Indian Institute of Space Science and Technology

Department of Avionics

MTech in VLSI and Microsystems

Revised Syllabus – 2022

To be implemented from August 2022

Semester – I

Code	Course Title	Lecture Hours	Tutorial Hours	Practical Hours	Total Credits
AVM611	Fundamentals of VLSI Devices	3	0	0	3
AVM612	Introduction to Micro Electromechanical Systems (MEMS)	3	0	0	3
AVM613	Analog VLSI Circuits	3	0	0	3
AVM614	Digital VLSI Circuits	3	0	0	3
E01	Elective – 1	3	0	0	3
AVM631	VLSI Design Lab	0	0	3	1
AVM851	Electronic Hardware Design Project	0	0	3	2
	Total	15	0	6	18

Semester – II

Code	Course Title	Lecture Hours	Tutorial Hours	Practical Hours	Total Credits
AVM621	Micro/Nano Fabrication Technology	3	0	0	3
E02	Elective – 2	3	0	0	3
E03	Elective – 3	3	0	0	3
E04	Elective – 4	3	0	0	3
AVM641	MEMS Lab	0	0	3	1
AVM642	Microelectronics Lab	0	0	3	1
AVM852	Engineering Design Project	0	0	0	2
	Total	12	0	6	16

Any one of the 4 electives can be taken as a Swayam/NPTEL course

Semester – III

Code	Course Title	Lecture Hours	Tutorial Hours	Practical Hours	Total Credits
AVM853	MTech Project – Phase I	0	0	0	18
	Total	0	0	0	18

Semester – IV

Code	Course Title	Lecture Hours	Tutorial Hours	Practical Hours	Total Credits
AVM854	MTech Project – Phase II	0	0	0	18
	Total	0	0	0	18

Total Credits: 18 + 16 + 18 + 18 = 70 credits

List of Electives:

The electives are divided into three buckets: VLSI bucket, Microelectronics/ Microsystems bucket and Interdisciplinary bucket. The students may choose any combination from any of the buckets. In addition any one relevant NPTEL/Swayam course can be taken as an elective.

VLSI Bucket

Course Code	Course Title
AVM861	Mixed Signal VLSI Design
AVM862	RF Integrated Circuits
AVM863	VLSI Digital Signal Processing
AVM864	Advanced VLSI Design
AVM865	High Speed IO Circuits

Microelectronics/ Microsystems Bucket

Course Code	Course Title
AVM871	Physics of Nanoelectronic Devices
AVM872	Microsystem Integration
AVM873	RF MEMS
AVM874	Sensors and Actuators
AVM875	Thin films: Materials and characterization
AVM876	Power semiconductor devices
AVM877	Compound semiconductor devices and Technology
AVM878	Photonic Integrated Circuits

Interdisciplinary Electives

Course Code	Course Title
AV491	Advanced Sensors and Interface Electronics
AVD611	Modern Signal Processing
AVP867	Electronic System Design
MA619	Advanced Mathematics

Syllabus of Core Courses

AVM611 – Fundamentals of VLSI Devices

Syllabus

Review of quantum mechanics, E-k diagrams, effective mass, electrons and holes in semiconductors, band diagram of silicon, carrier concentration, carrier statistics, career transport, junction devices(P-N junction, Metal –semiconductor junctions, solar cells etc), MOS capacitor as a building block for MOSFETs (Ideal MOS, real/Non ideal MOS, band diagrams, C-V characteristics, electrostatics of a MOSCAP), MOSFET, I-V characteristics, scaling, short channel and narrow channel effects, high field effects. Reliability of transistor.

References:

1. Donald A Neamen, Semiconductor Physics and Devices: Basic Principles, McGraw-Hill (1997) ISBN 0-256-24214-3
2. Yuan Taur & Tak H Ning, Fundamentals of Modern VLSI Devices, Cambridge University Press, 1998
3. Robert F. Pierret, Semiconductor Device Fundamentals, Addison-Wesley (1995), ISBN 020154393-1
4. E. H. Nicollian and J. R. Brews, MOS Physics and Technology, John Wiley, 1982.
5. K. K. Ng, Complete Guide to Semiconductor Devices, McGraw Hill, 1995.

