FACULTY OF ENGINEERING

Syllabus for the

M.E. Electrical (Control Systems)

(w.e.f. 2008-2009)

UNIVERSITY OF PUNE

THE SYLLABUS IS PREPARED BY :

BOS- Electrical Engineering,

University of Pune.

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Note : This syllabus is subject to change without prior notice by the concerned BOS

Structure of M.E. (Electrical) - Control System (2008 Course)
ELECTRICAL ENGINEERING BOARD,
University of Pune.

Semester- I

Subject Code No.	Subject	Teaching Scheme		Examination Scheme				Total marks	Credits
		Lect	Pract	Paper	TW	OR	PR		
503101	Advance Mathematical Technique for Control System	3	--	100	--	--	--	100	3
503102	Process Control Management	3	--	100	--	--	--	100	3
503103	Nonlinear Control System	3	--	100	--	--	--	100	3
503104	Elective - I	3	--	100	--	--	--	100	3
503105	Elective - II	3	--	100	--	--	--	100	3
503106	Lab. Practice - I	--	6	--	50	--	--	50	3
503107	Seminar - I	--	4	--	50	--	--	50	2
	Total	**15**	**10**	**500**	**100**	**---**	**---**	**600**	**20**

Semester- II

Subject Code No.	Subject	Teaching Scheme		Examination Scheme				Total marks	Credits
		Lect	Pract	Paper	TW	OR	PR		
503108	Multivariable & Optimal Control System	3	--	100	--	--	--	100	3
503109	System Identification & Adaptive Control	3	--	100	--	--	--	100	3
503110	Advanced Digital Control Technique	3	--	100	--	--	--	100	3
503111	Elective - III	3	--	100	--	--	--	100	3
503112	Elective - IV (Open)	3	--	100	--	--	--	100	3
503113	Lab. Practice - II	--	6	--	50	--	--	50	3
503114	Seminar - II	--	4	---	50	--	--	50	2
	Total	**15**	**10**	**500**	**100**	**---**	**---**	**600**	**20**

Semester- III

Subject Code No.	Subject	Teaching Scheme		Examination Scheme				Total marks	Credits
		Lect	Pract	Paper	TW	OR	PR		
603101	Seminar - III	--	04	--	50	--	--	50	2
603102	Project Stage - I	--	18	--	50	--	--	50	6
	Total	**---**	**22**	**---**	**100**	**---**	**---**	**100**	**08**

Semester- IV

Subject Code No.	Subject	Teaching Scheme		Examination Scheme				Total marks	Credits
		Lect	Pract	Paper	TW	OR	PR		
603102	Project Stage - II	--	18	--	150	50	--	200	12
	Total	**---**	**18**	**---**	**150**	**50**	**---**	**200**	**12**

Note: - The contact hours for the calculation of load of Teacher - Seminar- 01Hr / Week / Student
Project- 02Hr / Week /

Continue on next page

Continue, Structure of M.E. (Electrical) - Control System (2008 Course)

- **Lab- Practice- I & Lab. Practice - II** will have minimum 10 experiments each.
- **Seminar III** will be based on the Project Work.
- The Term Work of Project stage II of semester IV should be assessed jointly by the pair of internal and external examiners, along with the oral examination of the same.

Elective - I

i) Automation & Robotics
ii) Modeling & Dynamic System

Elective - II

i) Advanced Topics in Control Systems
ii) Computer Aided Control Systems Design.
iii) SCADA System & Applications

Elective - III

i) Robust Control Systems
ii) Stochastics Dynamical Systems
iii) Large Scale System

Elective - IV

i) Intelligent Control
ii) Advanced Drives & Control
iii) Open *

* Candidate will have option for any one of the elective subject from the existing Pune University PG programmes, either from the same Board or from any other Board, with the consent of his guide.

PROF. M. G. UNDE

Date: 08-02-2008

CHAIRMAN
B.O.S. ELECTRICAL ENGG.
UNIVERSITY OF PUNE

503101: Advanced Mathematical Techniques for Control Systems

Teaching Scheme
Theory: 3 Hrs/Week

Examination Scheme
Paper: 100 Marks

Unit I: Mathematical Concepts
Review of Euclidean, Linear Algebraic equations, convex sets, extrema of functions, real valued function, partial derivatives gradient vector, Taylor series, Directional derivatives, direction of steepest descent, local and global extrema, limitations of method of differential calculus, unconstrained extrema of differentiable functions, constrained extrema, method of Lagrange multipliers. (6 Hrs.)

Unit II: Optimization and Classical Techniques
Engineering applications of optimization, optimization problem, classification of optimization problems and techniques, single variable, multivariable optimization with no constraints, equality constraints, inequality constraints unconstrained minimization, conditions for optimality, convexity, steepest descent method, conjugate gradient method, Newton's method.
(6 Hrs.)

Unit III: Linear Programming
Linear programming problems, solution of a system of linear simultaneous equations, LP problems, involving LE constraints, simplex method, revised simplex method, duality, dual simplex method.
(6Hrs.)

Unit IV: Nonlinear Programming
One dimensional minimization method, unimodel function, elimination methods, dichotomous search, Fibonacci method, Golden section method, interpolation methods, unconstrained optimization technique, direct methods - univariate method. (6 Hrs.)

Unit V: Dynamic Programming
Multistage decision process, suboptimization and principle of optimality, computational and calculus method of solution, final value and initial value problems continuous dynamic programming.
(6 Hrs.)

Unit VI: Integer and Stochastic Programming
Integer and stochastic programming, zero-one programming, mixed integers, integer linear programming, graphical representation, Gomory cut method, Integer nonlinear programming, and polynomial.Basic concept of probability stochastic linear programming and nonlinear programming, dynamic programming. (6 Hrs.)

