



M.Tech. - ECE (Microelectronics & VLSI Designs) Common Syllabus

Semester – 1:

Paper Type	Paper Code	Paper Name	Instruction Hours			Credit
			L	T	P	
C-Th	MVLSI 101	Advanced Engg Maths	3	1	0	4
C-Th	MVLSI 102	VLSI Device & Modelling	4	0	0	4
C-Th	MVLSI 103	Digital IC Design	4	0	0	4
C-Th	MVLSI 104	Microelectronic Technology & IC Fabrication	4	0	0	4
E-Th	MVLSI 105A 105B 105C 105D	Elective – I: 1. Bioelectronic System 2. <i>Embedded System Fundamentals</i> 3. <i>AI & Neural Networks</i> 4. Advanced Digital Communication	4	0	0	4
		Total of Theory	19	1	0	20
C-Pr	MVLSI 191	CAD Tools for VLSI Design	0	0	3	2
E-Pr	MVLSI 192A 192B	1. <i>Microelectronic Technology</i> 2. Embedded Systems	0	0	3	2
		Total of Practical	0	0	6	4
S	MVLSI 181	Seminar	0	2	0	1
		Total	19	3	6	25



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Semester – 2:

Paper Type	Paper Code	Paper Name	Instruction Hours			Credit
			L	T	P	
C-Th	MVLSI 201	Processor Architecture for VLSI	4	0	0	4
C-Th	MVLSI 202	Digital Signal Processing & Applications	4	0	0	4
C-Th	MVLSI 203	Analog IC Design	4	0	0	4
E-Th	MVLSI 204A 204B 204C 204D	Elective – II: 1. Quantum & Nano-science 2. Error Control & Coding 3. Sensors 4. Physical Design & Testing	4	0	0	4
E-Th	MVLSI 205A 205B 205C 205D 205E	Elective – III: 1. RF Circuits & Systems 2. Low Power VLSI Design 3. Mobile Communication 4. Advanced Micro & Nano Devices 5. Advanced FET Technology	4	0	0	4
		Total of Theory	20	0	0	20
E-Pr	MVLSI 291A 291B	1. Microelectronic Technology 2. Embedded Systems	0	0	3	2
		Total of Practical	0	0	3	2
S	MVLSI 281	Term paper leading to Thesis	0	1	0	1
V	MVLSI 282	Comprehensive Viva Voce				4
		Total credit	20	1	3	27

Semester – 3:

Paper Type	Paper Code	Paper Name	Instruction Hours			Credit
			L	T	P	
C-Th	MVLSI 381A 381B	1. Project Management or 2. Teaching & Research Methodologies	4	0	0	4
AE-Th/Pr	MVLSI 302/392	Elective Theory or Practical Papers to be suggested by College.	4	0	0	4
		Total of Theory	8	0	0	4+4
S	MVLSI 383	Dissertation – Part I	0	2	0	1
		Total of Credit				25



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Semester – 4:

Paper Type	Paper Code	Paper Name	Instruction Hours			Credit
			L	T	P	
S	MVLSI 481	Dissertation – Part II (Completion)	24			6
	MVLSI 482	Post submission defence of dissertation				18
		Total of Credit				24

Details:

VLSI Devices & Modelling [Sem -1] 3 (L) (40 lectures)

Pre-requisite: Knowledge of basic physics of diodes, BJTs, FETs, MOS structures.

Semiconductors, Junctions and MOSFET Overview: Introduction, Semiconductors, Conduction, Contact Potentials, P-N Junction, Overview of the MOS Transistor.