AVM612 – Introduction to Micro Electro Mechanical Systems

Syllabus

-Broad-stroke overview – History of Microsystem Technology with overview on commercial products, Sensing & Actuation Principles of Microsystems, Applications

-MEMS Materials and Fabrication Technology Microelectronic technologies for MEMS, Micromachining Technology: Surface and Bulk Micromachining,

-Design and modelling of MEMS/Microsystem: Mechanics of MEMS/Microsystems-Elasticity-Stress/strain analysis of beams, membranes etc., thin film stress-Dynamics of Microsystems

MEMS Transduction Mechanisms: Optical, piezoelectric, piezoresistive, FET based transduction etc.

MEMS sensors and applications and case studies

References:

1. S. D. Senturia, Microsystem Design (2005 edition)
2. Foundations of MEMS Chang Liu, Pearson
3. Minhang Bao "Analysis and Design Principles of MEMS Devicess",
4. Marc Madau, Fundamentals of Microfabrication Science of Miniaturization, CRC Press
5. G. K. Ananthasuresh , K. J. Vinoy, S. Gopalakrishnan, K. N. Bhat , V. K. Aatre Micro and Smart Systems Technology and Modeling (January 2012)

Peer reviewed international journals such as IEEE/ASME Journal of MEMS, IOP Journal of Micromechanics and Microengineering, IOP Journal of Nanotechnology, Elseivier Sensors and Actuators etc. and conference proceedings such as IEEE MEMS, IEEE Nanotechnology, Transducers etc..

AVM613 – Analog VLSI circuits

Syllabus

Basic MOS device. Overview of non-ideal behaviour of deep sub-micron MOS transistors. Analysis and design of current mirrors and current sources. Analysis and design of single stage amplifiers, differential amplifiers: Small signal analysis, frequency response, noise, linearity. Analysis and design of OTA circuits – differential pair, cascodes, folded-cascodes, two-stage OTAs. Stability, frequency compensation, CMRR, PSRR. Feedback. Fully differential op-amps, CMFB. Bandgap references. Output stages. Switched-capacitor circuits, comparators.

Text Books

Same as References

References

Design of Analog CMOS Integrated Circuits by Behzad Razavi, McGrawHill

Analog Design Essentials by Willy M. C. Sansen, Springer

Analysis and Design of Analog Integrated Circuits by Gray, Hurst, Lewis and Meyer, Wiley

AVM614 – Digital VLSI circuits

Syllabus

Overview of CMOS device fundamentals (DC Characteristics, AC Characteristics, Processing overview).

CMOS inverters, combinational logic and sequential CMOS logic, Modelling of interconnect wires. Optimization of designs with respect to cost, reliability, performance, and power dissipation. Sequential circuits:-timing considerations, and clocking approaches. Design of large system blocks, including arithmetic, interconnect, memories, and programmable logic arrays. VLSI design: Introduction, Process, Architectural design, Logic design, Physical design Layout styles: Custom layout, Gate-array layout, Standard-Cell layout, Macro-Cell layout, PLA, FPGA layout. Circuit partitioning: Problem definition, Cost function constraints, approaches to partitioning problem. Placement: Complexity of placement, Problem definition, estimation of wire-length. Floor planning: Floor planning model, Cost functions, terminology. Grid routing, Global routing, Channel routing. Design Technology: Introduction to Hardware Description Language Layout Generation and Verification: Behavioral, Structural, Physical level

References:

