Communication via parallel port . Interrupt-based Data Acquisition.Software Design Strategies-Hardware Vs Software Interrupts-Foreground/ background Programming Techniques- Limitations of Polling . Circular Queues

References:

1. Ernest O Doeblin., *'Measurement Systems: Application and Design',* McGraw Hill (Int. edition) 1990
2. George C.Barney, *'Intelligent Instrumentation'*, Prentice Hall of India Pvt Ltd., New Delhi, 1988.
3. Ibrahim, K.E., *'Instruments and Automatic Test Equipment*', Longman Scientific & Technical Group Ltd., UK, 1988.

4. John Uffrenbeck, *'The 80x86 Family ,Design, Programming, And Interfacing*', Pearson Education , Asia, 2002
5. Bates Paul, *'Practical digital and Data Communications with LSI*', Prentice Hall of India, 1987.
6. G.B. Clayton, *'Operational Amplifiers*', Butterworth &Co, 1992
7. A.K Ray, *'Advanced Microprocessors and Peripherals*', Tata McGrawHill, 1991
8. Oliver Cage, *'Electronic Measurements and Instrumentation'.*, McGraw-Hill, (Int. edition) 1975

EE6122D BIOMEDICAL INSTRUMENTATION

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course outcomes

CO1: State and recognize the practical problems faced in objective analyses of biomedical signals.
CO2: Describe and interpret the various mathematical techniques involved in biomedical signal processing
CO3: Illustrate and examine the characteristics of signals like EEG and apply the signal processing techniques to obtain the medically significant information from the signals concerned.
CO4: Analyze and infer the entities associated with bio-signals.
CO5: Evaluate and conclude the medically significant information obtained from the task of biomedical signal processing.

Module 1: (10hours)

Fundamentals of medical instrumentation – physiological systems of body –regulation of medical devices– origin of bio potentials – Sodium –Potassium pump –Goldman Hodgkin – Katz equation – biomedicaltransducers – electrode-electrolyte interface – half cell potential – ECG – 12 lead systems – heart rate variability – cardiac pacemakers – defibrillators - EMG – EEG

Module 2: (10 hours)

Measurement of cardiac output – indicator dilution method – ultrasonic blood flow meter – electromagnetic blood flow meter – blood pressure measurement – oximetry – ear oximeter – pulseoximeter –skin reflectance oximeter -measurement on pulmonary system – spirometry – pulmonaryfunction analyzers –ventilators

Module 3: (9 hours)

Lasers in medicine – Argon laser – Carbon dioxide laser -laser safety –X ray applications –X-ray machine– dental X-ray machine – ultrasound in medicine –electro therapy – hemodialysis –artificial kidney –dialyzers –membranes for hemodialysis.

Module 4: (10 hours)

Measurement of pH, pCO_2, pO_2 - radiotherapy– audiometry - electrical safety in hospitals.
Introduction to Biomedical signals, Characteristics of bio medical signals, bio signal acquisition, Artifacts, Fourier transform and Time-frequency analysis of biomedical signals.

References:

1. Geddes & Baker, "*Principles of applied biomedical instrumentation*" Wiley Inter science, 3rd edition,1975
2. R S Khandpur, *"Hand book of biomedical instrumentation*", TMH,4th edition, 1987
3. Cromwell Leslie, *"Biomedical instrumentation and measurements"*, PHI, 1980
4. Brown Carr, *"Introduction to Biomedical equipment technology"*, Prentice Hall, 1981
5. John Enderle, *"Introduction to Biomedical Engineering"*, Academic Press, 2005
6. Joseph D Bronzino, *"Biomedical engineering hand book"*, CRC Press, 2000
7. MetinAkay (editor), *"Wiley encyclopedia of biomedical Engineering*", Wiley, 2003
8. E.N.Bruce, *"Biomedical Signal Processing & Signal Modeling*", Wiley, 2001
9. L.Sörnmo, P Laguna, *"Bioelectrical Signal Processing in Cardiac & Neurological Applications",* Elsevier, 2005.
10. R.M.Rangayyan, *"Biomedical Signal Analysis:A case study approach*", IEEE Press and Wiley 2002.

11. Semmlow, Marcel Dekker, *"Biosignal and Biomedical Image Processing*", 2004
12. Enderle, *"Introduction to Biomedical Engineering"*, 2/e, Elsevier, 2005
13. D.C.Reddy , *"Biomedical Signal Processing: Principles and techniques*", Tata McGraw Hill, New Delhi, 2005
14. A. Cohen, *"Biomedical Signal Processing",* Vol. I and II, CRC, Boca Raton, FL, 1986
15. W. J. Tompkins (Editor), "*Biomedical Digital Signal Processing*", Prentice Hall, 1995
16. S. R. Devasahayam, "*Signals and Systems in Biomedical Engineering: Signal Processing and Physiological Systems Modeling"*, Kluwer Academic/ Plenum, New York, NY, 2000

EE6123D PERFORMANCE MODELLING OF SYSTEMS I

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: **39**

Course outcomes:

CO1: Explain the general operational characteristics and frequency response characteristics of instruments.
CO2: Describe different operations involved in set theory
CO3: Describe different components involved in general graph theory
CO4: Design petrinet and S-net graphs using active graph theory

Module 1: General Operational Characteristics (10 hours)

Input-Output configuration of measuring systems . Static characteristics . Dynamic characteristics . Mathematical models . General concepts of transfer functions . Classification of instruments based on their order .dynamic response . frequency response studies.

Module 2: General Concepts in Set Theory (10 hours)

Preliminaries.Basic set theory.Terminology.Functions . Relations - Combinatorics . Theory of counting-Multiplication rule- Ordered samples and permutations-Ordered samples with and without repetitions.-Brief theory of bags .

Module 3: General Graph Theory (10 hours)

Graphs and algorithms . Concepts of Nodes and Arcs- Trees . Spanning of trees .Minimal spanning trees; Prime.s algorithm- Binary trees and tree searching- Planar graphs and Euler.s theorem- Cut sets .Adjacency /incidence matrices . Graph having multiple edges . Determination of Euler cycles- The shortest path problem.

Module 4: Active Graph Theory (9 hours)

Performance models .Petrinet graph- Concepts of places .Transitions . Arcs and Tokens .Concurrency and conflict- Deadlocks - Markings- Reachability sets-Matrx equations- Reachability problems- Popular extensions . S-Nets .Introduction to Petrinet and S Net Models.

References:

1. Ernest O Doeblin., *'Measurement Systems: Application and Design',* McGraw Hill (Int. edition) 1990
2. Oliver and Cage, *'Electronic measurements and Instrumentation*' , McGraw Hill Int. Editions, 1971
3. C.L. Liu, *'Elements of Discrete Mathematics*', McGraw Hill Int. Editions, 1985.
4. Robert J. McEliece, Robert B Ash, Carol Ash, *'Introduction to Discrete Mathematics*', McGraw Hill Int. Editions, 1989.
5. J.L. Peterson., *'Petrinet Theory and Modelling of Systems'*, Prentice Hall Inc., Englewood Cliffs, N.J., 1981.
6. John O. Moody ,Panos J Antsaklis, *'Supervisory Control of Discrete Event System Using Petrinets',* Kluwer academic Publishers Boston/Dordrecht/ London, 1998.
7. N. Viswanathan, Y. Narahari, *'Performance Modelling of Automated Manufacturing Systems*' , Prentice Hall of India Pvt. Ltd., New Delhi,1994.
8. Proceedings : '*Conference on Advances in Computing CAD CAM 98'*, Allied Publishers Ltd., New Delhi, India, 1999

EE6124D PERFORMANCE MODELLING OF SYSTEMS II

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: **39**

Course Outcomes
CO1: Describe modeling philosophies of different systems.
CO2: Explain tools such as petrinet and S-net for performance modelling of systems
CO3: Develop model of automated manufacturing systems using active graphical modelling tools.
CO4: Illustrate popular extensions of petrinet and S-net theory and different case studies.

Module 1: Modelling Philosophies (10 hours)

Modelling philosophies.Rationales for mathematical modeling. Dynamic versus steady state models . General modelling principles . Degrees of freedom in modelling Transfer function models .Procedure for developing transfer function models.

Module 2: Modelling Tools and Applied Systems (10 hours)

Performance modelling . Modelling of automated manufacturing systems . Role of performance modelling . Performance measures .Petrinetmodels . Introduction to Petrinet . Basic definitions and analytical techniques . S-Net models . Preliminary definitions and analytical technique

Module 3: Active Graphical Modelling Tools (10 hours)

Modelling with active graph theory . General concepts . Events and conditions .Synchronisation . Mutual exclusion problems . Standard Problems - Dining philosophers problems . Readers/ writers problems .

Module 4: Analysis of Modelling Tools (9 hours)

Analysis problems of active graph .Petrinets . S-Nets . Their popular extensions . Different case studies of Petrinet and S-Net models related to super computer pipe line . Flexible manufacturing systems . Computer communication system . Computer controlled data acquisition system- computer communication network .Process control systems.

References:

1. Ernest O Doeblin., *'Measurement Systems: Application and Design'*, McGraw Hill (Int. edition) 1990
2. Oliver and Cage, *'Electronic measurements and Instrumentation'* , McGraw Hill Int. Editions, 1971
3. C.L. Liu, *'Elements of Discrete Mathematics'*, McGraw Hill Int. Editions, 1985.
4. Robert J. McEliece, Robert B Ash, Carol Ash , *'Introduction to Discrete Mathematics'*, McGraw Hill Int. Editions, 1989.
5. J.L. Peterson., *'Petrinet Theory and Modelling of Systems'* , Prentice Hall Inc., Englewood Cliffs, N.J ., 1981.
6. John O. Moody, Panos J Antsaklis, *'Supervisory Control of Discrete Event System Using Petrinets'*, Kluwer academic Publishers Boston/Dordrecht/ London, 1998.
7. N. Viswanathan, Y. Narahari, *'Performance Modelling of Automated Manufacturing Systems'*, Prentice Hall of India Pvt. Ltd., New Delhi,1994.
8. Proceedings : '*Conference on Advances in Computing CAD CAM 98'* , Allied Publishers Ltd., New Delhi, India, 1999
9. Seborg, *'Process dynamic control'*, Wiley, 2007

EE6125D ADAPTIVE CONTROL THEORY

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Integrate the concepts of norms and spaces to be applied in adaptive control theory
CO2: Apply identification techniques for design of adaptive controller
CO3: Explain direct and indirect adaptive control techniques
CO4: Describe advanced adaptive control methods along with case studies and computer simulations

Module 1: Preliminaries (10 Hours)

Norms and Lp spaces-positive definite matrices-input –output stability-Lp stability-small gain theorem-Positive real functions and stability-Analysis of Dynamical Systems ,Analysis of Solutions to Differential Equations., Equilibria and Stability. Invariant Sets. Lyapunov Stability Theory and Performance Analysis.,Nonautonomous Systems., LaSalle Extensions, Barbalat Lemma. Basic approaches to adaptive control -Applications of adaptive control. Introduction to types of Adaptive Control-Model Reference-Variable Structure-Sliding Mode- Neuro-Fuzzy-Learning Control-Intelligent Control using schematic diagrams and literature survey.

Module 2: Identification (10 hours)

Identification problem- Identification of linear time-invariant systems.Adaptive observers.Sufficient richness condition for parameter convergence. Equation error and output error methodsGradient *and* least-squaresalgorithms: Linear error equation. Gradient and normalized gradient algorithms. Least-squares algorithms (batch, recursive, recursive with forgetting factor). Convergence properties.Identification for Control.
Frequency-domain analysis and averaging approximations: Averaging of signals. Averaging theory for one-time scale and two-time scale systems.Applications to adaptive systems.

Module 3: Model Reference Adaptive Control (10 hours)

Indirect adaptive control: Pole placement adaptive control. Model reference adaptive control.Predictive control.Singularity regions and methods to avoid them.
Direct adaptive control: Filtered linear error equation. Gradient and pseudo-gradient algorithms.Strictly positive real transfer functions and Kalman-Yacubovitch-Popov lemma.Lyapunov redesign.Passivity theory. Direct model reference adaptive control. One case study of MRAC and computer based design.

Module 4: Methods in Adaptive Control (9 hours)

Adaptive Backstepping.,Adaptive Output Feedback Control, Adaptive NeuroControl., Examples of Adaptive Control.One case study and computer simulation.

References:

1. K.J. Astrom and B. Wittenmark, '*Adaptive Control',* Addison-Wesley, 2nd edition, 1995.
2. P.A. Ioannou& J. Sun, '*Robust Adaptive Control'*, Prentice Hall, Upper Saddle River, NJ, 1996..
3. I.D. Landau, R. Lozano, and M. M'Saad, '*Adaptive Control'*, Springer Verlag, London, 1998.
4. K.S. Narendra and A.M. Annaswamy, '*Stable Adaptive Systems'*, Prentice-Hall, 1989.
5. S. Sastry and M. Bodson*, 'Adaptive Control: Stability, Convergence, and Robustness'*, Prentice-Hall, 1989.

EE6126D ADVANCED TOPICS IN CONTROL SYSTEMS

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: **39**

Course Outcomes
CO1: Apply the concepts of fuzzy and neuro-fuzzy systems in various control engineering problems
CO2: explain the characteristics of MIMO systems and design MIMO controllers
CO3: Integrate the knowledge of chaotic systems in control and physiological systems
CO4: Design and analyse variable structure systems

Module 1: Neuro-Fuzzy Modelling and Control of Systems (10 hours)

Fuzzy Models- Mamdani and Takagi Sugeno Models- Construction of fuzzy models . Neural networks .
Adaptive networks .supervised learning . Adaptive neuro-fuzzy inference systems- ANFIS architecture- ANFIS as a universal approximator - Simulation examples.

Module 2: Linear Multi-Input-Multi-Output Control Systems (10 hours)

Representations of MIMO systems- Equivalent transformations- Canonical forms- Solution of state equations- System response - Controllability and pole allocation- Observability and state estimator- System characterization by transfer matrix- Noninteractive and model matching control design.

Module 3: Chaos, fractals, applications and Aerospace Guidance Systems (10 hours)

Non linearsystems .chaos .fractals .dimensions .attractors .Lorenz attractor . Mandelbrot set, bifurcations,synthesis of some chaotic systems using neural net work. some control applications. fractals and chaos in medicine and physiology .
Introduction .trajectory aspects . inertial and optical sensors . inertial guidance for cruise vehicles, guidance and control of rocket vehicles . guidance and control of mobile-launched ballistic missiles.

Module 4: Variable Structure Systems (9 hours)

Introduction . Variable Structure Systems (VSS) . VSS for fast response . VSS for stability . VSS with sliding mode . Sliding mode motion . Existence Condition - Second order control problem . Sliding mode motion on switching line . Sliding mode motion on switching surface . Design of stable switching surface . Invariance Conditions in VSS . Variable structure model following control (VSMFC)

References

1. Robert Babuska :*'Fuzzy Modelling and Control'* - . International Series in Intelligent Technologies, Kluwer Academic Publications . 1998
2. Jang J SR ,Sun C T, Mizutani E : *'Neuro-fuzzy and Soft Computing . MATLAB curriculum Series*', Prentice Hall International, 1997
3. Apte Y.S., *'Linear Multivariable Control Theory*', Tata McGraw Hill Publishing Co. Ltd., 1994.
4. Chen C.T., '*Linear System Theory and Design*', Holt Reinhart and Winston Inc., 1984
5. Wolovich W.A., *'Linear Multivariable Systems*', Springer- Verlag , New york- Heidelberg- Berlin, 1974.
6. Thomas Kailath, *'Linear Systems*', Prentice Hall Inc., Englewood Cliffs, N.J. , 1980
7. Leondis C T .*'guidance and Control of Aerospace Vehicles*' . McGraw Hill Book Company Inc New York 1963
8. U. Itkis .*'Control Systems of variable structure*', New York, Wiley, 1976
9. A.S.I. Zinober (Edited by) – *'Deterministic Control of Uncertain Systems*', British Library Cataloguing in Publication Data, Peter Peregrinus Ltd. 1990
10. B. Drazenovic .*'The invariance conditions in variable structure systems*', Automatica, Vol. 5, pp 287-295, 1969.

