Indian Institute of Space Science and Technology

Department of Space, Govt. of India

Thiruvananthapuram

Curriculum and Syllabus for

M.TECH CONTROL SYSTEM

[From Academic Period 2022-23]

(Approved By Academic Council on 27-4-2022)

Version 1 / 17-5-2022

Program Educational Objectives (PEO)

1. Strengthen analytical skills and the technical knowledge in the interdisciplinary area of control theory and applications
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 analyze 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. Instill deep sense of ethics, social values, professionalism and inter-personal skills among students.

Program Outcomes (PO)

1. An ability to independently carry out research /investigation and development work to solve practical problems.
2. An ability to write and present a substantial technical report/document.
3. Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program.
4. Analytical skills for dynamical system modeling and control system design.
5. An ability to simulate and implement feedback control systems using advanced software and embedded tools.

COURSE STRUCTURE

Semester I

Code	Course Title	L	T	P	C
AVC611	Linear Systems Theory	3	0	0	3
AVC612	Nonlinear Dynamical Systems	3	0	0	3
AVC613	Control System Design	3	0	0	3
MA619	Advanced Mathematics	3	1	0	4
E01	Elective I*	3	0	0	3
AVC851	Embedded System Design Lab	1	0	1	2
	Total	16	1	1	18

Semester II

Code	Course Title	L	T	P	C
AVC621	Optimal Control Systems	3	0	0	3
AVC622	Nonlinear Control Systems	3	0	0	3
E02	Elective II*	3	0	0	3
E03	Elective III*	3	0	0	3
E04	Elective IV*(Swayam or Department Elective)	3	0	0	3
AVC852	Control System Design Project	0	0	0	3
	Total	15	0	0	18

Semester III

Code	Course Title	L	T	P	C
AVC853	Project - Phase I	0	0	0	17
	Total	0	0	0	17

Semester IV

Code	Course Title	L	T	P	C
AVC854	Project - Phase II	0	0	0	17
	Total	0	0	0	17

Summary

Semester	Credits
I	18
II	18
III	17
IV	17
Total	**70**

DEPARTMENT ELECTIVE COURSES

Code	Course Title	L	T	P	C
From Control Systems					
AVC861	Modeling and Control of Robotic Systems	3	0	0	3
AVC862	Mobile Robotics and Visual Servoing	3	0	0	3
AVC863	Adaptive Control	3	0	0	3
AVC864	Geometric Approach to Mechanics and Control	3	0	0	3
AVC865	Modelling of Launch Vehicle Dynamics	3	0	0	3
AVC866	Robust Control Systems	3	0	0	3
AVC867	Spacecraft Dynamics and Control	3	0	0	3
AVC868	Advanced Sensors and Interface Electronics	3	0	0	3
AVC869	System Identification and Parameter Estimation	3	0	0	3
AVC870	Fractional Calculus and Control	3	0	0	3
From other M.Tech Specialisation					
AVD864	Computer Vision	3	0	0	3
AVD867	Pattern Recognition and Machine learning	3	0	0	3
AVD870	Deep Learning for Computational data sciences	3	0	0	3

Code	Course Title	L	T	P	C
AVD871	Applied Markov Decision Processes and Reinforcement Learning	3	0	0	3
AVD887	Internet of Things	3	0	0	3
AVP 613	Control of AC Motor Drives	3	0	0	3
AVP 865	Power System Dynamics and Control	3	0	0	3
AVP 867	Electronics System Design	3	0	0	3
MA611	Optimization Techniques	3	0	0	3
MA613	Data Mining	3	0	0	3
MA624	Advanced Machine Learning	3	0	0	3
AE820	Multidisciplinary Design Optimization	3	0	0	3

- **Any other relavant approved elective from different branch can be taken after taking approval from PG coordinator**

SEMESTER I

AVC611	**Linear Systems Theory**	3	0	0	3

Introduction to Modern Control Theory: Introduction to state-space versus transform methods in linear systems; internal versus input/output formulation; discrete-time and continuous- time systems; Solution to LTI and LTV systems for homogeneous and non-homogeneous cases. Computation of matrix exponentials using Laplace transforms and Jordan Normal form. Applications of Eigen values and Eigen vectors.

Stability: Internal or Lyapunov stability, Lyapunov stability theorem, Eigen value conditions for Lyapunov stability, Input-Output stability: BIBO stability, Time domain and frequency domain conditions for BIBO stability.BIBO versus Lyapunov stability.

Controllability and Stabilizability: Controllable and reachable subspaces, Physical examples and system interconnections, Reachability and controllability Grammians, Open loop minimum energy control, Controllability matrix(LTI), Eigen vector test for controllability, Lyapunov test for controllability, Controllable decomposition and block diagram interpretation, Stabilizable system, Eigen vector test for stabilizability, Popov-Belevitch_Hautus (PBH) Test for stabilizability, Lyapunov test for stabilizability.

Observability and Detectability: Unobservable and unconstructable subspaces, Physical examples, observability and Constructability Grammians, Grammian based reconstruction, Duality(LTI), Observable decompositions, Kalman decomposition theorem, State estimation, Eigen value assignment by output injection,

Application - Modelling, controller design and analysis of the Physical system – Analysis of implementable controllers and observers

Text Books/References

1. Joao P. Hespanaha, Linear Systems Theory. Princeton University Press, 2009.
2. Chi-Tsong Chen, Linear System Theory and Design, 3rd ed., Oxford,1999.
3. P. Antsaklis and A. Michel, Linear Systems Theory, McGraw Hill, 1997.
4. Wilson J. Rugh, Linear System Theory, Prentice Hall, 1996
5. Chi-Tsong Chen, Linear System Theory and Design, Holt, Rinehart and Winston, 1970.
6. T. Kailath, Linear Systems, Prentice Hall, 1980.
7. Dennis S. Bernstein, Matrix Mathematics: Theory, Facts, and Formulas with Application to Linear Systems Theory, Princeton University Press, 2006.