1. CMOS VLSI design: A circuits and systems perspective, Neil H.E. Weste, David Money Harris, Addison-Wesley(Pearson)
2. J.M. Rabaey, A. Chandrakasan and B. Nikolic, Digital Integrated Circuits- A Design Perspective, 2nd ed., PHI, 2003
3. CMOS digital integrated circuits: Analysis and design, Sung-Mo Kang, Yusuf Lablebici, TATA McGraw-Hill
4. Theoretical foundation of VLSI design, edited by K. McEvoy, J.V. Tucker, Cambridge University Press
5. VLSI Physical design automation: Theory and Practice, Sadiq M. Sait, Habib Youssef, World Scientific Publishing
6. VLSI Circuit Layout: theory and design, Edited by T.C Hu, Ernest S. Kuh, IEEE Press
7. VLSI design: A Practical guide for FPGA and ASIC implementation, Vikram Arkalgud Chandrasetty, Springer
8. VLSI design techniques for Analog and Digital circuits, Randall L. Geiger, Phillip E. Allen, Noel R. Strader, McGraw- Hill Publishing company

AVM621 – Micro/Nano Fabrication Technology

Syllabus

Classical scaling in CMOS, Moore's Law, Clean room concept, Material properties, crystal structure, lattice, Growth of single crystal Si, Cleaning and etching, Thermal oxidation, Dopant diffusion in silicon, Deposition & Growth (PVD, CVD, ALD, epitaxy, MBE, ALCVD etc.),Ion-implantation, Lithography (Photolithography, EUV lithography, X-ray lithography, e-beam lithography etc.), Etch and Cleaning, CMOS Process integration, Back end of line processes (Copper damascene process, Metal interconnects; Multi-level metallization schemes), Advanced technologies(SOI MOSFETs, Strained Si, Silicon-Germanium MOS, High K, metal gate electrodes and work function engineering, Double gate MOSFETs, FinFETs, Gate All Around (GAA) etc..) , emerging research devices and architectures

References:

1. James Plummer, M. Deal and P.Griffin, Silicon VLSI Technology, Prentice Hall Electronics
2. Stephen Campbell, The Science and Engineering of Microelectronics, Oxford University Press, 1996
3. S.M. Sze (Ed), VLSI Technology, 2nd Edition, McGraw Hill, 1988
4. C.Y. Chang and S.M.Sze (Ed), ULSI Technology, McGraw Hill Companies Inc, 1996.

Peer reviewed international journals such as IEEE Electronic Device Letters, Transactions on Electron Devices, Journal o Microelectronics, etc and conference proceedings such as International Electron Device Meeting (IEDM), IRPS etc.

Lab courses

AVM631 – VLSI Design Lab

Syllabus

Introduction of software: Analog design flow, digital design flow

Digital:

Design of a complex digital circuit (eg. an ALU or a multiplier) using high level ardware description languages, logic simulation and timing simulation. Extraction of critical paths and circuit simulation of critical path sub-circuits. Circuit partitioning and realisation using FPGAs or PALs.

Analog:

Basic MOS device characterization. Current mirrors – design and simulation to meet given specifications. Design and simulation of single stage amplifiers. OTA design – at least two topologies meeting different sets of specifications. Analog layout and extraction. Design of an analog subsystem meeting a given requirement.

AVM641 – MEMS lab

Module 1: Design and simulation

This module focuses on design and simulation aspects of sensors, actuators and sensor systems. The laboratory course provides an overview of numerical and analytical modelling and design of microsystems using leading softwares in the field such as Coventor, MEMS+ or COMSOL Multiphysics for MEMS

Module 2 Fabrication and characterization of MEMS devices

1. Familiariztion of unit processes and Fabrication of MEMS structures such as Microcantilever beam/suspended membrane etc..
2. Characterization (Electrical, Mechanical and Electromechanical)of MEMS structures

Reference: (List same as that for the theory courses on MEMS and Thin films)

AVM642 – Microelectronics lab

Module 1: Microelectronics Device and Process Simulation

Syllabus

This module focuses on the simulation of fabrication processes and the microelectronics devices such as short channel MOSFET etc. using TCAD tools for Micro and nanoelectronic devices. The process simulation enables one to experiment with the device fabrication flow. The device simulation involves simulating the electrical characteristics of a process simulated/fabricated device.

