Indian Institute of Space Science and Technology
Department of Space, Government of India
Thiruvananthapuram

Curriculum and Syllabus for
M.TECH
Power Electronics

FIRST SEMESTER

Code	Course Title	Lecture Hours	Tutorial Hours	Practical Credits	Total Credits
AVP 611	Mathematics for Electrical Engineering	3	0	0	3
AVP 612	Advanced Power Electronics - I	4	0	0	4
AVP 614	Control of DC Drives and Special Machines	3	0	0	3
AVP 615	Control of AC Motor Drives	3	0	0	3
AVC 613	Digital Control and Embedded Systems	3	0	0	3
AVP 631	Advanced Power Electronics Lab- I	0	3	1	1
AVC 631	Digital Control and Embedded Systems Lab	0	3	1	1
Total		**16**	**6**	**2**	**18**

SECOND SEMESTER

Code	Course Title	Lecture Hours	Tutorial Hours	Practical Credits	Total Credits
AVP 621	Advanced Power Electronics - II	3	1	0	4
	Elective I	3	0	0	3
	Elective II	3	0	0	3
	Elective III	3	0	0	3
AVP 641	Advanced Power Electronics Lab- II	0	3	1	1
AVP 851	Seminar	0	3	0	3
Total		**12**	**7**	**1**	**17**

Summer Internship (During Summer Vacation)

Code	Course Title	Lecture Hours	Tutorial Hours	Practical Credits	Total Credits
AVP 852	Internship Project	0	0	0	3
Total		**0**	**0**	**0**	**3**

THIRD SEMESTER

Code	Course title	Lecture Hours	Tutorial Hours	Practical Credits	Total Credits
AVP 853	Project Work Phase - I	0	0	0	14
Total		**0**	**0**	**0**	**14**

FOURTH SEMESTER

Code	Course title	Lecture Hours	Tutorial Hours	Practical Credits	Total Credits
AVP 854	Project Work Phase - II	0	0	0	18
Total		**0**	**0**	**0**	**18**

ELECTIVE COURSES

Elective – I & II

Course Code	Course Name
AVP 861	Power Electronics in Power Systems
AVP 862	HVDC and FACTS
PH 626	Device Physics and Nanoelectronics
AVM 867	Power Semiconductor Devices
AVM 868	Compound semiconductor devices and technology
AVP 863	Electromagnetic Interference / Compatibility
AVD 622	Digital signal processors for real time applications
AVP864	Interface Electronics

Elective – III

Course Code	Course Name
AVC 621	Optimal Control Systems
AVC 622	Non Linear Dynamical Systems
AVC 623	Robust Control Design
AVC 863	Adaptive Control
AVP865	Power System Dynamics and Control

AVP611 Mathematics For Electrical Engineering (3- 0 - 0) 3 credits

Linear algebra: linear system of equations range and null space, singular value decomposition of a matrix, pseudo-inverse of a matrix, optimal solution of a system.

Probability: random experiments, sample space, events, sigma algebra, probability measure random variables, probability distribution function, discrete and continuous distributions, joint distributions, distribution of functions of random variables, some random processes.

Fourier series and Fourier transform LTI system, signals, sampling and sampling theorem, discrete and continuous signals, DFT, Wavelet transforms.

Complex analysis, Introduction to vector algebra and phasors.

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, 3rd edition, Narosa, 1998.
8. J Heading, "Mathematical Methods in Science and Engineering", 2nd ed.
9. Trevor P. Humphreys, A Reference Guide to Vector Algebra

AVP612 Advanced Power Electronics - I (4- 0 - 0) 4 credits

Introduction: Power Electronics, structure, applications. Power Semiconductor Devices: Diodes, SCRs, BJT, MOSFET and IGBT. Device ratings, Gate Driver Circuits, Snubber circuits. Secondary breakdown in devices. 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 design, Dynamic model in discontinuous conduction mode.

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.
4. M H Rashid, Power Electronics - Circuits, Devices and Applications; PHI, New Delhi.
5. L. Umanad, Power Electronics - Essentials and Applications; Wiley India Pvt. Ltd

AVP614 Control of DC Drives and special Machines (3- 0 - 0) 3 credits

Introduction: Electro-mechanical energy conversion, classification of electric drives, requirements of electric drives, two quadrant and four quadrant operations, Modeling of electrical machines. Selection of motors for different applications, estimation of torque requirements for sinusoidal and trapezoidal profiles, load locus analysis.

