# ECE 3445 Computer Architecture

**Fall 2020**

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| **Professors:** | Lecture: | Dr. Xiaofang Maggie Wang (xwang@villanova.edu); Office: Tolentine 431; Phone: 610-519-3830 |
| | Lab: | Dr. Ed Hepler (hepler@vlsi-concepts.com) for Sections 001 & 002;<br>Dr. Kyle Juretus (kyle.juretus@villanova.edu) for Section 003 |
| **TA:** | Stephen Donchez; sdonchez@villanova.edu | |
| **Credits:** | 4 | |
| **Lectures:** | TR, 9:35 am to 10:50 am & 12:45 pm to 2 pm; Live through Zoom | |
| **Lab time:** | **Friday**, 09:00 am to 10:50 am (001) & 12:40 pm to 02:30 pm (002); **Monday**: 06:00 pm to 07:50 pm (003) | |
| **Office Hours:** | Wang: TR 2:30 – 3:30 pm, or by appointment, through Zoom. | |
| **Course Web:** | Lecture slides and videos, lab assignments, homework assignments, etc. will be posted in the Blackboard. Students are required to check the blackboard regularly. Any future policy change will be made available by emails of in the blackboard general information folder. | |
| **Textbook:** | David A. Patterson and John L. Hennessy, "**Computer Organization and Design: The Hardware/Software Interface," 5th edition**, Morgan Kaufmann, ISBN: 9780124077263. Available online through the Blackboard.<br>The book's companion web page and the CD that comes with the book contain a large amount of material related to the textbook, including advanced topics, Appendices, and supporting software. Students are encouraged to study them. | |

**Required Background:**

Fundamentals of digital logic design and basic assembly programming (ECE2042/ECE2043 and ECE 2044/2045).

## Course Overview

Computer architecture is the science and art of selecting and interconnecting hardware components to create a computer that meets functional, performance, power, and cost goals. This course examines in-depth the inner-workings of modern computer hardware design and the design tradeoffs at the hardware-software interface. The MIPS processor is employed as an example throughout the course. The topics include: instruction set architecture, MIPS assembly programming, integer and floating-point arithmetic circuits, processor datapath and control design, pipelining, memory hierarchy, I/O and storage devices, multi-core processor design, etc.

An integral component of this course will be a sequence of hands-on hardware laboratory assignments where you will step-by-step design and implement several versions of the 32-bit MIPS processor. The Altera DE2 FPGA development board will be used in the labs for you to test and evaluate the processors. Quartus II and ModelSim will be used throughout the course.

## Course Objectives

After a successful completion of the course, the student will understand from the engineering's perspective how a computer hardware system works and will be able to design and implement pipelined processors and their basic peripherals from basic logic gates on an FPGA board. Students will also be able to understand and evaluate various factors that affect computer system performance.

## Grading Policy

- Homework assignments: 25%
- Lab: 30%
- Midterm 20%
- Final 35%

**Note:**

The lecture slides will be available on the course web page after the class meeting. Homework is normally due at the beginning of the Tuesday class unless announced otherwise. Homework problems will be posted on the blackboard content page. **You will lose 20% of homework points for each school day if failing to submit homework on time**

The specific information related to lab requirements can be found through the lab folders in Blackboard.
The midterm and final exams are closed book and closed notes. One 8 1/2" x 11" sheet of notes may be used for the two exams. All sheets must be *one-sided* and *in your own handwriting*.
The scale used to assign letter grades is:

| Letter Grade | Numerical Grade | Letter Grade | Numerical Grade |
|---|---|---|---|
| A | 94 to 100 | C | 73 to 76 |
| A- | 90 to 93 | C- | 70 to 72 |
| B+ | 87 to 89 | D+ | 67 to 69 |
| B | 83 to 86 | D | 63 to 66 |
| B- | 80 to 82 | D- | 60 to 62 |
| C+ | 77 to 79 | F | Less than 60 |