AVC612	Nonlinear Dynamical Systems	3	0	0	3

Introduction to Nonlinear systems: Non-linear elements in control systems, overview of analysis methods.

Phase plane analysis: Concepts of phase plane analysis, Phase plane analysis of linear and nonlinear systems, Existence of limit cycles.

Fundamentals of Liapunov 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.

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.

Text Books/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. Mathukumalli Vidyasagar, Nonlinear syste.ms analysis, SIAM, 2002.

AVC613	Control System Design	3	0	0	3

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 using transformation 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.

Text Books/References

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, Björn Wittenmark, 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.

MA619	**Advanced Mathematics**	3	1	0	4

Vectors: Representation and Dot products, Norms, Matrices: The Four Fundamental Spaces of a Matrix, The Matrix as a Linear Operator, The Geometry associated with matrix operations, Inverses and Generalized Inverses, Matrix factorization/Decompositions, rank of a matrix, Matrix Norms. Vector spaces: Column and row spaces, Null Space, Solving Ax=0 and Ax=b, Independence, basis, dimension, linear transformations, Orthogonality: Orthogonal vectors and subspaces, projection and least squares, Gram-Schmidt orthogonalization, Determinants: Determinant formula, cofactors, inverses and volume, Eigenvalues and Eigenvectors: characteristic polynomial, Eigenspaces, Diagonalization, Hermitian and Unitary matrices, Spectral theorem, Change of basis, Positive definite matrices and singular value decomposition, Linear transformations, Quadratic forms

Review of Probability: Basic set theory and set algebra, basic axioms of probability, Conditional Probability, Random variables - PDF/PMF/CDF - Properties, Bayes theorem/Law of total probability, random vectors - marginal/joint/conditional density functions, transformation of Random Variables, characteristic/moment generating functions, Random sums of Random variables, Law of Large numbers (strong and Weak), Limit theorems - convergence types, Inequalities - Chebyshev/Markov/Chernoff bounds.

Random processes: classification of random processes, wide sense stationary processes, autocorrelation function, and power spectral density and their properties. Examples of random process models - Gaussian/Markov Random process, Random processes through LTI systems.

Text Books/References

1. Introduction to linear algebra - Gilbert Strang, SIAM, 2016.
2. Introduction to probability - Bertsekas and Tsitsiklis, Athena, 2008
3. Probability and Random processes for Electrical Engineers, Leon Garcia Addison Wesley, 2nd edition, 1994
4. Probability and Random Processes, Geoffrey Grimmett, David Stirzaker, 3rd Edition, Oxford University Press,2001.
5. Probability and Stochastic Process, Roy D Yates, David J Goodman, 2nd edition Wiley, 2010

E01	Elective 1	3	0	0	3

- Refer Elective List

AVC 851	Embedded System Design Lab	1	0	1	2

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/ microcontroller (PSoC), Architecture of PSoC-5 LP, PSoC Creator edit 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 onboard ADC of PSoC5 - issues with sampling time and input frequency, find max, min, average, RMS of the input signal.

Filter implementation: Nth order IIR filter implementation, time constant relationship with sampling times, Nth order FIR filter implementation, memory requirements for filters, Sampling 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 PI controller, implementation of a 2 DOF controller.

FPGAs: Hardware description language (HDL - VHDL), Program architecture (Functional and behavioral 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):

1. Auto volume leveler with microcontroller and audio source
2. A PWM module implemented with FPGA (Xilinx Spartan-3 series)
3. Electronic speed controller for BLDC - 1 axis reaction wheel system - control of orientation
4. Magnetic levitation with hardware building (2 students)

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.

SEMESTER II

AVC621	Optimal Control Systems	3	0	0	3

Basic mathematical concepts: Finite dimensional optimization, Infinite dimensional optimization, Conditions for optimality, Performance measures for optimal control problems.

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, and Explicit model following design.

Text Books/References

1. D.E.Kirk, Optimal Control Theory- An Introduction, Dover Publications, New York, 2004.
2. Alok Sinha, Linear Systems- Optimal and Robust Controls, CRC Press, 2007.
3. Daniel Liberzone, Calculus of variations and Optimal control theory, Princeton University Press, 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. Brian D. O. Anderson, John Barratt Moore, Optimal control: linear quadratic methods,
8. Dover, 2007.
9. Brian D. O. Anderson, John Barratt Moore, Optimal filtering, Dover, 2005.

AVC622	Nonlinear Control Systems	3	0	0	3

Nonlinear Control: An introduction to vector fields, flows and integral curves of differential equations, Lie Brackets, Frobenious theorem, Orbits, accessibility and controllability, Control design based on Liapunov's method

Feedback Linearization: Feedback Linearization and the canonical form, Input-state Linearization of SISO systems, Input output Linearization of SISO systems

Sliding Mode Control: Sliding surfaces, Filippov's construction of the equivalent dynamics, direct implementations of switching control laws, Continuous approximations of switching control laws,

Text Books/References

1. H. K. Khalil, Nonlinear Systems -, Prentice Hall, 2002
2. Jean- Jacques Slotine and Weiping Li, Applied nonlinear Control, Prentice Hall,1991.
3. V. Arnold, Ordinary Differential Equations -, Springer, 1992.
4. A. Isidori, Nonlinear Control Systems -, Springer, 1989.
5. H. Neijmier and A. Van der Schaft ,Nonlinear Control Systems -, Springer,1992.