Module 2: Microfabrication and characterization

1. Familiarization of Microfabrication environment in clean room
2. Familiarization of different unit processes, Fabrication of MOS Capactior
3. Electrical characterization: High frequency capacitance-voltage measurement (HFCV) and High frequency capacitance-voltage measurement (LFCV), I-V and reliability measurements, parameter extraction of MOS devices, M-S and P-N junction devices

Electives

AVM861 – Mixed Signal VLSI Design

Syllabus

Basics of data conversion systems. Sampling theory. Sample and hold circuits. Linearity, noise in mixed signal systems. Comparator design. Preamplifier design. Offset – source, analysis, offset cancellation. ADC topologies – comparative study and analysis. Analysis and design of multiple DAC architectures. Deriving opamp specifications from system level requirements. Non-idealities in ADCs and DACs and compensation techniques. Impact of layout parasitics on the performance of ADCs and DACs. Introduction to high-speed wireline communication circuits. Transmitter architectures, and circuits, equalization techniques. Receiver architecture, overview of clock and data recovery circuits, equalization.

Text Books

Same as References

References

CMOS Mixed-Signal Circuit Design by R. Jacob Baker, Wiley

CMOS – Circuit Design, Layout and Simulation by R. Jacob Baker, Wiley

Design of Analog CMOS Integrated Circuits by Behzad Razavi, McGrawHill

Analog Design Essentials by Willy M. C. Sansen, Springer

AVM862 – RF Integrated Circuits

Syllabus

On-chip RF passive components, resonant circuits, matching circuits. Noise – source, modelling, noise figure, noise temperature, noise figure of cascaded systems. Linearity – HD, IMD, IP2, IP3. ACLR, AACLR. Basics of wireless communication. LNA design, Input matching for power, input matching for noise. Advanced LNA circuits. Mixer topologies – active and passive. Receiver architectures. Voltage controlled oscillator topologies – theory and design, phase noise. Phase locked loops (PLL) – theory, design of individual elements and the complete system. Power amplifier classes and topologies – theory and design. Transmitter and receiver architectures.

Text Books

Same as References

References

RF Microelectronics by Behzad Razavi, Pearson

The Design of CMOS Radio-Frequency Integrated Circuits by Thomas H. Lee, Cambridge

AVM863 – VLSI Digital Signal Processing

Syllabus

Introduction to Digital Signal Processing ; Need of VLSI DSP algorithms. main DSP Blocks and typical DSP Algorithms. Number Representation: Fixed point Representation Floating point Representation; Binary Adders; Binary Multiplier; Binary Dividers; Floating point Arithmetic Implementation: CORDIC architectures; Multiply Accumulator unit ; Computation of Special functions using MAC cells. Redundant arithmetic, redundant number representations , carry free radix 2 addition and subtraction . Hybrid radix 4 addition. Radix 2 hybrid redundant multiplication architectures , data format conversion. Redundant to nonredundant converter. Numerical strength reduction.

Bit level arithmetic structures- parallel multipliers, interleaved floor plan and bit plan based digital filters. Bit serial multipliers. Bit serial filter design and implementation. Canonic signed digit arithmetic, Distributed arithmetic.

Synchronous pipelining and clocking styles, clock skew and clock distribution in bit level pipelined VLSI designs.

Parallel FIR filters. Pipelining of FIR filters. Parallel processing. Pipelining and parallel processing for low power FIR filters. Pipeline interleaving in digital filters.

Pipelining and parallel processing for IIR filters. Low power IIR filter design using pipelining and parallel processing, Pipelined adaptive digital filters.

Systolic Array Architectures and fast convolution algorithms.

Round off noise and its computation. State variable description of digital filters, Scaling using slow-down, retiming and pipelining.

