



**EE 653 Advanced Topics in Microarchitecture**

**Units: 4 units**

**Fall 2020—Tuesday/Thursday—2pm-3:50pm:**

**Location:** TBD

**Instructor:** Xuehai Qian

**Office:** EEB 204

**Office Hours:** 4-5pm Tuesday/Thursday

**Contact Info:**

[xuehai.qian@usc.edu](mailto:xuehai.qian@usc.edu)

213-740-9803 (office)

**Teaching Assistant:** *N/A*

**Office:**

**Office Hours:**

**Contact Info:**

**IT Help:** *N/A*

**Hours of Service:**

**Contact Info:**

## Course Description

This course discusses the advanced and new topics of computer system architecture. Due to the end of Moore's law and Dennard scaling, in less than twenty years, computer architecture had undergone two important transitions from high frequency single processor to multicore, and then to the domain-specific architecture. While the basic principles of computer architecture are still important, the design of emerging computing platforms requires developing new technologies. In addition, with domain-specific architecture, the vertical integration becomes essential, the computer system needs to be designed and optimized across the whole system stack from application, domain-specific language/framework, to architecture and new technology. Thus, the emphasis of this course is not constrained to architecture level but also include domain-specific data analytics systems for graph processing and machine learning, and new technologies such as quantum computing.

The course includes the following components: 1) memory consistency model; 2) hardware security; 3) NVM-based systems; 4) GPU architecture and GPU-accelerated systems; 5) graph processing acceleration and systems; 6) machine learning acceleration frameworks; and 7) quantum computing basics. The course will be research oriented and discussion based. For each topic, the instructor will give several lectures to provide the background and context and the students will be assigned with papers to read and present. In addition, all students are expected to write the review/critique of each paper. At the end of the semester, the students are required to complete a course project and write a final report (e.g., a survey paper) on any topic covered in the course.

## Learning Objectives

The students will learn the background and the current research on the topics covered in the course. The students are expected to understand the papers in all topics with a combination of reading and listening the presentation of other students. After taking the course, the students should obtain the basic skills to conduct research and development on at least one of the topics covered. This is assessed with the quality of the course project. Students' understanding of the papers is assessed by the quality of written critiques/reviews, the presentations, and final report. The course will not have a text book and is mainly based on research papers.

**Prerequisite(s):** EE 457 or EE 560 (no longer EE557)

**Co-Requisite(s):**

**Concurrent Enrollment:**

**Recommended Preparation:** EE 451

*Please note that this course will be taught as 4 units. In order to receive 4 units of credit, please register concurrently in EE 690 (1), following these steps:*

*\*Through myviterbi.usc.edu, Directed Research, Ming Hsieh Dept., choose EE 690 (1 unit), Xuehai Qian.*

*\*You will then be given clearance for EE 690 (1)*

*\*Register for both EE 653 and EE 690*

*\*At the end of the semester you will receive a letter grade for EE 653 and CR/NC for EE 690.*

*\*Students who pass EE 653 with a grade of C or better will receive CR in EE 690*

## Course Notes

The students will be given the numeric grade. We will create a Piazza page for the course. The slides of the instructor and student presentations will be uploaded to and managed by Piazza.

## Technological Proficiency and Hardware/Software Required

The lectures and student presentations will be in the classroom, but the projects may be done in USC supercomputer.

## Required Readings and Supplementary Materials

We will provide a list of papers and background slides.

### **Description and Assessment of Assignments**

The students will be assessed with the quality of the course project, written critiques/reviews, final report, and the presentations.

## Grading Breakdown

Assignment	Points
Discussion paper reviews	10
Discussion paper presentations	10
Practice projects	35
Final project proposal	15
Final project presentation	10
Final report	20
<b>TOTAL</b>	<b>100</b>

### Class Project

This class has both practice projects and a final project. For the practice projects, students should complete them individually. For each topic, we will prepare a partially completed project with clear

**Project description:** For each topic, we will prepare a partially completed project with clear instructions to execute, some examples that you can try on the software or simulators, detailed tasks for you to implement, and results should be generated and analyzed. The student should finish the given problems based on the provided environment individually. It is similar to programming assignments in other courses, but based on more complex/modern systems. For the final project, students can form a group (max 3) to conduct a more substantial project based on one of the practice projects. The proposal and presentation should include problem statement, motivation, solution outline, experiment plan, etc. The project presentation at the end of semester should explain implementation details and show results. Each group should submit a final report (8-pages, double column, including reference).