11. K.K.D. Young .*'Design of Variable Structure Model Following Control Systems*', IEEE Transactions on Automatic Control, Vol. 23, pp-1079-1085 – 1978
12. A.S.I. Zinobar, O.M.E. El-Ghezawi and S.A.Billings – *'Multivariable variable structure adaptive model following control systems*' . Proc. IEE., Vol. 129., Pt. D., No.1, pp-6-12, 1982

EE6127D OPTIMAL ESTIMATION AND FILTERING

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: **39**

Course Outcomes
CO1: Integrate the concepts of random variables and processes for optimal estimation and filtering
CO2: Design linear optimal filters and predictors
CO3: Design smoothers and develop implementation algorithms
CO4: Design nonlinear filters by incorporating practical aspects

Module 1: Random Process and Stochastic Systems (10 hours)

Probability and random variables – statistical properties of random variables and random processes – linear random process models – shaping filters and state augmentation – mean and covariance propagation – relationship with model parameters – orthogonality principle

Module 2: Linear Optimal Filters and Predictors (10 hours)

Kalman filter – KalmanBucy Filter – Optimal linear predictors – Correlated noise sources – relation between KalmanBucy and winer filters- Quadratic loss function – Matrix Riccati differential equation and in discrete time – model equations for transformed variables – Application of Kalman filters

Module 3: Optimal Smoothers & Implementation Methods (10 hours)

Fixed Interval, fixed lag and fixed point smoothers – algorithms . Computer round off –effect of round off errors on Kalman filters- factorization methods for square root filtering – square root UD filters – other implementation methods

Module 4: Nonlinear Filtering & Practical Considerations (9 hours)

Quasi-linear filtering —extended Kalman filers – iterated EKF - sampling methods for nonlinear filtering-Detecting and correcting anomalies – bad data and missing data – stability of Kalman filters – Suboptimal- and reduced order filters – Memory throughput. Word length considerations - computational efforts – reduction – Error budgets and sensitivity analysis – optimizing measurement selection policies

References

1. Mohinder S Grewal and angus P Andrews, *'Kalman Filtering Theory and Practice Using MATLAB ',* John Wiley and Sons , 2008
2. B D O Anderson, John B Moore , *'Optimal Filtering'* , Prentice Hall Inc. 1979
3. Meditch J S, *'Stochastic Optimal Estimation and Control*', 1982

EE6128D VARIABLE STRUCTURE CONTROL SYSTEMS

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: **39**

Course Outcomes

CO1: Design stable systems from unstable structures and simulate using MATLAB
CO2: Design sliding mode controllers and simulate using MATLB
CO3: Design stable switching surfaces for higher order systems and devise chattering reduction techniques.
CO4: Design variable structure model following control systems

Module 1: (10 hours)

Variable Structure Systems(VSS)-Introduction- Synthesis of stable systems from unstable structures-VSS for improving speed of response,-VSS for stability- simulation using MATLAB®-Simulation using SIMULINK®.

Module 2: (10 hours)

Variable structure systems with sliding mode- sliding mode motion- existence condition- equivalent control for sliding mode motion- sliding mode motion on switching line- Invariance conditions- Design of sliding mode controllers using feedback linearisation for non-linear systems- simulation of sliding mode controller using Matlab and simulink.

Module 3: (10 hours)

Sliding mode motion on switching surface- design of stable switching surfaces- design of sliding mode controller for higher order systems- Sliding mode controller design for a robotic manipulator- Chattering-Chattering reduction techniques.

Module 4: (9 hours)

Variable Structure Model Following Control (VSMFC) Systems- Conditions for perfect model following-sliding mode equivalent control- Sliding mode discontinuous control- Design of VSMFC for second order system- Design of VSMFC for higher order systems- Simulation using MATLAB and SIMULINK.

References:

1. U Itkis, *'Control Systems of Variable Structure*, New York,Wiley, 1976.
2. A S I Zinober, *'Deterministic Control of Uncertain Systems.*', British Library, 1990
3. B. Drazenovic, *'The invariance conditions in variable structure systems,*' Automatica., Vol. 5, pp 287 . 295, 1969.
4. K.K.D.Young, *'Design of Variable Structure Model Following Control Systems*'., IEEE Transactions on Automatic Control, Vol. 23, pp 1079-1085, 1978.
5. A.S.I. Zinobar, O.M.E. El-Ghezawi and S.A. Billings,*'Multivariable variable structure adaptive model following control system',*. Proc. IEE., Vol. 129, Pt.D., No.1, pp 6-12, 1982.
6. J.J. Slotine and S.S. Sastry, *'Tracking control of non-linear systems using sliding surfaces, with application to robot manipulators*'. International Journal of Control, 1983, Vol. 38, No.2, pp 465-492.
7. Vadim I. Utkin, *'Variable Structure Systems with Sliding Modes*'. IEEE Transactions on Automatic Control, April 1977, pp 212-222.

EE6129D LARGE SCALE SYSTEMS

Pre-requisites: Nil

L	T	P	C
3	1	0	3

Total hours: 39

Course Outcomes:

CO1: Summarize and apply the concept of modelling and analysis of Large Scale Systems.
CO2: Analyse and design control for the Large Scale Systems issues.
CO3: Summarize and apply the concept of Modal Analysis and- Aggregation Methods for Model r Reduction for reduction and control of Large Scale Systems.
CO4: Summarize and apply the concept of Frequency Domain and Norm Based Methods for Model Reduction for reduction of Large Scale Systems.

Module 1: Modelling (10 Hours)

Modelling Large Scale Systems- interacting subsystems exchanging matter, energy, or information with the environment-Lumped-distributed-time varying systems-Ordinary Differential Equation Modelling-Differential Algebraic Equations- Linearization- determination of Jacobian- Difference Equations-Basics for analysis of systems-Singular Values- Order and Dimension-State Space-Parameter Space-Vector space-norms-2 norm-Hankel matrices-Sparsity-Modelling power systems-Microgrids-Thermal systems-tall buildings-flexible structures- Fractional order & integer order modelling

Module 2: Stability & Control (10 Hours)

Stability & Control of Large Scale Systems Controllability-Observability- grammians-computation-vector Lyapunov function methods, vector dissipativity theory, and decentralized control architectures. - continuous-time, discrete-time, and hybrid large-scale systems. - finite-time stability and finite-time decentralized stabilization, thermodynamic modeling, maximum entropy control, and energy-based decentralized control.

Module 3: Model Order Reduction and Control: Modal Analysis and- Aggregation Methods (9 Hours)

Modal Analysis: Reduced Order Model Using Davison, Chidambara and Marshall Techniques, Suboptimal Control Using Davison and Chidambara Models, Control Law Reduction Approach Using Davison Model and Chidambara Models, Choice of Reduced Model Order.
Aggregation Methods*:* Aggregation of Control Systems Determination and Properties of Aggregated System Matrix, Error in Aggregation, Modal Aggregation- Reduced Order Model Stability of Feedback System, Aggregation by Continued Fraction.

Module 4: Model Order Reduction: Frequency Domain and Norm Based Methods (10 Hours)

Frequency Domain Methods: Moment Matching, Pade' Approximation Methods, Routh Approximation Techniques, Continued Fraction Method.
Norm Based Methods :Norms of Vectors and Matrices, Singular Value Decomposition, Grammian Matrices and Hankel Singular Values , Matrix Inversion Formulae, Model Reduction by Balanced Truncation, Balanced Realization, Steady State Matching Reduction of Unstable Systems, Properties of Truncated Systems Frequency-Weighted Balanced Model Reduction Model Reduction by Impulse/Step Error Minimization, Optimal Model Order Reduction

Reference:

1. Mohammad Jamshidi, "*Large-scale systems: modelling control and fuzzy logic*", Prentice Hall, 1997.
2. Jan Lunze, "*Feedback control of large scale systems*" ,Prentice-Hall, 1992.
3. Jose B. Cruz, "*Advances in Large Scale Systems: Theory and Applications',* JAI Press, 1984
4. Richard Saeks,"*Large-scale Dynamical Systems*" Point Lobos Press, 1976
5. Andrew P. Sage, "*Methodology for large-scale systems*", McGraw-Hill, 1977

6. *Efficient Modeling and Control of Large-Scale Systems*, edited by Javad Mohammadpour, and Karolos M., Springer, 2010.
7. M. *JAMSHIDI, Large-Scale Systems - Modeling and Control*, Elsevier North- *Holland*, New York, NY, 1983.
8. L. Fortuna, G. Nunnari and A. Gallo, "*Model Order Reduction Techniques with Applications in Electrical Engineering*", Springer-Verlag London, 1992.
9. Dr. S. Janardhanan, "*Model Order Reduction and Controller Design Techniques*".

EE6130D QUANTITATIVE FEEDBACK THEORY

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Explain the basics of QFT
CO2: Design QFT controller for SISO and MISO LTIV systems
CO3: Design QFT controller for MIMO LTIV systems
CO4: Apply discrete quantitative technique for MISO Systems

Module 1: Introduction to QFT (7 Hours)

Review of conventional control theory and introductory S-S theory- Need for QFT- QFT design objective- QFT basics- QFT design- Benefits of QFT- QFT applications

Module 2: QFT design for SISO and MISO LTIV systems (12 hours)

Basics of SISO feedback controlled systems- Basic frequency domain characteristics- closed loop specifications- Performance limitations of NMP or unstable systems- Loop shaping- Synthesis of LTI controllers for MISO LTI Plants- one DoF system-Two DoF system

Module 3: QFT design for MIMO LTIV systems (10 hours)

Specifications of desired closed loop performance measures- Representation of MIMO plants as SISO and MISO plants- One degree of freedom feedback system- Two DOF feedback system- Minimum phase diagonal elements- formulation using LFT notation- Sensitivity reduction and trade off non-minimum phase feedback systems.

Module 4: Discrete quantitative feedback technique (10 hours)

Bilinear transformation- Discrete MISO module with plant uncertainty- QFT W domain digitization design- Basic design procedure for a MISO sample data control system- QFT technique pseudo continuous time system- Digital controller implementation

References:

1. C.H. Houpis, S.I. Raslussen,*'Quantitative Feedback Theory: Fundamentals and applications'*, Marcel Dekker, 1999.
2. O. Yanid, *'Quantitative Feedback Design of Linear and Nonlinear Control Systems'*, Kluwer Academic, Boston, 1999
3. I.M. Horowitz,*'Quantitative Feedback Theory'*, Vol 1, Colorado Press, Boulder, Colorado , 1993
4. M. Gopal,*'Digital Control and State Variable Methods'*, Tata McGraw- Hill publishing company Ltd., 2nd Ed., 2003
5. K.Ogata, *'Discrete-time Control Systems'*, Pearson Education Ltd., Singapore, 2ndEdn. ,2002.

EE6131D MULTIVARIABLE CONTROL SYSTEMS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Develop mathematical models of multivariable systems

CO2: Analyse stability of multivariable feedback control systems

CO3: Design controllers for multivariable systems

CO4: Develop realization and synthesis techniques for multivariable systems

Module 1: Modeling of multivariable system (10 Hours)

Dynamic models of typical multivariable systems- Linear models and deviation variables-Linearization of nonlinear models-interacting and non-interacting systems- examples-multivariable transfer functions-poles and zeros-Smith and Smith McMillan forms- Relations between poles, zeros and eigen values of system matrix- pole vectors and directions- zero directions- FaddeevLeverrier Algorithm-Review of vector spaces-Quadratic form-sign definiteness-Sylvester's criterion- Norms , induced and infinity norms.

Module 2: Stability of multivariable feedback control systems (10 hours)

Closed loop stability- Well-posedness of feedback loop- internal stability- The Nyquist stability criterion-coprime factorization over stable transfer functions- stabilizing controllers- strong and simultaneous stabilization- controllability- observability- controllability and observability Gramians- Eigenvalue sensitivity-output controllability- stabilizability- detectability-parameterization of all stabilizing compensators- simultaneous stabilization

Module 3: Multivariable control system design (10 hours)

Performance specification in multivariable systems and their limitations- state feedback design-sequential loop closing- Output feedback design-characteristic locus method- PI controller for MIMO systems- internal model control(IMC)- IMC based PID controller- Decoupling- Diagonal controller-Nyquist array method-Exact model matching- approximate model matching

Module 4: Realization and synthesis of multivariable systems (9 hours)

S-S Realization of external descriptions-existence and minimality of realization- Realizations in controller/ observer form and using singular value decomposition- systems represented by polynomial matrix descriptions- Diophantine equation- Two degrees of freedom feedback controllers- controller implementation configurations.

References:

1. P.J. Antsaklis, A.N. Michel ,'*Linear Systems'*, McGraw-Hill International Editions, 1998.
2. Thomas Kailath*, 'Linear Systems'*, Prentice-Hall, 1980
3. M. Vidyasagar,*'Control system synthesis: A factorization approach'*, The MIT Press, 1985
4. S. Skogestad, Ian Postlethwaite, *'Multivariable feedback control: Analysis and design'* Wiley Publications, 2nd Ed., 2007
5. B.W. Bequette, *'Process control Modeling, Design and simulation'* , PHI Learning Pvt. Ltd,2013
6. C.A. Smith, A.B. Corripio, *'Principles and practice of automatic process control'* , John Wiley and sons Inc, 2nd Ed., 1997
7. B.A. Ogunnaike, W.Harmon Ray, *' Process dynamics, modeling and control',* Oxford University press, 1994
8. JM Maciejowski, *'Multivariable feedback design'*, Addison Wesley publishing company, 1989
9. Chi-Tsong Chen, *'Linear system theory and design',* Oxford University Press, 4thEdn., 1993.
10. Y S Apte, *'Linear Multi-Input-Output control',* New Age International Ltd,1996
11. W.A. Wolovich, *'Linear Multivariable Systems',* Springer- Verlag New York ,1974

EE6132D NUMERICAL METHODS FOR CONTROL SYSTEM DESIGN

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Explain the advanced topics of matrices in linear algebra
CO2: Explain the numerical methods linear algebra for system analysis
CO3: Apply numerical methods for control system analysis
CO4: Choose suitable numerical methods for control system design
CO5: Develop simulations on computer for control system studies

Module 1: (10 Hours)

Review of Linear Algebra: Vector spaces, Orthogonality, Matrices, Vector and Matrix Norms, Kronecker Product. Moore Penrose Inverse, Matrix Inversion Lemma, Recursive Algorithm- Large scale Matrix computations-Rank-Condition Number-Singular Values, Similarity Transformations, rotations-Hermitian matrices, Toeplitz matrix, some selected software and computer based exercises.