DC Motor Drives : Basic principles, different types of DC Drives, Dynamic models, speed-torque characteristics, different control schemes like torque control, closed loop speed and position control schemes, advantages, disadvantages and stability analysis, Phase controlled converter fed DC drives, active front end converters, DC-DC Converter fed drives,. Digital implementation of control loops, velocity control, current control and sampling requirements and stability.

Control of special electric motors: Control of Brush-less DC Motor: different commutation schemes, advantages, Switched Reluctance Motor and Stepper Motor, Control of 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. 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

AVP615	Control of AC Motor Drives	(3- 0 - 0) 3 credits

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: 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, 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.

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

AVC613	Digital Control and Embedded systems	(3- 0 - 0) 3 credits

Introduction, Overview of design approaches, continuous versus digital control, Sampling theorem, ZOH, effect of sampling rate, Calculus of difference equations, z-transform, Frequency domain analysis, Signal flow graphs. State space approach: Controllability, Observability, Discretization of continuous transfer functions; Digital filter properties. Controller design using transformation techniques: z-plane specifications. Design in the w, w' domain. PID controller, deadbeat controller. State space methods: Pole placement design, stabilization and all stabilizing controllers, Different types of A to D converters, Quantization effects: limit cycles and dither.

The concept of embedded systems design, Embedded microcontroller cores, embedded memories, Examples of embedded systems, Technological aspects of embedded systems: interfacing between analog and digital blocks, signal conditioning, digital signal processing, sub-system interfacing, interfacing with external systems, user interfacing, interrupt and polled mode of operation, Software aspects of embedded systems: real time programming languages and operating systems for embedded systems.

A brief introduction to cyber physical systems, DSP processors and pulse width modulation.

Texts/References:

1. Kannan M. Moudgalya, Digital Control, Wiley India, 2007.
2. J.W. Valvano, "Embedded Microcomputor System: Real Time Interfacing", Brooks/Cole, 2000.
3. Jack Ganssle, "The Art of Designing Embedded Systems", Newnes, 1999.
4. David Simon, "An Embedded Software Primer", Addison Wesley, 2000.
5. K.J. Ayala, "The 8051 Microcontroller: Architecture, Programming, and Applications", Penram Intl, 1996.
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.

AVP621 Advanced Power Electronics - II (4- 0 - 0) 4 credits

Advanced control schemes for DC-DC converters, Current programmed control -, advantages, modeling and control, stability analysis.

Soft switching Converters : Switching loss, hard switching, soft switching, basic principles, ZVS, ZCS, ZVZCS Resonant Load Converters: Resonant Switch Converters (quasi resonant) Resonant Transition Phase Modulated Converters, Soft Switched Bidirectional DC-DC Converters PWM Converters with Auxiliary Switch, ZVT /ZCT PWM Converters: Isolated and Non-isolated topologies with auxiliary switch ; Auxiliary Resonant Commutated Pole Inverters: ZVT and ZCT concepts used for Inverters; Resonant DC Link Inverters.

AC- AC Converters: Review of Single-phase AC regulator; Three-phase AC regulators, Single-phase and three-phase Cyclo-converters; Matrix converters.

Applications : Power electronics in space systems, Interfacing converters with grid, UPS, Induction heating, Reactive power compensation, STATCOM, Renewable energy.

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.
4. M H Rashid, Power Electronics - Circuits, Devices and Applications; PHI, New Delhi.
5. L. Umanad, Power Electronics - Essentials and Applications; Wiley India Pvt. Ltd

Elective Courses

AVP861	**Power Electronics in Power Systems**	**(3- 0 - 0) 3 credits**

Basics of Flexible AC transmission systems (FACTS). Principles of series and shunt compensation.. Thyristor controlled compensators - static var compensators (SVC), series compensators (TCSC), phase shifters (SPS), series compensator (SSSC) and Unified power flow controller (UPFC) - structure and circuit analysis.

Power quality problems distribution system and their mitigation using power electronic converters: harmonic mitigation using passive filters. Active filters, hybrid filters. Sag & swell mitigation using Dynamic voltage restorers, STATCOM/DSTATCOM, Unified power quality conditioners (UPQC).

