Indian Institute of Space Science and Technology

Department of Space, Govt. of India

Thiruvananthapuram

Curriculum and Syllabus for

M. Tech in Power Electronics

[From Academic Period 2024-25]

(Approved by the Academic Council on 18-07-2024)

Version 1 (18 July 2024)

PROGRAM EDUCATIONAL OBJECTIVES (PEO)

1. Strengthen analytical skills and the technical knowledge in the area of digital signal processing as well as in allied fields.
2. Enable the graduates to pursue research by adopting dynamic academic curriculum; implement innovative learning and research practices to harness curiosity and creativity; inspire and educate the students to analyse and solve complex problems.
3. Enhance the employability of the graduates in Industry/Academia/R&D organizations by inculcating strong theoretical and experimental knowledge in the domain with exposure to real-life and practical applications.
4. Instil a deep sense of ethics, social values, professionalism, and interpersonal skills among students.

PROGRAM OBJECTIVES (PO)

Program Objectives	Statements
PO1:	Ability to independently carry out research /investigation and development work to solve practical problems.
PO2:	Ability to write and present a substantial technical report/document.
PO3:	Students should be able to demonstrate a degree of mastery over power electronics. The mastery should be discernible in both analytical and practical areas of engineering.
PO4:	Develop analytical skills to model power electronic systems, to design and control power conversion systems.
PO5:	Instil the ability to design and implement power electronic systems using state of the art embedded tools and controllers.

COURSE STRUCTURE

SEMESTER I

Code	Course Title	L	T	P	C
AVP 611	Switched Mode Power Conversion	3	0	0	3
AVP 612	Grid Connected Converters	3	0	0	3
AVP 613	PWM Power Converters and Applications	3	0	0	3
AVC 613	Control System Design	3	0	0	3
	Elective (Group-I)	3	0	0	3
AVP 631	Advanced Power Electronics Lab - I	0	0	3	1
AVP 632	Embedded Systems for Power Electronics Lab	0	0	3	1
	Total	15	0	6	17

SEMESTER II

Code	Course Title	L	T	P	C
AVP 621	Control of Electric Drives	3	0	0	3
	Elective (Group-II)	3	0	0	3
	Elective (Group-II)	3	0	0	3
	Elective (Group-III)	3	0	0	3
	Elective (Group-III)	3	0	0	3
AVP 641	Advanced Power Electronics Lab - II	0	0	3	1
AVP 851	Real-time Controllers for Power Apparatus Lab	0	0	3	1
	Total	15	0	6	17

SEMESTER III

Code	Course Title	L	T	P	C
AVP852	Internship Project	0	0	0	3
AVP853	Project Work Phase - I	0	0	0	12
	Total	0	0	0	15

SEMESTER IV

Code	Course Title	L	T	P	C
AVP 854	Project Work Phase - II	0	0	0	21
	Total	0	0	0	21

List of Elective Courses

Electives (Group-I)

Course Code	Course Name
MA 812	Mathematical Methods
MA619	Mathematics for Electrical engineering
MA611	Optimisation Techniques
MA618	Foundations of Machine Learning

Electives (Group-II)

Course Code	Course Name
AVP 811	Power Electronics in Power Systems
AVP 812	HVDC and FACTS
AVP 816	Electronic Systems Design
AVP 817	Electromagnetic Interference / Compatibility
AVP 818	Soft Switched Converters: Theory and design

Electives (Group-III)

Course Code	Course Name
AVC 621	Optimal Control Systems
AVC 612	Non-linear Dynamical Systems
AVC 866	Robust Control Design
AVC 863	Adaptive Control
AVM622	Micro/Nano Fabrication Technology
AVM 868	Power Semiconductor Devices
AVM865	Sensors and Actuators
AVP 813	Power System Dynamics and Control
AVP 814	Interface Electronics
AVP 815	Emerging and selected topics in Power Electronics
	Electric Vehicles
	Renewable Energy
	Microgrids
	Power Electronics in Distributed Generation
	Artificial Intelligence
	Machine Learning

Summary

Semester	Credits
I	17
II	17
III	15
IV	21
Total	**70**

SEMESTER I

AVP 611 Switched Mode Power Conversion (3-0-0) 3 Credits

Introduction: Power Electronics, structure, applications. Power Semiconductor Devices, Device ratings, Gate Driver Circuits. Reactive elements in power electronic circuits.

DC-DC Converters: Limitations of linear power supplies, Switched Mode Power Conversion, Switch realization, Non-isolated DC-DC Converters: Buck, Boost, Buck-boost, Cuk and SEPIC converters – operations in CCM and DCM, non-idealities. Isolated DC-DC Converters: Flyback, Forward and Push-pull topologies.

Converter dynamics and Control: Modeling of DC-DC converters, Review of controller design in frequency domain, Controller design for single loop voltage feedback.

Input Filter: Requirement, effect of input filter on system stability, design.

Current programmed control: advantages, modeling and control, stability analysis.

References:

1. R. Erickson and D. Maksimovic, " Fundamentals of Power Electronics," 2nd Edition 2001, Springer International Edition.

2. Ned Mohan, Tore M, Undelnad, William P, Robbins (3 Edition), " Power Electronics: Converters, Applications and Design," Wiley 2002.

3. Philip T Krein: Elements of Power Electronics; published by Oxford University Press.

Course Outcomes (COs):

Course Outcomes	Statements
CO1	Understanding of active and passive components used in switched mode power converters.
CO2	Analyze different topologies for DC power conversion in various operational modes from a designer's perspective
CO3	Understand the development of dynamic model and subsequent controller design.
CO4	Design ripple filters and assess their influence on stability of the overall system.

AVP 612 Grid Connected Converters (3-0-0) 3 Credits

Review: Diode bridge rectifiers, thyristor based controlled rectifiers, cyclo-converters and matrix converters.

Single Phase Active Front-End Converters: Power balance, harmonic analysis, power factor correction, modeling of single phase FEC, cascaded control of 1-ph FEC, harmonic filters.

Three Phase Active Front-End Converters: Power balance and reactive power, power factor correction, modeling of three phase FEC, vector control of grid-connected converters, cascaded control of 3-ph FEC.

Operation and control of Grid-connected converters: Phase locked loops for 1-ph and 3-ph grids, operation of grid connected converters as UPF FEC, STATCOM, UPS, battery chargers etc.

