

Course Contents of Masters in Integrated Circuits Design

EL-5003 Advanced Digital System Design

Review of Hardware Description Language Concepts: Modules, Simulation and Synthesis, Combinational Circuit RTL, Sequential Circuit RTL, Structural modeling, Data type & operator, Constant, Array, Loop, Advanced HDL concepts: Functions, tasks, Generate statement, Compiler Directive, Built-in Primitives, SRAM Model, and Multivalued logic and Signal Resolution.

State Machine, SM Charts and Microprogramming: State Machine (Moore and Mealy Machine), SM Charts, Microprogramming, and Linked State Machines.

Designing with FPGA: Implementation Functions in FPGAs, Implementation Function using Shannon Decomposition, Carry Chains in FPGA, Cascade Chains in FPGA, Dedicated Memory FPGAs, Dedicated Multiplier in FPGA, FPGAs and One hot state Assignment, Cost of Programmability, FPGA Capacity: Maximum gate versus usable gates, Design transition, and Mapping, placement & routing.

Digital Arithmetic: Fixed point Representation, Fixed point Addition, Fixed point Multiplication, Floating representation, Floating point addition, Floating point multiplication, other floating- and fixed-point operations

EL-5004 Analog VLSI Design

Moore's Law and its impact VLSI Fabrication Process Secondary Effects in MOSFETs: Channel Length Modulation, substrate effect, threshold voltage variation, Drain Induced Barrier Lowering, subthreshold conduction, mobility degradation and drift velocity saturation, CMOS Latch up Effect, Hot Carrier Effect. Voltage, Frequency and feature size scaling Modern FET Structures: High K Metal Gate, SoI, Fin FET, GAAFET, Parasitic modelling in ICs: Resistance, inductance, capacitance interconnects and Delays.

IC Packaging: Wire bonding and flip chip technology, IC packages ESD Modelling.

VLSI Layout Design: Floor planning, technology routing stack and PDK, bond pads, ON-chip Passive component

design: Resistors, Capacitors, Inductors, Transformers, Robustness: Process variation, design corners, reliability.

EL-5005 Electronic Design Automation

Overview of the design automation process EDA tools and frameworks.

Digital Circuit Design: Logic synthesis and optimization, Gate-level and RTL design, Design for Testability (DFT): Test generation and fault simulation, Built-in self-test (BIST) and scan chain design.

Analog and Mixed-Signal Design: Analog circuit simulation and analysis, Mixed-signal design and verification

High-Level Synthesis (HLS): Behavioral modeling and synthesis, HLS tools and methodologies.

Design for Manufacturability (DFM): Manufacturing variability and yield analysis, DFM guidelines and rules.

Emerging Trends in EDA: Artificial intelligence and machine learning in EDA, Cloud-based EDA and hardware acceleration.

EL-5008 Embedded Systems for Artificial Intelligence

Review of AI fundamentals: Methods of knowledge representation, perception, reasoning, problem solving, data-mining, and machine learning in Artificial Intelligence (AI). Supervised learning, Unsupervised learning and Reinforcement learning, Overview of Deep learning. Design of Embedded Hardware for AI: Key Metrics and Design Objective, Kernel Computation, Designing of Accelerators, Operation Mapping on Accelerators.

AI Algorithm optimization for Embedded System: Reducing Precision, Exploiting Sparsity, Power and utilization efficient AI models.

Introduction to neuromorphic computing: neuromorphic computing potential for future AI hardware. Hardware acceleration techniques for deep learning inference.

EL-5006 Design of System on Chip

System-On-Chip (SoC) architectures: Processors, memories, peripherals, and communication fabrics. Bus architectures for embedded systems, Memory management and optimization techniques for embedded systems. Power-aware design principles for low-power embedded systems.

Real-Time Operating Systems (RTOS): Introduction and scheduling algorithms. Inter-process communication (IPC) mechanisms, Real-time task management and scheduling techniques. RTOS kernel design principles and development considerations. Hardware-Software Co-Design, Design methodologies for co-optimizing hardware and software components. Hardware/Software Interface (HSI) design principles and protocols.

Advanced Programming for Embedded Systems: Interrupt handling mechanisms and programming techniques. Device driver design principles and development considerations. Real-time programming languages and tools Memory management and optimization techniques for embedded systems programming. Design patterns and coding practices for robust and maintainable embedded software.

System Design, Analysis, and Optimization: Design methodologies for complex embedded systems. System modeling and performance analysis techniques. Embedded system debugging and troubleshooting techniques.

EL-5007 Advanced Digital VLSI Design

TCL and its SDC Extension: TCL Basics: TCL Variables, TCL Lists, TCL Expression and Operators, TCL Control Flow Statements, Miscellaneous TCL Commands SDC Overview: Constraints for Timing, Constraints for Area and Power, Constraints for Design Rules, Constraints for Interfaces, Constraints for Specific Modes and Configurations, Exceptions to Design Constraints.

