

Master Course Description

Title: Introduction to VLSI Design

Credits: 5

[UW Course Catalog Description](#)

Coordinator: Visvesh S. Sathe

Course Goals:

1. This course represents the first of several major design experiences that students in the VLSI concentration will experience. Effective planning, coordination and execution of a team project is a major goal of this course.
2. Understand the fundamentals of CMOS logic starting from its connection to Shannon's expansion theorem down to effective schematic and layout design of CMOS logic gates, DC-transfer functions.
3. Understand gate-delay, and the connection between gate delay and data arrival times to critical path optimization. Inverter sizing and logic optimization for speed minimization.
4. Understand power dissipation in CMOS circuits, both dynamic and static. Understand the effect of circuit parameters of cross-over power dissipation. Understand the role of V_{th} and subthreshold swing in total energy per computation.
5. Understand the design and operation of basic timing elements (level-sensitive latches, BA flip-flops), their associated parameters (setup, hold, T_{clk-q} , T_{d-q}) and their impact on race immunity and pipelining overhead. Understand the role of clock uncertainty on timing slack.
6. Appreciate power reduction as a constrained optimization problem with performance and reliability as common constraints. Basic understanding of clock gating and voltage scaling as a power-reduction technique.
7. Apply understanding of CMOS concepts to circuit design and simulation, inclusive of mask layout in an industrially relevant CMOS process using industry standard tools. Design assignments begin with an inverter and subsequently include flip-flops and LFSRs.
8. Understand and apply best-practices toward building digital systems in the areas of analysis, construction, and verification.
9. Use industry standard design tools to design VLSI structures for custom and automated physical design, simulation and verification that complement lecture material.
10. Project: Students work in teams to build a 16-bit 16 entry register file driving a full-custom 16-bit ALU design. Students judged on design quality, work partitioning, verification, performance and energy efficiency..

Learning Objectives:

1. A strong grasp of the fundamentals of VLSI circuits and systems, with a particular emphasis in making connections between low-level theoretical concepts (power, delay, wire-parasitics, noise-margins), architecture-level considerations (latency of data-movement, the case for heterogeneous computing), and a student-group defined application. Once these connections are made, the student-teams need to plan on executing a design that fulfills the stated objectives.
2. A strong grasp of planning, analysis, preparation, and execution of high-quality system designs.
3. Developing the fundamentals for design for test, and simple verification techniques in design.

Textbook: Weste & Harris, *CMOS VLSI Design: A Circuits and Systems Perspective*, 4th ed., Addison-Wesley, 2010

Prerequisites by Topic:

1. ECE 215 Fundamentals of Electrical Engineering
2. Basic understanding of digital logic

Course Structure: There are 4 hours of lecture per week, plus 1 hour of discussion. The discussion will be used for student presentations of project progress, and tips-and-tricks for effective use of tool-flows and/or related skills around linux, scripting or spice simulation. Because a large portion of the course involves learning new material, the project is designed to emphasis effective teamwork, partitioning and execution of a high-quality design that is somewhat limited in scope. A significant portion of the learning in this course happens in the student design labs through peer interaction, and that with the TA who holds regular office hours in the design lab.

Grading:

- CAD Assignments (40%)
- 2 Midterm Exams (15% each)
- Project (30%)

Syllabus: Note. Items Marked (T) are theory learning topics that remain in the course

Week No.	Lecture Topics	Discussion/Lecture Topics	HW/Peer assessment /Project write-ups
1	Introduction, CMOS Logic Gates	Introduction to Linux	
2	Basic Long-channel MOSFET model, Introduction to basic CMOS fabrication	Introduction to Virtuoso	Tutorial 1
3	Inverter DC transfer function	Introduction to Spice	CAD1
4	Inverter Delay, Inverter Gate sizing	Review of CAD1	CAD2
5	Timing Elements,	Review of CAD2	CAD3
6	Putting it together: Regfile design	Review of CAD3	CAD4
7	CMOS Power dissipation	Midterm	
8	VLSI Datapaths (Encoders, Decoders, Adders)	Effective Project Planning strategies (MWE, milestones etc.)	
9	Memory elements (RAM, ROM, DRAM)	Midterm Review	
10	Final Course Presentations		

Outcome coverage:

- 1) (high) *an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.* Much of the class is heavily based on application of math, physics, and engineering knowledge. This is emphasized in class and assessed through application in project hand calculations and planning. For each of the design projects, the student must analyze the requirements, then design, implement, and test the design, to verify its performance and characteristics.
- 2) (Medium) *an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.* In the final project, students are posed with a design problem and design specifications for a real-world application. The project provides an opportunity to develop hardware designs that are dependable and robust, essential for silicon systems that continue to drive growth and improve our quality of life.
- 3) (high) *an ability to communicate effectively with a range of audiences.* Effective communication, managing team-dynamics, and documentation is heavily emphasized and evaluated through team project efforts and team presentations.

- 4) (medium) *an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.* We discuss the tradeoffs in different engineering approaches and the greater societal consequences of developing VLSI systems.
- 5) (high) *an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.* Team projects are a major component of this course, and seek to foster a collaborative, inclusive environment even in a competitive design situation. Students effectiveness with social media will be leveraged to encourage discussions on the online discussion boards, incentivised by bonus credits.
- 6) (high) *an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.* Each of the CAD projects require a significant amount of experimentation, evaluation of resulting simulation data and judgement to determine the optimal choices for design.
- 7) (high) *an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.* The lectures and CAD assignments are co-designed to effectively train students to continually translate newly learned concepts into actual designs.

Prepared By: Visvesh S Sathe

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