Power converters for microgrid and grid connection of renewable energy sources: design, control of converters, grid synchronization and filtering requirements, MPPT.

Lifetime estimation of power converters: Capacitor currents for various topologies, selection criteria for capacitor selection, lifetime estimation, switch currents, and thermal models of converters.

References:

1. T.J.E. Miller, Static Reactive Power Compensation, John Wiley & Sons, New York, 1982.
2. ArindamGhosh& Gerard Ledwich, " Power Quality Enhancement Using Custom Power Devices," IEEE Press.
3. IEEE Publications

Course Outcomes (COs):

Course Outcomes	Statements
CO1:	Understand the basics of the control of a grid connected converter.
CO2:	Control power flow through AC-DC power converters
CO3:	Interpret and estimate life cycle of power converters and typical operational life-time of power components
CO4:	Evaluate the performance of the grid connected converters integrated with renewable energy sources.

AVP 613 PWM Power Converters and Applications (3-0-0) 3 Credits

Basic concepts of switched mode power conversion, realization of switches, selection of switching devices and reactive elements. Switched Mode DC-AC converters, basic concepts, classification.

Voltage source inverters: Single phase and three phase inverters, square wave operation, harmonic analysis, selective harmonic elimination. Voltage space vector structure of 3-phase voltage source inverters. Pulse width modulation (PWM) techniques: Sinusoidal PWM (SPWM) and space vector PWM (SVPWM), current mode control.

Multilevel voltage source inverters: Topologies, voltage space vector structure, PWM control schemes.

Current Source Inverters: Single phase and three-phase topologies, control schemes, current space vector structure, space vector PWM.

Applications: Control of AC motor drives: Constant v/f ratio control of induction motor drives and its implementation. Micro-grids: Grid following and grid forming inverters.

References:

1. Mohan, Undeland and Robbins, Power Electronics: Converters, Application and Design, John Wiley and Sons, 1989.
2. Robert W Erickson, DragoaMaksimovic: Fundamentals of Power Electronics; published by Springer
3. Joseph Vitahyathil, Power Electronics - Principles and Applications; Tata McGraw Hill
4. L. Umanad, Power Electronics - Essentials and Applications; Wiley India Pvt. Ltd.
5. M H Rashid, Power Electronics - Circuits, Devices and Applications; PHI, New Delhi
6. Philip T Krein: Elements of Power Electronics; published by Oxford University Press.
7. Bin Wu, High Power Converters and AC Drives, IEEE Press
8. B.K.Bose, Power Electronics and AC Drives, Prentice Hall.

Course Outcomes (COs):

Course Outcomes	Statements
CO1	Analyse operation of DC to AC power converter topologies
CO2	Analyse the modulation techniques of voltage source inverters
CO3	Understand the operation of current source inverters and their control
CO4	Apply power converters to control drives and microgrids

AVC 613	Control System Design	(3-0-0) 3 Credits

Basics of feedback control: History and motivation for feedback; terminologies, Frequency response, Stability concepts, Bandwidth, Transient response, Closed loop design specifications w.r.t tracking and disturbance rejection, Sensitivity to parameter variations.
Linear Control System Design Techniques: PD, PI and PID controllers, Lead and Lag compensators, Controller design with root locus technique, frequency response technique and state-space technique.
Introduction to Digital Controllers: Continuous versus digital control, Sampling theorem, ZOH, effect of sampling rate, Discretization of continuous transfer functions; Digital filters, digital controller design usingtransformation techniques.
Limitations of performance in SISO Feedback systems: Time domain design limitations- Integrators and overshoots, Open RHP poles and overshoots, Open RHP zeros and undershoots, Frequency domain design specifications, Algebraic design tradeoffs, Analytic design tradeoffs, The Bode gain-phase relation, The Bode sensitivity integral, The Poisson sensitivity integral, The Middleton Complementary sensitivity integral, The Poisson complementary sensitivity integral, Sensor noise vs. plant disturbance tradeoffs, uncertainty and other factors which impose fundamental limits on feedback performance.

Reference Books

1. Nise, Norman S. Control Systems Engineering, John Wiley & Sons, 2007.
2. Ogata, Katsuhiko, and Yanjuan Yang. Modern control engineering. Vol. 4. Prentice-Hall, 2002.
3. Gopal, Madan. Digital Control & State Variable Method. Tata McGraw-Hill Education, 2012.
4. Aström, Karl Johan, and Richard M. Murray. Feedback systems: an introduction for scientists and engineers. Princeton university press, 2010.
5. J.S. Freudenberg with C.V.Hollot and D.P. Looze, A first graduate course in feedback control, ebook.
6. Karl Johan Åström, BjörnWittenmark, Computer-controlled systems: theory and design, Prentice Hall, 1996.
7. Gene Franklin, Ellis-Kagle Press, J. David Powell, Digital Control of Dynamic Systems, Pearson Education, 2005

Course Outcomes (COs):

Course Outcomes	Statements
CO1	Comprehend fundamentals of feedback control
CO2	Apply control system design techniques
CO3	Evaluate performance limitations in SISO feedback systems
CO4	Synthesize optimal solutions for feedback systems

AVP 631 Advanced Power Electronics Lab-I (0-0-3) 1 Credit

Introduction to components, oscilloscope, pcbs and other measuring equipments.

Datasheet familiarization of active components

Experiment on buck converters at different switching frequencies.

Experiment on boost converters,

Experiment on flyback/buck-boost converters.

Experimental validation of analysis on discontinuous conduction mode.

Closed loop control of buck converters.

Course Outcomes (COs):

Course Outcomes	Statements
CO1	Developing ability to define the operating regions of devices from datasheets and configureICs for experimental requirements.
CO2	Being able to demonstrate the experimental objectives.
CO3	Ability to explain the source of difference between experimental and analytical waveforms, if any

AVP 632	**Embedded Systems for Power Electronics Lab**	**(0-0-3) 1 Credit**

Introduction: Introduction to C: 'Hello World!' program, Fizz-buzz program, and Fizz-Buzz-Zazz program.

Micro controllers and DSP: Getting started with Code composer studio/ PSoC Creator.

Architecture and review of Digital Signal Controllers (TMS series controllers)/ microcontroller (PSoC), Architecture of controller, release and debug modes.

Blinking of an LED with one second ON, half second OFF, Programing requirements for time critical control applications:

Enabling of Hardware triggered interrupts, triggering Hardware interrupts with Timers and PWM, Program structure for time critical events, use of putty (Serial interface through USB) to turn on and off an LED, Modulation of LED brightness using PWM.

