# ECEN 3593/CSCI 4593 Syllabus

**Computer Organization**

**Semester: Spring 2021**

|  |  |  |  |
| --- | --- | --- | --- |
| Instructor | Steve Sheafor | E-mail | [stephen.sheafor@colorado.edu](mailto:stephen.sheafor@colorado.edu) |
| Office | N/A (via Zoom only) |  |  |
| Instructor Office Hours  Instructing support team: | MWF 2:00 to 3:00 pm (via Zoom); via Slack; and by request  Kaiyuan Hou Office Hours TBD  Xavion Cowans Office Hours TBD |  |  |

## Overview

Rational:

It is estimated that 43+ billion embedded systems were shipped in 2017 while 262 million PCs and 11 million computer servers were shipped. All of these systems require both digital design and embedded firmware interfacing the domains of software and hardware.

Embedded Systems, digital design, are the electronic foundation in the following areas:

* Electronics
* Aerospace
* Robotics
* Office Automation
* Machine Learning
* Drones
* Mechatronics
* Process Controls
* Artificial Intelligence
* Scientific Research

Transferring the requirements of the above systems into digital designs and solutions will better the student’s position for internships, their capstone project, research, and a job upon graduation in this wide reaching and important segment of electrical engineering. Kiplinger Report rated Electrical Engineering as the most lucrative major in 2019 and Computer Engineering the third most lucrative.

### Lectures:

MWF 12:40pm-1:30pm, Remote (Zoom)

* The Lecture Zoom sessions are planned to be recorded and will be available for students to review.

### Zoom link:

* Lectures <https://cuboulder.zoom.us/j/96222932951>

### Anonymous student feedback link:

The below ECEE anonymous weblink is for students to provide feedback to the department on this course or any other issue that students would like to bring to the attention of the ECEE department. Student feedback is an important input into the department to improve the course instruction, the degree curriculum, and departmental environment.

<https://www.colorado.edu/ecee/electrical-computer-energy-engineering-feedback>

### Readings:

Course materials include papers, lecture slides, project guides, and other online materials.

* Required text book
  + “Computer Organization and Design RISC-V Edition” by Patterson and Hennessy, 2017, Morgan Kaufmann Publishers, ISBN: 978-0-12-812275-4

## Description and Content

The course material will convey both technical and industry requirements to enable proper engineering architectural decisions as well as implementation.

Topics include:

* + Instruction Set Architecture
  + Evaluating Performance
  + Caching subsystems
  + Memory Management
  + Memory Hierarchy
  + Virtual Memory
  + CPU control
  + Data path design
  + Performance via parallelism
  + System design
  + System Hierarchy
  + High Level Architectural Programming
    - CodAL

## Objectives and Expected Outcomes

1. Implement a complex project similar to those in commercial environments
2. Design the control path of a CPU or embedded system
3. Develop the data path of a processor or embedded system
4. Make the engineering tradeoffs between power, performance, and cost
5. Implement a system memory hierarchy
6. Maximize the efficiency of a caching subsystem
7. Understand the values and disadvantages of different memory technologies
8. Examine the tradeoffs in a Microcontroller (MCU) system design

**At the end of this course, students will be able to:**

* Model a processor, memory hierarchy, and subsystems in an integrated development environment
  + CodAL high level architectural language
* Implement a CPU control block
* Develop a CPU data path
* Optimize a L1 cache based on end application algorithm and space requirements
* Implement a system level memory hierarchy
* Design and debug a computer architecture cycle accurate processor model
* Make the proper engineering decisions between energy, performance, and cost

## Requirements and Format

### Prerequisites:

* ECEN 2350 Logic Design
* ECEN 3350 Programming of Digital Systems (or ECEN 2120 Computer as Components, or CSCI 2400)
* Programming in C (or C++)

### Attendance and Participation:

Attendance in the Zoom lectures is expected. If you get confused or start to fall behind, attend office hours or schedule an appointment with the professor as soon as possible. If you must miss a lecture, please let the instructor know in advance, if possible.

Students are expected to participate in class discussions of course topics. In addition, students are expected to assist other students in understanding course material and assignments.

Students are expected to complete assignments on time.

### Homework:

Homework will be assigned that will cover the material that has been presented in lectures or reading. The assignments will be submitted via Canvas.

There will be 5 Homework assignments, administered as Canvas Quizzes. Late submissions will be accepted for partial credit and approval. No homework assignments will be dropped.

Homework assignments are provided to reinforce or expand on topics discussed in lecture. They may touch on topics that will be covered in exams. Homework is to be done individually unless explicitly specified by the professor.

Any questions regarding the grading of a homework problem must be raised within the first week of its return.

### Course Project:

The Course Project will implement and simulate a RISC-V processor using a commercial tool from Codasip. The project will include 12 Phases, with a preliminary structure described below (subject to change). The project is expected to require 5-15 hours per week outside class. All Phases must be completed correctly, and the score for the phase will be a function of the time it is submitted correctly, much like an Engineering project in industry.  The Project must be completed independently by each student.