Basic Device Physics:

Two Terminal MOS Structure: Flat-band voltage, Potential balance & charge balance, Effect of Gate-substrate voltage on surface condition, Inversion, Small signal capacitance;

Three Terminal MOS Structure: Contacting the inversion layer, Body effect, Regions of inversion, Pinch-off voltage;

Four Terminal MOS Transistor: Transistor regions of operation, general charge sheet models, regions of inversion in terms of terminal voltage, strong inversion, weak inversion, moderate inversion, interpolation models, effective mobility, temperature effects, breakdown p-channel MOS FET, enhancement and depletion type, model parameter values, model accuracy etc;

Small dimension effects: channel length modulation, barrier lowering, two dimensional charge sharing and threshold voltage, punch-through, carrier velocity saturation, hot carrier effects, scaling, effects of surface and drain series resistance, effects due to thin oxides and high doping. Sub threshold regions.

CMOS Device Design: Scaling, Threshold voltage, MOSFET channel length;

CMOS Performance Factors: Basic CMOS circuit elements; parasitic elements; sensitivity of CMOS delay to device parameters; performance factors of advanced CMOS devices.

Bipolar Devices, Design & Performance:

Outcome: Student will be able to model devices and study their performance in analog and digital circuits.

Assignment: Simple Circuit simulation using Spice.

Text:

Fundamentals of Modern VLSI Devices by Yuan Taur & Tak H. Ning (Cambridge)

The MOS Transistor (second edition) **Yannis Tsividis** (Oxford)

Reference:

CMOS Analog Circuit Design (second edition) **Phillip E. Allen and Douglas R. Holberg** (Oxford)

Digital IC Design [Sem-1] 3(L) 1(T) 2 (P)

Prerequisite: Overview of CMOS VLSI fabrication, CMOS process steps; fabrication; yield; design rules for custom layout; Layout - hand layout, graphical layout, low-level language; design rule checking; stick diagrams; placement of cells; simulation of design; function generation from masks; test pattern generation; structured design methodology for VLSI; hierarchical design techniques and examples. Concept of Mask design, Mask layout, Stick diagram, Standard cell Vs Custom design,

1. Specification Methods: Language based methods including VHDL/Verilog, hierarchical state machine



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Electives:

Embedded Systems Fundamentals

Introduction to embedded systems:

Concept, Difference between embedded computer systems and general purpose computer Systems, Classification, Characteristics, Applications

Overview of Embedded Processors:

Classification:

- GPP, ASIP, SPP, ASSP, MULTI-CORE, SOFT-CORE
- Examples

Overview of Embedded Memories & Interfacing:

SRAM, DRAM, EEPROM, FLASH, DUAL-PORT, CACHE, INTERLEAVED MEMORIES

Overview of Embedded Networking & Standards:

RS232, RS485, SPI, USB, ISA, PCI, I2C, CAN, LIN
IrDA, Bluetooth, Zigbee.

Overview of Embedded Sensors and Transducers:

Pressure, Temperature, Acceleration, Image, Rain, Proximity, Hall-effect, Artificial eyes

Overview of I/P-O/P devices & Interfacing

Keypad, TWS, JoyStick, SSL, LCD, VGA

Case study: The Weather Station

Advanced digital communication

- *Pre-requisites:*
 - Fourier Expansion, Fourier transform, Normalized power spectrum, Power spectral density, Effect of transfer function on output power spectral density, Parseval's theorem.
 - Autocorrelation & cross correlation between periodic signals, cross correlation power.
 - Relation between power spectral density of a signal, its autocorrelation function and its spectrum.
 - Distinction between a random variable and a random process.
 - Probability, sample space, Venn diagramme, joint probability, bay's theorem, cumulative probability distribution function, probability density function, joint cumulative probability distribution function, joint probability density function.
 - Mean/average/expectation of a random variable and of sum of random variables.
 - Standard deviation, variance, moments of random variables, - explanation with reference to common signals.
 - Tchebycheff's inequality.
 - Gaussian probability density function – error function & Q function
 - Central limit theorem.
- Spectral analysis of signals:
 - Orthogonal & orthonormal signals. Gram-Schmidt procedure to represent a set of arbitrary signals by a set of orthonormal components; - numerical examples.
 - The concept of signal-space coordinate system, representing a signal vector by its orthonormal components, measure of distinguishability of signals.
- Characteristics of random variables and random processes:
 - Common probability density functions, - Gaussian, Rayleigh, Poisson, binomial, Rice, Laplacian, log-normal, etc.
 - Probability of error in Gaussian Binary symmetric channel.
 - Random processes – time average, ensemble average, covariance, autocorrelation, cross correlation, stationary process, ergodic process, wide sense stationary process.
 - Power spectral density and autocorrelation, power spectral density of a random binary signal.
 - Linear mean square estimation methods.
- *Revision* of source coding: Sampling theorem, instantaneous/ flat top/ natural sampling, band width of PAM signal,