AVC852	Control System Design Project	0	0	3	3

- Modelling and simulation of a physical systems
- Control system design using time and frequency domain methods
- Experimental validation/demonstration

Note: Students are advised to do projects independently. Evaluation is based on midterm and final presentation of the work done.

E02	Elective 2	3	0	0	3

- Refer Elective List

E03	Elective 3	3	0	0	3

- Refer Elective List

E04	Elective 4 (Swayam or Department Elective)	3	0	0	3

- Refer Elective List

Semester III

AVC853	**Project - Phase I**	**0**	**0**	**0**	**17**

- Midterm evaluation is based on interim report and presentation before a committee
- A final report in the prescribed format on the literature survey, theoretical analysis, design guidelines, simulation and experimental results etc. to be submitted to the committee during end semester evaluation
- Final evaluation is done based on the technical presentation before an expert committee, report submitted and supervisor's assessment

Semester IV

AVC854	**Project - Phase II**	**0**	**0**	**0**	**17**

- Midterm evaluation is based on interim report and presentation before a committee
- A final report in the prescribed format on the literature survey, theoretical analysis, design guidelines, simulation and experimental results etc. to be submitted to the committee during end semester evaluation. The final dissertation should include both Phase I and Phase II work
- Final evaluation is done based on the technical presentation before an expert committee, dissertation submitted and supervisor's assessment
- Students are encouraged to report their work in peer reviewed International conferences and journals.

Elective Courses

(From Control Systems)

AVC861	Modeling and Control of Robotic Systems	3	0	0	3

Introduction: Components and mechanisms of robotic systems, Robot Manipulators, Wheeled Robots, Legged robots, Autonomous Robots, Joint actuators and Sensors.

Robot Kinematics: Rotation Kinematics, Rotation matrix, Euler angles, Axis-angle representation, Rodrigues formula, Different types of Coordinate transformations, Kinematics of rigid motion, Homogeneous transformation, Modified DH Convention, Typical examples

Differential Kinematics and Statics: Joint configuration space and Task space of robots, Jacobian matrix and Differential motion, Kinematic singularities, Redundancy analysis, Closed loop Inverse Kinematics, Statics, Kineto-static duality, Velocity and force transformations, Spatial vector algebra, Unified representation for rigid motion, Rigid body transformation matrix

Dynamics: Joint space inertia matrix, Computation of kinetic and potential energies, Dynamical model of simple manipulator structures, Dynamics of Serial chain multibody systems, Euler-Lagrange and Newton-Euler formulations, Forward dynamics and inverse dynamics

Motion control: The control problem, Joint space control, Decentralized control, Computed torque feedforward control, Centralized control, PD Control with gravity compensation, Inverse dynamics control, Task space control, Control of redundant robotic manipulators.

Force Control: Manipulator interaction with environment, Compliance control, Impedance control, Force control, Constrained motion, Hybrid force/motion control

Text Books / References

1) Course notes on "Modelling and Control of Robotic Systems" by Sam K Zachariah.
2) M.W.Spong, S.Hutchinson and M. Vidyasagar, Robot Modelling and Control, John Wiley & Sons Inc., 2006.
3) Abhinandan Jain, Robot and Multibody dynamics – Analysis and Algorithms, Springer, 2011
4) Edward Y.L. Gu , A Journey from Robot to Digital Human, Springer, 2013
5) B.Siciliano, L. Sciavicco, L. Villani, G.Oriolo, Robotics- Modelling, Planning and Control, Springer, 2009.
6) B. Siciliano, O. Khatib (Eds), Springer Handbook of Robotics, Springer, 2008.
7) S.V.Shah, S.K. Saha and J. K. Dutt, Dynamics of Tree-Type Robotic Systems, Springer, 2018.

AVC862	Mobile Robotics and Visual Servoing	3	0	0	3

Mobile Robotics: Introduction to mobile robots, Nonholonomic constraints, Kinematic models. Unicycle, Bicycle, Chained form, Dynamic model of mobile robots.

Trajectory Planning: Path and Timing laws, Flat outputs, Path planning, Trajectory planning, Optimal trajectories.

Motion Control: Trajectory tracking, Cartesian regulation, Posture regulation, Odometric localization. Obstacle avoidance and Motion planning: The canonical problem, Configuration space, Different types of obstacles, Planning via retraction, Planning via cell decomposition, Probabilistic planning, Planning via artificial potentials, Motion planning for manipulators.

Visual Servoing: Vision for control, Different types of configuration, Image processing, Pose estimation, Interaction matrix, Stereo vision, Camera calibration Visual servoing problem: Position based visual servoing, Image based visual servoing, Hybrid visual servoing.

Text Books / References:

1) B.Siciliano, L. Sciavicco, L. Villani, G. Oriolo, Robotics- Modelling, Planning and Control, Springer, 2009.
2) Peter Corke, Robotics, Vision and Control, Springer, 2016
3) M.W.Spong, S.Hutchinson and M. Vidyasagar, Robot Modelling and Control, John Wiley & Sons Inc., 2006.
4) B. Siciliano, O. Khatib (Eds), Springer Handbook of Robotics, Springer, 2008.

AVC863	Adaptive Control	3	0	0	3

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.

Text Books/References

1. K.J. Astrom and B. Wittenmark, Adaptive Control, 2nd ed., Pearson Education, 1995.
2. Petros Ioannou and Baris Fidan, Adaptive Control Tutorial, SIAM, 2006.
3. P.A. Ioannou and J. Sun, Robust Adaptive Control, Prentice Hall, 1995.
4. Sankar Sastry 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. Torsten Söderström, Instrumental variable estimation, Springer, 1983.
9. Harold Wayne Sorenson, Parameter estimation: principles and problems, M Dekker, 1980.

