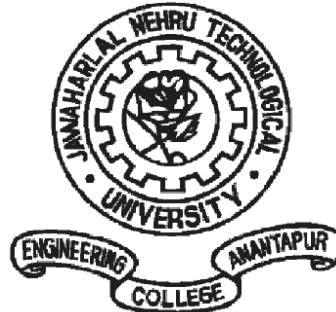Approved Syllabus for

# Master of Technology

in

# *CONTROL SYSTEMS*

**From Academic Year 2015 - 2016**

in

SECOND BOARD OF STUDIES MEETING HELD

on

April 25th & 26th , 2015



**DEPARTMENT OF ELECTRICAL ENGINEERING**

**COLLEGE OF ENGINEERING *(AUTONOMOUS), ANANTHAPURAMU***

**JAWHARLAL NEHRU TECHNOLOGICAL UNIVERSITY ANANTAPUR**

<div align="center"><u>**INFORMATION ON THE COURSE**</u></div>

**1.1 Name of the Course**

| Name of Degree / Diploma | Name of Specialization | Intake (Full / Part time) | Year of Starting | Duration (Total) | Name of Degree & Branch eligible for admission |
|---|---|---|---|---|---|
| M. Tech. | Control Systems | 25+7 Sponsored Full time | 2009 – 10 | 2 Yrs/ 4 Semesters | 4 Year Degree Course B. Tech./B.E. (EEE/EIE/ECE/ICE/EConE) |

**1.2 Course Structure and scheme of evaluation (Semester – wise)**

| Name of the Subject | L | T | P | C |
|---|---|---|---|---|
| **I – SEMESTER** | | | | |
| 1.  15D22101  Modern Control Theory | 4 | - | - | 4 |
| 2.  15D22102  Advanced Digital Signal Processing | 4 | - | - | 4 |
| 3.  15D22103  Non - Linear Control Theory | 4 | - | - | 4 |
| 4.  15D22104  Optimal Control | 4 | - | - | 4 |
| 5.  Elective - I | 4 | - | - | 4 |
| 6.  Elective - II | 4 | - | - | 4 |
| 7.  15D22108 Control Systems Lab | - | | 4 | 2 |
| **Electives:** | | | | |
| 1. 15D22105  PLC & Automation | | | | |
| 2. 15D22106  Robust Control | | | | |
| 3. 15D23103  Machine Modeling and Analysis | | | | |
| 4. 15D22107  Embedded Systems | | | | |
| | | | | |
| **II – SEMESTER** | | | | |
| 1.  15D22201  Adaptive Control | 4 | - | - | 4 |
| 2.  15D22202  Digital Control Systems | 4 | - | - | 4 |
| 3.  15D22203  Intelligent Algorithms | 4 | - | - | 4 |
| 4.  15D22204  Estimation of Signals and Systems | 4 | - | - | 4 |
| 5.  Elective - III | 4 | - | - | 4 |
| 6.  Elective – IV | 4 | - | - | 4 |
| 7.  15D54201  Research Methodology (Audit Course) | 2 | - | - | 0 |
| 8.  15D22207  Control System Simulation Lab | - | - | 4 | 2 |
| **Electives:** | | | | |
| 1. 15D22205  Real Time Systems | | | | |
| 2. 15D21207  Solar Energy Conversion Systems | | | | |
| 3. 15D21208  Wind Energy Conversion Systems | | | | |
| 4. 15D22206   Process Dynamics and Control | | | | |
| **III SEMESTER** | | | | |
| 1.  15D22301 Seminar - I | - | - | 4 | 2 |
| **IV SEMESTER** | | | | |
| 1.  15D22401 Seminar – II | - | - | 4 | 2 |
| **III & IV SEMESTER** | | | | |
| 1. 15D22302 Project Work | - | - | - | 44 |

## 15D22101 MODERN CONTROL THEORY

**Unit  I**

Fields, Vectors, and vector spaces; State space representation, state equations for dynamic systems, solution of state equations; State transition matrix – Properties of state transition matrix; evaluation. Fadeeva algorithm for conversion from state space to transfer function, Linearization of non-linear models

**Unit II**

Non uniqueness of state model, Similarity transformation, Invariance of system properties. Controllability – necessary and sufficient condition - Pole assignment using State feedback – Ackerman's formula for feedback gain determination; Observability. Duality.  Effect of state feedback on controllability and observability. Controllable subspace – decomposition of state into controllable and uncontrollable components.

**Unit  III**

Design of full order observer – Bass Gura algorithm. The separation principle - Combined observer – controller compensator. Design of reduced order observer. Unobservable subspace – decomposition of state into observable and unobservable components – Canonical decomposition theorem.

**Unit  IV**

Reducibility – realization of transfer function matrices. Model decomposition and decoupling by state feedback. Design of robust control system for asymptotic tracking and disturbance rejection using State variable equations. Transfer function interpretations – transfer function form of observer and state estimate feedback. State space interpretation of internal model principle.

**Unit V**

Discrete time linear state regulator – Algorithm for the solution, Use of observer in implementing the control law. Continuous time linear state regulator – Matrix Riccati equation. Time invariant linear state regulator – the reduced matrix Riccati equation - An iterative method to solve the reduced matrix Riccati equation. Suboptimal linear regulator.

**Text Books**:

1. Modern Control Engineering, Katsuhiko Ogata, 5th Edition, Prentice Hall India, 1997
2.  Modern Control System Theory, M. Gopal, Revised 2nd Edition, New Age International Publishers, 2005.