Text Book:
1. Optimization Theory and Applications: S. S. Rao, New Age International Publications

Reference Book:
1. Optimization Methods in Operations and Research Systems Analysis: K. V. Mital and C. Mohan, New Age International Publications
2. Optimization Concepts and Applications in Engineering: A. D. Belegundu and T. R. Chandrupatla, Pearson Education

503102: Process Control Management

Teaching Scheme | **Examination Scheme**
Theory: 3 Hrs/Week | Paper: 100 Marks

Unit I: Management Process

Motivation- Motives, classification of motives. Leadership – definition importance – leadership style – models and theories of leadership styles. Group dynamics and teams, theories of group formation, formal organization and informal groups and their interaction. Conflict management, stress management, strategies for solving destructive conflicts. (6 Hrs.)

Unit II: Process Dynamics

Introduction to Process Control, Control Strategies, control Objectives, Benefits of Control, and importance of Control Engineering. Mathematical Modeling Principles - A Modeling Procedure, Modeling examples, Linearization.

Dynamic behavior of typical process systems - Series structure of a simple systems, Parallel structure of a simple systems, Recycle structure, Staged processes, multiple-Input multiple-output systems, an empirical model building, process reaction curve. (6 Hrs.)

Unit III: Feedback Control and PID Tuning and Management

Process and Instrument Elements of the Feedback Loop, Block Diagram, Control Performance Measures for Common Input Changes, Selection of Variables for Control.

PID Controller Tuning for Dynamic Performance - Determining Tuning Constants for Good Control Performance, Correlations for Tuning Constants, Fine-Tuning the Controller Tuning Constants, Controller tuning based on stability –Dead beat and self tuning controller, Ziegler-Nichols Closed-Loop, some important interpretations.

(6 Hrs.)

Unit IV: Digital Implementation Management of Process Control

Structure of the Digital Control System, Effects of Sampling a continuous signal, The Discrete PID Control Algorithm, Effects of Digital control on stability, Tuning and performance.

Practical Application of Feedback Control - Equipment Specification, Input Processing, Feedback Control Algorithm, Output Processing. (6 Hrs.)

Unit V: Cascade Control and Feed forward Control

Design Criteria, Cascade Performance, Controller Algorithm and Tuning, Implementation Issues.

(4 Hrs.)

Unit VI: Multivariable Control

Modeling and Transfer Functions, Influence of interaction on the Possibility of Feedback Control, Process Interaction - Important Effects on Multivariable System Behavior, Process Interaction - The Relative Gain Array (RGA), Effect of Interaction on Stability and Tuning of Multi loop Control Systems. (8 Hrs.)

Text Book:

1. T E Marlin – "Process Control - Designing processes and Control system for dynamic performance", McGraw-Hill, International Edition, New York 1995.
2. G. Stephanopoulos: "Chemical process control – An introduction to Theory & Practice", Prentice Hall of India Ltd, New Delhi.

Reference Book:

Books:

1. Organization behavior, 9th Ed. – Stephen Robbins 2. Human behavior at work – Davis and Newstorm 3. Organization behavior – Uma Sekaran
2. "Management Concepts and Practices" – Hannagan

503103: Non Linear Control Systems

Teaching Scheme	**Examination Scheme**
Theory: 3 Hrs/Week	Paper: 100 Marks

Unit I: Introduction to Non Linear System
Classification of non-linearity, types of non-linearity in physical system, jump phenomena and critical jump resonance curve, methods of analysis of non-linear systems and comparison, linearization, slope, isoclines, singular point, limit cycle. (6 Hrs.)

Unit II: Phase Plane Analysis
Concept of phase plane, phase trajectory, phase portraits, methods of plotting phase plane trajectories Vander Pol's equation, stability from phase portrait, time response from trajectories, isoclines method, Pell's method of phase trajectory, Delta method of phase trajectory construction. (6 Hrs.)

Unit III: Frequency Domain Analysis
Absolute stability, circle criterion, Popov criterion Describing function, DF of typical nonlinearities stability analysis using DF method, DIDF, pole zero shifting transformation. (6 Hrs.)

Unit IV: Liapunov Stability
Autonomous Systems: Stability of equilibrium point. Concepts of positive definite/semi definite, negative definite/ semi definite, indefinite functions, Lyapunov function Liapunov Stability: asymptotic stability, global asymptotic stability. (6 Hrs.)

Unit V: Stability Criterion
Linear systems, linearization of nonlinear systems about equilibrium point. Liapunov's indirect method. Stability analysis of nonlinear system using Liapunov's theorem. (8 Hrs.)

Unit VI: Nonlinear Control Design
Feedback linearization, Input Output linearization, sliding mode control (4 Hrs.)

Text Book:

1. Automatic Control System: George J. Thaler Brown, Jaico Publications
2. Nonlinear Systems: Hasan A. Khalil, Printece Hall of India

Reference Book:

1. Control Systems Theory and Application: Samarjit Ghosh, Pearson Education
2. Control System Engineering: Nagrath and Gopal, Wiley Eastern
3. Introduction to Control Engineering: A. K. MandaI, New Age International Publications

503104(i): Automation and Robotics

Teaching Scheme
Theory: 3 Hrs/Week

Examination Scheme
Paper: 100 Marks

Unit I: Introduction

Basic concept of automation, types of automation: fixed, flexible and programmable and their comparative study. Robotics: A brief history, definition, laws of Robotics,
Introduction to NC and CNC machines - Basic concept, block diagram difference and comparison with robots, advantages, disadvantages and applications. Robot like devices such as prostheses, exoskeletons, telecherics, locomotive mechanism, robot manipulator etc. Concept of Workcell, Basic components of robot, Specifications of robot: degrees of freedom (DOF), accuracy, repeatability, spatial resolution, compliance, loads carrying capacity, speed of response, work volume, work envelope, reach etc. (6 Hrs.)

