Course: CPE 380-001 / CS 380-001

Title: Computer Organization and Design

Term: Spring 2025
Credit hours: 3
Meeting days/time/location: Tuesday & Thursday, 2:00-3:15PM,
323 Robotics & Manufacturing Building

Instructor Information

Name: Professor Henry (Hank) Dietz
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Office phone: (859) 257 4701
Office hours: Schedule & live office camera at http://aggregate.org/hankd
Preferred method of communication: email

Course Description

Official catalog version is: Hardware and software organization of a typical computer; machine language and assembler language programming, interfacing peripheral devices, and input-output programming; real-time computer applications, laboratory included.

A more detailed revision is: Hardware and software organization of computer systems; introduction to computer hardware architecture, performance evaluation; machine and assembly language and compilation, arithmetic, pipelining, memory hierarchy, interface to peripheral devices, basic OS control, and parallel processing. Verilog and simulators are used.

Course Prerequisites

Engineering standing, CS 215 and EE/CPE 282 or EE 280.

Required Materials

Various materials for the course will be provided, primarily via canvas or the course website,http://aggregate.org/CPE380. The textbook is ***Computer Organization & Design, The Hardware/Software Interface, Fifth Edition: The Hardware/Software Interface***, Patterson & Hennessy, Morgan Kaufmann publisher, 2013 – however, any MIPS-oriented edition from the 2nd onward is usable. Although the course approximately follows the content of this text, it is not directly used, and is thus ***optional***.

Associated Expenses

Rather than requiring software to be installed on personal computers or in-person use physical lab facilities, Verilog and simulation software are provided in forms that allow work to be done using a web browser interface that gives access to software running on machines in 108 Marksbury (Dietz's research lab). Students are expected to have personal systems able to use this web browser interface. You are warned that, at this writing, the course URLs are **`http:`** sites; unfortunately, the latest Chrome browser by default automatically changes **`http:`** to **`https:`** unless you have added the site to a safe exceptions list. Students also need access to a computer that can pack their project files into either a **`tar`** or **`zip`** archive containing the files for submission.

Activities Outside of Regular Class Meetings

Generally, there will be an *optional* class meeting to tour a supercomputing facility, typically 108A Marksbury.

If any regular class meeting is not held in person for any reason, the material *usually* will be made available online via a recorded presentation, perhaps with the option of live Zoom attendance, rather than by scheduling in-person make-up sessions.

Skill and Technology Requirements

Students are expected to have some C/C++ programming experience and exposure to digital logic design, and they are generally expected to be computer literate. Students need access to a system that allows them to use various WWW form interfaces provided for the projects and other course materials. There is also portable, open-source, software provided that they can install and use on their own computers as alternatives to some of the WWW form interfaces.

For technical assistance, contact ITS Customer Services 24/7 at 859-218-HELP (4357) for urgent needs. For non-urgent matters, visit the ITS web page at https://its.uky.edu/ or submit a: Customer Services Assistance Request form.

Student Learning Outcomes

After completing this course, a student will be able to:

- Describe the levels of software and hardware in a computer system and the meaning and purpose of an Instruction Set Architecture (ISA)
- Analyze, evaluate, and compare the performance of computers
- Describe how specific high-level-language program constructs are implemented in assembly and machine language for various computers

- Write and run programs on a simulator for a designed computer
- Describe how computers perform integer and floating-point (IEEE 754 format) addition, subtraction, multiplication, and division/reciprocal
- Organize, and design at the gate and register level, the datapath, control, and memory of a simple computer
- Describe pipelining, speculation, and various other modern architectural features
- Describe how Verilog HDL implementations of various computer subsystems work
- Understand the historical and continuing evolution of computing systems and the effects of technological changes on computer design

Regular and Substantive Interaction / Academic Engagement

Regular and substantive interaction (RSI) mechanisms will be used to ensure academic engagement between students and course staff if circumstances dictate that portions of this nominally in-person course must be taught using online mechanisms.

Course Details

Tentative Course Schedule

The internal schedule of this course was significantly restructured in Fall 2024 with the main goal of pushing the projects as early as possible. Spring 2025 will use a similar schedule, thus allowing more time for students to work on the last project without having it collide with end-of-semester assignments for their other classes.