Reference Books

- Keshab K. Parhi, *VLSI Digital Signal Processing Systems - Design and Implementation*, Wiely, 2010
- K. J. Ray Liu, *High-Performance VLSI Signal Processing – Innovative Architectures and Algorithms, Systems Design and Applications*, IEEE Press, 1998
- Thorsten Grotker, et al, *System Design with SystemC*, Kluwer Academic Publishers, 2002
- U Meyer Baese Digital Signal Processing with Field Programmable Gate Arrays Springer 2009
- Roger Woods …[et al]. FPGA-based Implementation of Signal Processing Systems / (2008)
- Jose E. France, Yannis Tsividis,“Design of Analog-Digital VLSI Circuits for Telecommunication and Signal Processing”, Prentice Hall, 1994.

AVM864 – Advanced VLSI Design

Syllabus:

Power-speed-noise trade-off. Ultra-lower power VLSI design. Leakage power vs dynamic power. Minimum energy point concept. Low voltage analog, mixed-signal design. VLSI design for IoT applications. Low voltage memories.

Designing for high speed/performance. Dynamic voltage and frequency scaling. Selected topics on clock skew, clock routing, power routing. Selected topics on layout techniques in mixed-signal circuits – guard rings, etc. Role of calibration in modern ICs.

Textbooks:

Same as references

References:

Journal and conference papers.

AVM865 – High Speed IO Circuits

Syllabus:

Introduction to high speed links. Review of PCB trace behaviour at high frequencies. Concepts of cross-talk, dispersion, inter-symbol interference (ISI). Transceiver schemes. Design of transmitter, output impedance matching, multiplexing techniques, clocking, signalling techniques. Pre-distortion and equalization. Link budgets. Design of receivers – continuous time linear equalizers, slicers, DFE techniques, clocking, critical paths, IIR/FIR implementations. PLLs, clock and data recovery circuits and schemes.

Textbooks and References:

S. Palermo, "CMOS Nanoelectronics Analog and RF VLSI Circuits." McGraw-Hill, 2011.

Journal papers, conference papers.

AVM871 – Physics of Nanoelectronic Devices

Second in a two part series, this nanoelectronics course provides an introduction to more advanced topics, including the Non-Equilibrium Green's Function (NEGF) method widely used to analyse quantum transport in nanoscale devices. This topic will explore a number of topics within nanoelectronics, taking a more in depth look at quantum transport, gaining greater insight into the application of the Schrodinger Equation, and learning the basics of spintronics which is now a days recent trends in next generation nanoelectronic

The quantum of conductance, Potential profile, Coulomb blockade Electrical resistance

Basic of Quantum Mechanics, The quantum of conductance, Potential profile, Coulomb blockade Electrical resistance

Hamiltonian Operator, Born-Openheimer approximation, Hydrogen Atom, Method of Finite Difference, Solution of Schrodinger Equation of 1D, 2D and 3D materials (spherical Coordinate).

Introduction of Energy level Diagram, E-K diagram, Nanotransistor, Electron flow, Quantum Conductance, Potential Profile, Molecular, Ballistic and Diffusive Transport, Landauer Model for Transistor, Landauer-Buttiker Formalism, Coulomb blockade, Hall effect, Scattering theory of Transport.

Modified Hamiltonian and Self-Consistent Field method, Relation to the Multielectron picture, Bonding, Coherent and non-coherent Transport, NEGF equation, Spin matrics, Spi-Orbit Introduction, Spin Density with Current and Torque.
Introdudction of nanotransistor with Virtual Source Model. Revisiting the Landauer model . The Ballistic MOSFET, The Velocity at the Virtual source model. The Transmission Theory of the MOSFET and connection to the Virtual source model with experiment.

Case study of different nanostructure (Quantum wells, wires, dots, and nanotubes). Computational approach to calculate band diagram and other electrical properties.

Reference: Journals and patents

AVM872 – Microsystem Integration

Syllabus

MEMS Foundry processes, CMOS-MEMS Integration: Design and technology, Bonding & Packaging of MEMS, MEMS reliability, non-silicon MEMS,

Interface electronics for sense and drive in microsystems, , MEMS and circuit noise sources, Noise and Offset Cancellation Technique, testing and calibration approaches in integrated microsystems.