* Phase 1 – Codasip environment
* Phase 2 – Instruction Accurate Model of the RISC-V architecture
* Phase 3 – Verification Test development
* Phase 4 – Schematic for a Cycle Accurate model of a RISC-V subset (three instructions)
* Phase 5 – Codasip implementation of the RISC-V subset
* Phase 6 – Add forwarding to the cycle accurate model and schematic
* Phase 7 – Add remaining ALU/branch/jump instructions to the cycle accurate model and schematics
* Phase 8 – Add memory operations to the cycle accurate model and schematics
* Phase 9 – Add new instructions to the cycle accurate model and schematics
* Phase 10 – Add a level 1 cache to the cycle accurate model and schematics
* Phase 11 – Implement some performance enhancements
* Phase 12 – Project Final Report

### Assessments:

There will be a mid-term and final examination.

The mid-term and final examination are to be done using individual effort alone.

## Evaluation and Grading Procedures

The course grade will be based on in-class participation, homework assignments, quizzes, course project, and 2 exams. The grade proportions are as follows:

* Homework 15%
* Project 50%
* Mid-Term 10%
* Final Exam: 25%

Grading will be based on total points accumulated from each of these areas. Assignment of grades will be based on an absolute scale with the minimum grade below to earn for that grade.

A : 93%

A-: 90%

B+: 87%

B : 83%

B-: 80%

C+: 77%

C : 73%

C-: 70%

D+: 67%

D : 65%

Fail: < 65%

Upon the professor’s discretion, assignment of grades can be based on both absolute and relative standards if it would be helpful to the overall class. To receive an A grade in this assignment of grades option, a student must show mastery of the material and need to acquire more than 90% of the points possible. A student earning less than 65% of the points possible will be given a failing grade. In between these marks, grades will be assigned as defined above.

**Make-up Exam Policy**: No make-up exams are given except for medical or other similar hardships where advanced arrangements are made with the instructor; or in case of non-selective medical emergencies with physician’s note or documentation. Otherwise, failure to take the exam at the scheduled time will result in a zero grade in the exam.

### Attendance and Participation:

All lectures will be presented via Zoom. Students are expected to keep up with the course material. If you get confused or start to fall behind, attend office hours or schedule an appointment with the professor or instruction support as soon as possible. It is the student’s responsibility to reach out to the instructing staff if they get behind or for help in understanding the course material. If you must miss a lecture, please let the instructor know in advance, if possible. Being in lecture will help you understand the course material as well as optimize the instructing team’s support of the students.

Students are expected to participate in class discussions of course topics. In addition, students are expected to assist other students in understanding course material and assignments. Teaching others is one of the best ways of learning.

Students are expected to complete assignments on time.

Expectations for Out-of-Class Study:

Beyond the time required to attend each class meeting, students enrolled in this course should expect to spend at least an additional 10-20 hours per week of their own time in course-related activities, including reading required materials, working on the class project, preparing for exams, quizzes, etc.

### Assessments:

There will be a mid-term examination, administered via Canvas during class time. The mid-term must be completed by the scheduled date and time. No late submission allowed for the mid-term.

The quizzes and mid-term are to be done using individual effort alone and adhere to the CU Honor Code.

### Participation:

Before most lectures and lab sessions, there will be one to four short videos average 4 to 13 minutes in length. Each video will have a question that must be answered. These videos are pertinent to the day’s lecture and lab which will help prepare you for class and the assignments. Completing these videos will aggregate into the participation grade of this course.

The participation videos must be watched and successfully answered the in-video course question by the due date and time to receive credit.

## Policies

# Classroom Behavior:

Both students and faculty are responsible for maintaining an appropriate learning environment in all instructional settings, whether in person, remote or online. Those who fail to adhere to such behavioral standards may be subject to discipline. Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, veteran status, political affiliation or political philosophy. For more information, see the policies on [classroom behavior](http://www.colorado.edu/policies/student-classroom-and-course-related-behavior) and the [Student Code of Conduct](https://www.colorado.edu/sccr/sites/default/files/attached-files/2020-2021_student_code_of_conduct_0.pdf).

# Requirements for COVID-19:

See the policies on [COVID-19 Health and Safety](https://www.colorado.edu/policies/covid-19-health-and-safety-policy) and [classroom behavior](http://www.colorado.edu/policies/student-classroom-and-course-related-behavior) and the [Student Code of Conduct](http://www.colorado.edu/osccr/). If you require accommodation because a disability prevents you from fulfilling these safety measures, please see the “Accommodation for Disabilities” statement on this syllabus.

All students who are new to campus must complete the [COVID-19 Student Health and Expectations Course](https://www.colorado.edu/protect-our-herd/how#anchor1). Before coming to campus each day, all students are required to complete the [Buff Pass](https://pass.colorado.edu/login).

Students who have tested positive for COVID-19, have symptoms of COVID-19, or have had close contact with someone who has tested positive for or had symptoms of COVID-19 must stay home. In this class, if you are sick or quarantined**,** please follow the same procedures as if you cannot attend class due to another illness. Students are expected to keep up with the course material. If you get confused or start to fall behind, attend office hours or schedule an appointment with the professor or instruction support as soon as possible. It is the student’s responsibility to reach out to the instructing staff if they get behind or for help in understanding the course material. If you must miss a lecture, please let the instructor know in advance, if possible.