AVC864	Geometric Approach to Mechanics and Control	3	0	0	3

Prerequisites: Vector Spaces (Linear Algebra)

An introduction to differentiable manifolds, tangent ff vectors, vector fields, co vector fields, immersions and submersions, Lie groups, actions of groups, Lie algebras, adjoint co-adjoint maps, symmetries. Vector fields, integral curves, push-forward and pull-back, differential forms and Riemannian geometry.

Euler Poincare reduction for the rigid body and heavy top, satellite dynamics and control with coordinate free models, inverted pendulum on a cart.

Text Books / References

1. D .D. Holm, T. Schmah and C. Stoica, Geometric Mechanics and Symmetry, Oxford University Press, 2009.
2. J. Marsden and T. Ratiu, Introduction to Mechanics and Symmetry, Springer-Verlag, 1994.
3. Agrachev and Y. Sachkov, Control Theory from the Geometric Viewpoint Springer, 2004.
4. L. W. Tu, An Introduction to Manifolds Springer 2008.
5. V. Arnold, Ordinary Differential Equations Springer, 1992.
6. J. A. Thorpe, Elementary Topics in Differential Geometry, Springer 2004.
7. M. Spivak, A Comprehensive Introduction to Differential Geometry, Publish or Perish, 1999.

AVC865	**Modelling of Launch Vehicle Dynamics**	**3**	**0**	**0**	**3**

Coordinate systems, Attitude dynamics and control, Rotational kinematics, Direction cosine matrix, Euler angles, Euler's eigen axis rotation, Quaternions, Rigid body dynamics of launch vehicle, Angular momentum, Inertia matrix, Principal axes, Derivation of dynamic equations, Effect of aerodynamics, structural dynamics and flexibility, propellant sloshing, actuator dynamics, gimballed engine dynamics, External forces and moments, Linear model for Aero-structure-control-slosh interaction studies.

Text Books / References

1. J.H.Blakelock, Automatic control of Aircraft and Missiles, Wiley India,1991
2. A.L.Greensite, Control Theory Vol. II- Analysis and Design of Space Vehicle Flight Control Systems, Spartan Books, 1970
3. N V Kadam ,Practical design of flight control systems for launch vehicles and Missiles , Allied Publishers Pvt. Ltd., 2009
4. Brian L. Stevens, Frank L. Lewis, Aircraft Control and Simulation, Wiley, 2003
5. K. J. Ball, G. F. Osborne, Space vehicle dynamics, Clarendon P., 1967
6. A. L. Greensite, Analysis and Design of Space Vehicle Flight Control Systems – Short Period Dynamics, Vol 1, NASA
7. A. L. Greensite, Analysis and Design of Space Vehicle Flight Control Systems, -- Trajectory Equations Vol 2, 1967, NASA

AVC866	Robust Control Systems	3	0	0	3

Vector and matrix Norms, Signal and System Norms, Singular Value Decomposition, Coprime factorization, LMIs, System representation, Sensitivity and Complementary sensitivity functions, pole and zero directions, performance imitations, well posedness, internal stability of feedback system, Nyquist plot, small gain theorem, Uncertainty representation (structured/parametric and unstructured), robust stability and robust performance, structured singular values, Kharitonov's theorem, linear fractional transformation, stabilizing controllers, H-infinity controllers, μ synthesis, applications of robust control in physical systems, Loop shaping design procedures.

Text Books / References

1. Sigurd Skogestad, Ian Postlethwaite, Multivariable Feedback Control: Analysis and Design, Wiley, 2005.
2. Essentials of Robust Control, Kemin Zhou,John C Doyle, Pearson, 1998.
3. Linear Systems-Optimal and Robust Control, Alok Sinha, CRC Press, 2007.
4. Robust Control Design with MATLAB, Da-Wei Gu, Petko H. Petkov, Mihail M Konstantinov, 2013.

AVC867	Spacecraft Dynamics and Control	3	0	0	3

Attitude Kinematics: Particle Kinematics and Vector Frames, Angular Velocities, Vector Differentiation and the Transport Theorem, Rigid Body Kinematics, Direct Cosine Matrix (DCM), Euler Angles, Quaternions, Differential Kinematic Equations, Attitude Determination using TRIAD Method and QUEST Methods.

Attitude Kinetics/Dynamics: Overview of Kinetics, Linear Momentum and Angular Momentum, Rigid Body Angular Momentum, Rigid Body Inertia Tensor, Rigid Body Kinetic Energy, Rigid Body Equations of Motion, Integrating Rigid Body Equations of Motion. Torque Free Motion with Axisymmetric Body, Torque Free Motion General Inertia, Overview of Momentum Exchange Devices.

Attitude Control: Nonlinear Rigid Body State and Rate Control, Global Stability of Nonlinear Attitude Control, Asymptotic Stability for Nonlinear Attitude Control

Text Books / References

1. Schaub, Hanspeter, and John L. Junkins. Analytical mechanics of space systems. AIAA, 2003.
2. Wie, Bong. Space vehicle dynamics and control. American Institute of Aeronautics and Astronautics, 2008.
3. Sidi, Marcel J. Spacecraft dynamics and control: a practical engineering approach. Vol. 7. Cambridge university press, 2000.
4. Wertz, James R., ed. Spacecraft attitude determination and control. Vol. 73. Springer Science & Business Media, 2012.
5. Hughes, Peter C. Spacecraft attitude dynamics. Courier Corporation, 2012.
6. Markley, F. Landis, and John L. Crassidis. Fundamentals of spacecraft attitude determination and control. Vol. 33. New York: Springer, 2014.
7. De Ruiter, Anton H., Christopher Damaren, and James R. Forbes. Spacecraft dynamics and control: an introduction. John Wiley & Sons, 2012.
8. Nijmeijer, Henk, and Arjan Van der Schaft. Nonlinear dynamical control systems. Vol. 175. New York: Springer-Verlag, 1990.