Fixed point operations: DAC initialization and updates, Fixed point arithmetic basics and development of Macros for (a) addition 4.12 + 4.12, (b) multiplication 4.12 and 4.12 numbers, (c) number format casting -4.12 to 8.24 and vice versa, integrators, signal generation of square wave with variable duty and frequency (fixed amplitude) upto 50 kHz, signal generator functions (sine, square, saw tooth, triangle generation with variable magnitude and variable frequency upto 500 Hz) frequency input to be given through UART interface.

Data Acquisition: ADC initialization, signal acquisition and setup, sensing signals using peripheral ADC with multiplexers - issues with sampling time and input frequency, find max, min, average, RMS of the input signal.

Text Books/References

1. Power Electronics: Essentials and Applications by L.Umanand, Wiley international.
2. Application notes for C2000 processors by Texas Instruments.
3. Application noted for Programmable Systems on Chip (PSoC) by Infineon.

Course Outcomes (COs):

Course Outcomes	Statements
CO1	Understand controller architecture, peripherals and requirements for real-time control
CO2	Use peripherals of the controller for open-loop applications
CO3	Evaluate and analyse suitability of hardware components for real-time embedded control
CO4	Create programs and algorithms for embedded applications.

SEMESTER II

AVP 621 Control of Electric Drives (3-0-0) 3 Credits

Introduction: Electro-mechanical energy conversion, classification of electric drives,requirements of electric drives, four quadrant operation, selection of motors for different applications.

DC Motor Drives:DC-DC Converter fed drives, basic concepts, closed loop control, stability.

Asynchronous Motor Drives: Modeling of induction motors, reference frame theory, speed-torque characteristics, scalar control of induction motors, closed-loop operation, vector control and field orientation, sensor- less control, direct torque and flux control.

Synchronous Motor Drives: Control of Brushless DC (BLDC) motor drives: modeling, commutation schemes, sensorless control, direct torque control.
Control of wound rotor synchronous motor drives and permanent magnet synchronous motor (PMSM) drives: Vector control, direct torque control, field weakening operation.

Control of special electric motors: Switched reluctance motor, stepper motor, synchronous reluctance motor.

References:

1. Paul C Krause, Oleg Wasynczuk, Scott D Sudhoff, Analysis of Electric Machinery and Drive System, Wiley Inter-science.
2. Leonhard W., Control of Electrical Drives, Springer-Verlag, 1985.
3. Krishnan, R., Electric Motor drives: Modeling, Analysis and Control, Prentice Hall.
4. Bin Wu, High Power Converters and AC Drives, IEEE Press
5. B.K.Bose, Power Electronics and AC Drives, Prentice Hall.

Course Outcomes (COs):

Course Outcomes	Statements
CO1	Evaluate electric drive, converter and load requirements for various applications
CO2	Analyse classical models and scalar control methods for AC Motor drives
CO3	Understand the dynamic model of AC Motors and special machines
CO4	Apply vector control-based strategies for speed control of AC motor drives

AVP 641 Advanced Power Electronics Lab-II (0-0-3) 1 Credit

Familiarization of inverter modules architecture.

DC motor speed control - Speed control of DC motor with H-bridge using PWM.

Optional: Cascaded control of DC motor with inner current loop, and outer speed loop

V/f control of induction motor, sine PWM and Space vector PWM implementation with a 3-phase converter

Implementation of a single-phase PLL and a 3-phase PLL with hall-effect based voltage sensors and digital controllers

Analysis, Circuit design, schematics and layout of a 1-phase or a 3-phase 2-level inverter.

Text Books/References

1. Power Electronics: Essentials and Applications by L.Umanand, Wiley international.

2. Application notes for C2000 processors by Texas Instruments.

Course Outcomes (COs):

Course Outcomes	Statements
CO1:	Analyze operation of a 3-phase voltage source inverter hardware and, gain familiarity with a digital signal controller
CO2:	Implement cascaded control of DC motor
CO3:	Implement V/f control of induction motor with sine PWM and SVPWM
CO4:	Implement 1-phase and 3-phase PLL for grid angle estimation

AVP851	**Real-time Controllers for Power Apparatus Lab**	**(0-0-3) 1 Credit**

Filter implementation: Nth order IIR filter implementation, time constant relationship with sampling times, Nth order FIR filter implementation, memory requirements for filters, Sapling and quantization errors, outputs for different input signals.

Controllers (simulated plant): Implementation of a P controller, implementation of an I controller,implementation of a PI controller, implementation of a 2 DOF controller.

Controllers (physical plant): The plant is RC filter (physical) with a varying load resistance. RC filter is fed with PWM module. Implementation of a P-controller, implementation of an I-controller, implementation of a P, I, PI controller, implementation of a 2 DOF controller.

FPGAs: Hardware description language (HDL - VHDL), Program architecture (Functional and behavioural models), Simple combinational blocks and look-up tables, multiplexer, demultiplexer implementation, introduction to design of sequential logic circuits.

Course projects (Any one in groups of 2 or 3):

Auto volume leveller with microcontroller and audio source

A PWM module implemented with FPGA (Xilinx Spartan-3 series)

Electronic speed controller for BLDC - 1 axis reaction wheel system - control of orientation

Magnetic levitation with hardware building

Text Books/References

1. Power Electronics: Essentials and Applications by L.Umanand, Wiley international.
2. Application notes for C2000 processors by Texas Instruments.
3. Application noted for Programmable Systems on Chip (PSoC) by Infineon

Course Outcomes (COs):

Course Outcomes	Statements
CO1	Understand implementation of digital filters
CO2	Use digital signal processor for implementation of P,I and PI controllers
CO3	Familiarisation of Hardware Description Language (HDL-VHDL)for FPGA programming
CO4	Create programs and algorithms for power electronics systems.

ELECTIVES (Group-I)

MA 812	Mathematical Methods	**(3-0-0) 3 Credits**

Linear Algebra: n- dimensional Euclidean spaces, linear transformation, Matrices, Eigen values and Eigen vectors, Generalised inverses, SVD.

Numerical Methods: Numerical Solution of nonlinear equations, Direct and iterative methods to solve system of linear equations, Numerical integration – Trapezoidal and Simpson's rule, Interpolation, Splines and curve fitting, Numerical solution of ODE – Euler's method and 4th order Runge- Kutta Method.

