Electrical & Computer ENGINEERING

Carnegie Mellon

Course Syllabus

18344: *Computer Systems and the Hardware/Software Interface*
Fall 2023

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Course Description: This course covers the design and implementation of computer systems from the perspective of the hardware software interface. The purpose of this course is for students to understand the relationship between the operating system, software, and computer architecture. Students that complete the course will have learned operating system fundamentals, computer architecture fundamentals, compilation to hardware abstractions, and how software actually executes from the perspective of the hardware software/boundary. The course will focus especially on understanding the relationships between software and hardware, and how those relationships influence the design of a computer system's software and hardware. The course will convey these topics through a series of practical, implementation-oriented lab assignments.

Number of Units: 12

Pre-requisites: 18-/15-213 (minimum grade: D), 18-240 (minimum grade: D)

Graduate Area: Hardware

Class Lecture: T/Th 9:30-10:50 HH1107, F 10:00-10:50 HH1107

Required Textbook: None

Brief List of Topics Covered: Computer Architecture, Compilers, Operating Systems, Optimization, Computer Performance Analysis

Homework Projects: 5 Programming Labs, Weekly Written Assignments, and 2 exams

Grading Algorithm: 70% labs (evenly distributed), 10% written assignments, 20% exams

Course Calendar: See website

Course Canvas: https://canvas.cmu.edu/courses/35799

Course Website: https://course.ece.cmu.edu/~ece344/

Suggested Reading:

Computer Organization and Design
https://www.amazon.com/Computer-Organization-Design-RISC-V-Architecture/dp/0128203315/ref=sr_1_1?crid=3DLD00Q3CFEI5&dchild=1&keywords=computer+organization+and+design+risc-v+edition+2nd+edition&qid=1629409744&sprefix=computer+organization+and+design+ris%2Cstripbooks%2C197&sr=8-1

Education Objectives (Relationship of Course to Program Outcomes)

The ECE department is accredited by ABET to ensure the quality of your education. ABET defines 7 Educational Objectives that are fulfilled by the sum total of all the courses you take. The following list describes which objectives are fulfilled by this course and in what manner they are fulfilled. The objectives are numbered from "1" through "7" in the standard ABET parlance. Those objectives not fulfilled by this course have been omitted from the following list:

1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

2. Students will demonstrate this objective through the first-principles engineering and development of computer architecture simulators and performance models. They will conduct quantitative design space iteration and performance optimization using mathematical optimization criteria.

3. 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

4. Students will learn about optimizing computer architectures for energy cost, area cost, and time. The course will make connections between computer architecture design choices and global energy consumption and commoditized computing costs.

5. An ability to communicate effectively with a range of audiences

6. Students will be required to answer open-ended long-form questions in their lab writeups. These questions will require effectively justifying the design and optimization choices that they make in their labs and in their system building exercises. Students will work in pairs on labs, further requiring communication with one another on each of the labs.

7. 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 The course includes content related to compute energy costs, which have a global impact at scale. The course includes a discussion of design optimization and design choices directly connected to the global chip shortage and its underlying supply chain causes. The course connects high-level computing concepts and performance optimization through architectural layers to the silicon implementation of a microarchitecture, making these issues relevant across the system stack.

8. 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

9. Students will work in teams of two on the lab assignments in the class. These team assignments will require close teamwork and will require defining project goals, planning to execute a project, and meet these goals. The simulator development and performance optimization assignments do not start from any substantial base-code, requiring each team to collaborate to develop a set of

10. requirements, plan their “attack” and complete the work.

11. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions

12. The labs include several quantitative design space optimization exercises including carrying out a design space sweep using the SPEC benchmarks, constructing a Pareto Frontier, and using the result to select optimal designs. Students have the freedom to plan and carry out their own experiments to identify designs and justify in writing their design choices.

13. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

14. Students will be given lectures, flipped classroom recitations, in-class workshop time, and office hours. During these times, they will be given, through direct instructions, new information about the systems that they are building and optimizing. In order to complete the lab assignments, students will have to generalize beyond the specific examples given during in-person contacts and apply the ideas to novel design scenarios. For example, lecture introduces branch prediction using a simple, bimodal predictor and the lab requires building both a local and global predictor. Another example, lectures focus on benchmarking using simple example programs, while the labs require using other programs and other inputs that expose novel behavior of the systems under design.