The final report is similar to a mini-research paper. You must have solid evaluation and analysis to support or reject your ideas. The outline of the report structure: 1) Introduction: problem, motivation, prior works, drawbacks, your ideas, summary of results; 2) Background and motivation: sufficient information to others to understand the problem, motivate your ideas; 3) Proposed ideas; 4) Implementation details; 5) Evaluation: setup/configuration, results, need to explain how the results can support/reject your proposed ideas; 6) Related work: that are not presented in background and motivation section; 7) Conclusion. We will ask each team to review the papers from all other teams, this will be affecting the final grades. Please be objective and careful: writing a too positive review for a mediocre paper may hurt your score; writing good reviews will help.

In the following, I will give two sample projects on security and graph processing, but we will have projects for other topics for students to choose from.

Hardware security sample project: We provide the instructions to install an architecture simulator, e.g., GEMS 5. The student will implement the architecture designs in one of the papers discussed in the hardware security part of the course in the simulator. Based on this implementation, the students should validate that the design can indeed defend the attacks due to speculation and also evaluate the execution time overhead due to the additional defense mechanisms. Bonus problem: how to further reduce the overhead of the defense mechanism?

Graph processing sample project: We provide the instructions to install a distributed graph processing framework (e.g., Gemini) in USC supercomputer. We will provide examples of several algorithms' implementation in the framework (e.g., SSSP, PageRank, BFS, WCC, etc.). We will explain an idea of reducing redundant communication and computation, the student should implement the basic idea, test and analyze the performance. Bonus problem: how to further optimize the performance?

**Project timeline:** proposal by 9/30, mid-term report by 10/30; final report by 12/1; project presentation will happen in the mid of Nov.

**Grading breakdown:** see the above course grade breakdown.

### **Assignment Rubrics**

N/A

### **Assignment Submission Policy**

Students are required to submit the critique of the paper presented a day before the lecture, all students are required to write the critique but one paper is only presented by one student. For the course project, students are required to submit the project proposal, codes, and report. Final course report is different from the project report and will be submitted separately. We will manage the submissions in Piazza.

### **Grading Timeline**

The feedback of project proposal will be given within 2 weeks after the submission. The students will get the feedback on the presentation in the class.

### **Additional Policies**

All students are expected to attend most of the classes, not only the ones when it is the student's turn to present.

## Course Schedule: A Weekly Breakdown

	Topics/Daily Activities	Readings and Homework	Deliverable/ Due Dates
<b>Week 1</b> 8/25 8/27	--Introduction --Basics of shared memory computer architecture (I)	Slides	
<b>Week 2</b> 9/1 9/3	--Basics of shared memory computer architecture (II) --Basics of shared memory computer architecture (III)	Slides	
<b>Week 3</b> 9/8 9/10	--Memory consistency model verification (I) --Memory consistency model verification (II)	Slides	
<b>Week 4</b> 9/15 9/17	--Memory consistency model verification (III) --Side-channel attack and defense (I)	Slides	<b>Practice project 1 (memory consistency verification) out (9/17)</b>
<b>Week 5</b> 9/22 9/24	--Side-channel attack and defense (II) --Side-channel attack and defense (III)	Slides	<b>Practice project 1 due (9/24) Practice project 2 (side-channel) out (9/26)</b>
<b>Week 6</b> 9/29 10/1	--Memory persistency --RDMA-enabled systems	Slides	<b>Practice project 2 due (10/3) Practice project 3 (RDMA) out (10/3)</b>
<b>Week 7</b> 10/6 10/8	--Graph processing system and architecture (I) --Graph processing system and architecture (II)	Slides	<b>Practice project 3 due (10/10) Practice project 4 (graph processing) out (10/10)</b>
<b>Week 8</b> 10/13	--Machine learning system and architecture (I) --Machine learning system and architecture (II)	Slides	<b>Practice project 4 due (10/17)</b>
<b>Week 9</b> 10/20 10/22	--Machine learning system and architecture (III) --Quantum computing (I)	Slides	<b>Practice project 5 (machine learning) out (10/22)</b>
<b>Week 10</b> 10/27 10/29	--Quantum computing (II) --GPU architecture and GPU-accelerated systems (I)	Slides	<b>Practice project 5 due (10/29) Practice project 6 (quantum computing) out (10/29)</b>
<b>Week 11</b>	-- GPU architecture and	3 papers TBA	<b>Practice project 6 due (11/5)</b>