Optimization Techniques: Maxima and Minima of functions of several variables, saddle point, Lagrange Multipliers, Steepest- Descent method.

Probability Distribution and Mathematical Statistics: Probability Distributions: Binomial, Poison and Normal

Sampling theory: Central Limit Theorem, Difference Between Two Sample Proportions, Sample Mean and Variance, Sample Proportion, Sampling Distributions, Sampling Procedures, Statistics for Normal Random Variables, Confidence interval, Testing of Hypothesis, Goodness of fit

References:

1. Stewart, J., Calculus: Early Transcendental, 5th ed., Brooks/Cole (2007).
2. Kreyszig, E., Advanced Engineering Mathematics, 9th ed., John Wiley (2005).
3. K B Datta: Matrix and Linear Algebra.
4. S.S Rao, Optimization Theory and Applications, Wiley eastern, 1984.
5. Applied Statistics and Probability for Engineers, Douglas C. Montgomery, 6th edition, 2016

MA 619 Mathematics for Electrical Engineering (3-0-0) 3 Credits

Linear Algebra:

(a) Vector Spaces: Definition of Vector space, Sub spaces, linearly independence and dependence,linear Span, Basis, Dimension

(b) System of linear equations: Range space and Null space of a matrix, Rank of a matrix, Existence and uniqueness of solution of the system of linear equations, Dimension of the Solution Space associated with the system of linear equations

(c) Eigen values and Eigen vectors: Definition of Eigen values and Eigen vectors of a square matrix and their properties including similarity matrices

(d) Diagonalization and SVD: Diagonalization of a square matrix, Singular-Value-Decomposition (SVD) and Pseudo-inverse of a matrix

Fourier Series and Transform:

(a) Fourier Series: Fourier Series of 2pi periodic functions, Cosine Series, Sine Series, Fourier series of a function defined on an interval [a,b] of length T=b-a, Point-wise Dirichlet convergence Theorem for Fourier Series.

(b)Fourier Transform: Representation of a function defined over R in Fourier Integral and representation of Fourier Integral as a pair of transformations: Fourier Transform and Fourier Inverse Transform, Properties of Fourier Transform

(c)Laplace transform: Definition and necessity of Laplace transform, Inverse Laplace transform, Properties of Laplace Transform

Introductory Complex Analysis

(a) Complex Differentiation: Definition of Continuity and Differentiability-Cauchy-Riemann Equation -Analytic function

(b) Complex Integration: Defintion of Contour-Contour Integration (Complex Line Integration)

Introductory Probability Theory:

Random variables, probability distribution functions, discrete and continuous distributions.If time permits, multivariate distribution to be added.

References

1.Bracewell R., Fourier Transform and its applications(3rd edition), McGraw Hill, 2000

2.Strang G., Linear Algebra and its applications, (4th edition), Thomson 2006.

3.Leon-Garcia A., Probability, statistics and Random Processes for Electrical Engineers, Pearson Prentice Hall, 2008.

4.K. Hoffman and R. Kunze; Introduction to Linear Algebra , Prentice-Hall, 1996, 2/e.

5.R. Horn and C. Johnson, Matrix Analysis; Cambridge, C.U.P.,1991

6.H. A. Priestley, Introduction to Complex Analysis, 2nd edition (Indian), Oxford, 2006.

7.J. H. Mathews and R.W. Howell, Complex Analysis for Mathematics and Engineering, 3rdedition, Narosa, 1998.

8.JHeading,Mathematical Methods in Science and Engineering, 2nd ed.9.Trevor P. Humphreys,A Reference Guide to Vector Algebra.

MA 611 Optimization Techniques **(3-0-0) 3 Credits**

Optimization: need for unconstrained methods in solving constrained problems, necessary conditions of unconstrained optimization, structure methods, quadratic models, methods of line search, steepest descent method; quasi-Newton methods: DFP, BFGS, conjugate-direction methods: methods for sums of squares and nonlinear equations; linear programming: simplex methods, duality in linear programming, transportation problem; nonlinear programming: Lagrange multiplier, KKT conditions, convex programing

References

1. Chong, E.K.andZak,S.H.,An Introduction to Optimization,2nd Ed.,Wiley India(2001).
2. Luenberger,D.G.andYe,Y.,Linear and Nonlinear Programming,3rd Ed.,Springer(2008).
3. Kambo,N.S.,Mathematical Programming Techniques, East-West Press(1997).

MA 618 Foundations of Machine Learning **(3-0-0) 3 Credits**

Machine learning basics: capacity, overfitting and underfitting, hyperparameters and validation sets, bias & variance; PAC model; Rademacher complexity; growth function; VC-dimension; fundamental concepts of artificial neural networks; single layer perceptron classifier; multi-layer feed forward networks; single layer feed-back networks; associative memories; introductory concepts of reinforcement learning, Markhov decision process.

References

1. Mohri, M., Rostamizadedh, A., and Talwalkar, A., Foundations of Machine Learning, TheMIT Press (2012).
2. Jordon, M. I. and Mitchell, T. M., Machine Learning: Trends, perspectives, and prospects, Vol.349, Issue 6245, pp. 255-260, Science 2015.
3. Shawe-Taylor, J. and Cristianini, N., Kernel Methods for Pattern Analysis, Cambridge Univ. Press (2004).
4. Haykin, S., Neural Networks: A Comprehensive Foundation, 2nd ed., Prentice Hall (1998).
5. Hassoun, M. H., Fundamentals of Artificial Neural Networks, PHI Learning (2010).
6. Ripley, B. D., Pattern Recognition and Neural Networks, Cambridge Univ. Press (2008).
7. Sutton R. S. and Barto, A. G., Reinforcement Learning: An Introduction, The MIT Press (2017)

ELECTIVES (Group-II)

AVP 811 — Power Electronics in Power Systems — (3-0-0) 3 Credits

Active Front End Rectifiers: Power factor correction, single-phase and three-phase, vector control schemes. Operation and control of Grid-connected converters such as UPF FEC, STATCOM, UPS, harmonic compensator etc.

Power converters for microgrid and grid connection of renewable energy sources: design, control of converters, grid synchronization and filtering requirements, MPPT.

Lifetime estimation of power converters: Capacitor currents for various topologies, switch currents, thermal models and impact on lifetime.

Economics of Power Converters: Payback period, Net Present Value or Effective initial cost, Cost of Energy.