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quantization, quantization noise, principle of pulse code modulation, delta modulation & adaptive delta modulation.

- Parametric coding/ hybrid coding/ sub band coding: APC, LPC, Pitch predictive, ADPCM, voice excited vocoder, vocal synthesizer.
- Line codes:
 - UPNRZ, PNRZ, UPRZ, PRZ, AMI, Manchester etc.
 - Calculation of their power spectral densities.
 - Bandwidths and probabilities of error P_e for different line codes.
- *Revision* of digital modulation: Principle, transmitter, receiver, signal vectors, their distinguish ability (d) and signal band width for BPSK, QPSK, M-ARY PSK, QASK, MSK, BFSK, M-ARY FSK.
- Spread spectrum modulation:
 - Principle of DSSS, processing gain, jamming margin, single tone interference, principle of CDMA, MAI and limit of number of simultaneous users.
 - Digital cellular CDMA system: model of forward link, reverse link, error rate performance of decoder using m-sequence chip codes.
 - Properties of m-sequences, their generation by LFSR, their PSDs, limitations of m-sequences.
 - Gold sequence, Kasami sequence – generating the sequences, their characteristic mean, cross correlation and variance of cross correlation, their merits and limitations as chip codes in CDMA.
- Multiplexing & multiple access:
 - TDM/TDMA, FDM/FDMA, Space DMA, Polarization DMA, OFDM, ALOHA, Slotted ALOHA, Reservation ALOHA, CSMA-CD, CSMA-CA – basic techniques and comparative performances e.g. signal bandwidth, delay, probability of error etc.
- Noise:
 - Representation of noise in frequency domain.
 - Effect of filtering on the power spectral density of noise – Low pass filter, band pass filter, differentiating filter, integrating filter.
 - Quadrature components of noise, their power spectral densities and probability density functions.
 - Representation of noise in orthogonal components.
- Characteristics of different types of channels:
 - Gaussian, Poisson etc.
- Band limited channel:
 - Characteristics of band limited channel, inter symbol interference (ISI) - it's mathematical expression.
 - Niquist's theorem for signal design for no ISI in ideal band limited channel, Niquist's criteria, raised cosine pulse signals.
 - Signal design for controlled ISI in ideal band limited channel, partial response signals, duobinary & partial duobinary signals - their methods of generation and detection of data.
 - Concept of maximum likelihood detection, log likely hood ratio.
 - Detection of data with controlled ISI by linear transverse filters.
 - Performance of minimum mean square estimation (MMSE) detection in channels with ISI.
- Base band signal receiver and probabilities of bit error:
 - Peak signal to RMS noise output ration, probability of error.
 - Optimum filter, it's transfer function.
 - Matched filter, it's probability of error.
 - Probability of error in PSK, effect of imperfect phase synchronization or imperfect bit synchronization.
 - Probability of error in FSK, QPSK.
 - Signal space vector approach to calculate probability of error in BPSK, BFSK, QPSK.



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- Relation between bit error rate and symbol error rate.
- Comparison of various digital modulation techniques vis-à-vis band width requirement and probabilities of bit error.