ECE Academic Integrity Policy (http://www.ece.cmu.edu/programs-admissions/masters/academic-integrity.html**):**

The Department of Electrical and Computer Engineering adheres to the academic integrity policies set forth by Carnegie Mellon University and by the College of Engineering. ECE students should review fully and carefully Carnegie Mellon University's policies regarding Cheating and Plagiarism; Undergraduate Academic Discipline; and Graduate Academic Discipline. ECE graduate student should further review the Penalties for Graduate Student Academic Integrity Violations in CIT outlined in the CIT Policy on Graduate Student Academic Integrity Violations. In addition to the above university and college-level policies, it is ECE's policy that an ECE graduate student may not drop a course in which a disciplinary action is assessed or pending without the course instructor's explicit approval. Further, an ECE course instructor may set his/her own course-specific academic integrity policies that do not conflict with university and college-level policies; course-specific policies should be made available to the students in writing in the first week of class.

This policy applies, in all respects, to this course.

CMU Academic Integrity Policy (http://www.cmu.edu/academic-integrity/index.html**):**

In the midst of self-exploration, the high demands of a challenging academic environment can create situations where some students have difficulty exercising good judgment. Academic challenges can provide many opportunities for high standards to evolve if students actively reflect on these challenges and if the community supports discussions to aid in this process. It is the responsibility of the entire community to establish and maintain the integrity of our university.

This site is offered as a comprehensive and accessible resource compiling and organizing the multitude of information pertaining to academic integrity that is available from across the university. These pages include practical information concerning policies, protocols and best practices as well as articulations of the institutional values from which the policies and protocols grew. The Carnegie Mellon Code, while not formally an honor

code, serves as the foundation of these values and frames the expectations of our community with regard to personal integrity.

This policy applies, in all respects, to this course.

The Carnegie Mellon Code

Students at Carnegie Mellon, because they are members of an academic community dedicated to the achievement of excellence, are expected to meet the highest standards of personal, ethical and moral conduct possible.

These standards require personal integrity, a commitment to honesty without compromise, as well as truth without equivocation and a willingness to place the good of the community above the good of the self. Obligations once undertaken must be met, commitments kept.

As members of the Carnegie Mellon community, individuals are expected to uphold the standards of the community in addition to holding others accountable for said standards. It is rare that the life of a student in an academic community can be so private that it will not affect the community as a whole or that the above standards do not apply.

The discovery, advancement and communication of knowledge are not possible without a commitment to these standards. Creativity cannot exist without acknowledgment of the creativity of others. New knowledge cannot be developed without credit for prior knowledge. Without the ability to trust that these principles will be observed, an academic community cannot exist.

The commitment of its faculty, staff and students to these standards contributes to the high respect in which the Carnegie Mellon degree is held. Students must not destroy that respect by their failure to meet these standards. Students who cannot meet them should voluntarily withdraw from the university.

This policy applies, in all respects, to this course.

Carnegie Mellon University's Policy on Cheating
(http://www.cmu.edu/academic-integrity/cheating/index.html) states the following:

According to the University Policy on Academic Integrity, cheating "occurs when a student avails her/himself of an unfair or disallowed advantage which includes but is not limited to:

- Theft of or unauthorized access to an exam, answer key or other graded work from previous course offerings.
- Use of an alternate, stand-in or proxy during an examination.
- Copying from the examination or work of another person or source.
- Submission or use of falsified data.
- Using false statements to obtain additional time or other accommodation.
- Falsification of academic credentials."

This policy applies, in all respects, to this course.

Carnegie Mellon University's Policy on Plagiarism
(http://www.cmu.edu/academic-integrity/plagiarism/index.html) states the following:

According to the University Policy on Academic Integrity, plagiarism "is defined as the use of work or concepts contributed by other individuals without proper attribution or citation. Unique ideas or materials taken from another source for either written or oral use must be fully acknowledged in academic work to be graded. Examples of sources expected to be referenced include but are not limited to:

- Text, either written or spoken, quoted directly or paraphrased.
- Graphic elements.
- Passages of music, existing either as sound or as notation.
- Mathematical proofs.
- Scientific data.
- Concepts or material derived from the work, published or unpublished, of another person."

This policy applies, in all respects, to this course.