References:

1. T.J.E. Miller, Static Reactive Power Compensation, John Wiley & Sons, New York, 1982.
2. ArindamGhosh& Gerard Ledwich, " Power Quality Enhancement Using Custom Power Devices," IEEE Press.
3. IEEE Publications

AVP 812	HVDC and FACTS	(3-0-0) 3 Credits

Introduction: Review of transmission lines; surge impedance loading; voltage profile along radial and symmetrical lines, Ferranti effect, load flow analysis. Power systems dynamics, stability analysis, role of reactive power compensators; series, shunt and unified compensation; effect on power flow and voltage profile.

HVDC Transmission: Evolution of HVDC Transmission, Comparison of HVAC and HVDC systems, Type of HVDC Transmission systems, Components of HVDC transmission systems, Required features of rectification circuits for HVDC transmission, Analysis of HVDC converter, HVDC system control features.

Flexible AC Transmission Systems (FACTS): Requirements of distribution systems, power quality (PQ) problems and classification, FACTS devices, The Static VAR Compensator (SVC); TCR, TSC, STATCOM, Thyristor Controlled Series Compensator (TCSC); Dynamic Voltage Restorer (DVR), Unified Power Flow Compensator (UPFC); Interline Power Flow Controller (IPFC)

References:

1. Song, Y.H. and Allan T. Johns, 'Flexible ac transmission systems (FACTS)', Institution of Electrical Engineers Press, London, 1999.
2. Hingorani. L, Gyugyi, 'Concepts and Technology of flexible ac transmission system', IEEE Press New York, 2000 ISBN –078033 4588.
3. R .Mohan Mathur and Rajiv K.Varma , 'Thyristor - based FACTS controllers for Electrical transmission systems', IEEE press, Wiley Inter-Science.
4. K.R.Padiyar, 'FACTS controllers for transmission and Distribution systems' New Age international Publishers 1st edition -2007.

AVP 816	Electronic Systems Design	(3-0-0) 3 Credits

Module 1: Role of Interface Electronics, Analog Electronic Blocks, OPAMP – internal structure, Open-loop gain, Input R, Output R, DC noise sources and their drifts, CMRR, PSRR, Bandwidth and stability, Slew rate, Noise – general introduction,OPAMP Circuits and Analysis - Difference and Instrumentation Amplifiers (3-opamp and 2-opamp), Effect of cable capacitance and wire-resistance on CMRR, IA with guards, Biomedical application, Current-mode IA (Howland), Current-input IA, filters, Filters with underdamped response, state-variable filters, All-pass filters, Current Sources (floating and grounded loads), PGA, V-to-f converters, Negative Resistance Generator, Gyrator, GIC and applications, Quadrature oscillator, Introduction to switched capacitor circuits and applications, OTA and applications.
Module 2: Frequency and Time Measurement, Sample Hold Circuits, ADCs and their properties, Different ADC Architectures – Single Slope, Dual Slope (with emphasis on DMM), SAR, Flash, Sigma-Delta. Voltage references and regulators,
Module 3: Basic electronic design concepts - potential divider, component packages, burden/loading effects, Error budgeting – Zener drift, resistance drift, voltage offsets and bias current errors, Transistor as amplifier – Basic circuit, loading effects; transistor as a switch – Darlington pairs, drivers, high-side drives, transistor latch.
Module 4: Analog controllers – temperature controller, error amplifier, integral controller, PI controller, PID controller, system TC Vs sensing TC.
Module 5: Transistor (linear) voltage regulator – over current protection, fold-back protection, voltage regulator with bypass, heat-sink design, regulator design with LDOs, current sources – high side loads, grounded loads with reference wrt. Ground, current sources with 3 pin regulator ICs, 4-20mA current transmitters, loop powered circuits.
Module 6: Special topics: PLL, isolation amplifiers, gate drivers, oscilloscope probes (gain selection circuits), techniques for power management.

References

1. Ramón Pallás-Areny, John G. Webster, *Sensors and Signal Conditioning*, 2nd Edition, Wiley, 2003
2. Sergio Franco, Design with Operational Amplifiers and Analog Integrated Circuits, 3rd Edition, McGraw hill, 2002
3. Ramón Pallás-Areny, John G. Webster, *Analog Signal Processing*, 1st Edition, Wiley, 2011
4. George Clayton, Steve Winder, "Operational Amplifiers", 5th Edition, Elsevier Newnes, 2003
5. Ramakant A. Gayakwad, "Opamps and Linear Integrated Circuits," PHI India, 4th Edition
6. *L. K. Baxter, Capacitive Sensors – Design and Applications, IEEE Press Series on Electronic Technology, NJ (1997)*
7. John P. Bentley, *Principle of Measurement Systems*, Pearson Education; 3rd Edition, 2006
8. Horowitz, P., & Hill, W. (2015). *The art of electronics* (3rd ed.). Cambridge University Press.

AVP 817 Electromagnetic Interference/ Compatibility (3-0-0) 3 Credits

Noise pickup modes and reduction techniques for analog circuits.Use of co-axial cables. Conducted and radiated noise emission and control in power circuits. EMI induced failure mechanisms in power circuits. Power supply and ground line distribution in digital circuits. Cross talk and reflection issues in digital circuits.PCB design for signal integrity.Shielding of electronic equipment.ESD issues. EMC standards and test equipment.

Text/Reference Books:

1. Ott, H.W., Noise reduction techniques in Electronic systems, 2nd Edition, John Wiley Interscience, New York 1988.
2. Paul, C.R., Introduction to electromagnetic compatibility, John Wiley and sons, Inc., 1991.

AVP 818	Soft Switched Converters: Theory and design	(3-0-0) 3 Credits

Soft switching Converters: Switching loss, basic principles of hard and soft switching.

Evolution of resonant converter topologies. Resonant Load Converters: analysis of series, parallel, LCC and LLC topologies. Resonant Switch Converters (quasi resonant). Resonant Transition Converters- phase modulated topologies, Soft Switched low power high frequency converters with Auxiliary Switch. Emerging trends in low power high frequency soft switched converters.

Dual Active Bridge (DAB) converters: Operation, design and control, applications. Different types of phase shift control scheme. Modelling and control of DAB converters using generalized averaging. Application of modular topologies with DAB as the core circuit in Microgrids, distributed generation, multiport topologies for interfacing renewable energy resources, storage and hybrid microgrids.