**References:**
1. Linear Systems, Thomas Kailath, Perntice Hall, 1980.
2. Control System Design, Graham C. Goodwin, StefanF. Graebe and Mario E. Salgado, Pearson Education, 2000.
3. Linear System Theory and Design, Chi-Tsong Chen,  OXFORD University Press.
4. Richard C. Dorf and Robert H. Bishop, Modern Control Systems, 11th Edition, Pearson Edu India, 2009.

# 15D22102 ADVANCED DIGITAL SIGNAL PROCESSING

**UNIT-I:**
Short introduction, Analog to digital and Digital to Analog conversion, sampled and Hold circuit, Continuous time Fourier Transforms.  Discrete-time signals and systems, Discrete-time Fourier transform- its properties and applications, Fast Fourier Transform (in time-domain and Frequency domain) , IDFT and its properties.

**UNIT-II: z- Transforms**
Definition and properties, Rational z-transforms, Region of convergence of a rational z- Transform, The inverse z- Transform, Z-Transform properties, Computation of the convolution sum of finite-length sequences, The transfer function.
**Digital Filter Structures:** Block Diagram representation, Equivalent structures, Basic FIR Digital Filter structures, Basic IIR Digital Filter structures, Realization of Basic structures using MATLAB, All pass filters, Computational complexity of Digital filter structures.

**UNIT III**: **IIR Digital Filter Design:**
Preliminary considerations, Bilinear transformation method of IIR Filter design, Design of low pass IIR Digital filters, Design of High pass, Band pass and band stop IIR digital filters, Spectral Transformations of IIR filter, IIR digital filter design using MATLAB, Computer aided design of IIR digital filters.

**UNIT IV:FIR Digital Filter Design:**
Preliminary considerations, FIR filter design based on windowed Fourier series, Computer aided design of Equiripple Linear phase FIR filters, Design of Minimum phase FIR filters, FIR digital filter design using MATLAB, Design of computationally efficient FIR digital filters.

**UNIT V: Analysis of Finite word length effects**:
The quantization process and errors, quantization of Fixed point numbers, Quantization of floating point numbers, Analysis of coefficient quantization effects, Analysis of arithmetic round off errors, Low sensitivity digital filters, Reduction of product round off errors using error feedback, Round off errors in FFT algorithms. The basic sample rate alteration devices, Multi rate structures for sampling rate conversion, Multistage design of decimator and interpolator, The Polyphase decomposition, Arbitrary-rate sampling rate converter, Nyquist Filters and some applications of digital signal processing.

**Text Books:**
1. S.K. Mitra**, Digital Signal Processing**-, Tata McGraw-Hill, Third Edition, 2006.
2. B.P. Lathi, **Principle of Signal Processing and Linear Systems**-, Oxford International Student Version, 2009
3. M. Mondal and A Asif, **Continuous and Discrete Time Signals and Systems**, Cambridge, 2007

**References:**
1. Li Tan, **Digital Signal Processing- Fundamentals and Applications**-, Indian reprint, Elsevier, 2008.
2. Alan V. Oppenheim, Ronald W. Schafer, and John R.Buck, **Discrete- Time Signal Processing**-, Pearson Edu, 2008.

## 15D22103 NONLINEAR CONTROL THEORY

**UNIT I:**

Linear versus nonlinear systems - Describing function analysis: Fundamentals, common nonlinearities (saturation, dead - zone, on - off non - linearity, backlash, hysteresis) and their describing functions.

**UNIT II:**

Describing function analysis of nonlinear systems. Reliability of describing method analysis. Compensation and design of nonlinear system using describing function method. Phase plane analysis: Phase portraits, Singular points characterization. Analysis of non - linear systems using phase plane technique. Existence of limit cycles. Linearization: Exact linearization, input - state linearization, input - output linearization.

**UNIT III:**

Concept of stability, Zero - input and BIBO stability, stability in the sense of Lyapunov and absolute stability, Stability in the small and stability in the large, Lyapunov stability definitions, First method of Lyapunov,. Second (or direct) method of Lyapunov stability theory for continuous and discrete time systems, Aids to generate Lyapunov function – Krasovskii's theorem, Variable gradient method.

**UNIT IV:**

Aizerman's and Kalman's conjecture. Construction of Lyapunov function - Methods of Aizerman, Zubov, Variable gradient method. Lure problem. Popov's stability criterion, generalized circle criterion, Kalman - Yakubovich - Popov Lemma. Popov's hyperstability theorem.

**UNIT V:**

Concept of variable - structure controller and sliding control, reaching condition and reaching mode, implementation of switching control laws. Reduction of chattering in sliding and steady state mode. Some design examples of nonlinear systems such as the ball and beam, flight control, magnetic levitation and robotic manipulator etc.

**Text Books**
1. J. E. Slotine and Weiping LI, Applied Nonlinear Control, Prentice Hall,
2. Hassan K. Khalil, Nonlinear Systems, Prentice Hall, 1996.

**References:**
1. Sankar Sastry, Nonlinear Systems Analysis, Stability and Control.
2. M. Vidyasagar, Nonlinear Systems Analysis, Prentice - Hall International editions,1993.

## 15D22104 OPTIMAL CONTROL

**UNIT I**
An overview of optimization problem - concepts and terms related to optimization - constrained and unconstrained problems and their solutions using different techniques.

**UNIT II**
 Convex set and convex function - convex optimization problem - quadratic optimization problem - Karush - Kuhn - Tucker (KKT) necessary and sufficient conditions for quadratic programming problem.

**UNIT III**
 Interior point method for convex optimization - linear programming - primal and dual problems and basic concept of multi - objective optimization problem. Concept of functional, different types of performance indices, Euler - Lagrange equation.