Module 2: (10 Hours)

Numerical Linear Algebra: Floating point numbers and errors in computations, Conditioning, Efficiency, Stability, and Accuracy, LU Factorization, Numerical solution of the Linear system Ax = b, QR factorization, Orthogonal projections, Least Squares problem, Singular Value Decomposition, Canonical forms obtained via orthogonal transformations, Heissenberg reduction of a matrix, sparse matrices, computations with sparse matrices, error analysis in various cases

Module 3: (10 Hours)

Control Systems Analysis: Linear State-space models and solutions of the state equations-Continuous time systems, discrete time systems- frequency response calculations- Controllability, Observability, Numerical Methods for Controllability and Observability, Difficulties with Theoretical Criteria, Stability, Inertia, and Robust Stability, Numerical solutions and conditioning of Lyapunov and Sylvester equations.

Module 4: (9 Hours)

Control Systems Design: Feedback stabilization, Eigenvalue assignment, Optimal Control, Quadratic optimization problems, Algebraic Riccati equations, Numerical Methods for State Feedback Stabilization, Eigenvalue Assignment (Pole-Placement) in both SISO and MIMO systems, Optimal Control via Riccati Equation- numerical solutions, H-infinity Control algorithms, Observer designs, State estimation and Kalman filter algorithms for discrete time state and parameter estimation problems. Computer based simulation of selected control systems.

References:

1. G. Strang, '*Introduction to Linear Algebra*', (5^{th} Ed), SIAM, USA, 2016
2. B.N. Datta, '*Numerical Methods for Linear Control Systems*', Elsevier Academic Press, 2005.
3. G.H. Golub & C.F. Van Loan, '*Matrix Computations*', (4^{th} Ed), John Hopkins University Press, 2012
4. J .H. Wilkinson, '*The Eigenvalue Problem*', Oxford University Press, 1992.
5. G Meurant, '*Computer Solution of Large Linear Systems*', Elsevier, North Holland, 2005
6. John Dorsey, '*Continuous and Discrete Control Systems*', McGrawHill, 2002
7. Mariano Martin Martin, *'Introduction to Software for Chemical Engineers*', CRC Press, 2015
8. Warren F Phillips, '*Mechanics of Flight*'(2^{nd} Ed), John Wiley & Sons, 2010

EE6133D FLIGHT CONTROL SYSTEMS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Integrate various concepts of aerodynamic systems for developing mathematical models
CO2: Classify aerospace vehicles and analyse aircraft dynamics
CO3: Analyse aerodynamics of helicopter flights
CO4: Integrate the various aspects of astrodynamics

Module 1: (8 Hours)

Aerodynamics-standard atmosphere-layers of atmosphere-Aerodynamic flows-Mach number-Reynolds number-Airfoils-airfoil nomenclature-generation of lift-lifting surfaces-wings-wing geometry-aspect ratio-chord line –angle of attack-Aerodynamic coefficients-lift, drag and moment coefficients-variation with angle of attack-aerodynamic centre and centre of pressure-Wind tunnels-control surfaces-elevator-aileron-rudder-canard-tail plane-loads on tail plane dihedral angle-dihedral effect-flaps-slots-spoilers. Earth, Body and Inertial Coordinates and basics of Reference frame transformations using 3D rotation matrices for rigid body. Degrees of freedom and mathematical methods for modelling the dynamics of motion of rigid bodies with six degrees of freedom.

Module 2: (10 hours)

Classification of aerospace vehicles-aircrafts-helicopters-launch vehicles-missiles-unmanned aerial vehicles and spacecraft.Equation of motion of aircraft-level, un-accelerated flight-take-off performance-landing performance.Aircraft Stability and Control - Longitudinal and lateral dynamics- stability -modes of motion-stability derivatives. Aircraft transfer functions-control surface actuator - autopilot - stability augmentation.

Module 3: (11 hours)

Introduction to helicopter flight-rotor aerodynamics-configuration-operation-vertical flight-disc loading and power loading- induced flow ratio Climb and Descent- Forward flight- Blade Element Analysis – Momentum theory-Type of rotors-flapping hinge-lead lag hinge- flapping angle. Helicopter performance-hovering and axial climb- forward flight performance-reverse flow.Stability and control- longitudinal and lateral dynamics- flying qualities.

Module 4: (10 hours)

Introduction to astrodynamics- fundamental of orbital Mechanics- orbital parameters- N body problem – two body problem- Different types of orbits- orbital transfer and rendezvous – space flight - space vehicle trajectories.Re- entry of space vehicles- re-entry dynamics. Attitude control of satellite-stabilization of satellites

References:

1. John D Anderson Jr, *'Introduction to Flight'* McGraw Hill International, 5/e,2005.
2. John D Anderson Jr, *'Fundamentals of Aerodynamics'*, Me Graw Hill International, 4/e, 2007.
3. Bernard Etkin, *'Dynamics of flight Stability and Control'*, John Wiley and Sons Inc. 3/e, 1996.
4. Wayne Johnson, *'Helicopter Theory'*, Dover Publications Inc., New York, Second Edition, 1994.
5. J. Gordon Leishman, *'Principles of Helicopter Aerodynamics'*, Cambridge University Press, Second Edition. 2006.
6. Roger R. Bate, *'Fundamentals of Astrodynamics'*, Dover Publications Inc., New York, 1971.
7. Marshall H. Kaplan, *'Modern Spacecrafts Dynamics and Control'*, John Wiley & Sons.
8. George M. Siouris, *'Missile Guidance and Control Systems'*, Springer Verlag , New York Inc., 2004.

EE6134D NETWORKED CONTROL AND MULTIAGENT SYSTEMS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Integrate the basic concepts to formulate networked control problems
CO2: Describe various decentralized control strategies for networked control systems
CO3: Develop various control strategies for multi-agent robotics
CO4: Develop models and strategies for mobile sensor and communication networks

Module 1: Basic concepts in networked control (8 Hours)

Review of Graph Theory-Connected Graph-Incidence Matrix-Tree-cutset-loop/cycles-Minimum Spanning Tree-Network Models -graphs, random graphs, random geometric graphs, state-dependent graphs-Networked control systems-Proximity graphs - Algebraic and spectral graph theory - Connectivity: Cheeger's inequality -switching networks- From biological swarms to graph-based models-Rendezvous: A canonical problem

Module 2: Decentralized Control (10 hours)

The agreement protocol: static case- Reaching decentralized agreements- Consensus equation: Static case- Leader networks and distributed estimation- Discrete time consensus.
The agreement protocol: dynamic case: Switched networks- Lyapunov-based stability- Consensus equation: Dynamic case-Biological models: Flocking and swarming- Alignment and Kuramoto's coupled oscillators.
Distributed estimation -Computational, communications, and controls resources in networked control systems-Distributed control- Convex Optimization -Optimization-based control design.

Module 3: Multi Agent Robotics (11 hours)

Formations - Graph rigidity -Persistence -Formation control, sensor and actuation models-distance based formations, rigidity, position based formations, formation infeasibility -Consensus problem- static, dynamic, distributed estimation, leader-follower architectures for consensus-Reaching decentralized agreements through cooperative control- leader-follower networks-Network controllability- Network feedback- Averaging Systems-Positive Systems- nonholonomic, double integrator, rigid body dynamics-Collision avoidance: potential fields, navigation functions. Introduction to artificial intelligence & deep learning for multi-agent robotics.

Module 4: Mobile sensor and communication networks (10 hours)

Sensor networks: Coverage control- Coverage and detection problems-Gabriel and Voronoi graphs-voronoi-based cooperation strategies-Random graphs - LANdroids: Communication networks - Communication models- mobile communications networks- connectivity, connectivity maintainance, sampling, delays, packet losses, quantization, security -Swarming-sensor networks: sensing constraints, aggregation, dispersion, coverage control, deployment, flocking. Internet of things(IOT)

References:

1. Mehran Mesbahi and Magnus Egerstedt, '*Graph Theoretic Methods in Multiagent Networks*,' Princeton University Press, 2010.
2. F. Bullo, J. Cortes, and S. Martinez, '*Distributed Control of Robotic Networks'*, Princeton, 2009.
3. C. Godsil and G. Royle, '*Algebraic Graph Theory'*, Springer, 2001.
4. P. J. Antsaklis and P. Tabuada,, '*Networked Embedded Sensing and Control',* Springer 2006.
5. C. Godsil and G. Royle, *'Algebraic Graph Theory'*, Springer, 2001.

M. Mesbahi and M. Egerstedt, '*Graph Theoretic Methods in Multi-Agent Networks'*, Princeton University Press, 2010.

6. Wei Ren, Randal W. Beard, *'Distributed Consensus in Multi-vehicle Cooperative Control'*, Communications and Control Engineering Series, Springer-Verlag, London, 2008

EE6135D FLEXIBLE STRUCTURES

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Develop basic mathematical models for flexible structures
CO2: Integrate different finite element methods for the modelling of flexible structures
CO3: Design of various controllers for flexible structures
CO4: Simulate the control strategies in various applications of flexible structures.

Module 1: Introduction to flexible structures (7 Hours)

Flexible structures -The Finite Element Method – The element characteristic matrix – Element assembly and solution for unknowns – Summary of finite element history. Basic equations of elasticity – Strain-displacement relations – Theory of stress and deformation – Stress-strain-temperature relations.

Module 2: Modelling of flexible structures (13 hours)

Stationary Principles, Rayleigh-Ritz Method and Interpolation: - Principle of stationary potential energy – Problems having many d.o.f – Potential energy of an elastic body – The Rayleigh-Ritz method – Piecewise polynomial field – Finite element form of Rayleigh-Ritz method – Finite element formulations derived from a functional – Interpolation – Shape functions for C0 and C1 elements – Lagrangian and Hermitian interpolation functions for one dimensional elements – Lagrangian interpolation functions for two and three dimensional elements Introduction to Weighted Residual Method: -Some weighted residual methods – Galerkin finite element method – Integration by parts – Axially loaded bar – Beam – Plane elasticity

Module 3: Analysis and control of flexible structures (12 hours)

Model order reduction for control design**:** Time Domain- modal cost analysis and component cost analysis-balancing method of model reduction. Frequency domain - Routh approximation method-Hankel norm model reduction
Passive control and active control-Feedback and feed forward control-LQR control-decentralised/hierarchical control-model reference adaptive control- robust control theory.

Module 4: Simulation studies of flexible structures (7 hours)

Applications of flexible structures- Flexible structures in robotics- Flexible aerospace structures- Control of flexible links

References:

1. Cook, Robert D., '*Concepts and applications of finite element analysis*', John Wiley & Sons, 2007.
2. Desai, Chandrakant S. '*Elementary finite element method." Civil Engineering and Engineering Mechanics Series', Englewood Cliffs': Prentice-Hall, 1979*
3. Chandrupatla, Tirupathi R.. '*Introduction to finite elements in engineering'*. Vol. 2. Upper Saddle River, NJ: Prentice Hall, 2002.
4. Krishnamoorthy, C. S. '*Finite element analysis: theory and programming'*. Tata McGraw-Hill Education, 1995.
5. Zienkiewicz, Olgierd Cecil, '*The finite element method*', Vol. 3. London: McGraw-hill, 1977.
6. Junkins, John L. *'Introduction to dynamics and control of flexible structures'.* , 1993.
7. Cavallo, Alberto, *'Active control of flexible structures–From modelling to implementation'*, Springer, 2010.

EE6136D GUIDANCE, NAVIGATION AND CONTROL

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Explain the theory related to navigation
CO2: Describe the various aspects in advanced navigation system
CO3: Articulate the theory related to navigation and guidance
CO4: Develop formulation of optimal control for performance of aerospace systems

Module 1: (10 hours)

Fundamentals of Navigation - geometric concepts of navigation- reference frames- Euler angles- direction cosine matrix- quaternion representation- coordinate transformations- comparison of transformation methods. Inertial navigation- inertial platforms- stabilized platforms – gimballed and strapdown INS – IMU Navigation equations- Schuler principle and mechanization

Module 2: (10 hours)

Inertial sensors, gyros- principle of operation- TDF and SDF gyros- precession- Nutation-gimbal lock-gimbal flip- gyro transfer function- rate gyro- integrating gyro- DTG – ring laser gyro- performance parameters. Accelerometers- transfer function- performance parameters.
Integrated navigation-externally aided navigation- introduction to radars- radar equations- operation – types of radar
Basics of satellite navigation- GPS and GNSS- principles of advanced navigation system.

Module 3: (10 hours)

Fundamentals of aerodynamics- airfoils -aerodynamic forces moments and coefficients- control surfaces-anatomy of aerospace vehicles- Equation of motion.Classification of missiles- Fundamentals of GuidanceTaxonomy of guidance laws- Command and Homing Guidance- Classical Guidance laws.Modern guidance Laws- Guidance Laws derived from optimal control Theory and Lyapunov method. Missile autopilots- FCS- Control surfaces

Module 4: (9 hours)

Launch Vehicle Guidance- implicit and explicit guidance- open loop and closed loop guidance- FE guidance-E guidance – VG guidance – Q guidance -Delta guidance
Formulation of optimal control for performance of aerospace systems- Riccatti equation – performance measure- optimal mid course Guidance

References:

1. Anthony Lawrence, *'Modern Inertial Technology'*, Second Edition. SpringerVerlag, New York, Inc., 2001.
2. David Titteron and John Weston, '*Strapdown Inertial Navigation Technology*', Second Edition IEE Radar, Sonar, Navigation and Avionics Series, 2005.
3. Ching-Fang Lin, '*Modern Navigation, Guidance and Control Processing*', Prentice-Hall Inc., Engle Wood Cliffs, New Jersey, 1991
4. George M. Siouris, '*Missile Guidance and Control Systems*', Springer Verlag , New York Inc., 2004.
5. Paul Zarchan , '*Tactical and Strategic Missile Guidance*', AIAA, Inc., Sixth Edition, 2012.
6. N.A. Shneydor, '*Missile Guidance and Pursuit: Kinematics, Dynamics and Control*', Ellis Horwood Publishers, 1998.
8. Robert C. Nelson, *'Flight Stability and Automatic Control'*, WCB McGraw-Hill, 2/e, 1998.

7.Roger R. Bate, '*Fundamentals of Astrodynamics*', Dover Publications Inc., New York, 1971.
9. Edward V. B. Stearns, '*Navigation and Guidance in Space*', Prentice-Hall Inc., Englewood Cliffs, New Jersey.

EE6138D SELECTED TOPICS IN CONTROL

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Summarize and apply the concept of modeling and analysis of Fractional order systems.
CO2: Relate and design the Fractional order Controllers and identify its implementation issues.
CO3: Summarize and apply the concept of modeling and analysis of Time-Delay systems.
CO4: Relate and design the controller for time-delay systems.

Module 1: Fractional order Systems (10 Hours)

Need for Fractional Order, Fractional-order Operators: Definitions and Properties, Fractional-order Integrals, Fractional-order Derivatives, Fractional-order Differential Equations, Fractional-order Systems Models and Representations, Stability, Analysis of Time and Frequency Domain Responses, Bode's Ideal Loop Transfer Function.
State-space Representation and Analysis:Continuous-time LTI State-space Realizations, Solution of the State Equation of Continuous LTI Commensurate-order Systems-Inverse Laplace Transform, Jordan Matrix Decomposition and Cayley–Hamilton Methods, Stability Analysis. Controllability and Observability of Continuous LTI Commensurate-order Systems.