Text Books:

1. Digital communication, 4th ed. - J. G. Proakis, MGH International edition.
2. Principle of Communication Systems – Taub, Schilling, TMH
3. Digital and Analog Communication Systems, 7th ed. – Leon W. Couch, PHI.
4. Principles of Digital Communication – Haykin
5. Digital Communication – Zeimer, Tranter.
6. Principle of Digital communication - J. Das, S. K. Mallick, P. K Chakraborty, New Age Int.
7. Communication Systems, 4th ed. – A. Bruce Carlson, Paul B. Crilly, Janet C. Rutledge, MGH International edition.
8. Digital Communications, 2nd ed. – Bernard Sklar, Pearson Education.
9. Electronic Communications, 4th ed. – Dennis Roddy, John Coolen, PHI

Processor Architecture for VLSI

Fundamentals:

Components of (an embedded) computer, Architecture organization, Von-Neumann vs Harvard, Microcoded vs hardwired, scalar and vector processors, Flynn's taxonomy
CISC arch, the RISC movement, ISA arch, basic structure, pipelining, pipeline hazards and solutions, comparison, merging RISC and CISC: the microchip PIC

Superscalar arch: parallel computation, Ways of parallelism, the IBM PowerPC

The DSP and Its Impact on Technology: Why a DSP is different. The evolving architecture of a DSP

VLIW arch: the TI TMS320C6x, advancement to EPIC

Coprocessor Approach: Need for accelerators, Accelerators and different types of parallelism, Processor architectures and different approaches to acceleration

General-Purpose Embedded Processor Cores: The ARM

Processors using course-grain parallelism: utilization of course-grain parallelism, chip-multiprocessors, multithreaded processors, SMT proc

Customizable Processors and Processor Customization: A benefits analysis of processor customization, Using microprocessor cores in SOC design, Benefiting from microprocessor extensibility, how microprocessor use differs between SOC and board-level design

Run-Time Reconfigurable Processors: Embedded microprocessor trends, Instruction set metamorphosis, Reconfigurable computing, Run-time reconfigurable instruction set processors, Coarse-grained reconfigurable processors

Stream Multicore Processors: Introduction, Raw architecture overview

Asynchronous and Self-Timed Processor: Motivation for asynchronous design, The development of asynchronous processors,



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Analog IC Design: [Sem – II] 3(L) 0(T) 0(P) 3 Lectures

Recapitulation:

12. CMOS models for analog circuits - Small signal equivalent circuit, temperature effect and sensitivity, overview of electrical noise. 2L
 13. Analog subcircuits : CMOS switch, resistors, current source, sink, current mirror, voltage and current references. 2L
 14. MOSFET Modelling for Circuit Simulation: 2L (*Assignment using Spice*)
3. **CMOS Amplifiers & CMOS Operation Amplifiers:** Basic concepts, Performance Parameters, One state OPAMP, Two stage OPAMP, Stability and Phase compensation, Cascode OPAMP, Design of two-stage and Cascode OPAMP, SPICE simulation of Amplifier, High performance CMOS OPAMPs, Micropower OPAMP, 6L + 6P
*Design examples, (**SPICE simulation – Laboratory**)
 2. **Switch Capacitor circuits:** General considerations, Switched capacitor integrators, First and second order switched capacitor filter circuits, 2L+3P
*Design examples, (**SPICE simulation – Laboratory**)
 3. **Data Converter Fundamentals & Architecture:** Ideal D/A converters, Ideal A/D converter, Serial and Flash D/A converters and A/D converters, Medium and High Speed converters, Over-sampling converters, performance limitations, Design consideration, SPICE simulation. 4L
 4. **Special Circuits:** CMOS voltage controlled oscillators, Ring oscillators, Phase locked loops with pump phase comparators, Gm-C Circuits.
*Design examples, (**SPICE simulation – Laboratory**) 4L+6P
 5. **RF Analog Circuits & Subcircuits:** Capacitors and Inductors in VLSI circuits, Bandwidth estimation techniques, Design of high frequency amplifiers, Design of low noise amplifiers, Design of Mixers of RF power amplifiers, Architectures of rf receivers and transmitters. 6L
 6. **Comparators:** Characterisation, Two state open loop comparators, Discrete time comparators, high speed comparator circuits, CMOS S/H circuits, 4L
*Design examples, (**SPICE simulation – Laboratory**)

Text: **The MOS Transistor** (second edition) **Yannis Tsividis** (Oxford)

Reference: **CMOS Analog Circuit Design** (second edition) **Phillip E. Allen and Douglas R. Holberg** (Oxford)

Intended Knowledge Outcomes

Understand the main elements of hierarchical VLSI design namely interested circuit technology, approaches to system design, architectural issues, design implementation and layout. The ability to analyse the effect of future integrated circuit technologies on device parameters.

