EE 599: Special Topic on Complex Digital ASIC System Design

Units: 4
Fall 2024 — Mon/Wed — 12:00pm - 1:50pm

Location: (TBD)

Instructor: Professor Christopher Torng
Office: EEB 204
Office Hours: (TBD)
Contact Info: ee599-staff-l maillist usc edu

Teaching Assistant: (TBD)
Office: (TBD)
Office Hours: (TBD)
Contact Info: (TBD)

IT Help: (TBD)
Hours of Service: (TBD)
Contact Info: (TBD)

Course Description and Learning Objectives

From their invention around 60 years ago, ICs are now found in almost everything we do (computers, smartphones, wearables, robots). While in the past, the focus was on designing high-performance general-purpose processors, the industry is now increasingly moving towards specialized ICs (called accelerators) such as graphics processing units (GPUs), machine learning accelerators, and image and video processing accelerators. This move towards specialization is driven by the high performance and energy efficiency demands of sensor-rich smartphones, autonomous robots, and large data centers running applications including image and video processing and analysis, graphics, speech processing, AI, and machine learning. This course will teach you how to design such specialized ICs.

EE 599 is a project-based class that will introduce you to the tools and methods to create CMOS integrated circuits from a top-down perspective with complex digital ASICs. Working in teams, you will create a small digital or mixed-signal VLSI design to be built using a modern design flow and EDA tools. The homework assignments will have students build a demonstrative hardware accelerator where you will write a SystemVerilog model of a neural network accelerator, create a testing/debug strategy for the chip, use synthesis and place-and-route tools to create the layout of the chip, and understand all the procedures you need to tape out a chip.

You will then propose and design your own hardware design for an application of your interest, with the goal of taping out your design in an advanced technology (i.e., sending the design to a real fabrication facility) and testing it in an ASIC prototyping lab environment in a future semester (separate course). As a project-based course, there is much material that we need to cover in the semester. As a result, you will be introduced to a number of new tools that you will learn through the weekly tasks that will help you in your homework as well as in your project. This course is useful for anyone who will build a chip in their Ph.D.

Course Prerequisites

Required:
- EE 457: Computer Systems Organization (or equivalent)
- EE 477: MOS VLSI Circuit Design (or equivalent)

Recommended:
- EE 557: Computer Systems Architecture
- EE 577: VLSI System Design

*** and approval from Course Instructor**

Course Notes

Grading will be letter-only. This course will use Piazza for online discussion. Lecture notes will be posted on the D2L platform.

Technological Proficiency and Hardware/Software Required

This is a project-based class. The majority of the work will be done on compute servers that have CAD tools already installed and PDKs already set up. You must own a laptop or other means to log into a remote cluster (e.g., a MacBook with a terminal will work). Please expect to spend a significant amount of time working on remote clusters using your machine.

You will interface frequently with CAD tools on a Unix-based terminal.

Required Readings and Supplementary Materials

There is one textbook that students are required to have access to for the course. Note that if students are unsure about whether or not they will enroll in the class, they should be able to delay purchasing until the second or third week of class without significantly hindering their progress in the course.

- **Weste and Harris** – The primary required textbook is "CMOS VLSI Design: A Circuits and Systems Perspective" (4th Edition). Please find this book at the USC store or on Amazon.

Participation

There are limited seats in this course. We will be holding sessions in a project-driven approach, in which students will present their project proposals to other students during class time. We will also hold design reviews. While attendance is not in any way reflected directly in your grades, please understand that it will be difficult to hold a successful project-based course without your presence.

Grading Breakdown

	Weighting	Comments
Homeworks (three to four)	20%	Equally divided across all homeworks
Project Overview Presentation	5%	
RTL / Schematic + Tests	20%	See schedule
Mid-Semester Design Review	15%	See schedule
Layout + Signoff	15%	See schedule
Final Presentation	15%	See schedule
Weekly Syncups	10%	

Grading Scale

This course will be adopting a philosophy of "grading for equity" where grading is exclusively used to assess mastery of the material covered in the course as opposed to rewarding effort and/or incentivizing specific behaviors. To this end, each part or criteria of every assignment is graded on a four-point scale without any curve.

A score of 4.25 is an A+, 4 roughly corresponds to an A, 3 roughly corresponds to a B, 2 roughly corresponds to a C, and so on. A score of 4.0 usually indicates that the submitted work demonstrates no misunderstanding (there may be small mistakes, but these mistakes do not indicate a misunderstanding) or there may be a very small misunderstanding that is vastly outweighed by the demonstrated understanding. A score of 3.0 usually indicates that the submitted work demonstrates more understanding than misunderstanding. A score of 2.0 usually indicates that the submitted work demonstrates more misunderstanding than understanding. A score of 1.0 usually indicates that the submitted work is significantly lacking in some way. A score of 4.25 is reserved for when the submitted work is perfect with absolutely no mistakes or is exceptional in some other way.