Module 2: Fractional order Controllers and Implementation (10 hours)

Need for Fractional-order Control, Concept of Integral and Derivative Action, Fractional-order PID Controller, F-MIGO: Fractional *M*s Constrained Integral Gain Optimization Method for Fractional-order Proportional Integral Controller Tuning for First-order Plus Delay Time Plants. Fractional-order PD Controller Design for a Class of Second-order Plants. Design Specifications and Tuning Problem of Fractional-order PID Controller. Tuning of Fractional-order Lead-lag Compensators.Robust Control Techniques- CRONE.
Continuous-time Implementations of Fractional-order Operators- Continued Fraction Approximations, Oustaloup Recursive Approximations Modified Oustaloup Filter, Discrete-time Implementation of Fractional-order Operators-FIR Filter Approximation, Discretization Using The Tustin Method with Prewarping

Module 3: Time-Delay Systems (10 hours)

Model with Time-Delay in engineering applications; system-theoretic preliminaries, Mathematical modelling of time-delay systems, frequency domain & modal analyses; state space and rational approximations, Stability analysis, stability notions; frequency sweeping; Lyapunov's method

Module 4: Controller for Time-Delay Systems (9 hours)

Stabilization methods- fixed-structure controllers; finite spectrum assignment; coprime factorization. Dead-time compensation –PID Control , Smith-Predictor Based Control and its modifications; implementation issues, Finite-spectrum Assignment, Handling uncertain delays-Lyapunov-based methods; unstructured uncertainty embedding, Optimal control and estimation-H2 optimizations

References:

1. Concepción A. Monje, YangQuan Chen, Blas M. Vinagre, DingyüXue and Vicente Feliu, '*Fractional-order Systems and Controls-Fundamentals and Applications*', Springer-Verlag London Limited , 2010.

2. Sabatier J., Lanusse P., Melchior P., Oustaloup, '*A Fractional Order Differentiation and Robust Control Design-CRONE, H-infinity and Motion Control*', Springer, 2015
3. Emilia Fridman, '*Introduction to Time-Delay Systems: Analysis and Control*', Springer International Switzerland 2014.
4. J. E. Marshall, H. Gorecki, A. Korytowski, and K. Walton, '*Time-Delay Systems: Stability and Performance Criteria with Applications*', London: Ellis Horwood, 1992.
5. K. Gu, V. L. Kharitonov, and J. Chen, *'Stability of Time-Delay Systems'*, Boston: Birkhauser, 2003.
6. R. F. Curtain and H. Zwart, '*An Introduction to Infinite-Dimensional Linear Systems Theory'*,. New York: Springer-Verlag, 1995.
7. Qing –ChnagZhong*, 'Robust Control of Time-delay System'*, Springer-Verlag London, 2006.

EE6140D ADVANCED SOFT COMPUTING TECHNIQUES

Pre-requisite**:** Nil

L	T	P	C
3	0	0	3

Total hours: **39**

Course Outcomes:
CO1: Construct intelligent systems and control using Artificial neural network
CO2: Integrate theoretic foundations of Fuzzy Logic Systems to be used in engineering applications.
CO3: Describe the concepts of genetic algorithms
CO4: Apply the knowledge of Soft Computing Techniques in engineering problems
CO5: Simulate intelligent control systems to evaluate the performance

Module 1: (9 hours)

Introduction Neural Networks, Biological Neuron, Biological and Artificial Neuron Models, types of Neuron Activation function, ANN Architectures, supervised, and unsupervised learning, Perceptron Models, training Algorithms, Limitations of the Perceptron Model and Applications, Computer based simulation

Module 2: (11 hours)

Multilayer Feed forward Neural Networks - Back propagation Algorithm, Limitations of Back propagation Algorithm, Radial Basis Function network structure - covers theorem and the separability of patterns - RBF learning strategies, Applications in forecasting and pattern recognition and other engineering problems, Computer based simulation

Module 3: (11 hours)

Introduction to classical sets - properties, Operations and relations; Fuzzy sets, Membership, Uncertainty, Operations, properties, fuzzy relations, cardinalities, membership functions., Fuzzification, Membership value assignment, development of rule base and decision making system, Defuzzification to crisp sets, Defuzzification methods - Mamdani Fuzzy Models, Sugeno Fuzzy Models - engineering applications

Module 4: (8 hours)

Introduction to Optimization, types of optimization problem, optimization algorithms, classification, History of evolutionary, Advantages of evolutionary computation, Introduction to genetic algorithms, The genetic computation process-natural evolution-parent selection-crossover-mutation-properties - classification - Application to engineering problems, Computer simulation practices.

References:

1. B.Yegnanarayana, *'Artificial Neural Networks'*, PHI, India, 2006.
2. Limin Fu, *'Neural Networks in Computer Intelligence',* McGraw Hill, 2003.
3. N. Yadaiah and S. Bapi Raju, *'Neural and Fuzzy Systems: Foundation, Architectures and Applications',* Pearson Education
4. Goldberg D.E., *'Genetic Algorithms in Search Optimization and Machine Learning',* Addison Wesley,1989

EE6202D POWER SYSTEM DYNAMICS AND CONTROL

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Design and analyze Automatic Generation control (AGC) and AVR for power systems considering economic dispatch.
CO2: Model and analyze dynamical systems to address various power system stability problems.
CO3: Execute digital simulation of large power system for small signal and transient stability analyses and develop stability enhancement methods.
CO4: Model and analyze voltage stability problem based on static and dynamic approach and develop stability enhancement methods.

Module 1: (10 hours)

Generation Control Loops. AVR Loop.Performance and Response.Automatic Generation Control of Single Area and Multi Area Systems. Static and Dynamic Response of AGC Loops – analysis using digital simulation - Economic Dispatch and AGC, AGC in a Deregulated Environment, Recent advances in AGC

Module 2: (10 hours)

Small signal angle instability (low frequency oscillations) - Power System Model for Low Frequency Oscillation Studies, damping and synchronizing torque analysis, Eigen value Analysis, Improvement of System Damping with Supplementary Excitation Control, Standard models for PSS representation-supplementary modulation control of FACTS devices, sub-synchronous frequency oscillations - Sub Synchronous Resonance and Countermeasures, IEEE Benchmark models for SSR studies

Module 3: (10 hours)

Transient Stability Problem, Modeling of Synchronous Machine, Loads, Network, Excitation Systems, Turbine And Governing Systems, Trapezoidal Rule of Numerical Integration Technique For Transient Stability Analysis, Simultaneous Implicit Approach for Transient Stability Analysis of Multi-machine Systems, Data For Transient Stability Studies, analysis using digital simulation - Transient Stability Enhancement Methods

Module 4: (9 hours)

Voltage Stability Problem.Real and Reactive Power Flow in Long Transmission Lines.Effect of ULTC and Load Characteristics on Voltage Stability. Voltage Stability Limit. Voltage Stability Assessment Using PV Curves. System Modelling-Static and Dynamic Analysis-Voltage Collapse Proximity Indices.Voltage Stability Improvement Methods.

References:

1. P. M. Anderson, A. A. Fouad, '*Power system control and stability'*, 2nd ed. John Wiley & Sons, 2008
2. P. Kundur, '*Power System Stability and Control'*, McGraw Hill, New York, 1994.
3. A.J. Wood, B.F. Wollenberg, '*Power Generation, Operation And Control'*, 2nd ed., John Wiley And Sons, New York, 1996.
4. O.I. Elgard, *'Electric Energy System Theory: An Introduction'*,2nd ed., McGraw Hill, New York, 1982
5. K.R. Padiyar, '*Power System Dynamics, Stability And Control'*, Interline Publishing (P) Ltd., Bangalore, 1999
6. M A Pai, D P Sen Gupta, K R Padiyar, '*Small Signal Analysis of Power Systems'*, Narosa Series in Power and Energy Systems, 2004

7. Leonard L Grigsby, '*Power Systems*, Electrical Power Engineering Handbook', CRC Press, New York, 2007.
8. C. Van Custem, T. Vournas, '*Voltage Stability Of Electric Power Systems'*, Rlever Academic Press
9. Yao-Nan-Yu, '*Electric Power System Dynamics',* Academic Press, 1983
10. J. Arrilaga, C.P. Arnold, B.J. Harker, '*Computer Modeling of Electrical Power Systems'*, Wiley, New York, 1983.
11. I.J. Nagrath, O.P. Kothari, '*Power System Engineering'*, Tata McGraw Hill Publishing Co. Ltd., New Delhi, 1994.

EE6327D IMPLEMENTATION OF DSP ALGORITHMS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Acquire knowledge about basics of DSP systems, transforms and algorithms.
CO2: Analyse and design digital filters and its implementation.
CO3: Explain about Quantization Noise, and significance of Sampling rate and its conversion.
CO4: Design DSP algorithms and implement in PDSP / FPGA systems.

Module 1 TRANSFORMS (13 hours)

Overview of Digital Signal Processing, Introduction to MATLAB , Applications of Digital Signal Processing; Discrete-time signals and systems - Discrete-time Signals, Discrete Systems, Convolution, Difference Equations; The Discrete-Time Fourier Analysis - The Discrete-Time Fourier Transform (DTFT), The Properties of the DTFT, The Frequency Domain Representation of LTI Systems, Sampling and Reconstruction of Analog Signals; The *Z*-Transform - The Bilateral *Z*-Transform, Important Properties of the *Z*-Transform, Inversion of the *z*-Transform, System Representation in the *Z*-Domain, Solutions of the Difference Equations; The Discrete Fourier Transform - The Discrete Fourier Series, Sampling and Reconstruction in the *Z*-Domain, The Discrete Fourier Transform, Properties of the Discrete Fourier Transform, Linear Convolution Using the DFT, The Fast Fourier Transform.

Module 2: DIGITAL FILTER IMPLEMENTATION (14 hours)

Implementation of discrete-time filters - Basic Elements, IIR Filter Structures, FIR Filter Structures, Lattice Filter Structures, Overview of Finite-Precision Numerical Effects, Representation of Numbers, The Process of Quantization and Error Characterizations, Quantization of Filter Coefficients; FIR filter design - Preliminaries, Properties of Linear-phase FIR Filters, Window Design techniques, Frequency Sampling Design Techniques, Optimal Equiripple Design Technique, IIR filter design, Some Preliminaries, Some Special Filter Types, Characteristics of Prototype Analog Filters, Analog-to-Digital Filter Transformations, Lowpass Filter Design, Frequency-band Transformations.

Module 3: SAMPLING RATE CONVERSION (12 hours)

Introduction, Decimation by a Factor *D,* Interpolation by a Factor *I,* Sampling Rate Conversion by a Rational Factor *I/D,* FIR Filter Designs for Sampling Rate Conversion, FIR Filter Structures for Sampling Rate Conversion; Round-off Effects in Digital Filters - Analysis of A/D Quantization Noise, Round-off Effects in IIR Digital Filters, Round-off Effects in FIR Digital Filters; Applications in Adaptive Filtering - LMS Algorithm for Coefficient Adjustment, System Identification or System Modeling, Suppression of Narrowband Interference in a Wideband Signal, Adaptive Line Enhancement, Adaptive Channel Equalization.

Note : Use MATLAB as a tool to implement all these DSP concepts and obtain the resulting plots. Convert this Matlab code and implement in PDSP and / or FPGA systems.

References:

1. Vinay K. Ingle ,John G. Proakis : Digital Signal Processing Using MATLAB®, Cengage Learning - Third Edition, ISBN-13: 978-1-111-42737-5.
2. Dimitris G Manolakis, John G. Proakis: Digital Signal Processing : Principles, Algorithms, and Applications, 4th Edition, Pearson, 2007, ISBN: 9788131710005, 8131710009.
3. HazarathaiahMalepati: Digital Media Processing: DSP Algorithms Using C, Elsevier Science Publisher, ISBN: 9781856176781, 1856176789.
4. Sanjit K Mitra, Digital Signal Processing: A computer-based approach ,TataMc Grow-Hill edition.1998.

5. Dimitris G .Manolakis, Vinay K. Ingle and Stephen M. Kogon, Statistical and Adaptive Signal Processing, Mc Grow Hill international editions .-2000
6. Alan V . Oppenheim, Ronald W. Schafer, Discrete-Time Signal Processing, Prentice-Hall of India Pvt. Ltd., New Delhi, 1997
7. John G. Proakis, and Dimitris G. Manolakis, Digital Signal Processing(third edition), Prentice-Hall ofIndia Pvt. Ltd, New Delhi, 1997
8. Emmanuel C. Ifeachor, Barrie W. Jervis , Digital Signal Processing-A practical Approach, Addison Wesley,1993
9. Abraham Peled and Bede Liu, Digital Signal Processing - Theory, Design and Implementation, John Wiley and Sons, 1976

EE6329D ADVANCED MICROPROCESSOR BASED SYSTEMS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total Hours: 39

Course Outcomes:

CO1: To understand the working of advanced microprocessors/controllers.
CO2: To learn how to program a processor in assembly language and develop an advanced processor based system.
CO3: Explain how to configure and use different peripherals in a digital system.
CO4: Able to compile, debug and execute Programs.

Module 1: Introduction (8 hours)

Technology trend in microprocessors - performance measurement –Comparing and summarizing performance - quantitative principles of computer design – Amdahl's law - Case studies.

History of the x86 family - Instruction Set architecture of a typical advanced x86 processor – using MASM32 for 32 bit assembly programming of x86 architectures

Module 2: 80386 to Pentium (8 hours)

Enhancements of 80386, Hardware Features, Protected virtual addressing mode -Virtual Memory, Memory Management Unit, Converting a Logical Address to a Physical Address, Calculating the size of the Logical Address Space, Protection, Multi Tasking, Interrupts of 80386, Privileged Instructions, The Enhanced Features of 80486, Data Alignment, The Pentium Processor, Pentium Pro, Pentium-II And Pentium-III, Pentium-IV, Latest Trends in Microprocessor Design

Module 3: ARM Introduction and Pipeline structures (13 hours)

Instruction Set Architecture (ISA) and ARM History, ARM architecture, Stack implementation in ARM, Endians, ARM organization and Implementation, Different Types of Instructions, ARM Instruction Set and Thumb Instruction set. Thumb state, Thumb Programmers model, Thumb Implementation, Thumb Applications. Thumb Instructions, Assembly Language Programming, condition codes, Data processing Instructions, High- Level Language Programming, System Development using ARM. Pipeline Hazards Interrupts and Exceptions, Exception Handlers, Reset Handling. Aborts, software Interrupt Instruction, undefined instruction exception. Interrupt Handling schemes, Interrupt Latency.

Module 4: ARM Memory and Hardware interfacing (10 hours)

Memory Hierarchy, Cache and Memory Management and Protection, Digital Signal Processing on ARM, Peripheral Programming and system design for a specific ARM processor (ARM7/9), PWM generation and Motor control using ARM processor board. .

References

1. Lyla B.Das '*The x86 Microprocessors –Architecture Programming and Interfacing -8086 to Pentium*', Pearson Education , 2010.
2. Daniel W. Lewis , '*Fundamentals of Embedded Software with the ARM Cortex-M3'*, PEARSON, 1st Edition, 2015, ISBN: 9789332549937, 9332549931
3. Jonathan W Valvano, '*Embedded Systems: Introduction to Arm® Cortex(TM)-M3 Microcontrollers'* , 2012.