MEMS Sensors and Actuators: Case Studies (Mechanical, Inertial, bio/chemical, Microfluidics, RF Applications.); Future Directions and developments (Integrated Nano-Electro-Mechanical Systems (NEMS), NEMS oscillators and sensors)

References:

1. S. D. Senturia, Microsystem Design (2005 edition)
2. Baltes, Brand, Fedder, Hierold, Kowenk, Tabata, Advanced Micro and Nanosystems, Vol. 1, Enabling Technology for MEMS and Nanodevices,Wiley-VCH, 2004.
3. Gray, Hurst, Lewis, & Meyer, Analysis and Design of Analog Integrated Circuits (4th edition), Wiley, 2004.
4. Marc Madau, Fundamentals of Microfabrication Science of Miniaturization, CRC Press
5. G. K. Ananthasuresh , K. J. Vinoy, S. Gopalakrishnan, K. N. Bhat , V. K. Aatre Micro and Smart Systems Technology and Modeling (January 2012)

Peer reviewed international journals such as IEEE/ASME Journal of MEMS, IOP Journal of Micromechanics and Microengineering, IOP Journal of Nanotechnology, Elseivier Sensors and Actuators etc. and conference proceedings such as IEEE MEMS, IEEE Nanotechnology, Transducers etc..

AVM873 – RF MEMS

Syllabus

Introduction to RF MEMS, , Electrical and mechanical modelling of MEMS devices, MEMS Switches: Introduction to MEMS switches; Capacitive shunt and series switches: Physical description, circuit model and electromagnetic modelling; Techniques of MEMS switch fabrication and packaging; Design of MEMS switches.

RF Filters and Phase Shifters: Modeling of mechanical filters, micromachined filters, surface acoustic wave filters, micromachined filters for millimeter wave frequencies; Various types of MEMS phase shifters; Ferroelectric phase shifters.

MEMS Varactor, MEMS Resonators

micromachined waveguide components; Micromachined antennas: Micromachining techniques to improve antenna performance, reconfigurable antennas.

Integration and Packaging for RF MEMS: Role of MEMS packages, types of MEMS packages, module packaging, packaging materials and reliability issues.

Textbooks/References:

1. Varadan, V.K., Vinoy, K.J. and Jose, K.J., "RF MEMS and their Applications", John Wiley & Sons. 2002.
2. Rebeiz, G.M., "MEMS: Theory Design and Technology", John Wiley & Sons. 1999.
3. De Los Santos, H.J, "RF MEMS Circuit Design for Wireless Communications", Artech House. 1999
4. Research papers and study material of Clark T.-C. Nguyen, Electrical Engineering and Computer Sciences , UC Berkeley Nguyen Book to be added

AVM874 – Sensors and Actuators

Syllabus

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

Applications and case studies: Microsensors and actuators in environmental sensing, RF/Electronics devices, Optical/Photonic devices, microsensors for space applications, MEMS sensors in navigation systems, radiation sensors, Medical devices, Bio-MEMS

References

1. Micromechanical Transducers: Pressure sensors, accelrometers, and gyroscopes by M.-H. Bao, Elsevier, New York, 2000
2. "Microsensors" by Richard S. Muller, Roger T. Howe, Stephen D. Senturia, Rosemary L. Smith, and Richard M. White, IEEE Press, IEEE Number PC 0257-6, ISBN 0-87942-254-9, New York, 1991.
3. "Micromechanics and MEMS: Classic and Seminal Papers to 1990. " by William Trimmer, IEEE Press, IEEE Number PC4390, ISBN 0-7803-1085-3, New York.
4. Beckwith T. G., Margoni R. D., Lienhard J. H. “Mechanical Measurements”, New York: Addison-Wesley Pub. Co, 1995
5. <u>Micro and Smart Systems</u> by G. K. Ananthasuresh, K. J. Vinoy, S. Gopalakrishnan, K. N. Bhat, and V. K. Aatre, Wiley-India, 2010.