Unit II: Fundamentals of Robot Technology

Basic structure, links and Joints, types of Joints, types of links, types of end effectors: Grippers: Mechanical, Vacuum cups, Magnetic, adhesive and miscellaneous. Tools as end effectors.
Wrist configuration: concept of: yaw, pitch and roll.
Robot classification: according to 1) Co-ordinate system: Cartesian, cylindrical, spherical, SCARA, Articulated 2) Control Method: Servo controlled and non-servo controlled, their comparative study 3) Form of motion: P-T-P (point to point), C-P (continuous path), pick and place etc. and their comparative study 4) Drive Technology: Hydraulic, Pneumatic, Electric (stepper motor, D.C. servo motor) in detail with selection criteria. Motion conversion: Rotary to rotary, rotary to linear and vice versa. (6 Hrs.)

Unit III: Industrial Applications and Robot Programming

Industrial Applications of Robots: Welding, Spray-painting, Grinding, Handling of rotary tools, Parts handling/transfer, Assembly operations, parts sorting, parts inspection, Potential applications in Nuclear and fossil fuel power plant etc. (Details for the above applications are selection criterion of robots, sensors used, selection of drives and actuators, methods of control, peripheral devices used etc)
Programming of Industrial Robots: Concept of on-line and off line programming, concept of teach pendant, three levels of robot programming such as 1) Specialized manipulation languages 2) Robot library for an existing computer language 3) Robot library for a new general purpose language.
Classification of robot specific languages on the basis of hardware level, point-to-point level, the motion level and structured programming level. (6 Hrs.)

Unit IV: Robot arm dynamics and transformation

Newton Euler Equations, Kinetic and potential energy, Lagrangian analysis for a single prismatic joint working against gravity and single revolute joint. Joint vector, Homogeneous co-ordinates. Matrix operators for translation and rotation. Homogeneous transformation matrix. Concept of "Hand Matrix". Effect of pre and post multiplication of a hand matrix by basic matrix operators. (6 Hrs.)

Unit V: Kinematics

Denavit-Hartenberg (D-H) representation of kinematics chains. Rules for establishing link co-ordinate frames. D-H matrix. Forward solution of robotic manipulator. Examples of forward solutions for Stanford and PUMA robots.
Inverse Kinematics: Inverse (back) solution by i) direct approach, ii) Geometric approach, iii) Geometric approach with co-ordinate transformation and iv) manipulation of symbolic T and A matrices. (6 Hrs.)

Unit VI: Robot Control

Open loop and closed loop control, Linear control Schemes, PD and PID control, Torque and Force control of robotic manipulators, Adaptive control, Hybrid control, Impedance control.

Manipulator Jacobian, Jacobian for prismatic and revolute joint. Jacobian Inverse, Singularities.

Control of Robot manipulator: joint position controls (JPC), resolved motion position controls (RMPC) and resolved motion rate control (RMRC). (6 Hrs.)

Text Books:

1. Richard D. Klafter, Thomas A. Chemielewski, Michael Neign "Robotic Engineering – An Integral Approach", Prentice Hall of India Pvt. Ltd., New Delhi. Eastern Economy Edition.
2. K. S. Fu., R. C. Gonzalez, C. S. G. Lee, "Robotics: Control Sensing, Vision and Intelligence", International Edition, McGraw Hill Book Co.
3. R. K. Mittal, I. J. Nagrath, "Robotics and Control", Tata McGraw Hill Publishing Company Ltd., New Delhi.

Reference Books:

1. Arthur J. Critchlow, "Introduction to Robotics"
2. Robert J. Schilling, "Fundamentals of Robotics: Analysis and Control", Prentice Hall of India, New Delhi
3. John J. Craig, "Introduction to Robotics: Mechanics and Control", Pearson Education
4. Mikell P. Groover, Mitchell Weiss, Roger N. Nagel, Nicholas G. Odrey, "Industrial Robotics: Technology, Programming and Applications", McGraw Hill Book Company

503104(ii): Modeling of Dynamic System

Teaching Scheme
Theory: 3 Hrs/Week

Examination Scheme
Paper: 100 Marks

Unit I
Dynamics systems, Examples of dynamic; systems, Definitions related to dynamic systems, Classification of system inputs, classification of system models. System modeling and simulation. (5 Hrs).

Unit II: Modeling of Mechanical and Electrical Systems:
Translational systems: Springs, Dampers, Mass, Rotational Systems: D'Alembert's Principle, Lagranges's Equation, Three dimensional motion
Elective Systems: Basic Elements, Passive Circuit Analysis, Active circuit analysis: The operational amplifier Mechanics. (6 Hrs)

Unit III: Fluid Systems:
Properties of fluids: Density, equation of state, Liquids and Gases, Viscosity, Propagation of speed, Thermal properties, Reynolds Number Effects.
Derivation of passive components, resistance, inductance and capacitance.
Thermal System: Basic Effects, conduction, convection and Radiation, Circuit analysis of static thermal system: Signal and Multiple lumped capacitance modeling. (7 Hrs)

Unit IV: Transform Methods for Generalized Response:
Impulse response, Convolution integral: Response to arbitrary inputs when impulse response is known, Frequency response, Response to periodic Inputs, transient inputs and random signal.
Simulation Methods: Limitations of analytical methods, Analog Simulation.
Digital Simulation: Specific Digital Simulation techniques. (6 Hrs)

Unit V: Generalized Modeling Methods:
Frequency response methods, Pulse testing methods, Random Signal testing methods, Parameter tracking methods, Multiple regression and least square methods, Subsystem Coupling Methods. (5 Hrs)

Unit VI: Applications (Distributed Parameter Models)
Longitudinal vibrations of a rod, Lumped Parameter approximations for rod vibration, Conduction heat translation in an Insulated Bar, Lumped parameter approximations for heat transfer in insulated bar.
Magnetic Levitation system for an Experimental Rail vehicle. (7 Hrs)

Text Books:

1. System Modeling and Response: Theoretical and Experimental Approaches. Ernest O. Dobling, John Wiley and Sons, 1980
2. Modeling and Simulation of Dynamic Systems: Robert Woods, Kent L. Lawrence, Prentice Hall

