Curriculum
for a Master's Degree in ECE
with focus on
Mixed Signal SOC Design

Department of
Electrical and Computer Engineering
The University of Texas at Austin

Overview

- The VLSI Design program is part of two tracks in the department:
  - Computer Engineering:
    - This area involves research and study in computer architecture, computer systems and networks, theory and design of digital systems, and software engineering. Investigations include architecture design, parallel processing, neural networks, microprocessor-based systems, fault-tolerant computing, design for testability, computer-aided design, computer vision, VLSI system design, embedded systems, local area networks, and hardware/software codesign.
  - Circuit Design:
    - This area involves research and study in analog and digital circuit design for next generation mixed-signal systems. The applications for this research encompasses various domains including: RF & wireless, low power processors and SOCs, AD/DA converters, etc.

Faculty

Name	Research Areas
Dr. Jacob Abraham	VLSI Testing and Design for Testability, Formal Verification, Design and Evaluation of Fault-Tolerant Systems
Dr. Tony Ambler	ASICS for safety critical applications, System Testability, Test Economics, Network Design
Dr. Adnan Aziz	VLSI design automation, Formal Verification, Sequential Synthesis, Binary decision diagrams, Timed/Stochastic systems, VLSI CAD
Dr. Craig Chase	Parallel computer architecture, Software environments for parallel and distributed systems
Dr. Margarida Jacome	Design Process Planning and Management, Design Theory, Assessment of Design Processes and Design Methodologies, Hardware/Software Codesign, Design Reuse
Dr. Lizy Kurian John	High Performance Processor Architecture, High Performance Memory Systems, Novel Cache Designs, Dynamic Computer Architectures using FPGAs, Program Behavior Studies, Optimizing Compilers
Dr Yale Patt	Architecture and microarchitecture of next generation “billion transistor” high performance microprocessors.
Dr. David Z. Pan	VLSI physical design, interconnect, low power, vertical integration of architecture, CAD, circuit and technology explorations
Dr. Nur Touba	Computer-Aided Design, Testing, Fault Tolerant Computing
Dr. Shoulli Yan	Low-voltage low-power mixed-signal integrated circuits MS ICs for wireless/wireline communications, over-sampling and Nyquist-rate A/D and D/A converters, continuous-time and switched-capacitor filters
Dr. Michael Orshansky	Statistical CAD algorithms for design for manufacturability and yield improvement, robust circuit design in the presence of process variability, low-power circuit design, modeling and characterization of semiconductor devices

MS-SOC Circuit Design Program

- Program is 3 years old.
- Started out as a program to educate next generation circuit designers in both the analog and digital domains.
- Currently morphing into a mixed signal “SOC” design program:
  - Combination of analog, digital and software systems.
- “Managed” by the “Circuit Board” which is composed of industry representatives from Texas based semi-conductor companies.

Industry Support

- Silicon Labs' founders donated $ 2.3 Million for a chair in mixed-signal design
- Adjunct faculty from local companies teaching key courses and helping with curriculum
  - Intel, AMD, IBM, Motorola, Silicon Labs, Cirrus Logic, Oasis, National Instruments
  - Department recruiting faculty in this area
- Support for teaching assistants (TAs) and laboratory remodeling, donated computer equipment and software licenses

Curriculum for M.S. Degree

- Four-semester program with specialization in Digital and Mixed-Signal Circuit Design
  - Program with 34 semester credit hours
- Required courses in circuit design: (16 hours)
- Electives (in circuit-related area): (9 hours)
- Breadth courses: (6 hours)
- 2-semester design project, basis of M.S. report (3 hours)

MS-SOC Circuit Design Course Sequence

Fall-1	Spring-1	Fall-2	Spring-2
Mixed Signal System Design & Modeling (3)	SOC System Design (3)	Elective (3)	Breadth Course (3)
Analog IC Design (3)	Advanced Analog Design (3)	Elective (3)	Elective (3)
VLSI-1 (3)	VLSI-2 (3)		
	Technical Entrepreneurship Seminar (1)	Embedded SOC System Lab-1 (3)	Masters Report (3)
9 hours	7-9 hours	6-9 hours	6-9 hours