4. Vincent Mahout, '*Assembly Language Programming: ARM Cortex-M3'* , Wiley , 2012
5. Jurij Silc, Borut Rob c, Theo Ungerer .Processor Architecture –From DataFlow to Super scalar and Beyond
6. Shibu K.V. Introduction to Embedded Systems Tata McGraw Hill, 2009
7. Robert Ashby *Designer's Guide to the Cypress PSoC Newnes* (An imprint of Elsevier), 2006
8. Sloss, Symes, Wright, ARM System Developer's Guide, Elsevier, 2014, ISBN: 9781493303748.
9. Oliver H. Bailey, *The Beginner's Guide to PSoC Express* Timelines Industries Inc.
10. Van Ess, Currie and Doboli Laboratory Manual for Introduction to Mixed-Signal, Embedded Design, Alphagraphics, USA
11. Steve Furber *ARM System-on-chip Architecture* ,Second Edition Pearson Education,2007
12. William Hohl ARM Assembly Language Programming CRC Press,2009
13. Andrew Sloss, Dominic Symes, Christ Wright, *ARM System Developer's guide –Designing and optimizing software* Elseiver Publishers ,2008
14. Andrew N. SLOSS, Dominic *SYMES and Chris WRIGHT: ARM System Developers Guide*, Designing and Optimizing System Software. ELSEVIER, 2004
15. Steve Furber*, ARM System-on-Chip Architecture*, Second Edition, PEARSON, 2013
16. Manuals and Technical Documents from the ARM Inc, web site.
17. Hennesy J. L. & Pattersen D. A., *Computer Architecture: A Quantitative approach*, 4/e, Elseiver Publications, 2007

EE6401D ENERGY AUDITING & MANAGEMENT

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course outcomes:

CO1: Recognize the role of energy managers and use the skills and techniques required to implement energy management.
CO2: Identify and quantify the energy intensive business activities in an organization.
CO3: Describe the standard methodologies for measuring energy in the workplace and energy audit Instruments
CO4: Analyze energy efficient control scheme for electric motors and perform case study on load matching and selection of motors.
CO5: Explain the energy conservation methods in motors, pumps, fans, compressors, transformers, geysers, lighting schemes, air conditioning, refrigeration, cool storage.
CO6: Conduct a walkthrough audit in various industries.

Module 1: (9 hours)

System approach and End use approach to efficient use of Electricity; Electricity tariff types; Energy auditing: Types and objectives-audit instruments- ECO assessment and Economic methods-specific energy analysis-Minimum energy paths-consumption models-Case study.

Module 2: (10 hours)

Electric motors-Energy efficient controls and starting efficiency-Motor Efficiency and Load Analysis-Energy efficient /high efficient Motors-Case study; Load Matching and selection of motors.
Variable speed drives; Pumps and Fans-Efficient Control strategies- Optimal selection and sizing - Optimal operation and Storage; Case study

Module 3: (10 hours)

Transformer Loading/Efficiency analysis, Feeder/cable loss evaluation, case study.
Reactive Power management-Capacitor Sizing-Degree of Compensation-Capacitor losses-Location-Placement-Maintenance, case study.
Peak Demand controls- Methodologies-Types of Industrial loads-Optimal Load scheduling-case study.
Lighting- Energy efficient light sources-Energy conservation in Lighting Schemes- Electronic ballast-Power quality issues-Luminaries, case study.

Module 4: (10 hours)

Cogeneration-Types and Schemes-Optimal operation of cogeneration plants-case study;
Electric loads of Air conditioning & Refrigeration-Energy conservation measures- Cool storage. Types-Optimal operation-case study; Electric water heating-Gysers-Solar Water Heaters- Power Consumption in Compressors, Energy conservation measures; Electrolytic Process; Computer Controls- software-EMS

References:

1. Y P Abbi and Shashank Jain, '*Handbook on Energy Audit and Environment Management*', TERI, 2006
2. Albert Thumann, William J. Younger, Terry Niehus , '*Handbook of Energy Audits*', 2009

3. Giovanni Petrecca, '*Industrial Energy Management: Principles and Applications*', The Kluwer international series -207,1999
4. Anthony J. Pansini, Kenneth D. Smalling, '*Guide to Electric Load Management*', Pennwell Pub; (1998)
5. Howard E. Jordan, '*Energy-Efficient Electric Motors and Their Applications*', Plenum Pub Corp; 2nd edition (1994)
6. Turner, Wayne C,' *Energy Management Handbook*', Lilburn, The Fairmont Press, 2001
7. Albert Thumann, '*Handbook of Energy Audits*', Fairmont Pr; 5th edition (1998)
8. IEEE Bronze Book, '*Recommended Practice for Energy Conservation and cost effective planning in Industrial facilities*', IEEE Inc, USA. 2008
9. Albert Thumann, P.W, '*Plant Engineers and Managers Guide to Energy Conservation',* Seventh Edition,TWI Press Inc, Terre Haute, 2007
10. Donald R. W., '*Energy Efficiency Manual',* Energy Institute Press, 1986
11. Partab H., '*Art and Science of Utilisation of Electrical Energy*', Dhanpat Rai and Sons, New Delhi. 1975
12. Tripathy S.C, '*Electric Energy Utilization And Conservation*', Tata McGraw Hill, 1991
13. NESCAP '*Guide Book on Promotion of Sustainable Energy Consumption*', 2004
14. IEEE Bronze Book, IEEE STD 739
15. IEEE '*Recommended Practices for Energy Management in Industrial and Commercial Facilities*'
16. Barney L. Capehart, Wayne C. Turner , William J. Kennedy, '*Guide to Energy Management*', Fairmont Press, 6th edition ,April 23, 2008.
17. Donald R. Wulfinghoff*, 'Energy Efficiency Manual: for everyone who uses energy, pays for utilities, designs and builds, is interested in energy conservation and the environment*', Energy Institute Press March 2000.
18. Albert Thumann., William J. Younger, '*Handbook of Energy Audits*', Fairmont Press, 7thEdition, November 12, 2007.
19. Certified Energy Manager Exam Secrets Study Guide: CEM Test Review for the Certified Energy Manager Exam CEM Exam Secrets Test Prep Team Mometrix Media LLC (2009)
20. Albert Thuman, D. Paul Mehta , '*Handbook of Energy Engineering*', Fairmont Press, 6th edition , June 24, 2008.

EE6402D PROCESS CONTROL & AUTOMATION

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Explain the process modelling, process dynamics and process instrumentation

CO2: Analyze various feedback and feed forward control strategies and design the control system based on frequency response analysis.

CO3: Demonstrate the process control of MIMO systems, control loop interactions, singular value analysis, decoupling control and real time optimization.

CO4: Describe advanced control strategies – Model predictive control, Adaptive control, Inferential Control and Batch process control.

CO5: Perform plant wide control design, instrumentation for process monitoring and statistical process Control.

Module 1: (9 hours)

Process Modeling- Introduction to Process control and process instrumentation-Hierarchies in process control systems-Theoretical models-Transfer function-State space models-Time series models-Development of empirical models from process data-chemical reactor modeling-. Analysis using softwares

Module 2: (10 hours)

Feedback & Feedforward Control- Feedback controllers-PID design, tuning, trouble shooting-Cascade control- Selective control loops-Ratio control-Control system design based on Frequency response Analysis-Direct digital design-Feedforward and ratio control-State feedback control- LQR problem- Pole placement -Simulation using softwares-Control system instrumentation-Control valves- Codes and standards- Preparation of P& I Diagrams.

Module 3: (10 hours)

Advanced process control-Multi-loop and multivariable control-Process Interactions-Singular value analysis-tuning of multi loop PID control systems-decoupling control-strategies for reducing control loop interactions-Real-time optimization-Simulation using softwares

Module 4: (10 hours)

Model predictive control-Batch Process control-Plant-wide control & monitoring- Plant wide control design- Instrumentation for process monitoring-Statistical process control-Introduction to Fuzzy Logic in Process Control-Introduction to OPC-Introduction to environmental issues and sustainable development relating to process industries. Comparison of performance different types of control with examples on softwares

References:

1. Seborg, D.E., T.F. Edgar, and D.A. Mellichamp, '*Process Dynamics and Control'*, John Wiley , 2004
2. Johnson D Curtis, '*Instrumentation Technology'*, 7th Edition, Prentice Hall India, 2002.
3. Bob Connel, *Process Instrumentation Applications Manual*, McGrawHill, 1996.
4. Edgar, T.F. & D.M. Himmelblau, '*Optimization of Chemical Processes'*, McGrawHill Book Co, 1988.
5. Macari Emir Joe and Michael F Saunders, '*Environmental Quality Innovative Technologies and Sustainable Development'*, American Society of Civil Engineers, 1997.
6. Nisenfeld,A.E ,(Ed), '*Batch Control: practical guides for measurement and control*, Instrument Society of America, 1996.
7. Sherman, R.E. (Ed), '*Analytical instrumentation'*, Instrument Society of America, 1996.
8. Shinskey, F.G., *Process Conrol Systems: Applications, Design andTuning* ,3rd Edition, McGrawHill Book Co, 1988.

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10. K. Krishnaswamy, '*Process Control'*, New Age International, 2007

EE6403D COMPUTER CONTROLLED SYSTEMS

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course outcomes:

CO1: Identify the scientific and mathematical principles and methodologies relevant to computer control of systems.
CO2: Describe the fundamentals of PLC and its architecture.
CO3: Explain the PLC programming fundamentals, process logic and human machine interface.
CO4: Describe DCS architecture and configuration.
CO5:Analyze in detail the case studies of PLC, SCADA and DCS.
CO6: Perform inter task communication, synchronization and real time memory management.

Module 1: Multivariable Control (11 hours)

Multivariable control- Basic expressions for MIMO systems- Singular values- Stability norms-Calculation of system norms- Robustness- Robust stability- H2 / H∞ Theory- Solution for design using H2 / H∞ - Case studies. Interaction and decoupling- Relative gain analysis- Effects of interaction-Response to disturbances- Decoupling- Introduction to batch process control.

Module 2: Programmable Logic Controllers (9 hours)

Programmable logic controllers- Organisation- Hardware details- I/O- Power supply- CPU- Standards-Programming aspects- Ladder programming- Sequential function charts- Man- machine interface-Detailed study of one model- Case studies.

Module 3: Large Scale Control System (11 hours)

SCADA: Introduction, SCADA Architecture, Different Communication Protocols, Common System Components, Supervision and Control, HMI, RTU and Supervisory Stations, Trends in SCADA, Security Issues

DCS: Introduction, DCS Architecture, Local Control (LCU) architecture, LCU languages, LCU - Process interfacing issues, communication facilities, configuration of DCS, displays, redundancy concept - case studies in DCS.

Module 4: Real Time Systems (8 hours)

Real time systems- Real time specifications and design techniques- Real time kernels- Inter task communication and synchronization- Real time memory management- Supervisory control- direct digital control- Distributed control- PC based automation.

References:

1. Shinskey F.G., '*Process control systems: application, Design and Tuning'*, McGraw Hill International Edition ,Singapore,1988.
2. Be.langer P.R., 'Control *Engineering: A Modern Approach'*, Saunders College Publishing , USA, 1995.
3. Dorf, R.C. and Bishop R. T , '*Modern Control Systems'* , Addison Wesley Longman Inc., 1999
4. Laplante P.A.,'*Real Time Systems: An Engineers Handbook'*, Prentice Hall of India Pvt. Ltd., New Delhi, 2002.
5. Constantin H. Houpis and Gary B. Lamont, '*Digital Control systems'*, McGraw Hill Book Company, Singapore, 1985.
6. Stuart A. Boyer: 'SCADA-*Supervisory Control and Data Acquisition'*, Instrument Society of America Publications, USA, 1999
7. Gordon Clarke, Deon Reynders, 'Practical Modern SCADA Protocols: DNP3, 60870.5 and Related Systems', Newnes Publications, Oxford, UK,2004
8. Efim Rosenwasser, Bernhard P. Lampe, '*Multivariable computer-controlled systems: a transfer function approach'*, Springer, 2006

EE6404D INDUSTRIAL INSTRUMENTATION

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Explain the industrial measurement system and different elements involved in it.

CO2: Describe the various sensors and transducers used for different industrial variables like torque, pressure, etc.

CO3: Explain signal conditional circuits like amplifiers, filters, ADC, etc. for working industrial measurement systems.

Module 1: (11 hours)

Industrial measurement systems – different types of industrial variables and measurement systems elements – sensors and transducers for different industrial variables like pressure, torque, speed, temperature etc– sensor principles – examples of sensors – sensor scaling – Industrial signal conditioning systems- Amplifiers – Filters – A/D converters for industrial measurements systems – review of general Industrial instruments.

Module 2: (8 hours)

Calibration and response of industrial instrumentation - standard testing methods and procedures – Generalized performance characteristics – static response characterization – dynamic response characterization - zero order system dynamic response characterizations – first order system dynamic response second order system dynamic response – higher order systems - Response to different forcing functions such as step, sinusoidal etc. to zero, first, second third and higher orders of systems.

Module 3: (11 hours)

Regulators and power supplies for industrial instrumentation – linear series voltage regulators – linear shunt voltage regulators – integrated circuit voltage regulators – fixed positive and negative voltage regulators – adjustable positive and negative linear voltage regulators – application of linear IC voltage regulators - switching regulators –single ended isolated forward regulators- half and full bridge rectifiers. pH and conductivity sensors. Piezo-electric and ultrasonic sensors and its application in process and biomedical instrumentation. Measurement of viscosity, humidity and thermal conductivity

Module 4: (9 hours)

Servo drives – servo drive performance criteria – servomotors shaft sensors and coupling – sensors for servo drives – servo control loop design issues- stepper motor drives types and characteristics – hybrid stepper motor – permanent magnet stepper motor – hybrid and permanent magnet motors – single and multi step responses.

References:

1. Ernest O. Doebelin, ‘*Measurement systems applications and design’*, McGraw – Hill International Editions, McGraw- Hill Publishing Company, 1990
2. Patric F. Dunn University of Notre Dame, ‘*Measurement and Data Analysis for engineering and science’*, Mc Graw Hill Higher education, 1995
3. Randy Frank, ‘*Understanding Smart Sensors’*, Artec House Boston. London, 2000
4. Muhamad H Rashid, ‘*Power electronics handbook’*, ACADEMIC PRESS, 2007
5. K Krishnaswamy, ‘*Industrial Instrumentation’*, New Age International Publishers, New Delhi, 2003
6. Gregory K. McMillan, Douglas M. Considine, ‘*Process/Industrial Instruments and Controls Handbook’*,5th Edition, Mc Graw Hill 1999

7. Steve Mackay, Edwin Wright, John Park, '*Practical Data Communications for Instrumentation and Control'*, Newness Publications, UK, 2003
8. John O Moody, Paros J Antsaklis, '*Supervisory Control of discrete event systems using petrinets'*, PHI, 2002
9. James L Peterson, '*Petrinet theory and modeling of system'*, 1981

EE6405D ARTIFICIAL INTELLIGENCE & AUTOMATION

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Identify potential areas for automation and justify need for automation
CO2: Select suitable major control components required to automate a process or an activity
CO3: Identify suitable automation hardware for the given application
CO4: Explain Artificial Intelligence and Identify systems with Artificial Intelligence.
CO5: Implement classical Artificial Intelligence techniques, such as search algorithms, minimax algorithm, neural networks, tracking, robot localization.