## Planned Schedule and Topics

Check the blackboard content homepage for more detailed information.

| Week | Lecture Topics |
|---|---|
| 1 | Course overview |
| | Computer technology evolution |
| 2 | Instruction set architecture (ISA) overview & MIPS processor instruction set |
| 3 | MIPS processor instruction set |
| | Signed and unsigned addition/subtraction & ALU design |
| 4 | Sequential and parallel multipliers |
| | Binary Division |
| 5 | Floating-point arithmetic operations |
| | Understanding computer performance |
| 6 | Single-cycle MIPS processor: Datapath |
| 7 | **Midterm Review (Exam is from 2:30 – 5 PM on Friday Oct. 2nd)** |
| | Single-cycle MIPS processor: Control |

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| 8 | Multi-cycle MIPS processor: Datapath |
| 9 | Multi-cycle MIPS processor: Control |
| | Ideal pipelined MIPS processor datapath and control |
| 10 | Pipelining: data hazards and solutions |
| | Pipelining: branch hazards and solutions |
| 11 | Memory introduction and memory technologies |
| | Cache |
| 12 | Cache |
| | Virtual memory |
| 13 | Virtual memory<br>Final review |
| 14 | Introduction to parallel architecture<br>Q & A for final exam |
| **Final Exam: TBD** | |

## Attendance

Students are expected to attend class zoom meetings and laboratory in person. Where possible, students should inform their instructors if they plan to be late or absent from class. In all cases, students should be prepared to provide documentation to petition for *excused* absences to the Associate Dean for Student and Strategic Programs, Dr. Stephen Jones. Students should use the form for requesting an *excused* absence. Excused absences do not count toward a failure in the course for first year students. Absence from class does not release the student from work assigned. Students who miss an in-class obligation (exam, presentation, etc.) due to an excused absence will not be penalized - the instructor may offer a make-up test, arrange an alternative time for a presentation, exempt a student from the assignment, or provide another arrangement. In the case of illness or injury, the form must be submitted within 24 hours of missing class.
The University's list of excused absences for all students includes the following:

- participation in NCAA athletic competitions
- participation in special academic events (e.g., conferences, field trips, project competitions)
- participation in official university business (e.g., student representatives attending meetings related to university governance)
- attendance at significant events involving the immediate family (e.g., funerals, weddings)
- religious holidays - see the University's policy on Religious Holidays
- college-approved participation in placement activities (e.g., job interviews, graduate school interviews, attending job fairs)

- legally required absence (jury duty, court appearance, short-term military service)
- documented serious illness, such as COVID, or disability

## Online Expectations

To foster a professional environment, please wear appropriate clothes, mute if you are not talking to cut down on background noise, refrain from eating, and select an appropriate setting when we are meeting online.

## Electronics Policy

Online portions of this class may be recorded so that students that are absent may view the content later.
Students are prohibited from making any audio or visual recordings (including taking photographs) of lectures, discussions, or other classroom activities, unless a student (1) has written permission in advance from the instructor, or (2) is permitted to record under terms and conditions as approved by the University's Office of Disability Services or Learning Support Services. Students who have received approval to record classes as an academic accommodation must provide supporting documentation from the Office of Disability Services or Learning Support Services in advance of any recording. Students may use authorized recordings only for the purposes of individual study in the course and may not disseminate or share them with a wider audience without explicit permission.

## Academic Integrity

The College of Engineering is committed to creating an environment of academic integrity and ethical decision-making that we hope is reflected in the actions of our students and graduates. As Villanova students, integrity is central to the University mission. As engineers, our code of conduct requires us to place honor and integrity at the forefront of everything we do. As engineering students, it is expected that you will begin to adopt these values and instill them into your work habits. Students violating the academic integrity policy will receive a zero on that assignment or exam and the violation will be reported to the Associate Dean for Academic Affairs.
Students are encouraged to read the University's academic integrity policy.
The College of Engineering has adopted the following exam guidelines:

- Students must arrive before the start of the exam. Under exceptional circumstances a student may need to arrive late, but he/she can enter the exam no later than 5 minutes after the start of the exam.
- All cell phones must be turned off and stored away until the student exits the exam room.
- The official Villanova class attendance policy must be followed when requesting excuses for absences or lateness to an exam.
- Each student must write and sign the following statement, "*I have neither given nor received any unauthorized assistance in the completion of this exam."* If taking an exam remotely, students still need to copy and sign this statement (even if signed for electronically).