References:

1. R. Erickson and D. Maksimovic, " Fundamentals of Power Electronics," 2nd Edition 2001, Springer International Edition.
2. M. K. Kazimierczuk and D. Czarkowski, "Resonant Power Converters", 2nd Edition, Wiley 2011.
3. Ned Mohan, Tore M, Undelnad, William P, Robbins (3 Edition), " Power Electronics: Converters, Applications and Design," Wiley 2002.
4. IEEE and IET publications

ELECTIVES (Group-III)

AVP 813 Power System Dynamics and Control (3-0-0) 3 Credits

Basic Concepts of dynamical systems and stability.Modelling of power system components for stability studies: generators, transmission lines, excitation and prime mover controllers, flexible AC transmission (FACTS) controllers.

Analysis of single machine and multi-machine systems: Small signal angle instability (low frequency oscillations): damping and synchronizing torque analysis, eigenvalue analysis. Mitigation using power system stabilizers and supplementary modulation control of FACTS devices. Small signal angle instability (sub-synchronous frequency oscillations): analysis and counter-measures.

Transient Instability: Analysis using digital simulation and energy function method. Transient stability controllers.Introduction to voltage Instability.Analysis of voltage Instability.

References:

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

AVP 814 Interface Electronics (3-0-0) 3 Credits

Role of Interface Electronics, Example: Linear Position Sensing, Signal conditioners + ADC, Contactless potentiometer (resistance-capacitance scheme) – Methodology, Interface Circuits, Need of Current/Pneumatic Transmission, Analog Electronic Blocks, OPAMP – internal structure, Open-loop gain, Input R, Output R, DC noise sources and their drifts, CMRR, PSRR, Bandwidth and stability, Slew rate, Noise – general introduction and noise in opamps and their analysis, Noise-equivalent Bandwidth, Output voltage swing, Compensation Techniques.

OPAMP Circuits and Analysis - Difference and Instrumentation Amplifiers (3-opamp and 2-opamp), Effect of cable capacitance and wire-resistance on CMRR, IA with guards, Biomedical application, Current-mode IA (Howland), Current-input IA, filters, Filters with underdamped response, state-variable filters, All-pass filters, Current Sources (floating and grounded loads), PGA, V-to-f converters, Negative Resistance Generator, Gyrator, GIC and applications, Quadrature oscillator, Introduction to switched capacitor circuits and applications, OTA and applications.

Magnetic Sensors - Hall Effect Sensors, Magnetoresistance Sensors, GMR Sensors, Linearization Electronics for Sinusoidal Encoders, Wiegand Effect, Special Topics: Interface Electronics for Remote-connected sensor elements, Front-end Electronics for Reluctance-Hall Effect Angle Transducer (Brake Wear Monitoring), Oscilloscope Probes.

Frequency and Time Measurement, Sample Hold Circuits, ADCs and their properties, Different ADC Architectures – Single Slope, Dual Slope (with emphasis on DMM), SAR, Flash, Sigma-Delta. Voltage references and regulators, Phase-locked loops, EMI and EMC-Techniques

References:

1. Ramón Pallás-Areny, John G. Webster, Sensors and Signal Conditioning, 2nd Edition, Wiley, 2003.
2. Sergio Franco, Design with Operational Amplifiers and Analog Integrated Circuits, 3rd Edition, McGraw hill, 2002.
3. Ramón Pallás-Areny, John G. Webster, Analog Signal Processing, 1st Edition, Wiley, 2011.
4. George Clayton, Steve Winder, "Operational Amplifiers", 5th Edition, Elsevier Newnes, 2003.
5. Ramakant A. Gayakwad, "Opamps and Linear Integrated Circuits," PHI India, 4th Edition.
6. L. K. Baxter, Capacitive Sensors – Design and Applications, IEEE Press Series on Electronic Technology, NJ (1997).
7. John P. Bentley, Principle of Measurement Systems, Pearson Education; 3rd Edition, 2006

AVM 869 Power Semiconductor Devices (3-0-0) 3 Credits

Fundamentals of Semiconductors: Carrier concentration of semiconductor, Transport Equations, P-N Junction Diode, Schottky Junction Diode and MOSFET. Fundamentals of Compound Semiconductors: Introduction of Compound Semiconductors, Properties of Compound semiconductors, Synthesis of Compound Semiconductors.

High Frequency Devices: Essential Condition of High frequency device and compound semiconductor, Fundamentals of MESFET, Concept of Pinch off and threshold voltage, I-V Characteristics of MESFET, trans conductance , equivalent circuit and figure of merits of MESFET, Short channel effect , Velocity saturation and velocity overshoot effect of GaAs based MESFET, Evolution of HEMT from MESFET structure, HEMT and triangular potential well, I-V and gate control, Fabrication of MESFET and HEMT structures.

Optical Devices: Fundamentals of compound semiconductor based optical devices, Optical density of States, fundamentals and formation of Heterostructures devices, Fundamentals of LED, essential band structures of LED. Fundamentals of semiconductor LASER with detail theory.

Technology: Synthesis of Compound semiconductors, Fabrication of MESFET and HEMT structures, Fabrication of LED and LASER structures.

References:

1. Semiconductor Optoelectronic Devices, Bhattacharya Pallab, Pearson.
2. Semiconductor Devices, M.K.Achuthan and K N Bhat, The McGraw Hill.
3. Fundamentals of Semiconductor Fabrication, Gary S. May, Simon M. Sze, Wiley

AVC 621	Optimal Control Systems	(3-0-0) 3 Credits

Basic mathematical concepts: Finite dimensional optimization, Infinite dimensional optimization, Conditions for optimality, Performance measures for optimal control problems. Dynamic programming: The optimal control law, The principle of optimality, Dynamic programming concept, Recurrence relation, computational procedure, The Hamilton-Jacobi-Bellman equations.

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 end point and variable end point control problems, Proof of the minimum principle, Properties of the Hamiltonian, Time optimal control problems.

The 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. Examples: Minimum energy control of a DC motor, Active suspension with optimal linear state feedback, Frequency shaped LQ Control.

LQR using output feedback: Output feedback LQR design equations, Closed loop stability, Solution of design equations, example.