**UNIT IV**
Calculus of variation   to optimal control problem  - Fundamental concepts, functionals of a single function, functional involving several independent functions, necessary conditions for optimal control, linear regulator problems. Linear quadractic regulator, remarks on weighting matrices, solution of Riccati equation.

**UNIT V**
 Frequency domain interpretation of linear quadratic regulator, robustness studies. Dynamic programming, Pontrygin's minimum principle, time optimal control, concept of system and signal norms, statement of problem and its solution.

**Text Books**:
1. Jasbir S. Arora, Introduction to optimum design, Elesevier, 2005.
2. A Ravindran, K.M. Ragsdell, and G.V. Reklaitis, Engineering optimization : Methods and applications, Wiley India Edition.
3. Donald E.Kirk, Optimal Control Theory an Introduction, Prentice - Hall Network series  - First edition, 1970.

**Reference Books:**
1. D.S. Naidu, Optimal control systems, CRC Press, First edition, 2002.
2. Arturo Locatelli, Optimal control: An Introduction, Birkhauser Verlag, 2001.
3. S.H.Zak, Systems and Control, Indian Edition , Oxford University, 2003.
4. Niclas Anreasson, Anton Evgrafov and Michael Patriksson, An introduction to continuous optimization, Overseas Press (India) Pvt. Ltd.

## 15D22108 CONTROL SYSTEMS LAB

**List of Experiments**

1. Determination of Transfer functions of an Electrical System.

2. Time Response Characteristics of a Second order System (Typical RLC network).

3. Characteristics of Synchros:

    (a) Synchro transmitter characteristics.

    (b) Implementation of error detector using synchro pair.

4. Determination of Magnetic Amplifier Characteristics with different possible connections.

5. Process Control Simulator:

    (a) To determine the time constant and transfer function of first order process.

    (b) To determine the time response of closed loop second order process with Proportional Control.

    (c) To determine the time response of closed loop second order process with Proportional-Integral Control.

    (d) To determine the time response of closed loop second order process with Proportional-Integral-Derivative Control.

    (e) To determine the effect of disturbances on a process.

6. To study the compensation of the second order process by using:

    (a) Lead Compensator.

    (b) Lag Compensator.

    (c) Lead- Lag Compensator

7. Realization of AND, OR, NOT gates, other derived gates and ladder logic on Programmable Logic Controller with computer interfacing.

8. To determination of AC servomotor Characteristics.

9. To study the position control of DC servomotor with P, PI control actions.

10. Analog Computer:

    (a) To examine the operation of potentiometer and adder.

    (b) To examine the operation of integrator.

    (c) To solve a second order differential equation.

## 15D22105 PLC & AUTOMATION

**Unit-I:**
PLC Basics: PLC system, I/O modules and interfacing, CPU processor, programming Equipment, programming formats, construction of PLC ladder diagrams, Devices connected to I/O modules.

PLC Programming: Input instructions, outputs, operational procedures, programming examples using contacts and coils. Drill press operation.

**Unit-II:**
Digital logic gates, programming in the Boolean algebra system, conversion examples
Ladder Diagrams for process control: Ladder diagrams & sequence listings, ladder diagram construction and flowchart for spray process system.

**Unit-III:**
PLC Resisters: Characteristics of Registers, module addressing, holding registers, Input Registers, Output Registers.

PLC Functions: Timer functions & Industrial applications, counters, counter function industrial applications, Arithmetic functions, Number comparison functions, number conversion functions

**Unit-IV:**
Data Handling functions: SKIP, Master control Relay, Jump, Move, FIFO, FAL, ONS, CLR & Sweep functions and their applications

Bit Pattern and changing a bit shift register, sequence functions and applications, controlling of two-axis & three axis Robots with PLC, Matrix functions.

**Unit-V:**
Analog PLC operation: Analog modules& systems, Analog signal processing, Multi bit Data Processing, Analog output Application Examples, PID principles, positions indicator with PID control, PID Modules, PID tuning, PID functions.

**Reference Books**:

1. Programmable Logic Controllers- Principles and Applications by John W. Webb & Ronald A. Reiss, Fifth Edition, PHI
2. Programmable Logic Controllers- Programming Method and Applications –JR.Hackworth &F.D Hackworth Jr. –Pearson, 2004

## 15D22106 ROBUST CONTROL

### UNIT I: Review of classical feedback control

Review of classical feedback control: The control problem, Transfer functions, Deriving linear models, Frequency response, Feedback control, Closed loop stability, Evaluating closed - loop performance, Controller design, Loop shaping, Shaping closed loop transfer functions.

### UNIT II: Introduction to Multivariable Control

Transfer functions for MIMO systems, Multivariable frequency response analysis, Control of multivariable plants, Introduction to robustness, General control problem formulation.
**Elements of Linear System Theory:** Internal stability of feedback systems, Stabilizing controllers, System norms, Input - Output Controllability, perfect control and plant inversion, Constraints on S and T.

### UNIT III: Limitations on Performance

**In SISO Systems:** Limitations imposed by RHP - zeros, Limitations imposed by RHP - poles,  Performance requirements imposed by disturbances and commands, Limitations imposed by input constraints, Limitations imposed by uncertainty.

**In MIMO Systems:** Constraints on S and T, Functional Controllability, Limitations imposed by RHP - zeros, Limitations imposed by RHP - poles, Performance requirements imposed by disturbances, Limitations imposed by input constraints, Limitations imposed by uncertainty.

### UNIT IV: Uncertainty and Robustness for SISO Systems

Introduction to robustness, Representing uncertainty, parametric uncertainty, Representing uncertainty in the frequency domain, SISO robust stability, SISO robust performance, Examples of parametric uncertainty.