AVM875 – Thin films: Materials and characterization

Syllabus

Material Science: introduction, structure, defects, bonds and bands, thermodynamics of material, kinetics, nucleation.

Thin film nucleation: Atomic view of substrate surfaces, thermodynamic aspects of Nucleation, Kinetic processes in Nucleation and growth.

Epitaxy: Lattice mismatch and defects in epitaxial film, epitaxy of compound semiconductors, High and low temp. methods of deposition.

structural and chemical characterization of films and surfaces. XRD, TEM, AFM, SEM,

Inter diffusion: compound formation, phase transformation in thin film, metal-smiconductor reaction, mass transport in thin film.

Mechanical properties of thin films: Mechanical testing and strength of thin films, analysis of internal stress,

References:

1. Micro- and Opto- Electronic Materials and Structures: Ephrahim Suhir, Y.C Lee, C. P Wong
2. Thin Film Phenomena: Kasturi L. Chopra
3. Thin Film Device Applications: Kasturi L. Chopra, Indrajeet Kaur
4. The materials Science of Thin Films: Milton Ohring
5. Hand book of thin films deposition processes and techniques; Priciples, methods, equipment, and application: Klaus K. Schuegraf
6. Thin Film Physics: O. S. Heavens

AVM876– Power semiconductor devices

Syllabus

Introduction to Power Semiconductor devices, Device Basic Structure and Characteristics , High current effects in diodes, Breakdown considerations for various devices, Schottky rectifiers.- P-i-N rectifiers Power BJTs, Parasitics in Power Transistors, Power MOSFETs, Thyristors , Power Insulated Gate Transistors, Heat transfer in power devices, device packaging

References

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

AV877 - Compound semiconductor devices and Technology

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 merit ofMESFET, Short channel effect , Velocity saturation and velocity overshoot effect of GaAsbased MESFET, Evolution of HEMT from MESFET structure, HEMT and triangularpotential well, I-V and gate control, Fabrication of MESFET and HEMT structures.
Optical Devices: Fundamentals of compound semiconductor based optical devices, Opticaldensity 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 HEMTstructures, Fabrication of LED and LASER structures.

Books:

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

AV878 - Photonic Integrated Circuits

Photonic Integrated Circuits (PIC) are highly promising to handle the quickly growing data traffic in the near future where pure copper based electronic will fail to satisfy the requirements of bandwidth and distance. This course deals with principles, devices and applications that enable the integration of various photonic devices and circuits on a single chip.
Electronic integrated circuits, Scaling of electronic devices, Electrical interconnects, issues with electrical interconnection, Optical interconnects-advantages-similarities with electrical interconnects Integration-Photonic Integrated Circuits (PIC)-brief history of PIC-Features- Materials for PIC platform-Si, Silica, SOI, III-V, LiNbO3
Basic theory of Planar and channel waveguide-effective index method-guided modes Types of waveguides-Optical losses in waveguides-(side wall scattering, bending, losses due to metal layer)-waveguide fabrication (LiNbO3 and III-V based)
Passive devices for photonic integrated circuits -waveguides-splitters-directional coupler-waveguide bends-coupled and uncoupled waveguides-application to directional coupler-gratings, DBR mirrors, Photonic crystals Switches and modulators for photonic integrated circuits -controlling guided waves-electro-optic effect,-electroabsorption effect, Quantum Confined Stark Effect (QCSE), -acousto-optic effect,– thermo-optic effect,-magneto-optic effect, plasma-dispersion effect, non-linear optic effect.
Phase modulators, intensity modulators, microring resonators, fabrication techniques, materials(Si, glass, polymer, III-V), multi-layer processing, all-optical switching, filters, transversemodulators, optical switches, self electro optic devices (SEED)
Light sources and detectors for photonic integrated circuits: Edge emitting lasers, vertical cavitysurface emitting lasers (VCSEL), advantages of VCSEL for interconnects, basic design.plasmonic lasers, single photon lasers, Resonant cavity enhanced photo detectors, pinphotodetector, MSM photo detector
Silicon photonics: advantages and disadvantages of Silicon for photonics-Fabrication of Siwaveguide devices-SIMOX-BESOI-Wafer splitting-SOI-submicron waveguides, Silicon lightsources (LED, LASER), porous Silicon, Si nanocrystals, Raman effect based Si devices SiGedevices, QCSE effect in SiGe, SiGe modulator.
PIC configuration: Examples of III-V based PIC, Si based PIC, III-V on Si based PIC, OPTO-VLSI, chip-chip, board-board interconnect architecture, bi-directional interconnects, selected configurations from recent literature, free space interconnection.