Reference Books:

1. Simulation Modeling and Analysis: Averill M. Law, W. David Kelton. McGraw Hill
2. System Dynamics: Modeling Analysis, Simulation, Design: Ernest O. Dobling, Marcel Dekker Inc.
3. Modeling of Dynamical Systems Vol. I: H. Nicholson (Editor), Peter Peregrinus Ltd., on behalf of IEE (Useful for unit 6) 116842, 1980 Edition
4. Dynamic Modeling and Control of Engineering Systems: J. Lowen Sheaser, Bohan T. Kulawski Macmillan Publishing Company NY, 158275, 1990 Edition

503105(i): Advanced Topics in Control Systems

Teaching Scheme
Theory: 3 Hrs/Week

Examination Scheme
Paper: 100 Marks

Unit I
Sliding Mode Control: notion of variable structure control, sliding surface, Uncertainties in system matrix, input matrix, external disturbance, dynamic sliding surface. (6 Hrs)

Unit II
Introduction to adaptive control, Different methods, Adaptive control using SMC. (6 Hrs)

Unit III
Pole placement techniques. State feedback and output feedback of single input and multi-input systems. (6 Hrs)

Unit IV
Multirate output feedback techniques - Periodic Output Feedback (POF) and Fast Output Sampling Feedback (FOS). Multirate output control. (5 Hrs)

Unit V
Introduction: Biological neurons and memory: Structure and function of a single neuron; Artificial Neural Networks (ANN). (5 Hrs)

Unit VI
Typical applications of ANNs : Classification, Clustering, Vector, Quantization, Pattern Recognition, Function Approximation, Forecasting, Control, Optimization; Basic Approach of the working of ANN - Training, Learning and Generalization. (8 Hrs)

Text Books:

1. Spurgeaon “Sliding mode control, theory and applications”
2. A Cichocki and R. Unbehauen, Neural Networks for Optimization and Signal Processing, John Wiley and Sons, 1993.

Reference Books:

1. K. Mehrotra, C. K. Mohan and Sanjay Ranka, “Elements of Artificial Neural Networks”, MIT Press, 1997 - [Indian Reprint Pen ram International Publishing (India), 1997]
2. Simon Haykin, Neural Networks - A Comprehensive Foundation, Macmillan Publishing Co., New York, 1994.

503105(ii): Computer Aided Control System Design

Teaching Scheme | **Examination Scheme**
Theory: 3 Hrs/Week | Paper: 100 Marks

Unit I: Introduction
Application of software and simulink for control system design.
Review of compensation technique and choice of optimum parameters to obtain desired performance. Absolute stability and relative stability concepts. (5 Hrs)

Unit II: Design of Linear Control Systems
Transient and steady state response; Polar, Bode, Root locus plots; Reshaping of these plots to obtain desired response, Initial condition and forced response, A simple lag – lead design. (7 Hrs)

Unit III: Design of control systems by state variable techniques
Controllability, Observability; Stability by using computer methods; solution of state and output equations of closed loop systems. Pole placement design, Observer design.
Linear / quadratic optimal control. Full and reduced order observers. (6 Hrs)

Unit IV: Design of nonlinear control systems
Phase plane technique, Describing Function method for nonlinearities like saturation, dead space, ON/OFF (Ideal Relay type nonlinearity). Simulation techniques. (6 Hrs)

Unit V: PID Controller
Use of digital computer as a compensator device, basic computer control scheme, tunable PID controller, Ziegler – Nichol's method,
Simulation of multiloop control system using P, PI, PD, PID controller and finding the system response. Standard compensator structures (P, PD, PI and PID control). (6 Hrs)

Unit VI: Design of digital control system
Technique and methodology; Computation of digital equivalent of the analog controller, simulation of performance of the design. Digital controller design, Regulator and observer design; Digital servo for inverted pendulum. (6 Hrs)

Text Books:

1. G. C. Goodwin, S. F. Graebe, M. E. Salgado, "Control System Design", Prentice Hall of India
2. Norman S. Nise, "Control Systems Engineering", 3rd Edition, Wiley
3. George Ellis, "Control System Design Guide – A Practical Guide", 3rd Edition, Academic Press

Reference Books:

1. M. Gopal, "Digital Control and State Variable Method", Tata McGraw Hill
2. Hadi Saadat, "Computational Aids in Control System Using MATLAB", McGraw Hill International
3. Ogata K., "Modern Control Engineering", 4th Edition, Prentice Hall
4. Ogata K. "System Dynamics", 3rd Edition, Prentice Hall
5. M. Gopal, "Control Systems Principles and Design", 2nd Edition, Tata McGraw Hill

503105(iii): SCADA Systems and Applications

Teaching Scheme Theory: 3 Hrs/Week

Examination Scheme Paper: 100 Marks

Unit I: Introduction to SCADA and PLC:
SCADA: Data acquisition system, evaluation of SCADA, communication technologies, monitoring and supervisory functions.PLC: Block diagram, programming languages, Ladder diagram, Functional block diagram, Applications, Interfacing of PLC with SCADA. (8 Hrs)

Unit II: SCADA system components:
Schemes, Remote Terminal Unit, Intelligent Electronic Devices, Communication Network, SCADA server. (5 Hrs)

Unit III: SCADA Architecture
Various SCADA Architectures, advantages and disadvantages of each system, single unified standard architecture IEC 61850 SCADA / HMI Systems. (6 Hrs)

Unit IV: SCADA Communication
Various industrial communication technologies- wired and wireless methods and fiber optics, open standard communication protocols. (6 Hrs)

Unit V: Operation and control of interconnected power system
Automatic substation control, SCADA configuration, Energy management system, system operating states, system security, state estimation. (6 Hrs)