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-Gaussian 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

Text/References:

1. D.E.Kirk, Optimal Control Theory- An Introduction, Dover Publications, New York, 2004.
2. AlokSinha, Linear Systems- Optimal and Robust Controls, CRC Press, 2007.
3. Daniel Liberzone, Calculus of variations & Optimal control theory, Princeton, 2012.
4. Frank L. Lewis, Applied optimal control & Estimation- Digital design and implementation, Prentice Hall and Digital Signal Processing Series, Texas Instruments, 1992.
5. Jason L. Speyer, David H. Jacobson, Primer on Optimal Control Theory, SIAM,2010.
6. Ben-Asher, Joseph Z, Optimal Control Theory with Aerospace Applications, American Institute of Aeronautics and Astronautics, 2010.
7. IT course notes on Principles of optimal control, 2008.
8. Brian D. O. Anderson, John Barratt Moore, Optimal control: linear quadratic methods, Dover, 2007.
9. Brian D. O. Anderson, John Barratt Moore, Optimal filtering, Dover, 2005.
10. Frank L. Lewis, Optimal estimation: with an introduction to stochastic control theory, Wiley Interscience, 1986.

AVC 622	Nonlinear Dynamical System	(3-0-0) 3 Credits

Introduction: Nonlinear system behavior, Nonlinear control.
Nonlinear system analysis: Phase plane analysis: Concepts of phase plane analysis, phase plane analysis of linear and nonlinear systems, Existence of limit cycles, Fundamentals of Lyapunov theory: Nonlinear systems and equilibrium points, Concepts of stability, Linearization and local stability, Lyapunov's direct method, Invariant set theorems, Lyapunov analysis of LTI systems, Krasovskii's method, Variable gradient method, Physically motivated Lyapunov functions, Performance analysis. Control design based on Lyapunov's direct method.
Advanced stability theory: Concepts of stability for Non-autonomous systems, Lyapunov analysis of non-autonomous systems, instability theorems, Existence of Lyapunov functions, Barbalat's Lemma and stability analysis, Positive real systems: PR and SPR Transfer functions, The Kalman-Yakubovich Lemma.
The passivity Formalism: passivity in linear systems., Absolute stability, Establishing boundedness of signals, Existence and Unicity of solutions.
Nonlinear Control systems design: Feedback Linearization and the canonical form, Input-state Linearization of SISO systems, Input-output Linearization of SISO systems, multi input systems.
Sliding Control: Sliding surfaces, Filippov's construction of the equivalent dynamics, direct implementations of switching control laws, Continuous approximations of switching control laws, modeling and performance trade-offs Lie derivative, Lie Bracket, Back stepping method for non-feedback linearizable systems.
Texts/References:

1. Jean- Jacques Slotine and Weiping Li, Applied nonlinear Control, Prentice Hall,1991, ISBN: 0-13-040890.
2. H.K. Khalil, Nonlinear Systems, 3rd ed., Prentice hall, 2002.
3. D. Elliott, Bilinear Systems, Springer, 2009.
4. Shankar Sastry, Nonlinear Systems; Analysis, Stability and Control, Springer. 1999.
5. P. LaSalle, Solomon Lefschetz, Stability by Liapunov's direct method: with applications, Joseph Academic Press, 1961.
6. MathukumalliVidyasagar, Nonlinear syste.ms analysis, SIAM, 2002.
7. Alberto Isidori, Nonlinear Control Systems - Volume 1, Springer, 1995.
8. Alberto Isidori, Nonlinear Control Systems – Volume 2, Springer, 1999.

AVC 623	Robust Control Design	(3-0-0) 3 Credits

Basics: Control system representations, System stabilities, Coprime factorization and stabilizing controllers, Signals and system norms Modelling of uncertain systems: Unstructured Uncertainties, Parametric uncertainty, Linear fractional transformation, Structured uncertainties.
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, Formulae for discrete time cases.
Loop- shaping design procedures: Robust stabilization against Normalized coprime factor perturbation, Loop shaping design procedures, Formulae for discrete time cases. m- Analysis and Synthesis: Consideration of robust performance, m-synthesis: D-K iteration method, m-synthesis: m -K iteration method.
Lower-order controllers: Absolute error approximation methods like Balanced truncation, Singular perturbation approximation and Hankel-norm approximation, Reduction via fractional factors, Relative error approximation and frequency weighted approximation methods.
Design case studies: Robust Control of a mass damper spring system, A triple inverted pendulum control system, Robust control of a hard disk drive.
Linear Matrix Inequalities: Some standard LMI problems – eigen-value problems, generalised eigen-value problems; Algorithms to solve LMI problems – Ellipsoid algorithm, interior point methods.

Texts/References:

1. D.-W.Gu, P.Hr.Petkov and M.M.Konstantinov, Robust Control Design with MATLAB, Springer, 2005.
2. AlokSinha, 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, PHC, 1996.
6. G Balsa, R.Y. Chiang, A.K.Packard and M.G.Safonov, Robust Control Toolbox (Ver. 3.0) User's Guide. Natick, MA: The MathWorks, 2005. http://www.mathworks.com/access/helpdesk/hellp/toolbox/robust
7. Kemin Zhou, John Comstock Doyle, Keith Glover, Robust & optimal control, PHCl, 1996.
8. Kemin Zhou, John Comstock Doyle, Essentials of robust control, Prentice Hall, 1998.
9. Stephen Boyd, Laurent El Ghaoul, Eric Feron, Linear Matrix Inequalities in System and Control Theory, SIAM, 1994.
10. "Robust Control"- Bhattacharya, Chapellat, Keel, Prentice Hall, 1995.

AVC 863 Adaptive Control (3-0-0) 3 Credits

Introduction: Parametric models of dynamical systems, Adaptive control problem Real time parameter estimation: Least squares and regression models, Estimating parameters in Dynamical Systems, Experimental conditions, Prior information, MLE, RLS, Instrument variable method.
Deterministic Self tuning regulators (STR): Pole placement design, Indirect self-tuning regulators, Continuous time self-tuners, Direct self-tuning regulators, disturbances with known characteristics.
Stochastic and Predictive Self tuning regulators: Design of Minimum variance and Moving average controllers, Stochastic self-tuning regulators, Unification of direct self-tuning regulators. Linear quadratic STR, adaptive predictive control.
Model reference adaptive control (MRAS): The MIT Rule, Determination of adaptation gain, Lyapunov theory, Design of MRAS using Lyapunov theory, BIBO stability, Output feedback, Relations between MRAS and STR.
Properties of Adaptive systems: Nonlinear dynamics, Analysis of Indirect discrete time self-tuners, Stability of direct discrete time algorithms, Averaging, Application of averaging techniques, Averaging in stochastic systems, Robust adaptive controllers.