Active Front End Rectifiers: Power factor correction, single phase and three-phase, control schemes.

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

Solid State Transformers technologies in Distribution system.

References:

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

3. IEEE Publications

AVP862 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

PH626 Device Physics and Nanoelectronics (3- 0 - 0) 3 credits

Introduction: Moore's law and technology development. International Technology Roadmap for Semiconductors (ITRS); Technology and material challenges limiting Moore's law.

Contacts: Fabrication of Junction, Metal-semiconductor contacts, Schottky barrier. Contact resistance: 2-probe and 4-probe measurements; Kelvin and van der Pau structures; pn junctions: carrier transport. Equilibrium conditions, Steady state conditions, Transients and AC conditions.

MOS devices: Oxide charges and band-bending, Capacitance – Voltage (C-V) behavior of pMOS and nMOS devices, dissipation factor, band-diagram and degeneracy at accumulation and inversion, depletion width, Mott-Schottky plot and carrier concentration. Frequency dispersion of capacitance, correction of high-frequency capacitance, interface states, parallel conductance measurements, Equivalent oxide thickness (EOT); Leakage current mechanisms through MOS devices – space charges and Child's law, Schottky emission, direct tunneling, band diagram under external field: Fowler-Nordheim tunneling, Poole- Frenkel charge injection.

MOSFET devices: Process technology of fabricating a MOSFET, degenerate states of inversion and formation of the channel, Operation of a MOSFET: Output characteristics: conduction through the channel at low fields; linear regime and Ohm's law: surface mobility and bulk mobility of charges in a semiconductor. Factors influencing the mobility and mobility saturation; pinch-off and drain-current saturation; Threshold voltage of a MOSFET, Sub-threshold conduction in a MOSFET, transfer characteristics, transconductance and subthreshold swing, cutoff frequency. The Non-ideal MOSFET behavior: effects of Shottky contacts, influence of the oxide charges.

MOSFET scaling: scaling roadmap, Short-channel effects: Short-channel effect in transfer and output characteristics.

Introduction to Nanoelectronics: Single molecule field effect transistors, Nanowire FET's, Single electron transistors, Single electron tunneling (SET) devices: Coulomb blockade phenomenon. Nano-scale flash memory devices – Yano memory devices, Resonant tunneling devices (RTD).

Optoelectronics devices: Photodiodes, Light emitting diodes, semiconductor lasers

References

1. Physics of Semiconductor Devices, S.M. Sze, Wiley Publications
2. Electronic Transport in Mesoscopic Systems, Supriyo Dutta, Cambridge University Press.
3. Semiconductor material and Device Characterization, D. K. Schroder, Wiley Interscience.

4. Metal-Oxide-Semiconductor (MOS) Physics and Technology, Nicollian and Brews, Wiley Interscience.

AVM867	Power Semiconductor Devices	(3- 0 - 0) 3 credits

Introduction to Power Semiconductor devices, Device Basic Structure and Characteristics , High current effects in diodes, Breakdown considerations for various devices, Junction Termination techniques for increasing breakdown voltage, edge termination in devices, beveling, open base transistor breakdown Structure & Performance of Schottky and PIN Power Diodes , Parasitic Circuit Elements in Power Diode Recitifiers, Circuit Requirements for Power Transistor Switches,Structure & Performance of Power Transistors: a. MOSFETs; b. BJTs and IGBTs, Parasitic Circuit Elements in Power Transistor Switches , Circuit Requirements for PNPN Thyristors, Structure & Performance of PNPN Thyristors, Parasitic Circuit Elements in PNPN Thyristors, Implementation of Power Electronic Devices using SiC & GaN, Heat transfer in power devices, packaging of power devices

Texts/References:

1. Baliga,G.J., Fundamentals of Power Semiconductor Devices ,Springer.
2. S.M. Sze, Physics of Semiconductor Devices, 2nd ed., Wiley, 1981.

AVD622	Digital signal processors for Real Time Applications	(3- 0 - 0) 3 credits

Computational characteristics of DSP algorithms and applications; their influence on defining a generic instruction-set architecture for DSPs.

Architectural requirement of DSPs: high throughput, low cost, low power, small code size, embedded applications. Techniques for enhancing computational throughput: parallelism and pipelining.