Standard Cell Characterization: CMOS Logic Circuits, Modeling of CMOS Cells, Timing Modeling, Timing Models - Combinational Cells, Timing Models - Sequential Cells, State- Dependent Models, Interface Timing Model for a Black Box, Power Dissipation Modeling, Other Attributes in Cell Library.

Physical Design: Floorplaning concepts and IO placement, Power planning, Placement strategies, DRV optimization, Buffer tree synthesis, Clock tree synthesis, Routing optimization, ECO timing closure.

Static Timing Analysis: Understanding Timing report, Setup Timing Check, hold timing Check, False Paths, Multi cycle, Timing across clock domain, Multiple clock.

Physical Design Verification: DRCs, LEC, LVS, ERC, Antenna DRC, IR Drop (Static and Dynamic).

EL-5009 Analog Integrated Circuits

Review of analog circuit fundamentals Cascode and active current mirrors with large signal response, Frequency response of amplifier configurations.

Noise and its statistical characteristics: representation of noise in circuits, noise in amplifiers.

Feedback circuits: Feedback topologies, effect of loading.

Op amp design: gain boosting, common mode feedback, power supply rejection Voltage regulators and power management.

Oscillators: LC oscillators, Voltage Control Oscillators.

EL-5010 Microwave Circuit Design

Resonant RLC networks: RLC networks as impedance transformers, maximum power transfer theorem, the L-match, the pi-match, the T-match.

Transmission line: types of transmission lines, Line characteristics impedance and physical parameters, Signal propagation, Waveform distribution and frequency dispersion, Transmission line of finite Lengths, Reflection, Transmission and Propagation constants of transmission line The Lumped-Element circuit model for a transmission line, wave propagation on a transmission line, the lossless line, Special cases of lossless terminated lines.

Smith Chart and S-parameters: Impedance Smith Chart, Admittance Smith Chart and Combined Impedance and Admittance Smith Chart, Impedance View point (Quarter wave transformer), Generator and Load mismatch.

Impedance and Equivalent Voltages and currents: Impedance and Admittance Matrices, The scattering matrix.

Microwave power divider, coupler, and filter design

EL-5011 Low Power Integrated Circuits

Introduction to Low Power Design: Motivation and challenges, Power consumption in ICs, Low power design metrics and benchmarks.

Fundamentals of Low Power Design: Device physics and leakage current, Voltage scaling and threshold voltage reduction, Dynamic voltage and frequency scaling.

Circuit Techniques for Low Power: Sub- threshold circuit design, Near-threshold voltage design, Ultra-low power logic circuits (e.g., pass-transistor logic, dynamic logic).

Low power memory circuits: low-power SRAM, DRAM).

Advanced ultra-low power techniques: energy harvesting, power gating.

Analog circuit design techniques: fractional- N synthesis, noise shaping.

EL-5012 Digital IC Verification

Introduction to Digital Design Verification: Importance of Verification in the Design Cycle, Verification vs. Validation, Verification Process and Goals.

Verification Methodologies: Verification Methodologies Overview, Simulation-Based Verification, Formal Verification, Creating a Verification Plan, Coverage Goals and Metrics.

Simulation-Based Verification: Concept of Simulation in Digital Design, Creating Effective Test benches, Generating Stimuli and Expected Results.

Formal Verification: Introduction to Formal Verification, Model Checking, Equivalence Checking.

System Verilog for Verification: Introduction to System Verilog, Assertion-Based Verification (System Verilog Assertions and Writing and Using Assertions).

Universal Verification Methodology: UVM Overview, UVM Library Basics, Interface UVCs, UVM Test-

bench development and Integration.

Coverage Analysis: Types of Coverage (Code Coverage and Functional Coverage), Analyzing Coverage Metrics, Techniques for Achieving Comprehensive Coverage.

Advance Topic in Verification: Low Power Verification, Post-Silicon Validation, AI and Machine Learning in Verification.

EL-5013 Embedded Processor Design

Introduction to Embedded Systems: Definition and Characteristics of Embedded Systems, Embedded System Architecture and Components, Types of Embedded Systems.

Embedded Processor Architectures: Microcontrollers vs. Microprocessors, Instruction Set Architectures (RISC vs CISC), Processor Design Considerations (Performance, Power, and Area Trade-offs).

Processor Design Fundamentals: Basic Processor Components (ALU, Register, Control Unit), Pipeline Architecture (Stages of Pipeline and Pipeline hazards & Solutions), Super scalar and VLIW Architecture.