AVC868	Advanced Sensors and Interface Electronics	3	0	0	3

Introduction and Background of state-of-art sensing and measurement techniques. Contactless potentiometer (resistance-capacitance scheme) – Methodology,Interface Circuits, Overview of Flight Instrumentation.

Analog Electronic Blocks, CMRR Analysis (Non-ideal opamps) of an Instrumentation Amplifier, Linearization circuits for single-element wheatstone bridges (application to strain gauge), Direct Digital Converter for Strain gauges, Signal conditioning for Remote-connected sensor elements. Inductive sensors and electronic circuits, Eddy-current based sensors, Synchros and Resolvers, Magnetic shielding techniques.

State-of-art Magnetic Sensors – Principle, Characteristics and Applications – Induction Magnetometer, Flux gate Magnetometer, Hall Effect Sensor, Magnetoresistance Sensors, GMR Sensors – Multi-layer and Spin Valve, Wiegand Effect, SQUID.

Case Study-1: GMR Based Angular Position Sensor, Sensing Arrangement, Linearization Electronics – Methodology, Circuit Design and Analysis.
Case study-2: Brake Wear Monitoring, Reluctance-Hall Effect Angle Transducer–Sensing Arrangement,Front-end Electronics. Overview of Basic Capacitive sensors. Various design considerations; guarding, stray fields, offset and stray capacitance, Ratio metric measurement – advantages and circuit implementations. RMS, Peak, Average Value Electronic Schemes for Capacitive Sensors, Synchronous Phase Detection – multiplier and switching type.
Case study-3: Liquid level detection – Concentric Cylindrical Plates, Plates on container walls – Dielectric and Conductive Liquids - Analysis.
Case study-4: Capacitive Angle Transducers and Front-end electronics.

Piezoelectric sensors, Seismic transducers. Introduction to MEMS, Piezoelectric, Electrodynamic and MEMS Capacitive Accelerometers, Principles of Ultrasonic sensors - Equivalent circuit and transfer function of a piezoelectric transmitter, crystal oscillator. NDT using ultrasonic and eddy-current.
Optical and Fibre Optic Sensors MEMS Pressure sensors, Vaccum-pressure estimation and important flow measurement (volume and mass flow rate) schemes, Flapper-nozzle systems. Sensing Schemes for Attitude, Position measurement and navigation, Instrumentation Systems for Occupancy Detection – Ultrasound, Inductive and Capacitive schemes. Non-contact current and voltage measurement, Newhuman vital-sign sensing techniques.

Text Books:

1. Ramón Pallás-Areny,John G. Webster, Sensors and Signal Conditioning, 2nd Edition, Wiley, 2003.
2. Doebelin, E.O., Measurement systems: Application and Design, 5th ed., McGraw hill, 2003.

References:

1. J. G. Webster, The Measurement, Instrumentation and Sensors Handbook, Vol 1 and 2, CRC Press, 1999.
2. L. K. Baxter,Capacitive Sensors – Design and Applications,IEEE Press Series on Electronic Technology, NJ (1997).
3. Jacob Fraden, Handbook of Modern Sensors – Physics, Designs and Applications, Springer, 4th Edition, 2010.
4. John P. Bentley, Principle of Measurement Systems, Pearson Education; 3rd Edition, 2006.
5. A. Barua, Fundamentals of Industrial Instrumentation, Wiley, 2013.

AVC869	System Identification and Parameter Estimation	3	0	0	3

Introduction, discrete systems, basic signal theory , Open-loop LTI SISO systems, time domain, frequency domain Least Squares Estimation, Covariance in Stationary, Ergodic Processes, White Noise, Detection of Periodicity and Transmission Delays, ARMA Processes.

Non-parametric identification: correlations and spectral analysis, Subspace identification, Identification with "Prediction Error"-methods: prediction, model structure, approximate models, order selection, validation, ARX and ARMAX Input Models, Ourput Error Model, Box-Jenkins Model.

Non-linear model equations, Linearity in the parameters, Identifiability of parameters, Error propagation, MIMO-systems, Identification in the frequency domain, Identification of closed loop systems, Non-linear optimization

Text Books / References

1. Karl Johan Åström, Lectures on system identification - Part 3, Department of Automatic Control, .Lund Institute of Technology, 1975
2. T. Söderström and P. Stoica, System Identification, Prentice Hall, 1989.
3. L Ljung, System identification – Theory for the user, Pearson Education, 1998.
4. Jerry M. Mendel, Lessons in Digital Estimation Theory, Prentice Hall, 1987.
5. Steven M. Kay, Fundamentals of Statistical Signal Processing, Prentice Hall, 2013.

AVC870	Fractional Calculus and Control	3	0	0	3

Fractional Calculus: Review of basic definitions of integer-order (IO) derivatives and integrals and their geometric and physical interpretations, Definition of Riemann-Liouville (RL) integration, Definitions of RL, Caputo and Grunwald-Letnikov (GL) fractional derivatives (FDs), Variousgeometrical and physical interpretations of these FDs, Computation of these FDs for some basic functions like constant, ramp, exponential, sine, cosine, etc., Laplace and Fourier transforms of FDs.

