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 2022-23]

(Approved by the Academic Council on 27-4-2022)

Version 1 (7 Jun 2022)

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. Instill a deep sense of ethics, social values, professionalism, and interpersonal skills among students.

Program Objectives (PO)

1. Ability to independently carry out research /investigation and development work to solve practical problems.
2. Ability to write and present a substantial technical report/document.
3. 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.
4. Develop analytical skills to model power electronic systems, to design and control power conversion systems.
5. Instill 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
MA 619	Advanced Mathematics	3	1	0	4
AVP 611	Advanced Power Electronics - I	3	0	0	3
AVP 612	AC Motor Drives	3	0	0	3
AVP 613	DC Drives and Special Machines	3	0	0	3
	Elective I	3	0	0	3
AVP 631	Advanced Power Electronics Lab - I	0	0	3	1
AVP 632	Digital Control and Embedded Systems Lab	1	0	3	2
	Total	16	1	2	19

SEMESTER II

Code	Course Title	L	T	P	C
AVP 621	Advanced Power Electronics - II	3	0	0	3
	Elective II	3	0	0	3
	Elective III	3	0	0	3
	Elective IV	3	0	0	3
AVP 641	Advanced Power Electronics Lab - II	0	0	3	1
AVP 851	Electronics Design Project	0	0	9	3
	Total	12	0	10	16

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

Elective courses: Elective – I, II & III Course Code	Course Name
AVC 613	Control System Design
AVP 811	Power Electronics in Power Systems
AVP 812	HVDC and FACTS
AVP 813	Power System Dynamics and Control
AVP 814	Interface Electronics
AVP 815	Emerging and selected topics in Power Electronics

Elective courses: Elective IV & V Course Code	Course Name
AVP 816	Electronic Systems Design
AVC 621	Optimal Control Systems
AVC 612	Non-Linear Dynamical Systems
AVC 866	Robust Control Design
AVC 863	Adaptive Control
PH 626	Device Physics and Nanoelectronics
AVM 868	Power Semiconductor Devices
AVM 869	Compound semiconductor devices and technology
AVP 817	Electromagnetic Interference / Compatibility

Summary

Semester	Credits
I	19
II	16
III	15
IV	21
Total	**71**

SEMESTER I

MA 619	Advanced Mathematics	(3-1-0) 4 Credits

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, Eigen spaces, 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.

References and Textbooks:

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

AVP 611 Advanced Power Electronics - I (3-0-0) 3 Credits

Introduction: Power Electronics, structure, applications. Power Semiconductor Devices: Diodes, SCRs, BJT, MOSFET and IGBT. Device ratings, Gate Driver Circuits, Snubber 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 design

References:

1. R. Erickson and D. Maksimovic, "Fundamentals of Power Electronics," 2nd Edition 2001, Springer International Edition.
2. Ned Mohan, Tore M, Undeland, 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. Umanand, Power Electronics - Essentials and Applications; Wiley India Pvt. Ltd.

AVP 612 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: 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.

Other AC machines: Control of Synchronous Motors, Permanent Magnet Synchronous Motors, Vector control of Synchronous motor, Reluctance motors.

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.

AVP 613 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.

AVC 613 Control Systems 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 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

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.

SEMESTER II

AVP 621 Advanced Power Electronics - II (3-0-0) 3 Credits

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

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.

AC- AC Converters: Review of Single-phase AC regulator; Three-phase AC regulators.

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, Undeland, William P, Robbins (3 Edition), "Power Electronics: Converters, Applications and Design," Wiley 2002.
4. IEEE and IET publications.

ELECTIVES

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. Arindam Ghosh & 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 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

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.

PH 626	**Device Physics and Nano Electronics**	**(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, cut-off frequency. The Non-ideal MOSFET behavior: effects of Schottky 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.

AVM 867 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 Rectifiers, 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

References:

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

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

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.

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. Alok Sinha, Linear Systems- Optimal and Robust Controls, CRC Press, 2007.
3. Daniel Liberzone, Calculus of variations and Optimal control theory, Princiton 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. 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. 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.

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. 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 Guide. Natick, MA: The MathWorks, 2005. http://www.mathworks.com/access/helpdesk/hellp/toolbox/robust
7. Kemin Zhou, John Comstock Doyle, Keith Glover, Robust and optimal control, Prentice Hall, 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.

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.

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.