11/3 11/5	GPU-accelerated systems (II) -- <b>Final project proposal presentation</b>		<b>Final project proposal due 11/8</b>
<b>Week 12</b> 11/10 11/12	-- GPU architecture and GPU-accelerated systems (III) -- Paper presentation (1)	papers TBA	<b>Practice project 7 (GPU system) out (11/10)</b>
<b>Week 13</b> 11/17 11/19	--Paper presentations (2) --Paper presentations (3)	papers TBA	<b>Practice project 7 (GPU system) due (11/17)</b>
<b>Week 14</b> 11/24	--Paper presentations (4)	papers TBA	
<b>Week 15</b> 12/1 12/3	--Project presentations (I) --Project presentations (II)		All students present the projects.
<b>FINAL</b>	<b>Final report</b>		<b>Final project proposal due 12/9</b>

## Statement on Academic Conduct and Support Systems

### Academic Conduct:

Plagiarism – presenting someone else’s ideas as your own, either verbatim or recast in your own words – is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in SCampus in Part B, Section 11, “Behavior Violating University Standards” [policy.usc.edu/scampus-part-b](http://policy.usc.edu/scampus-part-b). Other forms of academic dishonesty are equally unacceptable. See additional information in SCampus and university policies on scientific misconduct, [policy.usc.edu/scientific-misconduct](http://policy.usc.edu/scientific-misconduct).

### Support Systems:

*Student Health Counseling Services - (213) 740-7711 – 24/7 on call*  
[engemannshc.usc.edu/counseling](http://engemannshc.usc.edu/counseling)

Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention.

*National Suicide Prevention Lifeline - 1 (800) 273-8255 – 24/7 on call*  
[suicidepreventionlifeline.org](http://suicidepreventionlifeline.org)

Free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week.

*Relationship and Sexual Violence Prevention Services (RSVP) - (213) 740-4900 – 24/7 on call*  
[engemannshc.usc.edu/rsvp](http://engemannshc.usc.edu/rsvp)

Free and confidential therapy services, workshops, and training for situations related to gender-based harm.

*Office of Equity and Diversity (OED) | Title IX - (213) 740-5086*  
[equity.usc.edu](http://equity.usc.edu), [titleix.usc.edu](http://titleix.usc.edu)

Information about how to get help or help a survivor of harassment or discrimination, rights of protected classes, reporting options, and additional resources for students, faculty, staff, visitors, and applicants. The university prohibits discrimination or harassment based on the following protected characteristics: race,

color, national origin, ancestry, religion, sex, gender, gender identity, gender expression, sexual orientation, age, physical disability, medical condition, mental disability, marital status, pregnancy, veteran status, genetic information, and any other characteristic which may be specified in applicable laws and governmental regulations.

*Bias Assessment Response and Support - (213) 740-2421*

[studentaffairs.usc.edu/bias-assessment-response-support](http://studentaffairs.usc.edu/bias-assessment-response-support)

Avenue to report incidents of bias, hate crimes, and microaggressions for appropriate investigation and response.

*The Office of Disability Services and Programs - (213) 740-0776*

[dsp.usc.edu](http://dsp.usc.edu)

Support and accommodations for students with disabilities. Services include assistance in providing readers/notetakers/interpreters, special accommodations for test taking needs, assistance with architectural barriers, assistive technology, and support for individual needs.

*USC Support and Advocacy - (213) 821-4710*

[studentaffairs.usc.edu/ssa](http://studentaffairs.usc.edu/ssa)

Assists students and families in resolving complex personal, financial, and academic issues adversely affecting their success as a student.

*Diversity at USC - (213) 740-2101*

[diversity.usc.edu](http://diversity.usc.edu)

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*

[dps.usc.edu](http://dps.usc.edu), [emergency.usc.edu](http://emergency.usc.edu)

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) 442-120 – 24/7 on call*

[dps.usc.edu](http://dps.usc.edu)

Non-emergency assistance or information.