Carnegie Mellon University's Policy on Unauthorized Assistance
(http://www.cmu.edu/academic-integrity/collaboration/index.html) states the following:

According to the University Policy on Academic Integrity, unauthorized assistance "refers to the use of sources of support that have not been specifically authorized in this policy statement or by the course instructor(s) in the completion of academic work to be graded. Such sources of support may include but are not limited to advice or help provided by another individual, published or unpublished written sources, and electronic sources. Examples of unauthorized assistance include but are not limited to:

- Collaboration on any assignment beyond the standards authorized by this policy statement and the course instructor(s).
- Submission of work completed or edited in whole or in part by another person.
- Supplying or communicating unauthorized information or materials, including graded work and answer keys from previous course offerings, in any way to another student.
- Use of unauthorized information or materials, including graded work and answer keys from previous course offerings.
- Use of unauthorized devices.
- Submission for credit of previously completed graded work in a second course without first obtaining permission from the instructor(s) of the second course. In the case of concurrent courses, permission to submit the same work for credit in two courses must be obtained from the instructors of both courses."

This policy applies, in all respects, to this course.

Carnegie Mellon University's Policy on Research Misconduct (http://www.cmu.edu/academic-integrity/research/index.html) states the following:

According to the University Policy for Handling Alleged Misconduct in Research, "Carnegie Mellon University is responsible for the integrity of research conducted at the university. As a community of scholars, in which truth and integrity are fundamental, the university must establish procedures for the investigation of allegations of misconduct of research with due care to protect the rights of those accused, those making the allegations, and the university. Furthermore, federal regulations require the university to have explicit procedures for addressing incidents in which there are allegations of misconduct in research."

The policy goes on to note that "misconduct means:

- fabrication, falsification, plagiarism, or other serious deviation from accepted practices in proposing, carrying out, or reporting results from research;
- material failure to comply with Federal requirements for the protection of researchers, human subjects, or the public or for ensuring the welfare of laboratory animals; or
- failure to meet other material legal requirements governing research."

"To be deemed misconduct for the purposes of this policy, a 'material failure to comply with Federal requirements' or a 'failure to meet other material legal requirements' must be intentional or grossly negligent."

To become familiar with the expectations around the responsible conduct of research, please review the guidelines for Research Ethics published by the Office of Research Integrity and Compliance.

This policy applies, in all respects, to this course.

Take care of yourself. Do your best to maintain a healthy lifestyle this semester by eating well, exercising, avoiding drugs and alcohol, getting enough sleep and taking some time to relax. This will help you achieve your goals and cope with stress.

All of us benefit from support during times of struggle. You are not alone. There are many helpful resources available on campus and an important part of the college experience is learning how to ask for help. Asking for support sooner rather than later is often helpful.

If you or anyone you know experiences any academic stress, difficult life events, or feelings like anxiety or depression, we strongly encourage you to seek support. Counseling and Psychological Services (CaPS) is here to help: call 412-268-2922 and visit their website at http://www.cmu.edu/counseling/. Consider reaching out to a friend,

faculty or family member you trust for help getting connected to the support that can help.

If you have questions about this or your coursework, please let me know.

Every individual must be treated with respect. The ways we are diverse are many and are critical to excellence and an inclusive community. They include but are not limited to: race, color, national origin, sex, disability, age, sexual orientation, gender identity, religion, creed, ancestry, belief, veteran status, or genetic information. We at CMU, will work to promote diversity, equity and inclusion because it is just and necessary for innovation. Therefore, while we are imperfect, we will work inside and outside of our classrooms, to increase our commitment to build and sustain a community that embraces these values.

It is the responsibility of each of us to create a safer and more inclusive environment. Bias incidents, whether intentional or unintentional in their occurrence, contribute to creating an unwelcoming environment for individuals and groups at the university. If you experience or observe unfair or hostile treatment on the basis of identity, we encourage you to speak out for justice and support in the moment and and/or share your experience anonymously using the following resources:

Center for Student Diversity and Inclusion: csdi@andrew.cmu.edu, (412) 268-2150, www.cmu.edu/student-diversity

Report-It online anonymous reporting platform: www.reportit.net username**:** *tartans* password**:** *plaid*

All reports will be acknowledged, documented and a determination will be made regarding a course of action." All experiences shared will be used to transform the campus climate.