Unit VI: SCADA applications
Utility applications, transmission and distribution sector operation, monitoring analysis and improvement. Industries oil gas and water. Case studies, implementation, simulation exercises. (5 Hrs)

Text Books:

1. Stuart A Boyer: SCADA supervisory control and data acquisition
2. Gordan Clark, Deem Reynders, Practical Modem SCADA Protocols

Reference Books:

1. Sunil S. Rao, Switchgear and Protections, Khanna Publication

503106: Laboratory Practice – I

Teaching Scheme	**Examination Scheme**
Lab Practice: 6 Hrs/Week	Term Work: 50 Marks

Students should perform at least ten experiments under Lab. Practice – I covering the subjects taught during semester - I

503107 Seminar – I

Teaching Scheme	**Examination Scheme**
Seminar: 4 Hrs/Week	Term Work: 50 Marks

Each student is required to deliver a seminar in first semester on state of art of the topic of his/her own choice. The topic of the seminar should be out of the syllabus and relevant to the latest trends in Control Systems. The student is expected to submit the seminar report in standard format approved by the University of Pune.

503108: Multivariable and Optimal Control Systems

Teaching Scheme	**Examination Scheme**
Theory: 3 Hrs/Week	Paper: 100 Marks

Section I: Multivariable Control Systems

Unit I

Example of multivariable control systems, differential operator and transfer matrix, state-space models and system solution. (6 Hrs)

Unit II

Controllability, observability, state estimation pole allocation, stability and reproducibility, minimal realization of multivariable control systems. (6 Hrs)

Unit III

Decoupling and model matching control, extension of classical theory to multivariable control systems. (6 Hrs)

Section II: Optimal Control System

Unit IV

Pontryagin's minimum principle, application to discrete and continuous systems. (5 Hrs)

Unit V

Hamilton - Jacoby equation. Relation between the minimum principle and dynamic programming. Linear regular problem. Quadratic performance criterion. (8 Hrs)

Unit VI

Minimum time problems, Bang Bang Control, singular solutions. (5 Hrs)

Text Books:

1. Linear Multivariable Control System: Y. S. Apte, New Age International Publication 1996
2. Multivariable Control System: W. M. Wonham
3. Optimal Control- An Introduction: O. Kirk, Prentice Hall
4. Optimum Systems Control: A. P. Sage, II Edition

Reference Books:

1. Linear System Theory and Design: C. T. Chen, 3rd Edition, Oxford 1999
2. Multivariable Control: N. K. Sinha, Marcel Dekker Inc., New York
3. Control System Design: Goodwin, Graebe, Salgado
4. Optimization Theory and Applications: S. Rao, Wiley Eastern

503109: System Identification and Adaptive Control

Teaching Scheme
Theory: 3 Hrs/Week

Examination Scheme
Paper: 100 Marks

Unit I: Introduction to Identification techniques
Introduction, Basic concepts of Identification and Adaptive Control of Systems.
Identification Techniques -

a) Nonparametric Methods: Impulse Response and Correlation, Frequency Response, Fourier and Spectral Analysis, Need for Stochastic Identification.
b) Parametric Methods: Least Square Estimation, Maximum Likelihood, Instrumental Variable Method
c) Computation Methods: Levi son-type, Kalman- type and QR-type. (6 Hrs)

Unit II
Convergence and Consistency, Recursive Estimation, Bootstrapping, Experiment Design, Choice of Input, Model Structure and Order Determination, Model Validation, Practical Application. (5 Hrs)

Unit III: Learning Systems and Methods
Learning in Redundant computer configuration, Learning and pattern recognition, Parametric and non parametric training methods, Linear discreminal function, Learning systems with and without supervision, Decision theoretic methods, Bayesian learning, Stochastic approximation technique, Image processing, Feature extraction theory, Case studies. (6 Hrs)

Unit IV: Introduction to Adaptive Control and Real-Time Parameter Estimation
Introduction to Adaptive Control, Linear Feedback, Effects of Process Variations, Adaptive Schemes, the Adaptive Control Problem Real-Time Parameter Estimation - Least Squares and Regression Models, Estimating Parameters in Dynamical Systems, Experimental Condition, Simulation of Recursive Estimation. (6 Hrs)

Unit V: Self-Tuning Regulators (STR)
Pole Placement Design, Indirect Self-tuning Regulators, Continuous-Time Self-tuners, Direct Self-tuning Regulators, Disturbances with Known Characteristics, Stochastic Self-tuning Regulators, Unification of Direct Self-tuning Regulators, Linear Quadratic STR, Adaptive Predictive Control. (6 Hrs)

Unit VI: Model-Reference Adaptive Systems (MRAS)
Introduction, The MIT Rule, Determination of the Adaptation Gain, Lyapunov Theory, Design of MRAS Using Lyapunov Theory, Bounded-Input, Bounded-Output Stability, Applications to Adaptive Control, Output Feedback, Relations between MRAS and STR, Nonlinear Systems. (7 Hrs)

Text Books:

1. Ljung, System Identification Theory for the user, Prentice Hall, 1999.
2. Astrom K. J., Wittenmark B - "Adaptive Control", Addison Wesley, 1995.
3. Landau L. D., Lozano R., M'Saad M. - "Adaptive Control", Springer, 1997.
4. T. Soderstrom & P. Stoica, “System Identification”, Prentice Hall

Reference Books:

1. Eveleigh, V. W. "Adaptive Control and Optimization Techniques", McGraw Hill Book Company, New York, 1967.
2. Mendel, J.M. and Fu, K. S. "Adaptive Learning and Pattern Recognition Systems", Academic Press, New York, 1970.
3. A. Papoulis, “Probability, Random Variables and stochastic processes”, 2nd Ed., McGraw Hill, 1983.
4. A. Larson and B.O. Schubert, “Stochastic Processes”, Vol. I and II, Holden-Day, 1979. W. Gardener, Stochastic Processes, McGraw Hill, 1986.