Fractional-order Differential Equations: Study of basic functions like Gamma function, Mittag-Leffler function, Dawson's function, Hypergeometric function, etc, Analysis of linear fractionalorder differential equations (FDEs): formulation, Solution with different FDs, Initial conditions, Problem of initialization and the remedies.

Fractional-order Modeling: Concepts of 'memory' and 'non-locality' in real-world and engineeringsystems, non-exponential relaxation , 'Mittag-Leffler' type decay and rise, Detailed analysis of fractional-order (FO) modeling of: electrical circuit elements like inductor, capacitor, electrical machines like transformer, induction motorand transmission lines, FO modeling of viscoelastic materials, concept of fractionaldamping, Models of basic circuits and mechanical systems using FO elements, Concept of anomalous diffusion, non- Gaussian probability density function and the development of corresponding FO model, FO models of heat transfer, A brief overview of FO models of biological systems.

Linear Fractional-order Systems: Review of basic concepts of complex analysis, Concepts of multivalued functions, branch points, branch cuts, Riemann surface and sheets, Fractional-order transfer function (FOTF) representation, Concepts like commensurate and non-commensurate TFs, stability, impulse, step and ramp response, Frequency response, nonminimum phase systems, Root locus, FO pseudo state-space (PSS) representation and the associated concepts like solution of PSS model, controllability, observability, etc.

Fractional-order Control: Detailed discussion and analysis of superiority of FO control over the conventional IO control in terms of closed-loop performance, robustness, stability, etc., FO leadlag compensators, FO PID control, design of FO state-feedback, Realization and implementation issues for FO controllers, survey of various realization methods and the comparative study.

Text Books / References

1. K. B. Oldham and J. Spanier. The Fractional Calculus . Dover Publications, USA, 2006.
2. Kilbas, H. M. Srivastava, and J. J. Trujillo. Theory and Applications of Fractional Differential Equations, Elsevier, Netherlands, 2006.
3. Podlubny. Fractional Differential Equations . Academic Press, USA, 1999.
4. C. A. Monje, Y. Q. Chen, B. M. Vinagre, D. Xue, and V. Feliu. Fractional-order Systems and Control: Fundamentals and Applications Springer-Verlag London Limited, UK, 2010.
5. R. L. Magin. Fractional Calculus in Bioengineering. Begell House Publishers, USA, 2006.

6. R. Caponetto, G. Dongola, L. Fortuna, and I. Petras. Fractional Order Systems: Modeling and Control Applications. World Scientific, Singapore, 2010.
7. K. S. Miller and B. Ross. An Introduction to the Fractional Calculus and Fractional Differential Equations. John Wiley & Sons, USA, 1993.
8. S. Das. Functional Fractional Calculus for System Identification and Controls, Springer, Germany, 2011.
9. M. D. Ortigueira. Fractional Calculus for Scientists and Engineers. Springer, Germany, 2011.
10. Petras. Fractional-Order Nonlinear Systems: Modeling, Analysis and Simulation Springer, USA, 2011.

Electives From other M.Tech Specialisation

AVD864	Computer Vision	3	0	0	3

Course Objectives:

The course is an introductory level computer vision course, suitable for graduate students. It will cover the basic topics of computer vision, and introduce some fundamental approaches for computer vision research: Image Filtering, Edge Detection, Interest Point Detectors, Motion and Optical Flow, Object Detection and Tracking, Region/Boundary Segmentation, Shape Analysis, and Statistical Shape Models, Deep Learning for Computer Vision, Imaging Geometry, Camera Modeling, and Calibration. Recent Advances in Computer vision.

Prerequisites: Basic Probability/Statistics, a good working knowledge of any programming language (Python, Matlab, C/C++, or Java), Linear algebra, and vector calculus.

Grading: Assignments and the term project should include explanatory/clear comments as well as a short report describing the approach, detailed analysis, and discussion/conclusion.

Course evaluation: 4 Programming assignments 20% (5% each), Term project 20%, Exam 20%, End Sem 40 %.

Text Books / References

1. Simon Prince, Computer Vision: Models, Learning, and Interface, Cambridge University Press
2. Mubarak Shah, Fundamentals of Computer Vision
3. Richard Szeliski, Computer Vision: Algorithms and Applications, Springer, 2010
4. Forsyth and Ponce, Computer Vision: A Modern Approach, Prentice-Hall, 2002
5. Palmer, Vision Science, MIT Press, 1999,
6. Duda, Hart and Stork, Pattern Classification (2nd Edition), Wiley, 2000,
7. Koller and Friedman, Probabilistic Graphical Models: Principles and Techniques, MIT Press, 2009,
8. Strang, Gilbert. Linear Algebra and Its Applications 2/e, Academic Press, 1980.

Programming: Python will be the main programming environment for the assignments. The following book (Python programming samples for computer vision tasks) is freely available. Python for Computer Vision. For mini-projects, a Processing programming language can be used too (strongly encouraged for android application development)

AVD867	Pattern Recognition and Machine Learning	3	0	0	3

Course Objectives:

PR overview - Feature extraction - Statistical Pattern Recognition - Supervised Learning - Parametric methods - Non-parametric methods; ML estimation - Bayes estimation - k NN approaches. Dimensionality reduction, data normalization. Regression, and time series analysis. Linear discriminant functions. Fisher's linear discriminant and linear perceptron. Kernel methods and Support vector machine. Decision trees for classification. Unsupervised learning and clustering. K - means and hierarchical clustering. Decision Trees for classification. Ensemble/ Adaboost classifier, Soft computing paradigms for classification and clustering. Applications to document analysis and recognition

Text Books / References

1. Pattern classification, Duda and Hart, John Wiley and sons,2001.
2. Machine learning, T M Mitchel, McGraw Hills 1997 Pattern Recognition and Machine Learning, Christopher M. Bishop, Springer, 2006.