### UNIT V: Robust Stability, Performance Analysis and Control System Design

General control formulation with uncertainty, Representing uncertainty, Obtaining P, N and M, Definition of robust stability and performance, Robust stability of the M∆ - structure, RS for complex unstructured uncertainty, RS with structured uncertainty: Motivation, The structured singular value and RS, Properties and computation of μ, Robust performance, Application: RP with input uncertainty, μ - synthesis and DK - iteration, Further remarks on μ. Trade - offs in MIMO feedback design, LQG control, $H_2$ and $H_\infty$ control, $H_\infty$ loop - shaping design.

### Text Books:

1. Sigurd Skogestad and Ian Postlethwaite, Multivariable Feedback Control Analysis and Design - John Wiley & Sons Ltd., 2$^{nd}$ Edition, 2005.
2. D. W. Gu, P. Hr. Petkov and M. M. Konstantinov "Robust Control Design with MATLAB" Spring - Verlag London Ltd., 2005.

### References:

1. Kennin Zhou, "Robust and Optimal Control", Prentice Hall, Engle wood Cliffs, New Jersy.

## 15D23103 MACHINE MODELING & ANALYSIS

**UNIT -I: Basic Principles for Machine Analysis:** Magnetically Coupled Circuits, Machine Windings and Air-Gap MMF, Winding Inductances and Voltage Equations.
**Modeling And Analysis Of DC Machines**:
Elementary DC Machine, Voltage and Torque Equations, Types of DC Machines, Permanent and Shunt DC Motors, Time-Domain and State-Equations,

**UNIT-II: Reference Frame Theory**: Introduction to Transformations, Equations of Transformations, Change of Variables, and Transformation to an Arbitrary Reference Frame, Commonly used Reference Frames, Transformation between Reference Frames, Steady-State Phasor Relationships and Voltage Equations

**UNIT-III: Modeling & Dynamic Analysis of Three Phase Induction Machines:** Voltage and Torque Equations in Machine Variables, Voltage and Torque Equations in Arbitrary Reference Frame, Steady-State Analysis and its Operation.
Free Acceleration Characteristics viewed from Various Reference Frames, Dynamic Performance during Sudden Changes in Load Torque, Dynamic Performance during A Three-Phase Fault at the Machine Terminals

**UNIT-IV: Modeling & Dynamic Analysis of Synchronous Machine:** Voltage and Torque Equations in Machine Variables, Voltage Equations in Arbitrary and Rotor Reference Frame, Torque Equations in Substitute Variable, Steady-State Analysis and its Operation.
Dynamic Performance of Synchronous Machine, Three-Phase Fault, Comparison of Actual and Approximate Transient Torque Characteristics, Equal Area Criteria.

*UNIT -V: Modeling of Special Machines: Modeling of Permanent Magnet Brushless DC Motor Operating principle – Mathematical modeling of PM Brushless DC motor - PMDC Motor Drive Scheme.*

**Text books**
**1.** Krause, Wasynczuk, Sudhoff, **Analysis of Electric Machinery and Drive Systems**: 2$^{nd}$
    Edition, Wiley Interscience Publications, 2002.
2. P. C. Krause, Analysis of Electric Machinery, McGraw Hill-1980

**15D22107 EMBEDDED SYSTEMS**


**UNIT- I    Embedded System**s: **Processor & Memory Organization**
Embedded System, types of Embedded System, Requirements of Embedded System, Issues in Embedded software development, Applications, Structural units in a processor, Processor selection, Memory devices, Memory selection, Memory Allocation & Map; Interfacing

**UNIT-II**: **Devices, Device Drivers & Buses for Device Networks**
I/O devices, Timer & Counter devices, Serial Communication, Communication between devices using different buses, Device drives, Parallel and serial port device drives in a system, Interrupt servicing mechanism, context and periods for context switching, Deadline and Interrupt Latency.

**UNIT-III**:  **Real Time Operating Systems**
Operating System Services, I/O Subsystems, Network Operating Systems, Real-Time and Embedded System Operating Systems, Interrupt Routines and Handling of Interrupt Source Call in RTOS, RTOS task scheduling Models, Interrupt Latency and Response Times of the Tasks, Performance Metric in Scheduling Models for different Tasks, IEEE standard POSIX 1003.1b Functions for standardization of RTOS and Inter_Task Communication Functions, List of basic actions in a Preemptive Scheduler and Expected Times taken at a processor, Fifteen-point Strategy for Synchronization between the Processes, ISRs, OS Functions and Tasks for Resource Management, OS Security Issues, Mobile OS.

**UNIT-IV:   Hardware-Software Co-Design in an Embedded System**
Embedded System Project Management, Embedded system design and co-design issues in system development process, design cycle in development phase for Embedded System, Uses of its Emulator and In-Circuit Emulator (ICE), Use of Software tools for development of an Embedded System, Use of scopes and Logic Analyzers for system Hardware tests, Issues in Embedded system design

**UNIT-V: Applications**
Embedded System Design for: An Adaptive Cruise Control System in a car, Smart Card, Digital Clock, Battery-operated Smartcard Reader, Automated Meter Reading (AMR) System, Digital Camera


**TEXT BOOKS:**

1. Raj Kamal, "Embedded Systems : Architecture, Programming and Design", Tata McGraw Hill, 2005
2. Shibu. K. V, "Introduction to Embedded Systems", Tata McGraw Hill, 2009

## 15D22201 ADAPTIVE CONTROL

**Unit – I**

Introduction, Block Diagram of an Adaptive System, Effects of Process Variations on System Performance, Types of Adaptive Schemes, Formulation of the Adaptive Control Problem, Abuses of Adaptive Control, Least Squares Method and Regression Models for Parameter Estimation – Theorems, Estimating Parameters in Models of Dynamic Systems, The Finite Impulse Response Model, The Transfer Function Model, and The Stochastic Model.