503110: Advanced Digital Control Techniques

Teaching Scheme
Theory: 3 Hrs/Week

Examination Scheme
Paper: 100 Marks

Unit I: Digital Simulation and Digital Redesign

Introduction, Digital modeling with sample and hold devices, State variable formulation, Numerical integration, Frequency domain characteristics, Warping and Prewarping, Digital Redesiging, Closed form solution for G(T), Partial matching of states, solution of the feedback matrix by series expansion, Exact solution of E(T) by series expansion, Stability consideration and Constraints on the selection of weighing matrix. (8 Hrs)

Unit II: Design of Discrete Data control Systems by Conventional Methods

Design in the Z plane using root locus diagram, phase lead lag controller, digital P, PI, PD, PID controller, Pole zero cancellation. (4 Hrs)

Unit III: Pole Placement Design and State Observer

Introduction, Stability improvement by state feedback, Necessary and Sufficient conditions for arbitrary pole placement, State regulator design, Design of State Observers, Compensator design by separation principle, Servo Design - introduction of reference input by feed forward control. State feedback with integral control, digital control system with state feedback, deadbeat observer, Introduction to system identification and adaptive control. (6Hrs)

Unit IV

Multirate DSP, Decimation, Interpolation, Design of Practical Sampling, Rate Conversion, Design of FIR and IIR Filters, Finite word length effect in digital filters, discrete wavelet transform, adaptive filter components, algorithms. (8 Hrs)

Unit V

Digital Signal Processors - Features, Fixed and Floating point DSP, Selection of DSP. Architecture and Instruction set of TMS 320C5X, instruction pipelining, Application Programs. (5 Hrs)

Unit VI

Digital Signal Processors - Features, Fixed and Floating point DSP, Selection of DSP. Architecture and Instruction set ofTMS320C54X DSP Processor, instruction pipelining, Application Programs. (5 Hrs)

Text Books:

1. Discrete Time Control Systems, Pearson Education Asia, Katsuhiko Ogata
2. Digital Control and State Variable Methods (conventional and Neuro Fuzzy Control), Tata McGraw Hill, M. Gopal
3. Digital Signal Processing Implementation using DSP Microprocessors with Examples from TMS 320C54XX, Thomas Publication, Avatar Singh, S. Srinivasan
4. Digital Signal Processor, B. Venkatramani, M. Bhaskar, Tata McGraw Hill

Reference Books:

1. Digital Control Systems, Oxford Press, Koop
2. Digital Signal Processing, Principles, Algorithms and Applications, Pearson Education, John G. Proakis
3. Digital Signal Processing, Pearson Education, Ifeachar Jervis

503111(i): Robust Control System

Teaching Scheme | **Examination Scheme**
Theory: 3 Hrs/Week | Paper: 100 Marks

Unit I: Introduction
Some common robust control problems. Linear system tools: Jordan and Real Jordan canonical forms, structural decomposition. (4 Hrs)

Unit II: Structural mapping of Bilinear Transformations:
Mapping of continuous time to discrete time and vice a versa, existence condition of H∞ sub optimal controllers, continuous time system and discrete time system. (7 Hrs)

Unit III: Solution to Discrete time Riccati Equations:
Solutions to general DARE and H∞ -DARE. (7 Hrs)

Unit IV: Information in continuous time and discrete time H∞ optimization:
Full information feedback case, output feedback case, plants with imaginary axis zeros/unit circle zeros. (6 Hrs)

Unit V: Solutions to continuous time and discrete time H∞ problems:
Full state feedback, full order output feedback, reduced order output feedback. (6 Hrs)

Unit VI
Robust and perfect tracking of continuous time and discrete time systems, solvability conditions and solutions; solutions to measurement feedback case. (6 Hrs)

Text Book:

1. Robust and H∞ Control: Ben M. Chen, Springer Verlag, London, 2000
2. Essentials of Robust Control: K. Zhon, John C. Doyle, Prentic Hall Int. 1998

Reference Book:

1. Robust Control - The Parametric Approach: S. P. Bhattacharya, H. Chapellat, Prentice Hall Int. 1995
2. Robust Adaptive Control: Petros A. Ioannou, Jing Sun, Prentice Hall Int. Upper Saddle River, NJ07458
3. Robust Process Control: M. Morari and E. Zafiriou, Prentice Hall 1989
4. Feedback Control Theory: J. C. Doyle, B. A. Francis and A. R. Tannenbaum, Macmillan 1992
5. A Course in H∞ Control Theory: Francis
6. Optimal Controller, A General Robust Control in Control System Toolbox:- Robust Analysis, Robust Model Reduction:- MATLAB, Mathwork Inc. 1992

503111(ii): Stochastics Dynamical Systems

Teaching Scheme
Theory: 3 Hrs/Week

Examination Scheme
Paper: 100 Marks

Unit I
Finite - dimensional linear estimation. The geometrical structures of linear estimation. (5 Hrs)

Unit II
Stochastic processes and linear estimation. Stochastic processes, Hilbert space, Spaces of square – integrable variables. (7 Hrs)

Unit III
Orthogonal increments processes. General properties, counting processes, Brownian motion and white noise, Wiener integrals. (6 Hrs)

Unit IV
Estimation in dynamical systems. Multidimensional processes, linear stochastic equations, the innovations process, The Kalmann Filter. (6 Hrs)

Unit V
Linear Stochastic Control. Dynamic programming and the deterministic linear regulator, the stochastic linear regulator, Partial observations and the separation Principle, Infinite-time problems. (8 Hrs)

Unit VI
An outline of further developments. Nonlinear filtering and control, Distributed-parameter systems. (4 Hrs)

Text Books:

1. Paul Malliavin, "Stochastic Analysis", Springer (1997)
2. M.H.A. Davis, "Linear Estimation and Stochastic Control", Chapman and Hall, London (1977)

Reference Books:

1. Peter S. Maybeck, "Stochastic Models, Estimation and Control Vol.-I", Academic Press, New York (1979).
2. Peter S. Maybeck, "Stochastic Models, Estimation and Control Vol.-II", Academic Press, New York (1982).
3. Peter S. Maybeck, "Stochastic Models, Estimation and Control Vol.-III", Academic Press, New York (1982).