The final grade is calculated using a weighted average of all assignments. Detailed rubrics are provided to enable students to easily see how the score was awarded.

Academic Integrity

The University of Southern California is foremost a learning community committed to fostering successful scholars and researchers dedicated to the pursuit of knowledge and the transmission of ideas. Academic misconduct is in contrast to the university's mission to educate students through a broad array of first-rank academic, professional, and extracurricular programs and includes any act of dishonesty in the submission of academic work (either in draft or final form).

This course will follow the expectations for academic integrity as stated in the USC Student Handbook. All students are expected to submit assignments that are original work and prepared specifically for the course/section in this academic term. You may not submit work written by others or "recycle" work prepared for other courses without obtaining written permission from the instructor(s). Students suspected of engaging in academic misconduct will be reported to the Office of Academic Integrity.

Other violations of academic misconduct include, but are not limited to, cheating, plagiarism, fabrication (e.g., falsifying data), knowingly assisting others in acts of academic dishonesty, and any act that gains or is intended to gain an unfair academic advantage.

The impact of academic dishonesty is far-reaching and is considered a serious offense against the university and could result in outcomes such as failure on the assignment, failure in the course, suspension, or even expulsion from the university.

For more information about academic integrity see the student handbook or the Office of Academic Integrity's website, and university policies on Research and Scholarship Misconduct.

Course Content Distribution and Synchronous Session Recordings Policies

USC has policies that prohibit recording and distribution of any synchronous and asynchronous course content outside of the learning environment.

Recording a university class without the express permission of the instructor and announcement to the class, or unless conducted pursuant to an Office of Student Accessibility Services (OSAS) accommodation. Recording can inhibit free discussion in the future, and thus infringe on the academic freedom of other students as well as the instructor. (Living our Unifying Values: The USC Student Handbook, page 13).

Distribution or use of notes, recordings, exams, or other intellectual property, based on university classes or lectures without the express permission of the instructor for purposes other than individual or group study. This includes but is not limited to providing materials for distribution by services publishing course materials. This restriction on unauthorized use also applies to all information, which had been distributed to students or in any way had been displayed for use in relationship to the class, whether obtained in class, via email, on the internet, or via any other media. (Living our Unifying Values: The USC Student Handbook, page 13).

Course Schedule

Week	Topic	Due
Week 1 – August 26	Lecture: Course Overview	
	Lecture: Synthesis Overview	
Week 2 – September 2	--- No Lecture: Labor Day, September 2 ---	
	Lecture: Synthesis: Constraints, Corners, Basic Static Timing Analysis	
Week 3 – September 9	Lecture: HW 1 focus session	HW 1 Due (mul)
	Lecture: Synthesis: Static Timing Analysis, Timing Exceptions	
Week 4 – September 16	Lecture: Synthesis: Register Retiming, Clock Gating, Memory Macros	HW 2 Due (Iterative Multiplier Synthesis)
	Lecture: Synthesis: Clock Domain Crossings, Synchronization, Reset	
Week 5 – September 23	Lecture: Visual Introduction to Physical Design	
	Lecture: Modular Flow Generators	
--- September 27 ---	**Project Proposal Due (end of week)**	**Project**
Week 6 – September 30	Lecture: DNNs, Chip Constraints, Limitations of Accelerators	
	Designing Systems for Testability	
Week 7 – October 7	Lecture: DNNs (continued)	HW 3 Due
	Lecture: Creating a testing infrastructure	
Week 8 – October 14	Lecture: Creating a testing infrastructure (continued)	
	Lecture: P&R: Floorplanning + Intel Backend Flow Walkthrough	
Week 9 – October 21	Lecture: P&R: Floorplanning	
	Lecture: P&R: Placement + Intel Padframe Walkthrough + Intel SRAMs	
Week 10 – October 28	Mid-Semester Design Review, Functional Demo (two groups, 40 min each)	
	Mid-Semester Design Review, Functional Demo (two groups, 40 min each)	

--- November 1 ---	**RTL / Schematics + Tests Due (end of week)**	**Project**
Week 11 – November 4	Lecture: Corner setup + Your tapeout check list	
	Lecture: Systematically fixing DRCs + Adding hold margins + Useful skew + Gate-level simulations	
Week 12 – November 11	--- No Lecture: Veterans Day, November 11 ---	
	Lecture: Top-down integration flow + Top-level host2block and block2host interface + Ready-valid microprotocols + Signoff potpourri	
Week 13 – November 18	Special Topic (or Final Project Help)	
	Special Topic (or Final Project Help)	
--- November 22 ---	**Layout Due (end of week)**	**Project**
Week 14 – November 25	Special Topic (or Final Project Help)	
	--- No Lecture: Thanksgiving Break, November 27 ---	
Week 15 – December 2	Final Presentations (20 min)	
	Final Presentations (20 min)	
Tapeout (end of class)	**Submit designs to shuttle**	**Project**

Statement on Academic Conduct and Support Systems

Academic Integrity:
The University of Southern California is a learning community committed to developing successful scholars and researchers dedicated to the pursuit of knowledge and the dissemination of ideas. Academic misconduct, which includes any act of dishonesty in the production or submission of academic work, comprises the integrity of the person who commits the act and can impugn the perceived integrity of the entire university community. It stands in opposition to the university's mission to research, educate, and contribute productively to our community and the world.