Module 1: (10 hours)

Introduction: Overview and Historical Perspective, Turing test, Physical Symbol Systems and the scope of Symbolic AI, Agents. State Space Search: Depth First Search, Breadth First Search, DFID. Heuristic Search: Best First Search, Hill Climbing, Beam Search, Tabu Search. Randomized Search: Simulated Annealing, Genetic Algorithms, Ant Colony Optimization. Finding Optimal Paths: Branch and Bound, A*, IDA*, Divide and Conquer approaches, Beam Stack Search.

Module 2: (9 hours)

Problem Decomposition: Goal Trees, AO*, Rule Based Systems, Rete Net. Game Playing: Minimax Algorithm, AlphaBeta Algorithm, SSS*. Planning and Constraint Satisfaction: Domains, Forward and Backward Search, Goal Stack Planning, Plan Space Planning, Graphplan, Constraint Propagation. Logic and Inferences: Propositional Logic, First Order Logic, Soundness and Completeness, Forward and Backward chaining.

Module 3: (10 hours)

Automation – Introduction - Automation in Production System, Principles and Strategies of Automation, Basic elements of an Automated System, Advanced Automation Functions, Levels of Automations. Flow lines & Transfer Mechanisms, Fundamentals of Transfer Lines. (SLE: Analysis of Transfer Lines). Automated Manufacturing Systems: Components, Classification and Overview of Manufacturing Systems, Manufacturing Cells, GT and Cellular Manufacturing, FMS, FMS and its Planning and Implementation.

Module 4: (10 hours)

Control Technologies in Automation: Industrial Control Systems, Process Industries VS Discrete Manufacturing Industries, Continuous VS Discrete Control, Computer Process and its Forms. (SLE: Sensors, Actuators and other Control System Components). Computer Based Industrial Control: Introduction & Automatic Process Control, Building Blocks of Automation Systems: LAN, Analog & Digital I/O Modules, SCADA Systems & RTU. Distributed Control System - functional requirements, configurations & some popular Distributed Control Systems.

References:

1. M.P.Groover, '*Automation, Production Systems and Computer Integrated Manufacturing*', Pearson Education, 5th edition, 2009.
2. Krishna Kant, '*Computer Based Industrial Control*', EEE-PHI,2nd edition,2010
3. Tiess Chiu Chang & Richard A. Wysk , '*An Introduction to Automated Process Planning Systems*'.
4. Viswanandham, '*Performance Modeling of Automated Manufacturing Systems*', PHI, 1st edition, 2009.
5. Deepak Khemani, '*A First Course in Artificial Intelligence*', McGraw Hill Education (India), 2013
6. Stefan Edelkamp and Stefan Schroedl. '*Heuristic Search: Theory and Applications*', Morgan Kaufmann, 2011.

7. John Haugeland, '*Artificial Intelligence: The Very Idea'*, A Bradford Book, The MIT Press, 1985.
8. Pamela McCorduck, '*Machines Who Think: A Personal Inquiry into the History and Prospects of Artificial Intelligence',* A K Peters/CRC Press; 2 edition, 2004.
9. Zbigniew Michalewicz and David B. Fogel, '*How to Solve It: Modern Heuristics'*, Springer; 2nd edition, 2004.
10. Judea Pearl, 'Heuristics: *Intelligent Search Strategies for Computer Problem Solving'*, Addison-Wesley, 1984.
11. Elaine Rich and Kevin Knight., '*Artificial Intelligence'*, Tata McGraw Hill, 1991.
12. Stuart Russell and Peter Norvig, '*Artificial Intelligence: A Modern Approach'*, 3rd Edition, Prentice Hall, 2009.
13. Eugene Charniak, Drew McDermott, '*Introduction to Artificial Intelligence'*, Addison-Wesley, 1985.
14. Patrick Henry Winston, '*Artificial Intelligence'*, Addison-Wesley, 1992.

EE6422D ENGINEERING OPTIMIZATION AND ALGORITHMS

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Apply mathematical and numerical techniques of optimization theory to concrete Engineering problems.
CO2: Create, solve and analyze the optimization problems.
CO3: Describe the mathematical properties of general linear programming problems and obtain the solution of linear programming problems using appropriate techniques.
CO4: Formulate real-world problems as Linear Programming models, apply the simplex method and dual simplex algorithms in solving the standard LP problem and interpret the results obtained.
CO5: Apply linear programming in various engineering applications
CO6: Identify solution algorithms to find the best possible solution in nonlinear decision models.

Module 1: (10 hours)

Concepts of optimization: Engineering applications-Statement of optimization problem-Classification - type and size of the problem.

Classical Optimization Techniques: Single and multivariable problems-Types of Constraints .Semi definite case-saddle point.

Linear programming: Standard form-Geometry of LP problems-Theorem of LP-Relation to convexity - formulation of LP problems - simplex method and algorithm -Matrix form- two phase method.

Duality-dual simplex method- LU Decomposition. Sensitivity analysis .Artificial variables and complementary solutions-QP.

Engineering Applications: Minimum cost flow problem, Network problems-transportation, assignment & allocation, scheduling. Karmarkar method-unbalanced and routing problems

Module 2: (10 hours)

Nonlinear programming: Non linearity concepts-convex and concave functions- non-linear programming - gradient and Hessian.

Unconstrained optimization: First & Second order necessary conditions-Minimisation & Maximisation-Local & Global convergence-Speed of convergence.

Basic decent methods: Fibonacci & Golden section search - Gradient methods - Newton Method-Lagrange multiplier method - Kuhn-tucker conditions . Quasi-Newton method- separable convex programming - Frank and Wolfe method, Engineering Applications.

Module 3: (9 hours)

Nonlinear programming- Constrained optimization: Characteristics of constraints-Direct methods-SLP,SQP-Indirect methods-Transformation techniques-penalty function-Langrange multiplier methods-checking convergence- Engineering applications

Module 4: (10 hours)

Dynamic programming: Multistage decision process- Concept of sub optimization and principle of optimality- Computational procedure- Engineering applications.

Genetic algorithms- Simulated Annealing Methods-Optimization programming, tools and Software packages.

References:

1. David G Luenberger, '*Linear and Non Linear Programming'*., 2nd Ed, Addison-Wesley Pub.Co.,Massachusetts, 2003.
2. W.L.Winston, .'*Operation Research-Applications & Algorithms*',2nd Ed., PWS-KENT Pub.Co.,Boston, 2007.
3. S.S.Rao, '*Engineering Optimization'*., 3rd Ed., New Age International (P) Ltd,New Delhi, 2007
4. W.F.Stocker, '*Design of Thermal Systems*', 3rd Ed., McGraw Hill, New York. 1990
5. G.B.Dantzig, *'Linear Programming and Extensions'*. Princeton University Press, N.J., 1963.
6. L.C.W.Dixton,. '*Non Linear Optimisation: theory and algorithms'*. Birkhauser, Boston, 1980
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8. A. Ravindran, K. M. Ragsdell, G. V. Reklaitis, '*Engineering Optimization: Methods And Applications'*, Wiley, 2008.
9. Godfrey C. Onwubolu, B. V. Babu, '*New optimization techniques in engineering'*, Springer, 2004
10. Kalyanmoy Deb,.'*Optimisation for Engineering Design-Algorithms and Examples*', Prentice Hall India-1998.

EE6424D ROBOTIC SYSTEMS AND APPLICATIONS

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course outcomes:

CO1: Apply the mathematics of spatial descriptions and transformations

CO2: Explain the robot system components that combine embedded hardware, software and mechanical systems.

CO3: Describe manipulator kinematics and mechanics of robotic motion.

CO4: Explain the manipulator dynamics, transformation of acceleration, and robot controller architecture

CO5: Apply artificial intelligence techniques in robotics

CO6: Explain various robotics applications and their associated components and control systems.

Module 1: (8 hours)

Mathematics of Spatial Descriptions and Transformations-Robot definition. Robot classification. Robotic system components- Notations- Position definitions- Coordinate frames - Different orientation descriptions - Free vectors- Translations, rotations and relative motion - Homogeneous transformations.

Module 2: (10 hours)

Manipulator Kinematics and Mechanics of Robot Motion-Link coordinate frames- Denavit-Hartenberg convention - Joint and end-effector Cartesian space-Forward kinematics transformations of position-Inverse kinematics of position-Translational and rotational velocities -Velocity Transformations-Manipulator Jacobian -Forward and inverse kinematics of velocity-Singularities of robot motion-Static Forces-Transformations of velocities and static forces -Joint and End Effector force/torque transformations- Derivation for two link planar robot arm as example.

Module 3: (12 hours)

Manipulator Dynamics- Transformations of acceleration- Trajectory Planning- Control-Lagrangian formulation- Model properties - Newton-Euler equations of motion- Derivation for two link planar robot arm as example- Joint space-based motion planning - Cartesian space-based path planning-Independent joint control- Feed-forward control-Inverse dynamics control-Robot controller architectures. Implementation problems.

Module 4: (9 hours)

Robot Sensing and Vision Systems- Sensors-Force and torque sensors-low level vision-high level vision-Robot Programming languages-Introduction to Intelligent Robots-Robots in manufacturing automation.

References:

1. Fu, K.S., R.C. Gonzalez, C.S.G. Lee, '*Robotics: Control, Sensing, Vision & Intelligence*', McGrawHill, 1987.
2. Craig, John J., '*Introduction to Robotics: Mechanics & Control*', 2nd Edition, Pearson Education, 1989.
3. Gray J.O., D.G. Caldwell(Ed), '*Advanced Robotics & Intelligent machines*', The Institution of Electrical Engineers, UK, 1996.
4. Groover, Mikell P, '*Automation, Production Systems & Computer Integrated manufacturing*', Prentice hall India, 1996.
5. Groover Mikell P., M. Weiss, R.N. Nagel, N.G. Odrey, '*Industrial Robotics*', McGrawHill, 1986.
6. Janakiraman, P.A., '*Robotics & Image Processing*', Tata McGrawHill, 1995.
7. Sciavicco, L., B. Siciliano, '*Modelling & Control of Robot Manipulators*', 2nd Edition, Springer Verlag, 2000.

8. Robin R. Murphy, '*An introduction to AI Robotics'*, MIT Press, 2008
9. Oliver Brock, Jeff Trinkle and Fabio Ramos, '*Robotics-Science and Systems'*, Vol. IV, MIT Press 2009

EE6428D SCADA SYSTEMS & APPLICATIONS

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Describe the basic tasks of Supervisory Control Systems (SCADA) as well as their typical Applications.
CO2: Explain SCADA architecture and SCADA system components
CO3: Describe the single unified standard architecture IEC 61850
CO4: Explain SCADA communication system, various industrial communication technologies and open standard communication protocols.
CO5: Apply SCADA systems in transmission and distribution sectors and industries.

Module 1: (10 hours)

Introduction to SCADA: Data acquisition systems, Evolution of SCADA, Communication technologies, Monitoring and supervisory functions, SCADA applications in Utility Automation, Industries

Module 2: (10 hours)

SCADA System Components: Schemes- Remote Terminal Unit (RTU), Intelligent Electronic Devices (IED), Programmable Logic Controller (PLC), Communication Network, SCADA Server, SCADA/HMI Systems

Module 3: (10 hours)

SCADA Architecture: Various SCADA architectures, advantages and disadvantages of each system - single unified standard architecture - IEC 61850. SCADA Communication: various industrial communication technologies -wired and wireless methods and fiber optics. Open standard communication protocols

Module 4: (9 hours)

SCADA Applications: Utility applications- Transmission and Distribution sector -operations, monitoring, analysis and improvement. Industries - oil, gas and water. Case studies, Implementation, Simulation Exercises

References:

1. Stuart A. Boyer,'*SCADA-Supervisory Control and Data Acquisition'*, Instrument Society of America Publications,USA,2004.
2. Gordon Clarke, Deon Reynders, '*Practical Modern SCADA Protocols: DNP3, 60870.5 and Related Systems'*, Newnes Publications, Oxford, UK,2004.
3. William T. Shaw, '*Cybersecurity for SCADA systems'*, PennWell Books, 2006
4. David Bailey, Edwin Wright, '*Practical SCADA for industry'*, Newnes, 2003
5. Michael Wiebe, '*A guide to utility automation: AMR, SCADA, and IT systems for electric power'*, PennWell 1999.

EE6429D WIRELESS & SENSOR NETWORKS

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Apply the knowledge of wireless sensor networks(WSN) to various application areas.
CO2: Design and implement WSN.
CO3: Conduct performance analysis of WSN and manage WSN.
CO4: Formulate and solve problems creatively in the area of WSN.

Module 1: (11 hours)

Introduction: Introduction to Sensor Networks, unique constraints and challenges, Advantage of Sensor Networks, Applications of Sensor Networks, Mobile Adhoc NETworks (MANETs) and Wireless Sensor Networks, Enabling technologies for Wireless Sensor Networks. Sensor Node Hardware and Network Architecture: Single-node architecture, Hardware components & design constraints, Operating systems and execution environments

Module 2: (10 hours)

Introduction to TinyOS and nesC - Network architecture, Optimization goals and figures of merit, Design principles for WSNs, Service interfaces of WSNs, Gateway concepts. Deployment and Configuration: Localization and positioning, Coverage and connectivity, Single-hop and multi-hop localization, self configuring localization systems, sensor management

Module 3: (10 hours)

Network Protocols: Issues in designing MAC protocol for WSNs, Classification of MAC Protocols, S-MAC Protocol, B-MAC protocol, IEEE 802.15.4 standard and Zig Bee, Dissemination protocol for large sensor network. Routing protocols: Issues in designing routing protocols, Classification of routing protocols, Energy-efficient routing, Unicast, Broadcast and multicast, Geographic routing.

Module 4: (8 hours)

Data Storage and Manipulation: Data centric and content based routing, storage and retrieval in network, compression technologies for WSN, Data aggregation technique. Applications: Detecting unauthorized activity using a sensor network, WSN for Habitat Monitoring.

References:

1. Holger Kerl, Andreas Willig, ‘*Protocols and Architectures for Wireless Sensor Network’*, John Wiley and Sons, 2005 (ISBN: 978-0-470-09511-9).
2. Raghavendra, Cauligi S, Sivalingam, Krishna M., Zanti Taieb, ‘*Wireless Sensor Network’*, Springer 1st Ed. 2004 (ISBN: 978-4020-7883-5).
3. Feng Zhao, Leonidas Guibas, ‘*Wireless Sensor Network’*, Elsevier, 1st Ed. 2004 (ISBN: 13- 978-1-55860-914-3)
4. Kazem, Sohraby, Daniel Minoli, Taieb Zanti, ‘*Wireless Sensor Network: Technology’, Protocols and Application*, John Wiley and Sons 1st Ed., 2007 (ISBN: 978-0-471-74300-2).
5. B. Krishnamachari, ‘*Networking Wireless Sensors’*, Cambridge University Press.
6. N. P. Mahalik, ‘*Sensor Networks and Configuration: Fundamentals, Standards, Platforms, and Applications’*, Springer Verlag.

EE6430D NETWORK & DATA SECURITY

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Discuss about information security governance, and related legal and regulatory issues
CO2: Identify external and internal security threats to an organization
CO3: To be familiar with information security awareness and a clear understanding of its importance
CO4: Discover and analyze the threats to an organization and select suitable solution strategies.

Module 1: (10 hours)

Introduction: Basic objectives of cryptography, secret-key and public-key cryptography, Block ciphers: Modes of operation, DES and its variants, AES, linear and differential cryptanalysis, stream ciphers, message digest algorithms: properties of hash functions, MD5 and SHA-1, keyed hash functions, attacks on hash functions.