**Unit – II**

Block Diagram of Deterministic Self Tuning Regulator (STR), Pole Placement Design – Process Model, Model Following, Causality Conditions. Indirect STRs – Estimation, Continuous - Time STRs, Direct STRs – Minimum Phase Systems, Adaptive Control Algorithm, Feed Forward Control, Non Minimum Phase Systems – Adaptive Control Algorithm, Algorithm For Hybrid STR.

**Unit – III**

Design of Minimum Variance and Moving - Average Controllers, Stochastic STR – Indirect STR, Algorithm for Basic STR, Theorems on Asymptotic Properties. Unification of Direct STRs, Generalized Direct Self Tuning Algorithm, Self Tuning Feed Forward Control. Linear Quadratic STR – Theorems on LQG Control, Algorithms for Indirect LQG – STRs Based on Spectral Factorization and Riccati Equation.

**Unit –IV**

Model Reference Adaptive System (MRAS), The MIT Rule, Block Diagram of an MRAS for adjustment of Feed Forward Gain based on MIT Rule. Adaptation Gain – Methods for determination. Design of MRAS using Lyapunov Theory – Block Diagram of an MRAS based on Lyapunov Theory for a First Order System. Proof of The Kalman – Yakubovich Lemma, Adjustment Rules for Adaptive Systems, Relation between MRAS and STR.

**Unit – V**

Gain Scheduling – Principle, Block Diagram, Design of Gain Scheduling Controllers, Nonlinear Transformations, Block Schematic of a Controller based on Nonlinear Transformations. Application of Gain Scheduling for Ship Steering, Flight Control. Self Oscillating Adaptive System (SOAS) – Principle, Block Diagram, Properties of The Basic SOAS, Procedure for Design of SOAS. Industrial Adaptive Controllers and applications.

**Text books**

1. K.J.Astrom and Bjorn Wittenmark, Adaptive control, Pearson Edu., 2nd Edn.
2. Sankar Sastry, Adaptive control.

**References**

1. V.V.Chalam, Adaptive Control System - Techniques & Applications, Marcel Dekker Inc.
2.  Miskhin and Braun, Adaptive control systems, MC Graw Hill
3. Karl Johan Åström, Graham Clifford Goodwin, P. R. Kumar, Adaptive Control, Filtering and
   Signal Processing
4. G.C. Goodwin, Adaptive control.

5. Narendra and Anna Swamy, Stable Adaptive Systems.


# 15D22202 DIGITAL CONTROL SYSTEMS

## UNIT – I
Digital Control Systems – Block Schematic, Examples, Signal Forms, Advantages and Disadvantages of Digital Control, Data Conversion and Quantization, Sampling Process. Reconstruction of Original Signals from Sampled Signals - Sampling Theorem, Ideal Low – Pass Filter. Impulse Sampling and Data Hold-Transfer Function of Zero - Order Hold and First-Order Hold, Frequency Response Characteristics.

## UNIT – II
The Z-Transform and Inverse Z Transform, Z - Transform Method for Solving Difference Equations. The Pulse Transfer Function (PTF) – PTFs of Closed - Loop Systems, Digital Controllers, Digital PID Controller and Digital Control Systems. Mapping Between The          S – Plane and  Z – Plane - Primary and Complementary Strips. Stability Analysis – Jury Test, Bilinear Transformation and Routh Criterion, Lyapunov Method for LTI Discrete time systems. Design based on the Frequency Response Method and Bilinear Transformation.

## UNIT – III
State Space Representations of Discrete -  Time Systems, Solution of The Time - Invariant Discrete-Time State Equation, State Transition Matrix , Z-Transform Approach to The Solution of State Equation , Discritization of Continuous- Time State- Space Equations , Controllability and Observability of Discrete- Time Systems, Conditions, Principle of Duality.

## UNIT – IV
Design via Pole Placement – Necessary and Sufficient Condition for Pole Placement, Ackerman's Formula, Dead Beat Response, Design of Dead Beat Controllers. State Observers – Necessary and Sufficient Condition for State Observation. Full Order State Observer, Error Dynamics of The Full Order State Observer, Design of Prediction Observers –Ackerman's Formula.

## UNIT – V
Design of Minimum-Order Observer, Observed- State Feedback Control System with Minimum-Order Observer. Diophantine Equation, Polynomial Equation approach to Control System Design. Design of Model Matching Control Systems.

**Text books:**

1.  K. Ogata, Discrete Time Control Systems, PHI/Addison - Wesley Longman Pte. Ltd., India, Delhi, 1995.
2.  B.C Kuo, Digital Control Systems, 2$^{nd}$ Edition, Oxford Univ Press, Inc., 1992.

**Reference Books:**

1. .F. Franklin, J.D. Powell, and M.L. Workman, Digital control of Dynamic Systems, Addison -    Wesley Longman, Inc., Menlo Park, CA , 1998.
2.  Gopal, Digital Control and State Variable Methods, Tata McGraw Hill, India, 1997.
3.  C. H. Houpis and G.B. Lamont, Digital Control Systems, McGraw Hill, 1985.
4.  John S. Baey, Fundamentals of Linear State Space Systems,  Mc. Graw – Hill, 1$^{st}$ edition
5.  Bernard Fried Land, Control System Design, Mc. Graw – Hill, 1$^{st}$ edition
6.  Dorsay, Continuous and Discrete Control Systems, McGraw - Hill.