All students are expected to submit assignments that represent their own original work, and that have been prepared specifically for the course or section for which they have been submitted. You may not submit work written by others or "recycle" work prepared for other courses without obtaining written permission from the instructor(s).

Other violations of academic integrity include, but are not limited to, cheating, plagiarism, fabrication (e.g., falsifying data), collusion, knowingly assisting others in acts of academic dishonesty, and any act that gains or is intended to gain an unfair academic advantage.

The impact of academic dishonesty is far-reaching and is considered a serious offense against the university. All incidences of academic misconduct will be reported to the Office of Academic Integrity and could result in outcomes such as failure on the assignment, failure in the course, suspension, or even expulsion from the university.

For more information about academic integrity see the student handbook or the Office of Academic Integrity's website, and university policies on Research and Scholarship Misconduct.

Please ask your instructor if you are unsure what constitutes unauthorized assistance on an exam or assignment, or what information requires citation and/or attribution.

Students and Disability Accommodations:

USC welcomes students with disabilities into all of the University's educational programs. The Office of Student Accessibility Services (OSAS) is responsible for the determination of appropriate accommodations for students who encounter disability-related barriers. Once a student has completed the OSAS process (registration, initial appointment, and submitted documentation) and accommodations are determined to be reasonable and appropriate, a Letter of Accommodation (LOA) will be available to generate for each course. The LOA must be given to each course instructor by the student and followed up with a discussion. This should be done as early in the semester as possible as accommodations are not retroactive. More information can be found at osas.usc.edu. You may contact OSAS at (213) 740-0776 or via email at osasfrontdesk@usc.edu.

Support Systems:

Counseling and Mental Health - (213) 740-9355 – 24/7 on call
Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention.

988 Suicide and Crisis Lifeline - 988 for both calls and text messages – 24/7 on call
The 988 Suicide and Crisis Lifeline (formerly known as the National Suicide Prevention Lifeline) provides free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week, across the United States. The Lifeline is comprised of a national network of over 200 local crisis centers, combining custom local care and resources with national standards and best practices. The new, shorter phone number makes it easier for people to remember and access mental health crisis services (though the previous 1 (800) 273-8255 number will continue to function indefinitely) and represents a continued commitment to those in crisis.

Relationship and Sexual Violence Prevention Services (RSVP) - (213) 740-9355(WELL) – 24/7 on call

Free and confidential therapy services, workshops, and training for situations related to gender- and power-based harm (including sexual assault, intimate partner violence, and stalking).

Office for Equity, Equal Opportunity, and Title IX (EEO-TIX) - (213) 740-5086
Information about how to get help or help someone affected by harassment or discrimination, rights of protected classes, reporting options, and additional resources for students, faculty, staff, visitors, and applicants.

Reporting Incidents of Bias or Harassment - (213) 740-5086 or (213) 821-8298
Avenue to report incidents of bias, hate crimes, and microaggressions to the Office for Equity, Equal Opportunity, and Title for appropriate investigation, supportive measures, and response.

The Office of Student Accessibility Services (OSAS) - (213) 740-0776
OSAS ensures equal access for students with disabilities through providing academic accommodations and auxiliary aids in accordance with federal laws and university policy.

USC Campus Support and Intervention - (213) 740-0411
Assists students and families in resolving complex personal, financial, and academic issues adversely affecting their success as a student.

Diversity, Equity and Inclusion - (213) 740-2101
Information on events, programs and training, the Provost's Diversity and Inclusion Council, Diversity Liaisons for each academic school, chronology, participation, and various resources for students.

USC Emergency - UPC: (213) 740-4321, HSC: (323) 442-1000 - 24/7 on call
Emergency assistance and avenue to report a crime. Latest updates regarding safety, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible.

USC Department of Public Safety - UPC: (213) 740-6000, HSC: (323) 442-1200 - 24/7 on call
Non-emergency assistance or information.

Office of the Ombuds - (213) 821-9556 (UPC) / (323-442-0382 (HSC)
A safe and confidential place to share your USC-related issues with a University Ombuds who will work with you to explore options or paths to manage your concern.

Occupational Therapy Faculty Practice - (323) 442-2850 or otfp@med.usc.edu
Confidential Lifestyle Redesign services for USC students to support health promoting habits and routines that enhance quality of life and academic performance.