Module 2: (11 hours)

Modular arithmetic, gcd, primality testing, Chinese remainder theorem, finite fields. Intractable problems: Integer factorization problem, RSA problem, discrete logarithm problem, DiffieHellman problem, Publickey encryption: RSA, Elliptic curve cryptography. Key exchange: Diffie-Hellman algorithms. Digital signatures: RSA, DSS, DSA, ECDSA, blind signatures, threshold cryptography, key management.

Module 3:(13 hours)

Network Security – Electronic Mail Security- Pretty Good Privacy – S/MIME – IP security – overview and architecture – authentication header – encapsulating security payload – combing security associations – web security requirements Secure Socket Layer and Transport Layer Security – secure electronic transactions, Authentication applications: X-509, Kerberos, RADIUS.

Module 4: (5 hours)

Wireless network security - WEP, WPA2 (802.11i), security in Bluetooth.

References:

1. Stallings, W., '*Cryptography and network security: principles and practice",.* 4th ed. Upper Saddle River: Prentice Hall, 2006. ISBN 0-13-187316-4.
2. Stallings,' *Network security essentials applications and standards*', Pearson education, 1999.
3. Menezes, A. J., Van Oorschot, P. C.; Vanstone, S. A., '*Handbook of applied cryptography'*, Boca Ratón [etc.]: CRC Press, 1997. ISBN 0-8493-8523-7.
4. Stajano, F*., 'Security for ubiquitous computing*', Chichester: John Wiley and Sons, 2002. ISBN 0-470- 84493-0.

EE6432D ADVANCED ALGORITHMS AND DATA STRUCTURE ANALYSIS

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Explain algorithmic techniques such as brute force, greedy, and divide and conquer.
CO2: Apply advanced abstract data type (ADT) and data structures in solving real world problems.
CO3: Devise complete algorithmic solution to a given problem effectively combining the fundamental data structures and algorithmic techniques.

Module 1: (9 hours)

Review of order notation & growth of functions, recurrences, probability distributions, Average case analysis of algorithms, Basic data structures such as stacks, queues, trees, graphs linked lists, and applications, priority queues.

Module 2: (8 hours)

Direct access tables and hash tables, hash functions and relates analysis, Binary Search trees and Operations, AVL Trees and balancing operations, R B Trees, properties, operations. Dynamic Graphs, Strings, Succinct. Dynamic optimality, Memory hierarchy.

Module 3: (11 hours)

Quick sort randomized version, searching in linear time, More graph algorithms – maximal independent sets, colouring vertex cover, introduction to perfect graphs.

Module 4: (11 hours)

Algorithmic paradigms Greedy Strategy, Dynamic programming, Backtracking, Branch-and-Bound, Randomized algorithms. Generic programming methodology and algorithm design – microprogramming - ADC, Quantization, word length issues, floating point numbers, etc

References:

1 H. S. Wilf, *Algorithms and complexity*, Prentice hall.
2 T. H. Cormen, C. E. Leiserson, R. L. Rivest, *Introduction to Algorithms*, Prentice hall.

EE6434D INTERNET OF THINGS AND APPLICATIONS

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Discover the application areas of IOT ·
CO2: Realize the revolution of Internet in Mobile Devices, Cloud & Sensor Networks
CO3: Describe the building blocks of Internet of Things and characteristics
CO4: Explain cloud based sensor data analysis

Module 1: (10 hours)

Elements of an IoT ecosystem. Technology drivers, Business drivers. Typical IoT applications. Trends and implications. Overview of IoT supported Hardware platforms such as: Raspberry pi, ARM Cortex Processors, Arduino and Intel Galileo boards. IoT architecture: History of IoT, M2M - Machine toMachine, Web of Things, IoT protocols. Internet of Things (IoT) and Web of Things (WoT). Internet and Web Layering
Business aspects of the Internet of Things. Representational State Transfer (REST) and Activity Streams, Business Cases & Concepts Persuasive Technologies & Behavioral Change IoT Communication Protocols Big Data and Semantic Technologies

Module 2: (10 hours)

Overview and working principle of Wired Networking equipment - Router, Switches, Overview and working principle of Wireless Networking equipment – Access Points, Hubs, etc. Linux Network configuration concepts: Networking configurations in Linux Accessing Hardware &Device Files interactions.

Module 3: (12 hours)

Network Fundamentals: Anatomy of a Sensor Network, Examples of Sensor Networks, Topology of a Sensor Network Communication Media. Wired Networks, Wireless Networks, Hybrid Networks. Types of Sensor Nodes, How Sensors Measure Storing Sensor Data. XBee Primer, Building an XBee-ZB Mesh Network, Arduino-Based Sensor Nodes,Hosting Sensors with Raspberry Pi

Module 4: (IoT tutorial and mini-project) (7 hours)

Storing Sensor Data, Storage Methods - Local Storage Options for the Arduino, Local Storage Options for the Raspberry Pi, Remote Storage Options, MySQL
Local processing on the sensor nodes.

- Connecting devices at the edge and to the cloud.
- Processing data offline and in the cloud.
- Mini-project: Designing an IoT system

References:

1. J. Biron and J. Follett, '*Foundational Elements of an IoT Solution*', O'Reilly Media, 2016.
2. Keysight Technologies, '*The Internet of Things: Enabling Technologies and Solutions for Design and Tes't*, Application Note, 2016.
3. Charles Bell, '*Beginning Sensor Networks with Arduino and Raspberry Pi*', Apress, 2013.
4. D. Evans, '*The Internet of Things: How the Next Evolution of the Internet Is Changing Everything*', Cisco Internet Business Solutions Group, 2011
5. McKinsey& Company, '*The Internet of Things: Mapping the value beyond the hype*', McKinsey Global Institute, 2015

6. European Alliance for Innovation (EAI), '*Internet of Things: Exploring the potential'*, Innovation Academy Magazine, Issue No. 03, 2015
7. Digital Greenwich, '*Greenwich Smart City Strategy'*, 2015
8. ITU and Cisco, '*Harnessing the Internet of Things for Global Development'*, A contribution to the UN broadband commission for sustainable development.

EE6436D INDUSTRIAL LOAD MODELLING & CONTROL

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Explain the load control techniques in industries and its application.
CO2: Explain different types of industrial processes and optimize the process using tools like LINDO and LINGO.
CO3: Apply load management technique to reduce the demand of electricity during peak time.
CO4: Analyse different energy saving opportunities in industries.
CO5: Apply the techniques of reactive power control in industries and analyze different power factor improvement methods.
CO6: Explain the mathematical modelling and profiling of various loads such as cool storage, cooling and heating loads.

Module 1: (10 hours)

Electric Energy Scenario-Demand Side Management-Industrial Load Management; Load Curves-Load Shaping Objectives-Methodologies-Barriers; Classification of Industrial Loads- Continuous and Batch processes -Load Modelling; Electricity pricing – Dynamic and spot pricing -Models;

Module 2: (10 hours)

Direct load control- Interruptible load control; Bottom up approach- scheduling- Formulation of load models- optimisation and control algorithms - Case studies;

Reactive power management in industries-controls-power quality impacts-application of filters;

Module 3: (10 hours)

Cooling and heating loads- load profiling- Modeling- Cool storage-Types-Control strategies-Optimal operation-Problem formulation- Case studies;

Module 4: (9 hours)

Captive power units- Operating and control strategies- Power Pooling- Operation models; Energy Banking- Industrial Cogeneration; Selection of Schemes Optimal Operating Strategies-Peak load saving-Constraints-Problem formulation- Case study; Integrated Load management for Industries;

References:

1 C.O. Bjork, '*Industrial Load Management - Theory, Practice and Simulations'*, Elsevier, the Netherlands, 1989.
2. C.W. Gellings and S.N. Talukdar, *'Load management concepts'*. IEEE Press, New York, 1986, pp. 3-28.
3. Various Authors, '*Demand side management – Alternatives'*, IEEE Proceedings on DSM , Oct 1985
4. Y. Manichaikul and F.C. Schweppe,'*Physically based Industrial load'*, IEEE Trans. on PAS, April 1981
5. H. G. Stoll, *'Least cost Electricity Utility Planning'*, Wiley Interscience Publication, USA, 1989.
6. I.J.Nagarath and D.P.Kothari, '*Modern Power System Engineering*', Tata McGraw Hill publishers, New Delhi, 1995.
7. Cogeneration as a means of pollution control and energy efficiency in Asia 2000. Guide book by UNESC for ASIA and the Pacific , Book No: ST/ESCAP/2026, UNESCAP, Bangkok
8. IEEE Bronze Book, '*Recommended Practice for Energy Conservation and cost effective planning in Industrial facilities'*., IEEE Inc, USA.

9. ASHRAE Handbooks, 1997-2000, American Society of Heating, Refrigerating and Air-conditioning Engineers Inc., Atlanta, GA.
10. Richard E. Putman, '*Industrial energy systems: analysis, optimization, and control*', ASME Press, 2004

EC6302D COMMUNICATION NETWORKS

Pre-requisites: Nil

L	T	P	C
3	0	2	4

Total hours: 39L + 26P

Course Outcomes:

CO1: Describe the basic building blocks of a computer network and understand the architecture of the global Internet

CO2: Describe, analyze and compare a number of datalink, network, and transport layer protocols

CO3: Develop a strong theoretical foundation on performance analysis of various queueing models with applications to Internet

CO4: Develop the ability to explore the design and development of more resource efficient and eco-friendly networking technologies

Module 1: (12 hours)

Introduction: General issues in networking - Circuit switching, packet switching and virtual circuit switching - Layered architecture for Internet -Performance metrics for networks - Data link layer – Framing- Error detection- Reliable Transmission – Automatic repeat request (ARQ) schemes and performance analysis- Medium access control (MAC) protocols- Direct Link Networks- -Ethernet and multiple access networks - IEEE 802.11 wireless LANs: Distributed coordination function

Module 2: (12 hours)

Internetworking :IPV4 and IPV6 - Addressing in internet – Subnetting and supernetting– Routing in Internet –Routing protocols for Internet – Datagram forwarding in Internet - Address resolution protocol (ARQ) – Dynamic host configuration protocol (DHCP) – Mobile IP Transport layer protocol - TCP and UDP - End-to-end reliability in Internet – Time out computation in TCP - TCP flow control and congestion control

Module 3: (15 hours)

Broadband services and QOS issues: Quality of Service issues in networks- Integrated service architecture- Queuing Disciplines- Weighted Fair Queuing- Random Early Detection- Differentiated Services- Protocols for QOS support- Resource reservation-RSVP- Multi protocol Label switching- Real Time transport protocol.

Performance analysis: Introduction to Queuing theory: Markov chain- Discrete time and continuous time Markov chains- Poisson process- Queuing models for Datagram networks- Little's theorem- M/M/1 queuing systems- M/M/m/m queuing models- M/G/1 queue- Mean value analysis- Time reversibility- Closed queuing networks- Jackson's Networks.

References:

1. Peterson L.L. and Davie B.S., *Computer Networks: A System Approach*, Elsevier, 5th edition, 2012
2. James. F. Kurose and Keith.W. Ross, *Computer Networks, A top-down approach featuring the Internet*, Pearson Education, 5th edition, 2015
3. D. Bertsekas and R. Gallager, *Data Networks*, PHI, 2nd edition, 2000
4. S. Keshav, *An Engineering Approach to Computer Networking*, Pearson Education, 2005

EC6434D LINEAR & NONLINEAR OPTIMIZATION

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Outline an adequate mathematical background on optimization theory.
CO2: Analyze the basic techniques commonly used in linear programming problems.
CO3: Develop the basic skill to address the nonlinear programming problems.
CO4: Obtain the fundamental knowledge to oversee the constrained and unconstrained optimization problems.

Module 1: (10 hours)

Mathematical background: sequences and subsequences, mapping and functions, continuous functions infimum and supremum of functions minima and maxima of functions, differentiable functions. Vectors and vector spaces, matrices, linear transformation, quadratic forms, gradient and Hessian- Linear equations, solution of a set of linear equations, basic solution and degeneracy, convex sets and convex cones, convex hulls, extreme point, convex and concave functions, differentiable convex functions.

Module 2: (13 hours)

Linear Programming: introduction, optimization model, formulation and applications, classical optimization techniques: single and multi variable problems, types of constraints, graphical method, linear optimization algorithms: simplex method, basic solution and extreme point, degeneracy, primal simplex method, dual linear programs, primal, dual, and duality theory, dual simplex method, primal-dual algorithm. Post optimization problems: sensitivity analysis and parametric programming.

Module 3: (16 hours)

Nonlinear Programming: minimization and maximization of convex functions, local & global optimum, convergence. Unconstrained optimization: one dimensional minimization, elimination methods: Fibonacci & Golden section search, gradient methods. Constrained optimization: Lagrangian method, Kuhn-Tucker optimality conditions, convex programming problems. augmentedLagrangian method (ALM)
Applications of optimization theory in signal processing: signal processing via convex optimization, applications in weight design, linearizing pre-equalization, robust Kalman filtering, online array weight design, basic pursuit denoising (BPDN), compressing sensing and orthogonal matching pursuit (OMP).

References:

1. David G Luenberger, Linear and Non Linear Programming., Addison-Wesley, 2ndEdn., 2001
2. S.S.Rao, .Engineering Optimization.; Theory and Practice; John Wiley, 4thEdn.., 2013,
3. S.M. Sinha, Mathematical programming: Theory and Methods, Elsevier, 2006.
4. Hillier and Lieberman Introduction to Operations Research, McGraw-Hill, 8th Ed., 2005.
5. Kalyanmoy Deb, Optimization for Engineering: Design Algorithms and Examples, Prentice Hall, 1998.
6. Igor Griva, ArielaSofer, Stephen G. Nash: Linear and Nonlinear Optimization, SIAM, 2009.

EC6413D PATTERN RECOGNITION AND ANALYSIS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Apply knowledge of linear systems, probability theory, statistics and optimization theory for data representation.
CO2: Analyze basic mathematical and statistical techniques in pattern recognition.
CO3: Design and implement pattern recognition algorithms to classify real world data.
CO4: Create pattern recognition systems by forming sound decisions on real world problems.
CO5: Develop skill to conduct independent research in the area of pattern recognition

Module 1: (12 hours)

Introduction - features, feature vectors and classifiers, Classifiers based on Bayes Decision theory - discriminant functions and decision surfaces, Bayesian classification for normal distributions, Estimation of unknown probability density functions, the nearest neighbour rule. Linear classifiers - Linear discriminant functions and decision hyper planes.

Module 2: (15 hours)

The Perceptron algorithm, MSE estimation, Non-Linear classifiers- Two layer and three layer Perceptrons, Back propagation algorithm, Networks with Weight sharing, Polynomial classifiers, Radial Basis function networks, Support Vector machines, Decision trees, Boosting - combining classifiers.
Feature selection, Class separability measures, Optimal feature generation, The Bayesian information criterion, representation of images in spaces, KL transform, Nonlinear transform - kernel PCA, Isomap, LLE. Speech and audio features - Cepstrum, Mel-cepstrum, Spectral features. Context dependent classification - Bayes classification, Markov chain models, HMM, Viterbi Algorithm. Training Markov models on neural networks.