## 15D22203 INTELLIGENT ALGORITHMS

**UNIT I:** Introduction and motivation. Approaches to intelligent control. Architecture for intelligent control. Symbolic reasoning system, rule - based systems, the AI approach. Knowledge representation. Expert systems. Data Pre - Processing: Scaling, Fourier transformation, principal - component analysis and wavelet transformations.

**UNIT II**
Concept of Artificial Neural Networks and its basic mathematical model, McCulloch - Pitts neuron model, simple perceptron, Adaline and Madaline, Feed - forward Multilayer Perceptron. Learning and Training the neural network. Networks: Hopfield network, Self - organizing network and Recurrent network. Neural Network based controller, Case studies: Identification and control of linear and nonlinear dynamic systems using Matlab / Neural Network toolbox.

**UNIT III**
Genetic Algorithm: Basic concept of Genetic algorithm and detail algorithmic steps, adjustment of free parameters. Solution of typical control problems using genetic algorithm. Concept on some other than GA search techniques like tabu search and ant - colony search techniques for solving optimization problems.

**UNIT IV**
Introduction to crisp sets and fuzzy sets, basic fuzzy set operation and approximate reasoning. Introduction to Fuzzy logic modeling and control of a system. Fuzzification, inference and defuzzification. Fuzzy knowledge and rule bases.

**UNIT V**
Fuzzy modeling and control schemes for nonlinear systems. Self - organizing fuzzy logic control. Implementation of fuzzy logic controller using Matlab fuzzy - logic toolbox. Stability analysis of fuzzy control systems. Intelligent Control for SISO/MIMO Nonlinear Systems. Model Based Multivariable Fuzzy Controller.

**Text Books**
1. Simon Haykins, Neural Networks: A comprehensive Foundation, Pearson Edition, 2003.
2. T.J.Ross, Fuzzy logic with Fuzzy Applications, Mc Graw Hill Inc, 1997.
3. David E Goldberg, Genetic Algorithms.

   **References**
1. M.T.Hagan, H. B. Demuth and M. Beale, Neural Network Design, Indian reprint, 2008.
2. Fredric M.Ham and Ivica  Kostanic, Principles of Neurocomputing for science and Engineering, McGraw Hill, 2001.
3. N.K. Bose and  P.Liang, Neural Network Fundamentals with Graphs, Algorithms and Applications, Mc - Graw Hill, Inc. 1996.
4. Yung C. Shin and Chengying  Xu, Intelligent System -  Modeling, Optimization and Control, CRC Press, 2009.
5. N.K.Sinha and Madan M  Gupta, Soft computing & Intelligent Systems -  Theory & Applications, Indian Edition, Elsevier, 2007.
6. John Yen and Reza Langari, Fuzzy logic Intelligence, Control, and Information, Pearson  Education, Indian Edition, 2003.
7. Witold Pedrycz, Fuzzy Control and Fuzzy Systms, Overseas Press, Indian Edition, 2008.

### 15D22204 ESTIMATION OF SIGNALS AND SYSTEMS

**UNIT I**
Review of Probability theory and random variable - random process - A Family of Transfer function Models. Equation Error Model Structure, Linear Regression. ARMAX Model Structure, Other Equation. Error - Type Model Structures - Output Error Model Structure - Box - Jenkins Model Structure - A General Family of Model Structures - Continuous Time Black - Box Model.

**UNIT II**
Recursive least squares (RLS), Consistency of estimation, Weighted LS.

**UNIT III**
Parametric models - LS estimation, bias - Generalized Least Squares (GLS) and Instrumental Variable (IV) method. Persistently exciting input signal - Likelihood functions and Maximum Likelihood Estimation (MLE) - Singular Value Decomposition (SVD).

**UNIT IV**
Kalman filter, State estimation using Kalman filter, Parameter estimation using Kalman filter. Extended Kalman Filters for continuous and discrete time systems, State and Parameter estimations.

**UNIT V**
Multi - variable system representation, controllability and observability indices; Feedback system identification. Stochastic Approximation Algorithm (STA); Model order and structure determination.

**Text Books:**
1. Papoulis and Pillai, Probability, Random Variables and Stochastic Process, McGraw Hill, 2002.
2. Jerry M. Mendel, Lessons in Estimation Theory for Signal Processing, Communications, and Control, Prentice - Hall, 1995.
   **References:**
1. Karl J Astrom, Introduction to Stochastic Control Theory, Mathematics in Series and Engg., Vol. 70.
2. Michel Verhaegen and Vincent Verdult, Filtering and System Identification A Least Squares Approach, Cambridge Univ. Press, 2007.
3. M.S. Grewal and A.P. Andrews, Kalman Filtering Theory and Practice Using Matlab, John Wiley, 2008.

## 15D54201 RESEARCH METHODOLOGY

### (Audit Course)

### UNIT I

Meaning of Research – Objectives of Research – Types of Research – Research Approaches – Guidelines for Selecting and Defining a Research Problem – research Design – Concepts related to Research Design – Basic Principles of Experimental Design.

### UNIT II

Sampling Design – steps in Sampling Design –Characteristics of a Good Sample Design – Random Sampling Design.

Measurement and Scaling Techniques-Errors in Measurement – Tests of Sound Measurement – Scaling and Scale Construction Techniques – Time Series Analysis – Interpolation and Extrapolation.

Data Collection Methods – Primary Data – Secondary data – Questionnaire Survey and Interviews.