1/14	Introduction
1/16	Verilog
1/21	“”
1/23	*Individual Verilog project assignment*
1/28	Multi-cycle computer system design
1/30	“”
2/ 4	“” and first team project
2/ 6	Machine & assembly languages, compiler/OS overview
2/11	“”
2/13	“” and first individual homework assignment
2/18	Single-cycle machine design
2/20	“” and second team project
2/25	Integer & floating point arithmetic, with Verilog
2/27	“”
3/ 4	“” and second individual homework assignment
3/11	Pipelined machine design
3/13	“”

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3/18     No class; Spring break
3/20     No class; Spring break
3/25     Pipelined machine design and third team project
3/27     Pipelined machine design / project continued
4/ 1     Memory hierarchy and I/O interfacing
4/ 3     “”
4/ 8     “”
4/10     “” and third individual homework assignment
4/15     Parallel processing and performance
4/17     “”
4/22     this day reserved for schedule slippage
4/24     this day reserved for schedule slippage
4/29     Review for final exam (last class; no assignments)
5/ 1     No class; Reading Day
5/ 6     Final exam in person from 1:00–3:00PM
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The two dates shown in orange, 2/4 and 2/6, it is expected that Professor Dietz will be presenting research work at the Electronic Imaging 2025 (EI25) conference. Thus, these lectures might be conducted via Zoom rather than in person or the schedule might be shifted-back to allow that content to be presented in person and up to two other lectures presented as recordings. Any such variations in the schedule will be discussed in class and formally announced via Canvas.

Although this internal restructuring worked very well in Fall 2024, we are still tweaking the presentation and minor adjustments to the schedule are likely depending on how this group of students handles specific portions of the material. Such adjustments are most likely to involve slightly extending or contracting the time for individual topics. More significant changes may be required if the University of Kentucky has a closure due to weather or other circumstances beyond our control interfere with the normal operation of the course. Students would be notified of any significant changes to schedule or content via Canvas and/or the course web site: http://aggregate.org/CPE380/

Course Activities, Assignments, Exams

This semester, course activities are focused on projects and homework, with only one exam: the in-person final exam.

This course has been increasingly emphasizing the Verilog HDL (hardware description language), which is done in part by **four Verilog projects**. This emphasis is intended to ensure that you will be well-prepared for job interview questions involving computer architecture and HDLs. However, the main point of this course is to give you a complete view of how all the hardware and software elements of a computer system come together, with no mysterious "black boxes"

leaving gaps in your understanding. Throughout the course, you will see detailed implementations of key components in Verilog. In other words, the emphasis is on *reading* and *understanding* Verilog code rather than authoring lots of Verilog code. The first project will have you individually write and test a Verilog implementation of a simple combinatorial logic arithmetic function. The remaining three Verilog projects each will be done in teams of 3-4 students, and will involve making relatively minor changes to Verilog code implementing processors for variations on the basic 32-bit MIPS instruction set. All projects will be submitted via Canvas.

The **three homework assignments** planned are all to be completed individually. The first will be about instruction sets, with emphasis on MIPS assembly language. The second will be about integer and floating-point arithmetic. The last homework will be about memory systems and I/O.

The only exam in the course will be the **final exam**, which will be administered in person in the timeslot designated by the registrar: **1:00-3:00PM Tuesday, May 6, 2025**. The final exam will be comprehensive and may include any material covered as described in the review session – even topics that were not a component of any project or homework, such as material about parallel processing and performance analysis.

The expected weighting for computing your course grade is:

15% Individual first Verilog project
10% First team project (multi-cycle design)
10% First homework (instruction sets and MIPS)
10% Second team project (single-cycle design)
10% Second homework (arithmetic)
10% Third team project (pipelined design)
10% Third homework (memories)
25% Final exam

Although the above weightings worked reasonably well in Fall 2024, grades on the projects and homeworks tend to be high, so some students apparently reasoned that they could ignore the last portion of course material and still do well enough on the final exam to get their desired grade. Rather than making the final exam count for a higher percentage, this semester we may impose the additional rule that ***the letter grade for the course cannot be more than one***

letter grade above the letter grade earned on the final exam. For example, getting a perfect score on everything but the final exam and a high D on the final could numerically average to a low A, but the new rule would result in a letter grade of C for the course.