Required Courses

- VLSI I
- VLSI II
- Analog IC Design
- Design of Embedded Systems on a Chip
- Technical Entrepreneurship (seminar)
- Design Project

Elective Courses

- Three electives, at least one from each group

CAD and Algorithms

- Synthesis of digital systems
- Hardware verification
- Hardware/software co-design
- Physical design algorithms
- Design of nanometer circuits
- Optimization algorithms
- Analysis and design of CMOS circuits

Design technology

- Digital systems testing and design for testability
- Fault-tolerant systems
- Advanced analog circuits
- Mixed-signal system design
- Design of linear ICs
- Data converter design
- Design of RF circuits
- Design for low power

Possible Breadth Areas

- Computer Architecture
- Embedded Operating Systems
- Engineering Programming Languages
- Digital Signal Processing
- Wireless Communication Systems
- Deep Submicron Devices
- Semiconductor Manufacturing
- Software Engineering

Selected
Course Descriptions

Mixed Signal System Design and Modeling

- **Instructor: Eric Swanson**
- **Textbook: Selected papers & publications**
- **Course Description:**
  - **This is a course in mixed-signal integrated circuit architecture. For mixed-signal processing IC's, substantial R&D investments in modeling signal processing elements (analog sub-circuits and digital macro-blocks) at the behavioral level lead to the detailed specifications for those elements. This course, as a prerequisite for both "Gray and Meyer" analog and VLSI digital design courses, gives IC design graduate students some insight into the model-based development of sub-circuit specifications.**

CMOS Analog IC Design

- Instructor: Dr. Shouli Yan
- Textbook: B. Razavi, "Design of Analog CMOS Integrated Circuits", McGraw Hill, 2001.
- Course Description:
  - This course presents the design of analog integrated circuits in CMOS technology. The course begins with a review of CMOS technology and MOS transistor operation principles.
    - Basic CMOS analog building blocks, including current mirrors, inverting amplifiers, differential pairs, and cascode amplifiers, are then introduced.
    - Frequency response, stability, and frequency compensation are explained, followed by the design of one-stage and two-stage operational amplifiers.
  - The students will do design, simulation, and layout of analog circuits in Cadence design environment during the semester, and will complete a final project at the end of the semester.

SOC System Design

- Instructor: Mark McDermott (with help from industry based instructors)
- Textbook: Selected papers & publications
- Course description:
  - This course is intended to:
    - Provide an understanding of the concepts, issues, and process of system-level design of embedded systems, i.e., hardware-software co-design & co-verification.
    - Expose the student to the modeling and specification of an embedded system at a high level of abstraction
    - Use co-simulation to validate system functionality
    - Analyze the functional and nonfunctional performance of the system early in the design process to support design decisions
    - Analyze hardware/software tradeoffs, algorithms, and architectures to optimize the system based on requirements and implementation constraints
    - Understand hardware, software, and interface synthesis
    - Understand issues in interface design
    - Use contemporary software tools within a co-design environment

VLSI I

- Covers all aspects of VLSI Design Flow
- Lectures deal with fundamentals of CMOS design, verification and test
- Use of industry standard tools in laboratory
  - Cadence, Synopsys
- Deal with entire design flow
- Class project: teams of students design interesting chips
- Selected chips could be sent to MOSIS for
- fabrication

VLSI I Topics

- CMOS transistors
- Implementing static logic in CMOS
- CMOS dynamic logic
- Arithmetic units in CMOS
- Characterizing circuit resistance and capacitance
- Delay estimation
- Timing verification
- Performance optimization
- Latches and flip-flops
- Clocking
- Control design
- Datapath design
- Memory subsystems
- High-performance circuits
- Design verification
- Testing and design for test
- Design for low power
- SOI, Future technologies