References/Text book

1. Nishihara, Hiroshi, Masamitsu Haruna, and Toshiaki Suhara. "Optical integrated circuits."New York (1989)
2. Larry A. Coldren and Scott W. Corzine. Diode Lasers and Photonic Integrated Circuits. Wiley.

AV491 - Advanced Sensors and Interface Electronics

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.

Textbooks:

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

Reference:

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

AVD 611 - Modern Signal Processing

Analysis of LTI system: Phase and Magnitude response of the system, Minimum phase, maximum phase, Allpass. Multirate Signal Processing: Interpolation, Decimation, sampling rate conversion, Filter bank design, Polyphase structures. Time-frequency representation; frequency scale and resolution; uncertainty principle, short-time Fourier transform. Multi-resolution concept and analysis, Wavelet transform (CWT, DWT). Optimum Linear Filters: Innovations Representation of a Stationary Random Process, Forward and Backward linear prediction, Solution of the Normal Equations. Power Spectral Estimation: Estimation of Spectra from Finite Duration Observations of a signal, the Periodogram, Bartlett, Welch and Blackman, Tukey methods, Comparison of performance of Non-Parametric Power Spectrum Estimation Methods. Parametric Methods: Auto-Correlation and Model Parameters, AR (Auto-Regressive), Moving Average (MA), and ARMA Spectrum Estimation. Frequency Estimation-Eigen Decomposition of autocorrelation matrix, Piscaranko's Harmonic Decomposition Methods, MUSIC Method. Adaptive Filter Theory: LMS, NLMS and RLS, Linear Prediction. DSP Processor architecture- DSP Number representation for signals, Study of FIxed point and floating-point DSP processor and its architectures.

Reference Books:

1. Mitra, S. K., (2008), Digital Signal Processing, 3 rd Edition, McGraw Hill

2. Oppenheim, Alan V - Discrete-time signal processing, Pearson Education India.

3. Multirate Systems And Filter Banks, P.P. Vaidyanathan, Prentice-Hall, 1993.

4. Statistical digital signal processing and modeling, Monson H.Hayes, Jhon Wiley & Sons.

5.Y. T. Chan, (1993), Wavelet Basics, Kluwer Publishers, Boston.

6.Gerald Kaiser, (1992), A Friendly Guide to Wavelets, Birkhauser, New York

7. Proakis, John G. - Digital signal processing: principles algorithms and applications, PHI.

8. Haykin, Simon S. - Adaptive filter theory, Pearson Education India

Pre-requisites:

1. Undergraduate Signals and Systems

2. Undergraduate Digital Signal Processing

Evaluation:

The course will feature two midterm exams and a final exam. Continuous evaluation by class tests and problem sets.

AVP867 – Electronic System Design

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.

Mini Projects for internal assessment (Selected topics)

1. 250.000 mA precision current source design
2. 4-20mA current transmitter
3. Implementation of opamp based active filters
4. Capacitance multipliers or gyrators
5. One quadrant multiplier with PWM IC
6. Sensor linearization circuit
7. High fidelity headphone amplifier
8. Power grid voltage – angle detector with analog PLL

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.

MA 619 Advanced Mathematics

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.

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

Evaluation:

The course will feature two midterms and a final exam. There will be continuous evaluation using bi-weekly class tests, problem sets, and programming assignments.