We reserve the right to tweak the above weightings, or to apply modest adjustment to grades, if there are problems with a particular component for the class in general. For example, if a flawed project specification made some part more difficult to accomplish than we had intended, we might give all teams full credit for that part.

Although there is no grade for class attendance or participation per se, it is expected that all students will regularly attend class in person unless there is a good reason not to (illness, travel to represent a UK team or research, etc.). We intend to record class lectures, but might or might not make the recordings available to all students in the class; recordings are not intended to serve as a substitute for regular attendance of class unless you have a valid reasons for being unable to attend. Participation in team projects is more directly involved in your grade via peer evaluations that may be used to apply an offset to an overall grade for the team. Failure to appropriately contribute to a team project may result in a corresponding reduction in an individual's grade for that team project. In general, we will not apply that reduction to an individual's project score unless their lack of contribution is extreme or repeated across two or more projects.

Grading Scale

Nominally, the grading scale is:

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90 ≤ 100%   : A
80 <  90%   : B
70 <  80%   : C
60 <  70%   : D
   <  60%   : E
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Adjustments may be made to scores of specific graded materials as described in the previous section. Typically, any such adjustments are in the student's favor except for penalties imposed for failure to contribute to team projects.

Midterm Grades

For undergraduates, midterm grades will be posted in myUK by the deadline published in the Academic Calendar. (https://registrar.uky.edu/academic-

calendars/university). Note that midterm grades will be based on the work completed and graded up to that point, which does not have the same ratio between projects, homework, and final exam as the course overall. In order to make your midterm grade more predictive of your overall final grade for the course, the midterm grade may be computed by a weighting formula somewhat different from those given in the previous section.

Attendance Policy/Acceptable Documentation

Although this course does not give grades for attendance nor class participation, students are expected to regularly attend class, and there may be class time allocated for students to coordinate their work on project teams, which would be missed by those not attending in person. The University of Kentucky generally expects appropriate documentation for an excused absence: e.g. a letter from a healthcare provider. In this course, we will generally be more flexible and *notification beforehand via email* to hankd@engr.uky.edu, with "CPE380" in the subject line, will be accepted as a valid reason for an excused absence. Students missing class meetings generally are responsible for catching up on the material missed even if the absence is excused, although excused absences may be taken into account, for example, by extending assignment or project deadlines. Class presentation recordings generally will be made available to help those with an excused absence, but not necessarily to students with unexplained absences.

As described earlier, lack of appropriate participation in a project team can directly reduce your grade from the grade assigned for the team overall.

General university guidelines relating to attendance are summarized at: https://provost.uky.edu/proposals/guidance-course-proposals/standard-academic-policy-statements

Assignment Policies

Assignment Submissions

All assignments will be collected electronically using software to be discussed in class and via Canvas. Projects require submitting more than one file, in which case students are expected to submit either a **`tar`** or **`zip`** archive containing the files.

Returning Assignments to Students

Graded homework and projects generally will be available via Canvas, but not necessarily immediately after grading. Posting may be delayed somewhat to allow

students with excused absences time to submit. All grades will be posted before the class period in which we will review everything for the final exam. Generally, the course TA is the primary contact for questions about graded materials. The graded final exams are kept on file and can be accessed by meeting with the course instructor.

Late Assignments

Online assignments are expected to be submitted no later than the specified deadline, but the server will accept late submissions. Except in cases of excused absences, it is entirely at the discretion of the instructor as to how much, if any, credit will be awarded for a late submission. Late assignments that are submitted after the assignment answers are posted or discussed in class generally are given zero credit, but ones submitted before any answers have been made available are more likely to be given some credit. It is also useful to note that most assignments can be submitted multiple times without penalty, in which case only the last one submitted before the deadline is considered for grading.

Assignments Due during Prep Week

No assignments will be due during Prep or Reading Days. However, it is possible that make-ups for excused absences, review sessions, or optional activities (such as a lab tour) would be scheduled during that time.

Academic Policy Statements

A full list of UK academic policies is available at: https://provost.uky.edu/proposals/guidance-course-proposals/standard-academic-policy-statements .