# Accommodation for Disabilities:

If you qualify for accommodations because of a disability, please submit your accommodation letter from Disability Services to your faculty member in a timely manner so that your needs can be addressed.  Disability Services determines accommodations based on documented disabilities in the academic environment.  Information on requesting accommodations is located on the [Disability Services website](https://www.colorado.edu/disabilityservices/). Contact Disability Services at 303-492-8671 or [dsinfo@colorado.edu](mailto:dsinfo@colorado.edu) for further assistance.  If you have a temporary medical condition, see [Temporary Medical Conditions](http://www.colorado.edu/disabilityservices/students/temporary-medical-conditions) on the Disability Services website.

# Preferred Student Names and Pronouns:

CU Boulder recognizes that students' legal information doesn't always align with how they identify. Students may update their preferred names and pronouns via the student portal; those preferred names and pronouns are listed on instructors' class rosters. In the absence of such updates, the name that appears on the class roster is the student's legal name.

# Honor Code:

All students enrolled in a University of Colorado Boulder course are responsible for knowing and adhering to the Honor Code. Violations of the policy may include: plagiarism, cheating, fabrication, lying, bribery, threat, unauthorized access to academic materials, clicker fraud, submitting the same or similar work in more than one course without permission from all course instructors involved, and aiding academic dishonesty. All incidents of academic misconduct will be reported to the Honor Code ([honor@colorado.edu](mailto:honor@colorado.edu)); 303-492-5550). Students found responsible for violating the academic integrity policy will be subject to nonacademic sanctions from the Honor Code as well as academic sanctions from the faculty member. Additional information regarding the Honor Code academic integrity policy can be found at the [Honor Code Office website](https://www.colorado.edu/osccr/honor-code).

# Sexual Misconduct, Discrimination, Harassment and/or Related Retaliation:

The University of Colorado Boulder (CU Boulder) is committed to fostering an inclusive and welcoming learning, working, and living environment. CU Boulder will not tolerate acts of sexual misconduct (harassment, exploitation, and assault), intimate partner violence (dating or domestic violence), stalking, or protected-class discrimination or harassment by members of our community. Individuals who believe they have been subject to misconduct or retaliatory actions for reporting a concern should contact the Office of Institutional Equity and Compliance (OIEC) at 303-492-2127 or [cureport@colorado.edu](mailto:cureport@colorado.edu). Information about the OIEC, university policies, [anonymous reporting](https://cuboulder.qualtrics.com/jfe/form/SV_0PnqVK4kkIJIZnf), and the campus resources can be found on the [OIEC website](http://www.colorado.edu/institutionalequity/).

Please know that faculty and graduate instructors have a responsibility to inform OIEC when made aware of incidents of sexual misconduct, dating and domestic violence, stalking, discrimination, harassment and/or related retaliation, to ensure that individuals impacted receive information about options for reporting and support resources.

# Religious Holidays:

Campus policy regarding religious observances requires that faculty make every effort to deal reasonably and fairly with all students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance. In this class, please contact the instructor to make accommodations.

See the [campus policy regarding religious observances](http://www.colorado.edu/policies/observance-religious-holidays-and-absences-classes-andor-exams) for full details.

## Lecture Topics

Introduction to Computer Architecture

RISC-V Assembly Language and Instruction Set

CPU Components

Single Cycle Processor Analysis

5-Stage RISC-V Pipeline Implementation

Interrupts and Exceptions

Processor Performance Measures

Memory Types and Hierarchy

Direct and Multi-level Cache Implementation

Virtual Machines and Virtual Memory

Advanced Processor Architectures

## Rough Schedule

Week 1 (1/15) – Introduction to Computer Architecture

Week 2 (1/20-22) – RISC-V ISA – Holiday 1/18

Week 3 (1/25-29) – RISC-V ISA (Phase 1 due)

Week 4 (2/1-5) – RISC-V Machine Language (Phase 2 due) (Homework #1 due)

Week 5 (2/8-12) – Verification (Phase 3 due)

Week 6 (2/15-19) – Pipelining (Phase 4 due) (Homework #2 due) – Wellness Day 2/17

Week 7 (2/22-26) – Forwarding (Phase 5 due)

Week 8 (3/1-5) – Hazards (Phase 6 due)

Week 9 (3/8-12) – RISC vs. CISC

Week 10 (3/15-9) –Midterm Review, Midterm (Phase 7 due)

Week 11 (3/22-26) – Processor Performance (Pause Week)

Week 12 (3/29 – 4/2) – Memory Hierarchy (Homework #4 due) (Phase 8 due)

Week 13 (4/5-9) – Caching (Phase 9 due)

Week 14 (4/12-16) – Caching (Phase 10 due)

Week 15 (4/19-23) – Cache Performance, VM (Homework #5 due)

Week 16 (4/27-29) – TLBs (Phases 11 and 12 due)

## Examinations

Mid-Term: Wednesday, March 17, via Canvas

Final: TBD, via Canvas