AVD870	Deep Learning for Computational Data Science	3	0	0	3

Course Objectives:

Prerequisite: Linear algebra, Probability, and interest in programming

Description: Deep learning methods are now prevalent in the area of machine learning, and are now used invariably in many research areas. In recent years it received significant media attention as well. The influx of research articles in this area demonstrates that these methods are remarkably successful at a diverse range of tasks. Namely self driving cars, new kinds of video games, AI, Automation, object detection and recognition, surveillance tracking etc.

The proposed course aims at introducing the foundations of Deep learning to various professionals who are working in the area of automation, machine learning, artificial intelligence, mathematics, statistics, and neurosciences (both theory and applications).

This is a proposed course to introduce Neural networks and Deep learning approaches (mainly Convolutional Neural networks) and give a few typical applications, where and how they are applied. The following topics will be explored in the proposed course.

We will cover a range of topics from basic neural networks, convolutional and recurrent network structures, deep unsupervised and reinforcement learning, and applications to problem domains like speech recognition and computer vision.

Prerequisites: a strong mathematical background in calculus, linear algebra, and probability & statistics, as well as programming in Python and C/C++. There will be assignments and a final project.

1. Introduction to Visual Computing and Neural Networks

2. Basics of Multilayer Perceptron to Deep Neural Networks with Autoencoders

3. Unsupervised deep learning:

Autoencoders for Representation Learning and MLP Initialization

4. Stacked, Sparse, Denoising Autoencoders and Ladder Training

5. Cost functions, Learning Rate Dynamics and Optimization

6. Introduction to Convolutional Neural Networks (CNN) and LeNet

7. Convolutional Autoencoders and Deep CNN (AlexNet, VGGNet)

8. Very Deep CNN architecture for Classification (GoogLeNet, ResNet, DenseNet)

9. Computational Complexity and Transfer Learning of a Network

10. Object Localization (RCNN) and Semantic Segmentation

11. Generative Models with Adversarial Learning

12. Recurrent Neural Networks (RNN) for Video Classification

13. Deep reinforcement learning

14. NLP/Vision Application

Text Books / References

1. Ian Goodfellow, Yoshua Bengio, Aaron Courville. Deep Learning.
2. Duda, R.O., Hart, P.E., and Stork, D.G. Pattern Classification. Wiley-Interscience. 2nd Edition. 2001.
3. Theodoridis, S. and Koutroumbas, K. Pattern Recognition. Edition 4. Academic Press, 2008.
4. Russell, S. and Norvig, N. Artificial Intelligence: A Modern Approach. Prentice-Hall Series in Artificial Intelligence. 2003.
5. Bishop, C. M. Neural Networks for Pattern Recognition. Oxford University Press. 1995.
6. Hastie, T., Tibshirani, R. and Friedman, J. The Elements of Statistical Learning. Springer. 2001.
7. Koller, D. and Friedman, N. Probabilistic Graphical Models. MIT Press. 2009.

AVC871	Applied Markov Decision Processes and Reinforcement Learning	3	0	0	3

Review of basic probability and stochastic processes. Introduction to Markov chains. Markov models for discrete time dynamic systems, Reward, Policies, Policy evaluation, Markov decision processes, Optimality criteria, Bellman's optimality principle, Dynamic programming, Optimality equations, Policy search, Policy iteration, Value iteration. Generalized Policy Iteration, Approximate dynamic programming.

Exploration versus Exploitation in Reinforcement learning, Multiarmed and Contextual Bandits, Reinforcement learning setup and Model free learning, Monte Carlo learning, Q-learning & SARSA, Temporal difference learning, Function approximation, Policy gradient methods, Actor-critic methods, Stochastic approximation and its applications to reinforcement learning, Neural networks in reinforcement learning, Deep reinforcement learning.

Applications and case studies of Markov decision processes and Reinforcement Learning in Machine Learning, Control, Communication, Robotics, and Optimization.

Text Books / References

1. Richard S. Sutton and Andrew G. Barto. Reinforcement learning: An introduction. MIT press, 2018.
2. Dimitri P. Bertsekas, Dynamic programming and optimal control. Vols. I and II, Athena scientific, 2005.
3. Sheldon M. Ross. Applied probability models with optimization applications. Courier Corporation, 2013.
4. Sheldon M. Ross. Introduction to stochastic dynamic programming. Academic press, 2014.

Pre-requisites: Undergraduate Probability and Random Processes, Programming background

AVD887	Internet of Things	3	0	0	3

Course Objectives:

Evolution of the Internet and Big Data. Introduction to the Internet of Things (IoT). The Internet protocol stack. IPv4 and IPv6. TCP and UDP. DNS and the IoT IoT Protocol stack, Layers in the Internet of Things. Sensing and Actuator Layer, Network Layer, and Application Layer. Wireless Sensor Networks. Communication Technologies for the Internet of Things. CoAP, MQTT, and HTTP Protocols for IoT. Data aggregation and fusion. Operating Systems for IoT. Contiki OS, Tiny OS, and other IoT OSs. Databases for the Internet of things. Data mining for the Internet of Things. Blockchain design for the Internet of Things. Approaches of Big data analytics for IoT. Security issues and solutions in IoT. Applications of the Internet of Things. IoT for assisted living. Case studies of IoT. Internet of Medical Things. Introduction to the Digital Twins.