Academic Offenses (Cheating, Plagiarism, and Falsification or Misuse of Academic Records)

Whatever is stated in the following document applies: https://provost.uky.edu/proposals/guidance-course-proposals/academic-offenses

In the classroom, students should not take any actions that would disrupt the classroom environment (e.g., talking on a cell phone during class). In general, students are expected to behave in a respectful way towards their fellow students, the TA, and the instructor. Failure to follow University of Kentucky guidelines involving appropriate precautions against the spread of COVID-19 or other communicable diseases will be treated as a very serious offense and dealt with as specified by the University.

Students are expected to generally behave ethically, and violations will be treated as serious offenses. Altering graded exams and then submitting them for regrade is obviously unethical, but you do not need to be trying to enhance your grade in order for your behavior to be inappropriate. For example, attempts to break into computer accounts associated with this course or to falsely identify yourself are serious ethical violations even if there was no intent to "cheat" per se.

There are lots of study materials for this course, including old exams, widely available; using them as study aids is perfectly acceptable, but be warned that an apparent reuse of an old question usually has the question slightly reworded so that the old answer is not correct. Although students are encouraged to discuss course material with one another, everything you submit must be entirely your own original work. Similarly, for in-class exams that specify no textbooks, no calculators, etc., use of the banned resources is a serious offense. For assignments submitted online, the general rule is that referencing your notes, looking at online materials on the course website, etc. is OK. Submitting the work of another person, or of an AI tool, as your own original work is not OK.

Resources

There is a wide range of resources available to help you with this course, the most relevant of which will be cited on either Canvas or the course website. Arguably the most important resources are the instructor, TA, and your classmates – and you are strongly encouraged to interact.

The University of Kentucky and the Pigman College of Engineering offer a wide range of student support services. Below are links to a few good starting points for finding the support you may need for success in your studies:

- Center for Support and Intervention: https://studentsuccess.uky.edu/center-support-and-intervention/resources/student-resources
- UK Student Success services page: https://studentsuccess.uky.edu/find-services
- James and Gay Hardymon Center for Student Success https://www.engr.uky.edu/students/student-success
- Disability Resource Center: https://studentsuccess.uky.edu/disability-resource-center
- Tutoring and Coaching: https://studentsuccess.uky.edu/academicresources and https://www.engr.uky.edu/students/student-success/engineering-tutoring

Course Recordings

The University of Kentucky Code of Student Conduct defines Invasion of Privacy as using electronic or other devices to make a photographic, audio, or video record of any person without their prior knowledge or consent when such a recording is likely to cause injury or distress.

Meetings of this course may be recorded. All video and audio recordings of lecturers and class meetings, provided by the instructors, are for educational use by students in this class only. They are available only as linked through Canvas for this course and are not to be copied, shared, or redistributed.

As addressed in the Code of Student Conduct, students are expected to follow appropriate university policies and maintain the security of linkblue accounts used to access recorded class materials. Recordings may not be reproduced, shared with those not enrolled in the class, or uploaded to other online environments.

If the instructor or a University of Kentucky office plans any other uses for the recordings, beyond this class, students identifiable in the recordings will be notified to request consent prior to such use. In anticipation of such cases, students may be asked to complete an “authorization of use” form by a faculty member.

Video and audio recordings by students are not permitted during the class unless the student has received prior permission from the instructor. Any sharing, distribution, and or uploading of these recordings outside of the parameters of the class is prohibited. Students with specific recording accommodations approved by the Disability Resource Center should present their official documentation to the instructor.

Course Copyright

All original instructor-provided content for this course, which may include handouts, assignments, and lectures, is the intellectual property of the instructor. Students enrolled in the course this academic term may use the original instructor-provided content for their learning and completion of course requirements this term, but such content must not be reproduced or sold. Students enrolled in the course this academic term are hereby granted permission to use original instructor-provided content for reasonable educational and professional purposes extending beyond this course and term, such as studying for a comprehensive or qualifying examination in a degree program, preparing for a professional or certification examination, or to assist in fulfilling responsibilities at a job or

internship; other uses of original instructor-provided content require written permission from the instructor in advance.

Policy on Artificial Intelligence

AI tools, such as ChatGPT, may be used in limited ways, but an AI-generated response used directly is not considered to be your own work. It is also noteworthy that although LLMs regularly produce coherent-looking answers to homework questions and even can give justifications for their answers, for CPE380 we have found that the answers given by ChatGPT are factually wrong about 40% of the time. This leads to the disturbing observation that students assisted by ChatGPT tend to answer more questions incorrectly than they would on their own!