503111(iii): Large Scale Systems

Teaching Scheme | **Examination Scheme**
Theory: 3 Hrs/Week | Paper: 100 Marks

Unit I: Modeling and parameter estimation:
Introduction to probability theory, elements of estimation theory, application to parameter estimation for a dynamical model, some methods for the determination of transfer functions. (5 Hrs)

Unit II: Parameter estimation for large scale systems
Hierarchical parameter estimation, the multiple projection approach, recursive algorithm for the minimum variance estimator, simulation results. (5 Hrs)

Unit III: Aggregation:
Aggregation of control systems, problem statement, properties of the aggregated system matrix, determination of the Aggregation matrix;
Generation of feedback controls: linear dynamic optimization, bounds on sub optimality, eigenvalue assignment. (8 Hrs)

Unit IV: State space reduction techniques:
Model analysis approach, mathematical development, three basic methods, and a general approach.
Subspace projection methods, projection error minimization, and derivation of reduced model.
Optimal order reduction, problem formulation, conditions of optimality, numerical algorithm, polynomial input functions. A comparative study. Extension to discrete systems, preliminary analysis, two model reduction techniques, output error minimization. Examples. (6 Hrs)

Unit V
Model simplification using frequency domain techniques. Simplification by continued function expansions: three Cauer forms, a generalized Routh algorithm, simplified models, relationship to aggregation, and extension to discrete models;
Approximation methods for simplification: time moment matching, Padetype approximations, Routh-Hurwitz method. Minimal realization algorithms: conditions of reliability, Pade - type realizable models, aggregated model of Routh approximants. (6 Hrs)

Unit VI: Time scale analysis
Block-diagonalization of continuous systems: problem statement, numerical algorithms, basic properties, relation to model aggregation. Feedback control design: two stage eigenvalue placement.
Decoupling of discrete systems: fast slow separation, approximate analysis, state feedback design.
(6 Hrs)

Text Books:

1. Magdi S. Mahmoud and Madan G. Singh – "Large scale systems modeling", Pergamon press, Oxford.
2. Lan Lunze – "Feedback control of Large scale systems", Prentice Hall International, New York.
3. Prof. B. Bandopadhyay – "Large scale systems"

Reference Books:

1. Magdi S. Mahmoud, Mohamed F. Hassan, Mohamed G. Darwish- "Large scale control systems - Theories and Techniques", Marcel Dekkar, Inc, New York and Basel.
2. Yacov Y. Haimes – "Large scale systems", Publisher: North Holland publishing Co. Amsterdam.
3. Dragoslav D. Siljak – "Large scale dynamic systems: stability and structure", Norht Holland, New York.
4. International federation of automatic control (IFAC) symposia series, 1990, No. 9, "Large scale systems: theory and applications 1989"

503112(i): Intelligent Control

Teaching Scheme — Theory: 3 Hrs/Week

Examination Scheme — Paper: 100 Marks

Unit I: Introduction to Neural Networks

Introduction, Humans and Computers, Organization of the Brain, Biological Neuron, Biological and Artificial Neuron Models, Historical Developments. Essentials of Artificial Neural Networks:
Artificial Neuron Model, Operations of Artificial Neuron, Types of Neuron Activation Function, ANN Architectures, Classification Taxonomy of ANN - Connectivity, Neural Dynamics (Activation and Synaptic), Learning Strategy (Supervised, Unsupervised, Reinforcement), Learning Rules. (6 Hrs)

Unit II: Feed Forward Neural Networks

Introduction, Perceptron Models: Discrete, Continuous and Multi-Category, Training Algorithms: Discrete and Continuous Perceptron Networks, Perceptron Convergence theorem.
Multilayer feed forward Neural Networks. Credit Assignment Problem, Generalized Delta Rule, Derivation of Back propagation (BP) Training, Summary of Back propagation Algorithm, Learning Difficulties and Improvements. (6 Hrs)

Unit III: Associative Memories

Paradigms of Associative Memory, Pattern Mathematics, Hebbian Learning, General Concepts of Associative Memory (Associative Matrix, Association Rules, Hamming Distance, The Linear Associator, Matrix Memories, Content Addressable Memory), Bi-directional Associative Memory (BAM) Architecture, BAM Training Algorithms: Storage and Recall Algorithm, BAM Energy Function, Proof of BAM Stability Theorem. Self-Organizing Maps (SOM) and Adaptive Resonance Theory (ART).
Introduction, Competitive Learning, Vector Quantization, Self-Organized Learning Networks, Kohonen Networks, Linear Vector Quantization, Stability-Plasticity Dilemma, Feed forward competition, ART1, ART2. (6 Hrs)

Unit IV: Fuzzy set Theory

Fuzzy versus crisp, Crisp sets (operation, properties, partition and covering), fuzzy sets: membership function, Basic fuzzy set operations, properties of fuzzy sets, crisp relations: (Cartesian product, operation and relations), fuzzy relations. (Fuzzy Cartesian product, operation on fuzzy relations). (6Hrs)

Unit V: Fuzzy systems

Crisp logic (Laws on prepositional logic, Inference in prepositional logic), predicate logic (Interpretation of predicate logic formula, Inference in predicate logic), fuzzy logic (Fuzzy quantifiers, fuzzy Inference), fuzzy rule based system, defuzzification methods. (6 Hrs)

Unit VI: Applications

Neural network applications: Pattern recognition, control and Process Monitoring, fault diagnosis and load forecasting. Fuzzy logic application: Greg viot's fuzzy cruise controller, Air conditioner controller. (6 Hrs)

Text Book:

1. Neural Network Design-Hagan, Demuth, Beale- Thomas Learning, Vikas Publishing House
2. Introduction to Artificial Neural Systems - Jacek M. Zuarda, Jaico Publishing House, 1997.
3. Neural Networks, Fuzzy logic, Genetic algorithms: synthesis and applications by Rajasekharan and Rai - PHI Publication.