Memory Hierarchy and Management: Type of Memory, Memory Hierarchy, Memory Management Techniques.

Interfacing and Peripherals: I/O Interfacing, Memory Mapped IO, Interrupt, Interrupt Service Routine, Peripheral Integration (Timers, ADCs, DACs).

Advance Topic in Embedded System: Power Management, Security Issue in Embedded Systems, Reliability and Fault tolerance.

EL-5014 RF Integrated Circuit Design

Review of RF and Wireless technologies, industry and future directions.

Basic Concepts in RF Design: Units, time variance, non- linearity, effects of non- linearity (harmonic distortion, gain compression, cross modulation, intermodulation).

Noise: Noise as a random process, noise spectrum, device noise, representation of noise in circuits.

Low Noise Amplifiers: Problems of input matching, LNA topologies, case study.

Power Amplifiers: Effects of high currents, efficiency, linearity, Classification of Power Amplifiers (linear amplifiers and switching amplifier (Class A, B, AB), High efficiency Power Amplifiers (Class C, D, E, F).

Mixers: General Considerations, Performance Parameters, Mixer Noise Figure, Passive Down-conversion Mixers (Gain, LO Self mixing, Noise).

Oscillators: Performance metrics, Basic principles, cross coupled oscillator, three point oscillators, voltage control oscillator, phase noise basic concepts, effects of phase noise, analysis of phase noise, design procedure low noise VCO.

Phase Locked Loops: Basic concepts, Phase detector, Type I PLL, Alignment of a VCOs phase, simple PLL, Analysis of simple PLL, Loop dynamics, frequency multiplication, drawbacks of simple PLL.

EL-5015 RF Transceiver Design

Fundamentals of RF system modeling: Band-pass and low-pass RF system representation, Nonlinear issues including Harmonic distortions and gain compression, 1-dB compression point, desensitization and blocking, cross modulation, intermodulation distortions, noise issues.

Overview of Wireless communication systems: Wireless communication standards, RF transceiver at glance, Modern communication radio, software defined radio, digital transmitter, digital receiver, basic receiver and transmitter architectures (Super Heterodyne receiver, Homodyne receiver, low-IF receiver), one step, two step transmitters.

Transmitter Architecture: Introduction, synthesis, Homodyne, Low-IF and Super Heterodyne.

Receiver architectures: Systematic receiver synthesis, sensitivity, intermodulation characteristics, estimation of phase noise, interference blocking, adjacent and alternate channel selectivity, single tone desensitization, Rx gain and AGC, DR of ADC, Channel filter, Line-up analysis.

EL -5016 Research Methodology

Introduction: The nature and purpose of research, Research ethics and responsible conduct, Formulating research questions and hypotheses.

The research process: Planning, design, implementation, and dissemination.

Literature Review: Searching for and evaluating scholarly literature, Critical analysis of research articles, integrating research findings to build knowledge.

Quantitative Research Methods: Research designs (e.g., experimental, quasi-experimental, survey), Sampling techniques (e.g., probability, non-probability), Measurement and scaling, Data collection methods (e.g., surveys, questionnaires, experiments), Quantitative data analysis techniques (e.g., descriptive statistics, hypothesis testing).

Qualitative Research Methods: Research designs (e.g., case study, ethnography, phenomenology), Data collection methods (e.g., interviews, focus groups, observation), Qualitative data analysis techniques (e.g., thematic analysis, narrative analysis).

Advanced Research Topics: Mixed methods research, Research proposal development, Research grant writing, Data management and analysis software, scientific writing and communication.

Research Dissemination: Ethical considerations in research dissemination, presenting research findings effectively (written and oral formats), and Publishing research in academic journals.

EL-5017 Mixed Signal Design

Introduction to Mixed-Signal Design: Overview of mixed-signal ICs and their applications, Mixed-signal design flow and challenges.

Analog-to-Digital Converters (ADCs): ADC architectures (e.g., SAR, Flash, Sigma- Delta): ADC design considerations (e.g., resolution, speed, power).

Digital-to-Analog Converters (DACs): DAC architectures (e.g., binary-weighted, R-2R), DAC design considerations (e.g., resolution, speed, power).

Mixed-Signal Simulation and Verification: Introduction to mixed-signal simulation tools, Verification techniques for mixed-signal ICs.

Filter Design: Analog and Digital filter design, switched capacitor circuits.

EL-5018 Advanced Topics in Integrated Circuit Design

Nanoelectronics, Neuromorphic Computing, Quantum Computing, 3D ICs, Flexible and Wearable Electronics, Photonics, NEMS, Advanced CMOS Technology, Silicon Photonics, FinFET and GAAFET Transistors, Power Management ICs, Heterogeneous Integration and System-in-Package (SiP) – and various case studies.