Don’t let an AI convince you to give a wrong answer. Similarly, many WWW searches find unvetted and incorrect answers to questions posed in this course. Thus, for any AI and search tools you employ to help you create your original work answers, be sure to follow the old rule of “trust, but verify” for factual content. The course materials themselves are by far the most trustworthy sources for answers to questions.

This syllabus was last updated January 13, 2025 by H. Dietz.

Appendix: Classroom Emergency Preparedness and Response

Nothing is more important than the safety and well-being of our campus community. While the University of Kentucky Police Department continues to enhance campus safety measures, it's important to remember that everyone has a responsibility in keeping our community safe. To find more information visit Emergency Response Guide | University of Kentucky Police Department (uky.edu)

Emergency Reporting & Action

Reporting

If there is an emergency, **DIAL 911.** To report suspicious activity or non-emergency situations, call the UK Police Department at 859-257-8573 or #UKPD from any mobile phone.

If an emergency occurs in a classroom or residence hall with a red emergency button, press to quickly notify UKPD. Emergency responders will immediately be dispatched to your location.

Action

During an emergency, you are responsible for your own safety.

If an emergency occurs during class, your instructor will provide further direction based on university and department emergency plans.

Warning Systems

UK Alert

The university provides emergency notifications through UK Alert, which sends messages via email, text message, phone calls, building alarm systems, digital signage, social media and outdoor sirens. If you receive a UK Alert message during class, notify your instructor and classmates immediately.

For more information, visit https://police.uky.edu/get-notified/uk-alert.

LiveSafe

The university provides additional emergency preparedness information and safety tools through LiveSafe, a free mobile app for iOS and Android. You can report suspicious activity, message with UK Police and virtually escort your friends through the SafeWalk tool.

For more information, visit https://police.uky.edu/safety/livesafe.

Blue Emergency Towers

Blue Emergency Notification Towers are strategically placed at over 50 locations across campus to provide outdoor alert tones and broadcast emergency messages with loud speakers. Each tower also features an emergency push button speaker phone that reaches UKPD and a camera mounted above the tower.

For more information, visit https://police.uky.edu/safety/blue-emergency-towers.

Medical Emergency

If there is a medical emergency, dial 911 and do not act outside the scope of your medical training. After dialing 911, inform your instructor of the situation.

Appendix: Classroom Emergency Preparedness and Response

Evacuation

It is required to evacuate for a fire alarm or when university officials order us to do so. Evacuation routes are marked with illuminated exit signs throughout the building. Avoid using elevators during any evacuation.

Emergency Sheltering

Storm Sheltering

Report to the recommended shelter locations. Recommended shelter locations are marked throughout the building.

If shelter locations are unavailable, protect yourself from lightning and flying debris by moving to an interior room or hallway on the building's lowest level. Avoid outside doors and windows and get under a sturdy table and use your arms to protect your head and neck.

Shelter-in-Place

If a shelter-in-place order is issued, you will learn about this through UK Alert, the university's emergency notification system.
If you are inside, stay where you are unless the building you are in is affected. If the building is affected, and the fire alarm has been activated or directed by law enforcement, you should evacuate. If you are outdoors, proceed into the closest UK building or follow instructions from emergency personnel or alerts.

It is ideal to shelter-in-place in an interior room with the fewest or no windows and no doors to the outside if possible. Shut all windows and close exterior doors.

If a hazardous chemical release occurs outside the building, follow these same procedures.

Active Aggressor

In a situation where an aggressor is trying to attack you or others, follow three steps:

1. ***Run*** - Attempt to get away from the attacker.
2. ***Hide*** - If you cannot run, barricade yourself in a safe place. Turn your phone to silent and dim your

brightness. If possible, use the LiveSafe App to message UK Police and alert them to your location. If you don't have the app, dial 911. If you cannot speak, leave the line open and allow the dispatcher to listen.

3. ***Fight*** - If you cannot run or hide, do whatever you need to do to stop the attacker.

UK Police will communicate additional information through the UK Alert system during an active aggressor situation. Every UKY email automatically receives UK Alerts. You can also sign up in myUK to receive alerts via text and phone call.