Reference Books:

1. Neural and Fuzzy Systems: Foundation, Architectures and Applications, - N. Yadaiah and S. Bapi Raju, Pearson Education
2. Neural Networks - James A Freeman and Davis Skapura, Pearson, 2002.
3. Neural Networks - Simon Hykins, Pearson Education
4. Neural Engineering by C. Eliasmith and CH. Anderson, PHI

503112(ii): Advanced Drives & Control

Teaching Scheme
Theory: 3 Hrs/Week

Examination Scheme
Paper: 100 Marks

Unit I: Introduction to motor drives:
Classification, comparison of AC and DC drives, Basic elements, torque equations, component of load torque, multi-quadrant operation, equivalent drive parameters, components of power electronic drives-criteria for selection of drive components match between the motor and the load, calculation of time and energy in transient conditions, characteristics of mechanical systems, stability consideration, thermal consideration, thermal model of motor for heating and cooling, match between the motor and power electronics converter, closed loop control of drives. (7Hrs)

Unit II: DC drives
System model, motor rating, motor mechanism dynamics, drive transfer function, effect of armature current waveform, torque pulsations, adjustable speed drives, chopper fed and 1 phase converter fed drives, effect of field weakening. (5 Hrs)

Unit III: Induction Motor drives
Basic Principle of operation of 3 Phase motor, equivalent circuit, MMF space harmonics due to fundamental current, fundamental spatial MMF distributions due to time harmonics simulation, effect of time and space harmonics, speed control by varying stator frequency and voltage, impact of non-sinusoidal excitation on induction motors, variable square wave VSI drives, variable frequency CSI drives, line frequency variable voltage drives. (6 Hrs)

Unit IV: Induction Motor drives
Review of induction motor equivalent circuit, effect of voltage, frequency and stator current on performance of the m/c, effect of harmonics, slip power recovery schemes-static Kramer drive and dynamic d.q model, small signal model, voltage and current fed scalar control, direct and indirect vector control, sensor less vector control, direct torque and flux control. (6 Hrs)

Unit V: Synchronous motor drives:
Review of synchronous motor fundamental, equivalent circuit, dynamic d-q model, synchronous reluctance, sinusoidal and trapezoidal back emf permanent magnet motors, sinusoidal SPM machine drives, trapezoidal SPM machines drives, wound field machine drives, switched reluctance motor drives. (6 Hrs)

Unit VI: Closed loop control:
Motor transfer function-P, PI and PID controllers, current control-Design procedure, phase locked loop (PLL) control-microcomputer control. Industrial applications and modern trends in drive, effect of RMS voltage variation on drive behavior. (6 Hrs)

Text Books:

1. B. K. Bose, “Modern Power Electronics and AC drives”, Pearson Education, Asia, 2003.
2. M. H. Rashid, “Power Electronics”, Third Edition, PHI
3. G. K. Dubey, “Fundamentals of Electrical Drives”, Narosa Publishing house.

Reference Books:

1. V. Subrahmanyam, “Electric Drives-Concepts and Applications”, TMH
2. G. K. Dubey, “Power Semiconductor controlled drives”, PH 1989.
3. R. Krishnan, “Electric Motor Drives: Modeling, Analysis and Control”, PH, 1998.
4. P. Vas, “Sensor less vector and direct torque control”, Oxford Press, 1998.
5. W. Leonard, “Control of Electric Drives”, Springer Verlag, 1985.

503112(iii): Open Elective

Teaching Scheme	**Examination Scheme**
Theory: 3 Hrs/Week	Paper: 100 Marks

Candidate will have option for any one of the elective subject from the exiting Pune University PG programmers, either from the same Board or from any other Board, with the consent of his guide.

503113: Laboratory Practice – II

Teaching Scheme
Lab Practice: 6 Hrs/Week

Examination Scheme
Term Work: 50 Marks

Students should perform at least ten experiments under Lab. Practice – II covering the subjects taught during semester – II.

503114 Seminar – II

Teaching Scheme	**Examination Scheme**
Seminar: 4 Hrs/Week	Term Work: 50 Marks

The student is required to deliver a seminar in second semester on the topic relevant to latest trends in Control System preferably on the topic of his/her dissertation. The student is expected to submit the seminar report in standard format approved by the University of Pune.

603101 Seminar– III

Teaching Scheme	**Examination Scheme**
Seminar: 4 Hrs/Week	Term Work: 50 Marks

The Term Work will consist of a **report prepared by every student on a seminar topic on Advancement in Technology related to the selected dissertation topic or closely related to dissertation and oral presentation.** The student is expected to submit the seminar report in standard format approved by the University.

603102 Project Stage – I

Teaching Scheme	**Examination Scheme**
Project: 2 Hrs/Week/student	Term Work: 50 Marks

Project Stage – I is the integral part of the dissertation project. The project should be based on the knowledge acquired by the student during the coursework and should contribute to the needs of the society. The project aims to provide an opportunity of designing and building complete system or subsystems in an area where the student like to acquire specialized skills.

The student should present the progress of the project. It will consist of problem statement, literature survey; project overview and scheme of implementation (block diagram, PERT chart, etc.)

603102 Project Stage – II

Teaching Scheme
Project: 2 Hrs/Week/student

Examination Scheme
Term Work: 150 Marks
Oral: 50 Marks

The Project Stage-II will be evaluated on the basis of –

1. Understanding of the problem statement.
2. Physical inspection of the project in case of hardware project.
3. Project Report
4. Oral examination

Term-work will be assessed jointly by a pair of internal and external examiners along with the oral examination of the same.