Data-path of DSPs: multiple on-chip memories and buses, dedicated address generator units, specialized processing units (hardware multiplier, ALU, shifter) and on-chip peripherals for communication and control.

Control-unit of DSPs: pipelined instruction execution, specialized hardware for zero-overhead looping, interrupts.

Architecture of Texas Instruments fixed-point and floating-point DSPs: brief description of TMS320 C5x /C54x/C3x DSPs; Programmer's model. Architecture of Analog Devices fixed-point and floating-point DSPs: brief description of ADSP 218x / 2106x DSPs; Programmer's model.
Advanced DSPs: TI's TMS 320C6x, ADI's Tiger-SHARC, Lucent Technologies' DSP 16000 VLIW processors.

Applications: a few case studies of application of DSPs in communication and multimedia.
Introduction to FPGA, RTOS, OS, Basics of Embedded systems

Text/Reference Books:

1. Architectures for Digital Signal Processing; P. Pirsch: John Wiley, 1999.
2. Digital Signal Processing in VLSI; R. J. Higgins: Prentice-Hall, 1990.
3. Texas Instruments TMSC5x, C54x and C6x Users Manuals.
4. Analog Devices ADSP 2100-family and 2106x-family Users Manuals.
5. VLSI Digital Signal Processing Systems; K. Parhi: John Wiley, 1999.
6. Digital Signal Processing for Multimedia Systems; K. Parhi and T. Nishitani: Marcel Dekker, 1999.

AVP863	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. Otto, 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

AVC621	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-Guassian controller (LQG) and Kalman-Bucy Filter: LQG control equations, estimator in feedback loop, steady state filter gain, constraints and minimizing control, state estimation using Kalman-Bucy Filter, constraints and optimal control

Text/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, Princiton University
4. press, 2012.
5. Frank L. Lewis, Applied optimal control & Estimation- Digital design and implementation,Prentice Hall and Digital Signal Processing Series, Texas Instruments, 1992.
6. Jason L. Speyer, David H. Jacobson, Primer on Optimal Control Theory , SIAM,2010.
7. Ben-Asher, Joseph Z, Optimal Control Theory with Aerospace Applications, American Institute of Aeronautics and Astronautics, 2010
8. IT course notes on Principles of optimal control, 2008.
9. Brian D. O. Anderson, John Barratt Moore, Optimal control: linear quadratic methods,
10. Dover, 2007.
11. Brian D. O. Anderson, John Barratt Moore, Optimal filtering, Dover, 2005.
12. Frank L. Lewis, Optimal estimation: with an introduction to stochastic control theory, Wiley Interscience, 1986.

AVC622	**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 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, Performance analysis. Control design based on Liapunov'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. Mathukumalli Vidyasagar, 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.

AVC623	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,generaliszed 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. Alok Sinha, Linear Systems- Optimal and Robust Controls, CRC Press, 2007.
3. S. Skogestad and Ian Postlethwaite, Multivariable feedback control,John Wiley & Sons, Ltd, 2005.
4. G.E. Dullerud, F. Paganini, A course in Robust control theory- A convex approach, Springer, 2000.
5. Kemin Zhou with J.C. Doyle and K. Glover, Robust and Optimal control, Prentice Hall, 1996.
6. G Balsa, R.Y. Chiang, A.K.Packard and M.G.Safonov, Robust Control Toolbox (Ver. 3.0) User’s

7. Guide. Natick, MA: The Mathworks, 2005. http://www.mathworks.com/access/helpdesk/hellp/toolbox/robust
8. Kemin Zhou, John Comstock Doyle, Keith Glover, Robust and optimal control, Prentice Hall, 1996.
9. Kemin Zhou, John Comstock Doyle, Essentials of robust control, Prentice Hall, 1998.
10. Stephen Boyd, Laurent El Ghaoul, Eric Feron, Linear Matrix Inequalities in System and ControlTheory, SIAM, 1994.
11. "Robust Control"- Bhattacharya, Chapellat, Keel, Prentice Hall, 1995

AVC863	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 timeself tuners, Stabilty of direct discrete time algorithms, Averaging, Application of averaging techniques, Averaging in stochastic systems, Robust adaptive controllers.

Texts/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.