Intended Skill Outcomes

Ability to apply VLSI design methodology for the design of Application Specific Integrated Circuits.

Reading List

1. **Principles of CMOS VLSI Design** (Essential reading) Author: Weste N and Eshraghian K
Notes: Addison Wesley 1985
2. **Introduction to NMOS and CMOS VLSI Systems Design** (Essential reading) Author: Mukherjee A
Notes: Prentice-Hall 1986
3. **Introduction to VLSI Systems** (Essential reading)
Author: Mead and Conway Notes: Addison Wesley D C & Co



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AI & Neural Networks

Overview of AI - Introduction, hierarchical perspective and foundations. Problems of AI, AI techniques, Tic-Tac-Toe problem.

Basic problem solving methods: Production systems-State space search-Control strategies- Heuristic search techniques-Forward and backward reasoning-Hill climbing techniques-Best search.

Knowledge representation: Predicate logic- Resolution Question answering-Nonmonotonic reasoning-Statistical and probabilistic reasoning-Semantic nets-Frames -Scripts.

Neural Network: Biological neurons and brain, mathematical models of neuron, basic structure of a neural network, Learning rules, ANN training, back propagation algorithm, Hopfield nets and application of Neural Network.

Introduction to expert system-Design of an expert system-Fuzzy logic and neural network in control system, modeling estimation and design methodologies and real time application of Intelligent control system like TRMS, Robot and Magnetic levitation system.

AI languages : Important characteristics of AI languages-PROLOG.

Application of AI & neural networks in VLSI and embedded systems.

Electives- II:

Sensors

UNIT 1

Principles of Physical and Chemical Sensors: Sensor classification, Sensing mechanism of Mechanical, Electrical, Thermal, Magnetic, Optical, Chemical and Biological Sensors.

Sensor Characterization and Calibration: Study of Static and Dynamic Characteristics, Sensor reliability, aging test, failure mechanisms and their evaluation and stability study.

UNIT 2

Sensor Modeling: Numerical modeling techniques, Model equations, Different effects on modeling (Mechanical, Electrical, Thermal, Magnetic, Optical, Chemical and Biological) and examples of modeling.

Sensor Design and Packaging: Partitioning, Layout, technology constraints, scaling.

UNIT 3

Sensor Technology: Thick and thin films fabrication process, Micro machining, IOC (Integrated Optical circuit) fabrication process, Ceramic material fabrication process, Wire bonding, and Packaging.

Sensor Interfaces: Signal processing, Multi sensor signal processing, Smart Sensors, Interface Systems. Sensor Applications: Process Engineering, Medical Diagnostic and Patient monitoring,

UNIT 2

Introduction, Scaling, MEMS Markets and Applications MEMS materials and fabrication methods, with emphasis on silicon micromachining

Process simulation: basic lithography, deposition, and etching processes for mems.



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Physical Design & Testing: [Heavy syllabus; Needs modification]

Testing:

Testing: Why test? Difference between testing & verification.

Physical faults & their modeling: Fault equivalence, dominance & collapsing.

Fault simulation: parallel, deductive & concurrent techniques, critical path tracing.

Test pattern generation for combinational circuits: Boolean difference, D-algorithm, Podem, etc, exhaustive, random, weighted testpattern generation, aliasing and its effects on fault coverage.

Test pattern generation for sequential circuits: ad-hoc and structures techniques scan path and LSSD, boundary scan.