- In the case of virtual exams, the instructor may implement video proctoring or other measures to ensure academic integrity. For consent purposes, the instructor will announce ahead of time to students if they plan to use any form of video proctoring during an assessment and whether a recording will take place.

## Adherence to the Student Code of Conduct and the CARITAS Commitment

Students are expected to act in a professional and respectful manner to their fellow students, faculty, and staff. Students should become acquainted with and understand the responsibilities set forth in the Student Handbook, especially those in the sections on Policy and Regulations. Adherence to University regulations is expected and required for successful completion of the program of studies. Enforcement within the classroom of policies regarding classroom behavior is the responsibility of the faculty member. All other discipline problems are to be referred to the Dean of Students.

**Students, faculty, and staff are expected to comply with the CARITAS Commitment. Students should wear masks, practice social distancing and good hygiene, wipe down their work area upon arrival and departure, and request an excused absence if they are not feeling well.**

## Students with Disabilities

It is the policy of Villanova to make reasonable academic accommodations for qualified individuals with disabilities. If you are a person with a disability please contact me after class or during office hours to make arrangements.
If you have a non-physical disability you need to register with the Learning Support Office by contacting 610-519-5176 or at learning.support.services@villanova.edu as soon as possible. Registration is needed to receive accommodations.
The Office of Disability Services collaborates with students, faculty, staff, and community members to create diverse learning environments that are usable, equitable, inclusive and sustainable. The ODS provides Villanova University students with physical disabilities the necessary support to successfully complete their education and participate in activities available to all students. If you have a diagnosed disability and plan to utilize academic accommodations, please contact and register with Gregory Hannah, advisor to students with disabilities @ 610-519-3209 or visit the office on the second floor of the Connelly Center.

## Copyright Policy

The materials used in Villanova University courses ("Course Materials") generally represent the intellectual property of course instructors, third parties and/or the University which may not be disseminated or reproduced in any form for public distribution (e.g., sale, exchange, etc.) without the written permission of the course instructor. Course Materials include all written or electronic documents and materials, including syllabi,

current and past examination questions/answers, and presentations such as lectures, videos, PowerPoints, etc., provided by a course instructor. Course Materials may only be used by students enrolled in the course for academic (course-related) purposes.
Published course readings (book chapters, articles, reports, etc.) available in Blackboard are copyrighted material. These works are made available to students through licensed databases or fair use. They are protected by copyright law, and may not be further disseminated or reproduced in any form for distribution (e.g., uploading to websites, sale, exchange, etc.) without permission of the copyright owner.
Follow these links for more information about intellectual property, copyright, and computer acceptable use.

## The Learner's Studio

Villanova's Learners' Studio provides free content tutoring for over 100 courses (excludes writing, math, and entry level VSB courses). From quick homework clarification questions to prep for final exams, we can help! Our peer tutors are each endorsed by two faculty members and are trained according to CRLA national standards. All tutoring services at the university can be found here. Don't see the class you want listed? Click here. For more information, contact juliana.studer@villanova.edu or call 610-519-5862.

## The Center for Speaking and Presentation

Villanova's Center for Speaking and Presentation provides expert guidance on topics including organizing presentation material, performing as a cohesive group, voice modulation, vocal interruptions, speaking anxiety and more! All tutoring services at the university can be found here. For more information, contact juliana.studer@villanova.edu or call 610-519-5862.