Module 3: (12 hours)

Datasets, training and testing methods, accuracy, Receiver Operating Characteristics (ROC) curveClustering- Cluster analysis, Proximity measures, Clustering Algorithms - Sequential algorithms, neural network implementation. Hierarchical algorithms - Agglomerative algorithms, Divisive algorithms, Probabilistic clustering, K - means algorithm. Clustering algorithms based on graph theory, Competitive learning algorithms, Valley seeking clustering, Clustering validity.

References:

1. C. Bishop, Pattern Recognition and Machine Learning, Springer, 1st ed. 2006
2. Richard O. Duda, Hart P.E, and David G Stork, Pattern classification , 2nd Edn., John Wiley & Sons Inc., 2001.
3. S Theodoridis, K Koutroumbas, Pattern Recogntion, 4th Edition, Academic Press, 2009.

EC6421D DIGITAL IMAGE PROCESSING TECHNIQUES

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1:Demonstrate the methods of image acquisition, representation and manipulation to design and develop algorithms for solving image processing problems related to various applications like medicine, industry, communications etc.

CO2: Analyze various image processing algorithms for preprocessing, restoration, compression and segmentation using various spatial and frequency domain methods

CO3: Identify and solve complex real world problems in image processing using modern signal processing tools, active cooperative learning and be able to demonstrate them effectively.

CO4: Acquire skills to conduct independent study and analysis of image processing problems and techniques that would engage in lifelong learning.

Module 1: (12 hours)

Image representation: Gray scale and colour Images, image sampling and quantization, colour spaces. Connectivity and relations between pixels.Simple manipulations of pixels - arithmetic, logical and geometric operations. Various techniques for image enhancement and restoration - filters in spatial and frequency domains, histogram-based processing, homomorphic filtering, Image Registration. Examples and case studies.

Module 2: (13 hours)

Morphological Image Processing: The structuring element, Basic operations on sets, Erosion, Dilation, Opening and Closing, Hit-or-Miss Transform, Basic Morphological Algorithms and applications.
Image segmentation: Edge detection, line detection, curve detection, Edge linking and boundary extraction, boundary representation, region representation and segmentation - Thresholding, Otsu's Method, Variable and multi variable thresholding, Similarity based Segmentation - Segmentation Using Morphological Watersheds, Use of Motion in Segmentation.Image representation and object recognition: Descriptors for boundaries and regions, global descriptors – Pattern recognition as applied to images.

Module 3: (14 hours)

.Fundamental concepts of image compression - Compression models - Information theoretic perspective - Fundamental coding theorem - Lossless Compression: Huffman Coding- Arithmetic coding - Bit plane coding - Run length coding - Lossy compression: Quantization – Scalar and Vector, Transform coding - Image compression standards, Introduction to Sub band coding. Basic concepts of video compression, Introduction to video compression standards.

References:

1. R. C. Gonzalez, R. E. Woods*, 'Digital Image Processing'*, Pearson Education. III Ed.,2016
2. Jain A.K., '*Fundamentals of Digital Image Processing'*, Prentice-Hall, 2002.
3. Jae S. Lim, '*Two Dimensional Signal And Image Processing'*, Prentice-Hall, Inc, 1990.
4. Pratt W.K., '*Digital Image Processing'*, John Wiley, IV Edition, 2007.
5. K. R. Castleman, '*Digital image processing'*, Prentice Hall, 1

EC6401D LINEAR ALGEBRA FOR SIGNAL PROCESSING

Pre-requisites: Nil

L	T	P	C
4	0	0	4

Total hours: 52

Course Outcomes

CO1: Demonstrate the foundation concepts on Signal Theory and System Theory applicable to Communication Engineering and Signal Processing
CO2: Apply the mathematical framework of Signal Theory and System Theory for Analysis and Design
CO3: Recommend basic concepts that enable designs for environment-friendly direct applications
CO4: Develop ability to think clearly and express precisely, coupled with systematic logical reasoning.

Module 1: (17 hours)

Algebraic Structures:Definitions and properties of Semigroups, Groups, Rings, Fields, and Vector Spaces, Homomorphisms.
Vector Spaces and Linear Transformations:Linear Spaces and Subspaces, and Direct Sums; Linear Independence, Bases, and Dimension; Linear Transformations, Linear Functionals, Bilinear Functionals, and Projections.
Finite-Dimensional Vector Spaces and Matrices:Coordinate representation of vectors, change of basis and change of coordinates; Linear operators, Null space and Range space; Rank-Nullity theorem, Operator inverses, Application to matrix theory, Computation of the range space and null space of a matrix;Matrix of an operator, Operator algebra, change of basis and similar matrices.

Module 2: (18 hours)

Inner Product Spaces:Definition of inner product, norms, angle between vectors**;** Orthogonal sets, Fourier coefficients and Parseval's identity, Gram-Schmidt process, QR factorization; Approximation and orthogonal projection, Computations using orthogonal and non-orthogonal sets, Normal equations; Projection operator, Orthogonal complements, Decomposition of vector spaces, Gram matrix and orthogonal change of basis, Rank of Gram matrix.
Normed Linear Spaces:Metric and metric spaces, Neighborhoods, open and closed sets, Sequences and Series, Continuity and convergence; Norms, Completeness and compactness, Continuous linear transformations, Inverses and Continuous inverses, Complete Normed Linear Space; Norm induced by the Inner product, Hilbert spaces.

Module 3: (17 hours)

Diagonalizable linear operators:Eigenvalues and Eigenvectors, Spectrum and Eigen spaces of an operator, Properties of the characteristic polynomial, Geometric and algebraic multiplicities; Linear operators with an Eigen basis, Diagonalizability and Similarity Transformation; Cayley-Hamilton Theorem, Nilpotent Transformations. Jordan Canonical form.
Quadratic forms: Definition and Properties of quadratic forms; Hermitian forms, Orthogonal Diagonalization and the Principal axis theorem, Simultaneous diagonalization of quadratic forms.
Factorizations: Singular value and Polar Decompositions, The pseudoinverse and the generalized pseudoinverse.

References:

1. Gilbert Strang, *'Introduction to Linear Algebra'*, 4th Edition, Wellesley-Cambridge Press, MA, 2009.
2. Kenneth Hoffman, Ray Kunze, *'Linear Algebra'*, 2nd Edition, PHI Learning, Delhi, 2014.
3. Anthony N. Michel, Charles J. Herget, *'Applied Algebra and Functional Analysis'*, Dover Publications, NY, 1993.
4. Arch W. Naylor, George R. Sell, *'Linear Operator Theory in Engineering and Science'*, Springer-Verlag, NY, 2000
5. James M. Ortega, *'Matrix Theory: A Second Course'*, Plenum Press/Kluwer Academic, NY, 1987.

MA7165D STATISTICAL DIGITAL SIGNAL PROCESSING

Pre-requisites: Nil

L	T	P	C
3	1	0	3

Total hours: 39

Course Outcomes:
CO1: Students acquire knowledge about random processes and their classification.
CO2: Learn and apply concepts of signal modelling.
CO3: Understand basic results about Lattice filters and Wiener filtering.
CO4: Learn about power spectrum estimation and application to real world problems.

Module 1: (10 hours)

Discrete-Time Random Processes: Random Variables, Random Processes, Filtering Random Processes, Spectral Factorization, Special Types of Random Processes.

Module 2: (12 hours)

Signal Modeling: The Least Squares Method, The Pade Approximtion, Prony's Method, Finite Data Records, Stochastic Models

Module 3: (17 hours)

Lattice Filters and Wiener Filtering: The FIR Lattice Filter, Split Lattice Filter, IIR Lattice Filters, Stochastic Modeling, The FIR Wiener Filter, IIR Wiener Filter, Discrete Kalman Filter.

Spectrum Estimation: Nonparametric Methods, Minimum Variance Spectrum Estimation, The Maximum Entropy Method, Parametric Methods, Frequency Estimation, Principal Components Spectrum Estimation.

References:

1. M. H. Hayes; '*Statistical Digital Signal Processing and Modeling*', John Wiley & Sons, 2004.
2. G. J. Miao and M. A. Clements; '*Digital Signal Processing and Statistical Classification*', Artech House, London, 2002.
3. R. M. Gray and L. D. Davisson ; '*An Introduction to Statistical Signal Processing*', Cambridge University Press, 2004.

MA8154D WAVELETS THEORY

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Review fundamental concepts of linear algebra and understand the theory of Fourier transform.
CO2: Acquire knowledge about construction of discrete wavelets.
CO3: Learn the construction of continuous wavelets through iteration and their implementation.
CO4: Study about multi resolution analysis and construction.

Module 1: (10 hours)

Vector spaces and Bases, Linear transformation, Matrices and change of basis, Inner products, Hilbert Space, Fourier transforms, Parseval identity and Plancherel theorem, Basic Properties of Discrete Fourier Transforms , Translation invariant Linear Transforms ,The Fast Fourier Transforms.

Module 2: (18 hours)

Construction of wavelets on Z_N ,The Haar system, Shannon Wavelets, Real Shannon wavelets,Daubechie's D_6 wavelets on Z_N., Examples and applications.

Wavelets on Z:l^2 (Z), Complete orthonormal sets in Hilbert spaces,L^2 $(-\pi,\pi)$ and Fourier series,The Fourier Transform and convolution on l^2 (Z), First stage Wavelets on Z , Implementation and Examples.

Module 3: (11 hours)

Wavelets on R :L^2 (R) and approximate identities, The Fourier transform on R , Multiresolution analysis, Construction of MRA .

References:

1. Michael. W. Frazier, '*An Introduction to Wavelets through Linear Algebra*', Springer, Newyork, 1999.
2. Jaideva. C. Goswami, Andrew K Chan, '*Fundamentals of Wavelets Theory Algorithms and Applications*', John Wiley and Sons, Newyork. , 1999.
3. Yves Nievergelt, '*Wavelets made easy*', Birkhauser, Boston,1999.
4. G. Bachman, L.Narici and E. Beckenstein, '*Fourier and wavelet analysis*', Springer, 2006.

MS9001D RESEARCH METHODOLOGY

Pre-requisites: Nil

L	T	P	C
4	0	0	4

Total hours: 52

Course Outcomes

CO1: Explain the basic concepts of research.
CO2: Identify various sources of information for literature review and data collection.
CO3: Understand various research designs and techniques of data analysis.
CO4: Appreciate the components of scholarly writing and evaluate its quality.
CO5: Develop an understanding of the ethical dimensions of conducting research.

Module 1: (14 hours)

Research methodology- Understanding the language of research – Concepts, constructs, operational definitions, variables, propositions, hypotheses, theories, and models - Research process- Literature review -Types of research- Problem identification andformulation - Research question – Research hypothesis - Measurement issues - Methods of data collectionTypes of data- Primary data- Scales of measurement- Sources and collection of dataObservation method- Interview method– Survey- Experiments- Secondary data-Research design- Qualitative and Quantitative Research.

Module 2: (16 hours)

Processing and analysis of data- Sampling- Steps and characteristics of sampling designSampling: concepts of Population, Sample, Sampling Frame, - Sample size and its determination - Types of sampling distributions - Sampling error - Statistics in researchDescriptive statistics and inferential statistics- Measures of central tendency, dispersion, skewness, asymmetry- Measures of relationship- Correlation and regression- Simple regression analysis- Multiple regression -Hypothesis Testing - parametric and non-parametric tests- Analysis of single factor experiments.

Module 3: (12 hours)

Reporting and presenting research - Written and oral communications -Hallmark of great scientific writing – The reading toolkit - Pre-writing considerations - Format of dissertations, research reports, and research papers – Paper title and keywords – Writing an abstract – Writing the different sections of a paper - Revising a paper - Responding to peer reviews - Reviewing research papers - Plagiarism - Conference and poster presentations - Language aspects of report writing -Verb, tense and voice in scientific writing - Errors in grammar - Sentence and paragraph constructions -Paraphrasing - Measures of research impact.

Module 4: (10 hours)

Intellectual property rights - Copyright - Patents - The codes of ethics - Avoiding the problems of biased survey -Occupational health and safety.

References:

1. Cooper, D. R. and Schindler, P. S., (2009), '*Business Research Methods*', Tata McGraw Hill, 9th Edition.
2. Jackson, S.L., '*Research Methods and Statistics'*, Cengage Learning India Private Limited, New Delhi, 2009.
3. Krishnaswamy, K.N., Sivakumar, A.I., and Mathirajan, M., '*Management Research Methodology'*, Pearson Education , 2006.
4. Lebrun, J-L., '*Scientific Writing: A Reader and Writer's Guide'*, World Scientific Publishing Co. Pte. Ltd., Singapore, 2007.
5. MLA, MLA '*Handbook for Writers of Research papers'*, Seventh Edition, Affiliated EastWest Press Pvt Ltd, New Delhi, 2009.
6. Thiel, D. V., '*Research Methods for Engineers'*, Cambridge University Press, 2014.

ME6313D INDUSTRIAL AUTOMATION AND ROBOTICS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Understand the automation concepts, architecture, strategies, functions and levels generally followed in industries

CO2: Explain various types and subsystems of industrial control systems

CO3: Understand various subsystems of robots, types, applications, history, present and future trends in robots.

CO4: Develop the kinematic, static and dynamic models of Robotic manipulators

CO5: Design appropriate trajectory for robot based applications

Module 1: (10 hours)

Introduction to automation: definition, types, merits and Criticism, architecture of industrial automation systems, manufacturing plants and operations: automation strategies, basic elements of automated system, advanced automation functions, Levels of automation.

Module 2: (12 hours)

Industrial control Systems: process and discrete manufacturing industries, continuous and Discrete Control systems: an overview of Computer process control, fundamentals of automated assembly system, actuators and sensors: fluid power and electrical actuators, piezoelectric actuator; sensors for position, motion, force, strain and temperature.

Module 3: (17 hours)

Introduction to robotics: robotics system, classification of robots, robot Characteristics, kinematics for manipulator: frames and transformations, forward and inverse kinematics, DH representation,derivation of forward and Inverse kinematic equations for various types of robots, applications of robots.

Introduction to manipulator jacobian: singularity, jacobian in force domain, velocity propagation from link to link, static forces in manipulators, introduction to dynamic analysis: Lagrangian formulation, trajectory planning: joint space and cartesian space.

References:

1. John J. Craig, '*Introduction to Robotics, Mechanics and Control*', 3rd ed., Addison – Wesley, 2018.
2. Saeed B. Niku, '*Introduction to Robotics*, *Analysis, Systems and applications*', Prentice Hall India, 2002.
3. Mikell P. Groover, '*Automation, Production Systems and Computer Integrated Manufacturing*', Prentice Hall, India, 2004.
4. Mark W. Spong, and M. Vidyasagar, '*Robot Dynamics and Control*', John Wiley & Sons, 1989.
5. K. S. Fu, R. C. Gonzales, C. S. G. Lee, '*Robotics Control, Sensing, Vision and Intelligence*', McGraw Hill 1987.
6. R. P. Paul, '*Robot Manipulators Mathematics Programming', Control, The Computer Control of Robotic Manipulators*, The MIT Press, 1979.
7. Robert J. Schilling, '*Fundamentals of Robotics, Analysis and Control*', Prentice Hall of India 1996.
8. R. K. Mittal and I. J. Nagarath, '*Robotics and Control*', Tata McGraw-Hill, 2003.
9. M. Groover, and E. Zimmers, '*CAD/CAM-Computer Aided Design and Manufacturing*', Prentice Hall of India, 2000.
10. F. G. Shinskey, '*Process Control Systems – Application, Design and Tuning*', 4th ed., McGraw-Hill, 1996.