### UNIT III

Correlation and Regression Analysis – Method of Least Squares – Regression vs Correlation – Correlation vs Determination – Types of Correlations and Their Applications

### UNIT IV

Statistical Inference: Tests of Hypothesis – Parametric vs Non-parametric Tests – Hypothesis Testing Procedure – Sampling Theory – Sampling Distribution – Chi-square Test – Analysis of variance and Co-variance – Multi-variate Analysis.

### UNIT V

Report Writing and Professional Ethics: Interpretation of Data – Report Writing – Layout of a Research Paper – Techniques of Interpretation- Making Scientific Presentations in Conferences and Seminars – Professional Ethics in Research.

### Text books:

1. **Research Methodology:Methods and Techniques – C.R.Kothari, 2<sup>nd</sup> Edition,New Age International Publishers.**
2. **Research Methodology: A Step by Step Guide for Beginners- Ranjit Kumar, Sage Publications (Available as pdf on internet)**
3. **Research Methodology and Statistical Tools – P.Narayana Reddy and G.V.R.K.Acharyulu, 1<sup>st</sup> Edition,Excel Books,New Delhi.**

### REFERENCES:

1. Scientists must Write - Robert Barrass (Available as pdf on internet)
2. Crafting Your Research Future –Charles X. Ling and Quiang Yang (Available as pdf on internet)

## 15D22207 CONTROL SYSTEMS SIMULATION LAB

**List of Experiments**

The following experiments may be implemented in MATLAB/SIMULINK environment.

1. Preliminary Transformations:
    (a) Transfer function to State space models vice- versa.
    (b) Conversion of Continuous to Discrete time systems vice- versa.
    (c) Verification of controllability and observablity of a given system.
2. Design of state feedback controllers.
3. Stability analysis of a given system using:
    (a) Root Locus.
    (b) Bode plot.
    (c) Lyapunov stability.
4. Implementation of Kalman Filter.
5. Implementation of Least squares error method.
6. Implementation of PID controller and its effects on a given system.
7. Design of Lead, Lag, Lead- Lag compensators using frequency domain analysis.
8. Construction of Simulink model for an Induction motor.


**Note: At least four problems may be implemented from the following**

9. Solving steady state Ricatti Equation.
10. Construction of Simulink model foe single area and multi area Power system.
11. Solving an optimal control problem using Ricatti equation.
12. Implementation of Full order and minimum order Observer.
13. Implementation of Back-Propagation Algorithm.
14. Implementation of simple Fuzzy controller.
15. Implementation of storage and recall algorithm of Hopfield network model.

## 15D22205 REAL TIME SYSTEMS

**UNIT-I:**

Introduction to Real - time systems: Typical examples of RTS, Characteristic features of RT applications. Structural, Functional and Performance requirement of Reactive RTS. Distinctive features from Non - RT and Off - line system. Modeling RTS: Representation of time, Concurrency and Distributedness in discrete event systems.

**UNIT-II:**

Hierarchical representation of complex DES. Input, Output and Communication. Examples of modeling practical systems as RT DES. Modeling programs as RTS. Analyzing RTS: Analyzing logical properties of DES such as Reachability, Deadlock etc. Analyzing timing related properties, Specification and Verification of RT DES properties.

**UNIT-III:**

Temporal logic, Model checking. Example of checking safety and timing properties of industrial systems. Requirements and features of real - time Computing Environments: Real - time Operating Systems, Interrupts, clock, Device support.

**UNIT-IV:**

Real time System, Multi tasking, Static and Dynamical Scheduling of resource Allocation, Real - time Programming.

**UNIT-V:**

Real - time process and applications, Distributed Real - time systems.

**TEXTBOOK:**

1.   Jane W S Liu, "Real- Time Systems", Pearson  publications, 1$^{st}$ edition, 2006.

**REFERENCE BOOK**:
**1.**  Rajib Mall**, "**Real**-**Time Systems: Theory and Practice", Pearson Education India**,** 2009.

**15D21207 SOLAR ENERGY CONVERSION SYSTEMS**

**UNIT-I: SOLAR CELL FUNDAMENTALS**
Place of PV in world energy scenario – need for sustainable energy sources – current status of Renewable energy sources – place of photovoltaic in Energy supply – solar radiation – the sun and earth movement – angle of sunrays on solar collectors – sun tracking – estimating solar radiation empirically – measurement of solar radiation - Fundamentals of semiconductors – charge carriers and their motion in semiconductor – P-N Junction Diode – an introduction to solar cells.

**UNIT-II: DESIGN OF SOLAR CELLS**
Upper limits of cell parameters – short circuit current, open circuit voltage, fill factor, efficiency – losses in solar cells – model of a solar cell, effect of series and shunt resistance on efficiency , effect of solar radiation on efficiency – solar cell design – design for high $I_{SC}$ – Design for high $V_{OC}$ – design for high FF – Analytical techniques.

**UNIT-III: SOLAR PHOTOVOLTAIC MODULES**
Solar PV Modules from solar cells – series and parallel connection of cells – mismatch in module – mismatch in series connection – hot spots in the module , bypass diode – mismatching in parallel diode – design and structure of PV modules – number of solar cells in a module, wattage of modules, fabrication of PV module – PV module power output.

**UNIT-V: BALANCE OF SOLAR PV SYSTEMS**
Basics of Electromechanical cell – factors affecting performance – batteries for PV systems – DC to DC converters – charge controllers – DC to AC converters(Inverters) – Maximum Power Point tracking (MPPT) – Algorithms for MPPT.

**UNIT V: PV SYSTEM DESIGN AND APPLICATIONS**
Introduction to solar PV systems – standalone PV system configuration – design methodology of PV systems – design of PV powered DC fan without battery, standalone system with DC load using MPPT, design of PV powered DC pump, design of standalone system with battery and AC/DC load – wire sizing in PV system – precise sizing of PV systems – Hybrid PV systems – grid connected PV systems.

