Syllabus

Welcome to Computer Organization. This course is an intensive introduction to the fundamentals of computer organization. Relying heavily on the elementary principals taught in ECE 231 and ECE 232, we will discuss the basic design, or architecture, of computing hardware. Taking a largely bottom-up approach, we will focus on the microarchitecture level (the computing hardware itself) and the instruction set architecture level (the interface between software and the computing hardware). Topics include computer arithmetic, arithmetic unit, hardwired and microprogrammed control, memory, register-to-register, input-output operations. The course also provides an introduction to assembly language programming, using the MIPS processor. This course includes a demanding design component, in which you will design, implement, and simulate a simple processor (the MIPS) using VHDL, schematic capture, and the Xilinx Vivado design suite. The processor will be realized using the Digilent Basys3 board and programmed using assembly language.

Instructor
Jens-Peter Kaps
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`jkaps@gmu.edu`
`https://ece.gmu.edu/~jkaps`
Office Hours: Monday 3:00pm–4:00pm, Wednesday 10:00am–11:00pm. Office hours will be conducted in-person in my office and via Zoom (link on our Canvas course page).

Teaching Assistants
Ahmed Jaber (Course)
`ajaber2@gmu.edu`
Office Hours: TBA
Room: TBA

Ayomikun Akindahunsi (Labs 201 and 202)
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Kowsyap Musumuri (Lab 203)
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Office Hours: TBA
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Lecture and Lab Date & Time & Place
Lecture: Monday & Wednesday, 12:00pm–1:15pm, Engineering Building 1101.
Lab 201: Wednesday, 7:20pm–9:10pm, Engineering Building 1505.
Lab 202: Friday, 9:30am–11:20am, Engineering Building 1505.
Lab 203: Thursday, 7:20pm–9:10pm, Engineering Building 1505.

Course Web Page
The latest announcements, handouts, assignments, source code and useful/interesting web links will be posted on the course page on Canvas.

Course Schedule
The course schedule is provided in a separate document on Canvas.

Textbook

- David A. Patterson and John L. Hennessy, *Computer Organization and Design, The Hardware / Software Interface*, Morgan Kaufmann; 5th edition, 2014, ISBN: 978-0-12-407726-3 `https://www.elsevier.com/books/computer-organization-and-design-mips-edition/patterson/978-0-12-407726-3`

Hardware
For the labs in this class, each student is required to use the Digilent Basys 3 board that is also used for ECE 232. If you don't already have one, it can be purchased from the ECE shop, Nguyen Engineering Building, room 3916. Note: The ECE shop only accepts Mason Money.

Software
Each student is required to download and install Xilinx Vivadi Design Suit and either MARS or SPIM on their own computer.

- Xilinx Vivado Design Suite, `https://www.xilinx.com/`
- MARS, `https://courses.missouristate.edu/KenVollmar/MARS/`
- SPIM, `https://spimsimulator.sourceforge.net/`

Prerequisites
Knowledge of computer programming in C or C++ and digital system design.

- (ECE 331 or ECE 231) and (ECE 332 or ECE 232) with a grade of C or better and
- ECE 240, or CS 222, or CS 262 with a grade of C or better.

Attendance
Attendance is expected. You are responsible for all material covered in class. If you miss class you must consult with one of your classmates to obtain any information that was presented in class, as well as the answers to the class exercises completed in class.

Reading Assignments
The reading assignments are shown in the class calendar in the rightmost column and in the homework. They refer to sections in the Patterson and Hennessy book that need to be read by the

beginning of the week. Additional Reading is assigned from the materials uploaded on Canvas. You are highly encouraged to complete the reading assignments and the associated practice activities.

Homework
There will be weekly homework assignments. These will include reading assignments, questions, and programming exercises. The homework will not be collected or graded. The homework questions will be posted on Mondays, the solutions will be posted on Fridays. The following Monday, will be an in-class quiz based on the homework. The quizzes will be collected and graded. For maximum benefit of these homework assignments you are encouraged to try to solve the questions before the solutions are published. You should discuss your work with other students in the class. Once the solutions are published, try to learn from them and see where you went wrong.

Quizzes
There will be up to 12 quizzes during the course. The quizzes will be given on Mondays at the beginning of class and take approximately 15 minutes. No extra time will be given for late arrivals. The questions will be similar to the previous weeks homework. The quizzes will be closed book and closed notes.

Programming Assignments
There will be several MIPS Assembly Language programming assignments. Your solution must be submitted via Canvas as a single PDF file. You may not submit pictures of them. You are responsible for ensuring that your solutions are readable and understandable. Programming solutions must be submitted by 11:59 PM on the specified due date. Late submission will NOT be accepted.