References

1. K.J. Astrom and B. Wittenmark, Adaptive Control, 2nd ed., Pearson Education, 1995.
2. PetrosIoannou and BarisFidan, Adaptive Control Tutorial, SIAM, 2006.
3. P.A. Ioannou and J. Sun, Robust Adaptive Control, Prentice Hall, 1995.
4. SankarSastry and Marc Bodson, Adaptive Control- Stability, Convergence and Robustness, Springer, 2011.
5. M. Krstic, I. Kanellakopoulos and P. Kokotovic, Nonlinear and Adaptive Control Design, Wiley-Interscience, 1995.
6. H.K. Khalil, Nonlinear Systems, Prentice Hall, 3rd ed., 2002.
7. Jean- Jacques Slotine and Weiping Li, Applied nonlinear Control, Prentice Hall,1991.
8. TorstenSöderström, Instrumental variable estimation, Springer, 1983.
9. Harold Wayne Sorenson, Parameter estimation: principles and problems, M Dekker, 1980.

AVP 815	Emerging and Selected Topics in Power Electronics	(3-0-0) 3 Credits

Dynamic model of DC-DC converters in DCM: averaged switched model, small signal modelling of the low frequency model. High frequency dynamics of converter operating in DCM.

Forced commutated AC-AC converters – Matrix Converters: operation, topologies, commutation strategies, voltage modulation – Direct and Indirect schemes.Dynamic model, design of passive elements and control scheme.

Power Electronic/Solid State Transformer: Requirement and significance in future smart grid and traction. Developments in topology, devices, high frequency link transformer and future trends. Analysis of topologies with emphasis on modular two stage topologies: operation, modelling and control for input series and output parallel configuration.

Basic concepts of EMI and EMC - Conducted emission - Radiated emission - E-field and H- field coupling - grounding - EMI/EMC in power electronic circuits - Measurement of EMI - LISN – Filters.

References:

1. R. Erickson and D. Maksimovic, “Fundamentals of Power Electronics,” 2nd Edition 2001, Springer International Edition.

2. IEEE Journal of Emerging and Selected Topics in Power Electronics and other publications relevant to Power Electronics.

Evaluation method for AVP 815

A major of the course would consist of simulation exercises, mini design problems. The learning efficacy would be better if the evaluation structure allows and encourages the students to analyse and demonstrate their designs/understanding through simulation. Hence the proposed evaluation structure for AVP866 is, Quiz 1 and Quiz 2: 30 points total, Internal Assessment: 35 points, and End Semester: 35 points.

AVM622 Micro/Nano Fabrication Technology (3-0-0) 3 Credits

Classical scaling in CMOS, Moore's Law, Clean room concept, Material properties,crystal structure, lattice, Growth of single crystal Si, Cleaning and etching, Thermaloxidation, Dopant diffusion in silicon, Deposition & Growth (PVD, CVD, ALD,epitaxy, MBE, ALCVD etc.),Ion-implantation, Lithography (Photolithography, EUVlithography, X-ray lithography, e-beam lithography etc.), Etch and Cleaning, CMOSProcess integration, Back end of line processes (Copper damascene process, Metalinterconnects; Multi-level metallization schemes), Advanced technologies(SOIMOSFETs, Strained Si, Silicon-Germanium MOS, metal semiconductor source /drain junctions, High K, metal gate electrodes and work function engineering,Double gate MOSFETs, FinFETs, TunnelFETsetc..) , emerging research devices andarchitectures (Nanowire FETs, CNT FETs, Graphene transistors, Organic FETs etc..)

References

1. James Plummer, M. Deal and P.Griffin, Silicon VLSI Technology, Prentice Hall Electronics
2. Stephen Campbell, The Science and Engineering of Microelectronics, Oxford University Press, 1996
3. S.M. Sze (Ed), VLSI Technology, 2nd Edition, McGraw Hill, 1988
4. C.Y. Chang and S.M.Sze (Ed), ULSI Technology, McGraw Hill Companies Inc, 1996.
Peer reviewed international journals such as IEEE Electronic Device Letters, Transactions on Electron Devices, Journal o Microelectronics, etc and conference proceedings such as International Electron Device Meeting (IEDM), IRPS etc.

AVM865 Sensors and Actuators (3-0-0) 3 Credits

Introduction and historical background, Microsensors : Sensors and characteristics, Integrated Smart sensors, Sensor Principles/classification-Physical sensors (Thermal sensors, Electrical Sensors, tactile sensors, accelerometers, gyroscopes , Proximity sensors, Angular displacement sensors, Rotational measurement sensors, pressure sensors, Flow sensors, MEMS microphones etc.), Chemical and Biological sensors (chemical sensors, molecule-based biosensors, cell-based biosensors), transduction methods(Optical, Electrostatic, Electromagnetic, Capacitive, Piezoelectric, piezoresistive etc.), Microactuators : Electromagnetic and Thermal microactuation, Mechanical design of microactuators, Microactuator examples,-microvalves, micropumps, micromotors-Microactuator systems : eg. Ink-Jet printer heads, Micro-mirror TV Projector. Introduction to interfacing methods: bridge circuits, Programmable gain instrumentation amplifiers, A/D and D/A converters, microcontrollers Applications and case studies: Microsensors and actuators in environmental sensing, RF/Electronics devices, Optical/Photonic devices, microsensors for space applications, MEMS sensors in navigation systems, radiation sensors, Medical devices, Bio-MEMS

REFERENCES

1. Micromechanical Transducers: Pressure sensors, accelrometers, and gyroscopes by M.-H. Bao, Elsevier, New York, 2000

2. "Microsensors" by Richard S. Muller, Roger T. Howe, Stephen D. Senturia, Rosemary L. Smith, and Richard M. White, IEEE Press, IEEE Number PC 0257-6, ISBN 0-87942-254-9, New York, 1991.

3. "Micromechanics and MEMS: Classic and Seminal Papers to 1990. " by William Trimmer, IEEE Press, IEEE Number PC4390, ISBN 0-7803-1085-3, New York.

4. Beckwith T. G., Margoni R. D., Lienhard J. H. “Mechanical Measurements”, New York: Addison-Wesley Pub. Co, 1995

5. Micro and Smart Systems by G. K. Ananthasuresh, K. J. Vinoy, S. Gopalakrishnan, K. N. Bhat, and V. K. Aatre, Wiley-India, 2010