Text Books / References

1. Soldatos, John –Editor, Building blocks for IoT analytics internet-of-things analytics, River publishers, 2017.
2. Perry Lea, Internet of Things for Architects: Architecting IoT solutions by implementing, Packt Publishing Limited, 2018.
3. Raj Kamal, Internet of Things, McGraw Hill Education, 2017
4. C. Siva Ram Murthy and B. S. Manoj, Ad hoc Wireless Networks: Architectures and Protocols, Prentice Hall PTR, New Jersey, May 2004.
5. B. S. Manoj, “Internet of Things,” bsmp, Trivandrum, 2022.
6. Relevant research publications.

AVP 613	Control of AC Motor Drives	3	0	0	3

DC-AC Converters for control of AC Drives: Voltage Source Inverters, square wave operation, harmonic analysis, pulse width modulation (PWM) techniques, Space Vector PWM, Multilevel Inverters, Current Source Inverters.

Induction Motor Drives: Modelling 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, flux observers, Direct torque and flux control.

Control of Synchronous Motors, Permanent Magnet Synchronous Motors, Vector control of Synchronous motor.

Applications: Electric vehicles, Drives for space systems.

Text Books / 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. Mohan, Undeland and Robbins, Power Electronics: Converters, Application and Design, John Wiley and Sons, 1989.
4. Krishnan. R., Electric Motor drives: Modelling, Analysis and Control, Prentice Hall, March 2001.
5. B.K.Bose, Power Electronics and AC Drives, Prentice Hall.
6. Bin Wu, High Power Converters and AC Drives, IEEE Press.

AVP 865	Power System Dynamics and Control	3	0	0	3

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.

Text Books / 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.

AVC867	Electronics System Design	3	0	0	3

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.

Text Book / 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.

MA611	Optimization Techniques	3	0	0	3

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: sim- plex methods, duality in linear programming, transportation problem; nonlinear programming: Lagrange multiplier, KKT conditions, convex programing.

Text Books / References

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

MA613	Data Mining	3	0	0	3

Introduction to data mining concepts; linear methods for regression; classification methods: k-nearest neighbour classifiers, decision tree, logistic regression, naive Bayes, Gaussian discrim- inant analysis; model evaluation & selection; unsupervised learning: association rules; apriori algorithm, FP tree, cluster analysis, self organizing maps, google page ranking; dimensional- ity reduction methods: supervised feature selection, principal component analysis; ensemble learning: bagging, boosting, AdaBoost; outlier mining; imbalance problem; multi class classi-fication; evolutionary computation; introduction to semi supervised learning, transfer learning, active learning, data warehousing.

Text Books / References

1. Bishop, C. M., Pattern Recognition and Machine Learning, Springer (2006).
2. Hastie, T., Tibshirani, R., and Friedman, J., The Elements of Statistical Learning: Data Mining, Inference, and Prediction, Springer (2002).
3. Han, J., Kamber, M., and Pei, J., Data Mining: Concepts and Techniques, 3rd ed., Morgan Kaufmann (2012).
4. Mitchell, T. M., Machine Learning, McGraw-Hill (1997).

MA624	Advanced Machine Learning	3	0	0	3

Kernel Methods: reproducing kernel Hilbert space concepts, kernel algorithms, multiple kernels, graph kernels; multitasking, deep learning architectures; spectral clustering ; model based clustering, independent component analysis; sequential data: Hidden Markhov models; factor analysis; graphical models; reinforcement learning; Gaussian processes; motiff discovery; graph based semisupervised learning; natural language processing algorithms.

Text Books / References

1. Bishop, C. M., Pattern Recognition and Machine Learning, Springer (2006).
2. Hastie, T., Tibshirani, R., and Friedman, J., The Elements of Statistical Learning: Data Mining, Inference, and Prediction, Springer (2002).
3. Cristianini, N. and Shawe-Taylor, J., An Introduction to Support Vector Machines and other kernel-based methods, Cambridge Univ. Press (2000).
4. Scholkopf, B. and Smola, A. J., Learning with Kernels: Support Vector Machines, Regularization, Optimization, and Beyond, The MIT Press (2001).
5. Sutton R. S. and Barto, A. G., Reinforcement Learning: An Introduction, The MIT Press (2017).
6. Goodfellow, I., Bengio, Y., and Courville, A., Deep Learning, The MIT Press (2016).
7. Koller D. and Friedman, N., Probabilistic Graphical Models: Principles and Techniques, The MIT Press (2009).

AE820	Multidisciplinary Design Optimization	3	0	0	3

Multidisciplinary Design Optimization (MDO): Need and importance – Coupled systems – Anal-yser vs. evaluator – Single vs. bi-level optimisation – Nested vs. simultaneous analysis/design– MDO architectures – Concurrent subspace, collaborative optimisation and BLISS – Sensitivityanalysis – AD (forward and reverse mode) – Complex variable and hyperdual numbers – Gradi-ent and Hessian – Uncertainty quantification – Moment methods – PDF and CDF – Uncertaintypropagation – Monte Carlo methods – Surrogate modelling – Design of experiments – Robust,reliability based and multi-point optimisation formulations

Text Books / References

1. Keane, A. J. and Nair, P. B.,Computational Approaches for Aerospace Design: The Pursuitof Excellence, Wiley (2005).
2. Khuri, A. I. and Cornell, J. A.,Response Surfaces: Design and Analyses, 2nd ed., MarcelDekker (1996).
3. Montgomery, D. C.,Design and Analysis of Experiments, 8th ed., John Wiley (2012).
4. Griewank, A. and Walther, A.,Evaluating Derivatives: Principles and Techniques of Algo-rithmic Differentiation, 2nd ed., SIAM (2008).
5. Forrester, A., Sobester, A., and Keane, A.,Engineering Design via Surrogate Modelling:A Practical Guide, Wiley (2008).