**TEXT BOOKS:**
1. "Solar Photovoltaics Fundamentals, Technologies and Applications" by Chetan singh solanki, PHI publications.
**REFERENCES:**
1. Solar Energy Fundamentals and applications by H.P. Garg, J. Prakash "Tata McGraw- Hill publishers I$^{st}$ edition"
2. S.Rao & B.B.Parulekar, "Energy Technology", 4th edition, Khanna publishers, 2005.

## 15D21208 WIND ENERGY CONVERSION SYSTEMS

### UNIT-I: FUNDAMENTALS OF WIND TURBINES

Historical background - basics of mechanical to electrical energy conversion in wind energy - types of wind energy conversion devices – definition - solidity, tip speed ratio, power coefficient, wind turbine ratings and specifications - aerodynamics of wind rotors - design of the wind turbine rotor

### UNIT-II: WIND TURBINE CONTROL SYSTEMS & SITE ANALYSIS

Power speed characteristics - torque speed characteristics - Pitch angle control – stall control – power electronic control – Yaw control – Control strategy – wind speed measurements – wind speed statistics – site and turbine selection.

### UNIT-III: BASICS OF INDUCTION AND SYNCHRONOUS MACHINES

The Induction Machine – constructional features - equivalent circuit model - performance characteristics -  saturation characteristics – dynamic d-q model – the wound – field synchronous machine – the permanent magnet synchronous machine – power flow between two synchronous sources – induction generator versus synchronous generator

### UNIT-IV: GRID CONNECTED AND SELF-EXCITED INDUCTION GENERATOR OPEARTION

Constant – voltage, constant – frequency- single output system –double output system with current converter & voltage source inverter – equivalent circuits – reactive power and harmonics  – reactive power compensation – variable – voltage, variable – frequency generation – the self- excitation process – circuit model for the self – excited induction generator – analysis of steady state operation – the steady state characteristics – the excitation requirement – effect of a wind generator on the network .

### UNIT-V: WIND GENERATION WITH VARIABLE-SPEED TURBINES AND APPLICATION

Classification of schemes – operating area – induction generators – doubly fed induction generator – wound field synchronous generator – the permanent magnet generator – Merits and limitations of wind energy conversion systems – application in hybrid energy systems – diesel generator and photovoltaic systems – wind photovoltaic systems.

### TEXT BOOKS:

1.  S.N.Bhadra,D.Kastha, S.Banerjee, " wind electrical systems" Oxford University Press.

### REFERENCES:

1.   S.Rao & B.B.Parulekar, "Energy Technology", 4th edition, Khanna publishers, 2005.

2. "Renewable Energy sources & Conversion Technology" by N.K.Bansal, Manfred Kleemann, Michael Meliss. Tata Mcgraw Hill Publishers.

## 15D22206 PROCESS DYNAMICS AND CONTROL

**UNIT I:**
Introduction to Process Control, Representative Process Control Problems, Illustrative Example-A Blending process, Classification of Control Strategies, Hierarchy of Process Control activities, Dynamic versus Steady - state Models, The rationale of Dynamic Process models, General Modeling Principles, Dynamic model of CSTR, Degrees of freedom analysis, Linearization of Non-linear models. Processes with time delays, Approximation of Higher - Order transfer functions, Interacting and Non interacting Processes, Multiple - Input, Multiple - Output (MIMO) Processes.

**UNIT II:**
Basic Control modes, Features of PID Controllers, Typical process responses with Feedback control, Digital versions of PID Controllers, Transducers and Transmitters, Final Control elements, Accuracy in Instrumentation, Guidelines for selection of Controlled, Manipulated and Measured variables, Process safety and Process Control, Block diagram representation of Blending process composition control system, General stability criterion, Routh Stability criterion for time delay systems, Direct substitution method.

**UNIT III:**
Performance Criteria for Closed - Loop Systems, Model - based design methods - Direct Synthesis Method, Internal Model Control, Controller tuning relations, Controllers with two degrees of freedom, Online controller tuning, trial and error tuning, Continuous Cycling Method, Relay auto tuning, Process Reaction Curve Method, Guidelines for Common Control Loops, troubleshooting Control Loops.

**UNIT IV:**
Introduction to Feed forward Control, Ratio Control, Feed forward Controller Design based on Steady - State Models, Controller Design based on Dynamic Models, Tuning Feed forward Controllers, Configurations for Feed forward - Feedback Control, Cascade control, Design considerations for cascade control, Time delay compensation, Block diagram of the Smith predictor, Inferential control, Selective control/Override systems.

**UNIT V:**
Multi loop and multivariable control: Process Interactions and Control Loop Interactions, Pairing of Controlled and Manipulated Variables, Bristols RGA method, Calculation of the RGA, Methods for obtaining the steady state gain matrix, Measure of Process Interactions and Pairing recommendations, Dynamic considerations, Extensions of the RGA analysis, Singular value analysis, Selection of manipulated variables and Controlled variables, Tuning of multi loop PID Control systems, Decoupling and multi variable control strategies, Strategies for Reducing Control Loop Interactions.

**Text Books:**
Dale E. Seborg, University of California, Santa Barbara, Thomas F. Edgar, University of Texas at Austin, Duncan A. Mellichamp, University of California, Santa Barbara, Process Dynamics and Control, John Wiley & Sons, 2$^{nd}$ Edition, 2004.
**References:**
Brian Roffel, Ben Betlem, Process Dynamics and Control Modeling for Control and Prediction, John
    Wiley & Sons Ltd., 2007.