VLSI I Laboratory Exercises

- Lab 1:
  - Layout of two-port register cell, circuit simulation
- Lab 2
  - Schematic design of ALU (using library cells)
  - Static timing verification, redesign for performance
- Lab 3
  - Design of Wishbone SOC bus controller in Verilog
  - Simulation of controller with models of ARM-2 processor and DES chip (provided to students)
  - Synthesis of bus controller with library provided
  - Static timing verification
  - Place-and-route of bus controller, extraction of parasitics
  - Static timing verification with parasitics

VLSI-2

- Instructor: Mark McDermott (with help from industry based instructors)
- Textbook: Chandrakasan, Bowhill, Fox, Design of High-Performance Microprocessor Circuits, IEEE Press, 2000.
- Course description:
  - This course is intended to provide the student with the basic capability to design, analyze, characterize and optimize transistor level circuits. Current VLSI issues such as noise analysis, power delivery, power management, timing analysis, clocking, floor-planning/integration, and transistor/wire scaling will be covered. There is a team based project which focuses on the early design planning and feasibility analysis of a high-performance low power SOC.

Technical Entrepreneurship Seminar

- **Instructor: Mark McDermott with help the Venture Capital community and IC centric businesses in Austin.**
- **Course Description:**
  - **This course provides an introductory overview to the scope of knowledge and activities needed for technical entrepreneurship. The student will have an opportunity to gain new knowledge and skills that can be applied to their own entrepreneurial interests. An entrepreneurial venture is the result of a unique set of circumstances involving the entrepreneur, a business idea/strategy, the environment surrounding the business idea, and the activities undertaken to weave the entrepreneur/ business/ context into a feasible, viable, profitable, and on-going concern.**

Computer-Aided Circuit Design for DSM VLSI

- Instructor: Dr. Michael Orshansky
- Textbook: Selected papers & publications
- Course description:
  - This course reviews the major components of the modern computer-aided circuit design flow, concentrating on models and algorithms for physical design and timing analysis. An important motivation for the course is to explore the directions in which computer-aided circuit design evolves as it copes with the challenges brought about by the increased complexity of deep submicron silicon technology. The course will survey the major disruptive technological trends, and study their impact on timing analysis and physical design. It will also explore the techniques in computer-aided design for testability, reliability, and manufacturability. The course will build the links between solid-state technology, circuit design, and CAD, and will be of interest to students in all these areas.

Nanometer Scale IC Design

- Instructor: Dr. Michael Orshansky
- Textbook: Selected papers & publications
- Course Description:
  - This course explores the challenges of digital integrated circuit design in advanced CMOS technologies. The students will learn about the impact of new physical effects on the traditional circuit design solutions and methods, and on ways they need to adopt to enable successful integrated circuit design. The primary themes of the course will be the challenges of ensuring high yield, reliability, manufacturability, and robustness of advanced integrated circuits, including mixed-signal circuits.

Analysis & design of Digital Integrated Circuits

- Instructor: Dr. Nur Touba
- Textbook: CMOS Digital Integrated Circuits: Analysis and Design by Sung Mo Kang and Yusuf Leblebici McGraw-Hill
- Course description:
  - This course thoroughly covers the fundamentals in design and analysis of MOS digital integrated circuits. Topics to be covered include the following:
    - Modeling MOS Devices - Equations and SPICE Models
    - MOS Invertors - Voltage Transfer Characteristics, Noise Margin, Propagation Delay
    - MOS Logic Circuits - Static Logic, Transfer Gates, Clocked Static Circuits, Dynamic Logic, Pre-Charged Logic, Domino CMOS
    - Buffer and I/O Circuits - High Capacitance Drivers, Bootstrapping, Clock Generation, Input Protection
    - Semiconductor Memories - DRAM, SRAM, ROM
    - Low Power Design - Techniques and Logic Families for Minimizing Power

Project Course

- Teams design and prototype a mixed-signal system involving software, digital and analog hardware
- Spans entire degree program (M.S. Report)
- Technical Entrepreneurship Seminar: business plan, product plans
- Design of system
- Chip/PC board fabrication
- Complete prototype, report