Built-in self test techniques:

Design of testability:

Verification:

Introduction: Why verify? What is a test bench?

What is being verified: Formal verification, equivalence checking, model checking, functional verification, different approaches to verification, black box, white box, grey box, design verification and reuse.

Verification tools: Linting tools, simulators, verification intellectual property (VIP) – art of making VIP, waveform viewers, code & functional coverages.

Languages: Outline of e and Vera, temporal models & assertions, Linear Time Temporal Logic (LTL), Computation Tree Logic (CTL), assertion.

The verification plan: Role of verification plan, levels of verification, directed testbench approach, coverage-based random-based approach (CDV), generators, monitors & checkers.

Verification practices & architecture: overview of reference verification methodology (RVM) & verification methodology manual (VMM).

Design for verification:

Elective – III

RF circuits & Systems

Characterization of materials used for different RF electronic devices.

Heterostructure-overview.

High frequency transistors- BJT, field effect transistors .

Basics of resonant tunneling, RT devices.

Introduction to RF/Microwave Concepts .Active and passive RF components , circuit representations of two port RF/MW networks scattering and T parameters , smith chart.

Basic Considerations in Active Networks- Stability and noise considerations, Gain Considerations in Amplifiers.

Active Networks - Linear and Nonlinear Design, RF/MW Amplifier .

RF/MW Oscillators- Basic topologies ,VCO, Quadrature and single sideband generators.

Radio frequency Synthesizers- PLLS, Various RF synthesizer architectures and frequency dividers .

Overview of RF Filter design, design of rectifier , detector , mixer , RF/MW control circuit. Small RF/MW antenna and array .

RF/MW Integrated circuits - design and applications



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Low Power VLSI Design

Introduction to low power VLSI design-Need for low power-CMOS leakage current-static current-Basic principles of low power design-probabilistic power analysis-random logic signal-probability and frequency-power analysis techniques-signal entropy.

Circuit - transistor and gate sizing - pin ordering - network restructuring and reorganization - adjustable threshold voltages - logic-signal gating - logic encoding. Pre-computation logic.

Power reduction in clock networks - CMOS floating node - low power bus - delay balancing - SRAM.

Switching activity reduction - parallel voltage reduction - operator reduction -Adiabatic computation - pass transistor logic

Low power circuit design style - Software power estimation - co design.

TEXT BOOKS

1. Gary Yeap "Practical Low Power Digital VLSI Design", 1997
2. Kaushik Roy , Sharat C. Prasad, "Low power CMOS VLSI circuit design", Wiley Inter science Publications". (1987)

Micro and Nano Devices :

Prerequisite :

Fundamentals of semiconductor physics and basics of p-n junctions, bipolar transistors, JFETs, MOS capacitors, MOSFETs, CMOS, LEDs, laser diodes, photodetectors, solar cells; low and high frequency equivalent circuits of BJTs and MOSFETs, IC technology.

Course content :

Module-1 (14 lectures) – [Recapitulation of MOS scaling laws, Short channel effects, MOSFET models], Nano CMOS, Effects of gate oxide tunneling, Concept of EOT, high-k dielectrics, Effects of nanoscaling on MOSFET characteristics and performance, Technology trend, Advanced CMOS structures, SOI.

Module-2 (8 lectures) – Semiconductor heterojunctions; compound semiconductor and silicon-germanium heterostructures, superlattice, HBTs, PETs, MESFETs, advanced solar cell structures.

Module-3 (14 lectures) – Fundamental concepts of quantum structures and tunneling junctions, Nanotubes, Devices based on quantum wells, quantum wires/nanotubes and quantum dots – HEMTs, RTDs, CNT MOSFETs, SETs, Terahertz devices, advanced optoelectronic devices.

Module-4 (6 lectures) – Outline of nanofabrication – nanolithography, MBE, MOVPE; Introduction to molecular electronics.

Outcome:

Familiarity with advanced structures, their relative merits and demerits, areas of application,

Text Books:

Ning & Taur

B.R.Nag

S. M. Sze