Discussion Board
All questions about the material covered in this course, including questions about the class, homework assignments, exams, and laboratory experiments, will be addressed using the discussion board on Canvas.

Please subscribe to each of the forums – you will then receive an email each time a question or response is posted to one of the forums.

Class-related questions will not be addressed via email. Instead, all questions should be posted to the appropriate forum of the discussion board. Always check the forum before posting your question. The same,or a similar, question may have already been posted (and answered). Furthermore, you may post a "follow-up" question to an existing thread to foster additional discussion and/or to request a more detailed answer.

The GTAs and the Instructor will do their best to respond to all questions posted on the discussion board forums. In addition, you may provide a response to any question posted on one of the forums. Any questions or concerns regarding a personal matter should be emailed to the instructor directly. Do not post such comments on the discussion board.

Examinations
There will be two exams during the course. Exams will be closed book. A single (two-sided) blank note card (3" x 5") will be provided by the instructor on which you can write down your own notes. You are not allowed to use more than one card or to attach anything to this card. Your notes

have to be hand written. Additionally, the unmodified green MIPS Reference Data card from the textbook and a calculator will be allowed. There will be NO make-up exams. (See Dr. Kaps for an exception.) Students who are more than 15 minutes late for an exam may not be admitted and will be assigned a grade of zero for the exam.

The questions will be similar to the homework questions and the programming assignments. The final exam is cumulative.

If you fail one or both of the exams, I reserve the right to give you a failing grade for the course.

- **Midterm Exam:** Wednesday, March 5th, 12:00pm–1:15pm
- **Final Exam:** Monday, May 12th, 11:00am–1:15pm

Labs

The labs provide practical experience in the design, implementation, simulation, realization, and testing of a simple processor. The fundamental components of the processor, including the datapath and control unit, will require intense programming using VHDL. The top-level design will require the creation of a schematic to interconnect the components of the processor. Both the VHDL coding and the schematic capture will be facilitated using the Xilinx Vivado design tool.

The processor will be developed in stages. At each stage, the design will be realized using the Digilent Basys3 board, and tested using sample assembly language programs.

The simple processor to be implemented in these labs is the single-cycle MIPS. This processor is covered in detail in the course textbook. The completed design will implement a subset of the instructions included in the MIPS instruction set (see Appendix E of Hennessey and Patterson, 5th edition, or the MIPS Reference Card).

You will need to install the Xilinx Vivado design tool on your personal computer. The tool can be downloaded from the Xilinx website (see information provided at the beginning of this syllabus). Additional information about Vivado can be found at the Xilinx website.

A list of the labs is given below:

Lab		**Weight**
1.	VHDL Refresher and Xilinx Vivado IP Integrator	5%
2.	The MIPS Arithmetic and Logic Unit (ALU)	15%
3.	The MIPS Datapath for the R-type Instructions	25%
4.	The MIPS Datapath for the R-type and I-type Instructions	25%
5.	The MIPS Datapath for the R-type, I-type, and J-type Instructions	25%
6.	Implementation Analysis of the MIPS Datapath	5%

A detailed description of each lab will be provided by the TA and posted on Canvas. The lab syllabus and lab schedule is posted on Canvas. Please see the lab syllabus for a description of the lab policies, submission policies, and lab etiquette. Students must work on the labs individually.

Grading
The following weight distribution will be used to calculate the final grade:

- 5% Lecture Attendance and Participation
- 5% Programming Assignments
- 10% Quizzes
- 30% Labs
- 25% Midterm Examination
- 25% Final Examination

Grades will be based partially on the average grade of the class and the standard deviation σ. The following table shows how many points must be achieved for a certain grade. For example if your grade matches the average of the class you would get a B-. However, the minimum cut-off for a B- can never be lower than 65 or higher than 80.

Grade	Minimum Points
A-	$80 \leq average + \sigma \leq 90$
B-	$65 \leq average \leq 80$
C	$60 \leq average - \sigma \leq 70$
D	50

Please note that you are responsible for making sure that all of your grades are posted on Canvas and that they are correct. If you wish to challenge a grade you must do so within one week of it being posted on Canvas. Grades will not be changed more than two weeks after they were posted.

Learning Outcomes

1. Explain the difference between computer architecture and computer organization.
2. Identify the main components of a computing system (e.g. a computer).
3. Describe the von Neumann, Harvard and modified Harvard architectures and their differences.
4. Understand the trends in computer architecture, including CISC, RISC, and VLIW.
5. Describe an Instruction Set Architecture (ISA).
6. Explain the fetch-execute cycle.
7. Explain why a processor architect adopts multiple instruction formats, rather than a single format.
8. Convert assembly language to machine language, and machine language to assembly language.
9. Implement high-level language (HLL) constructs in assembly language and machine language.
10. Use a computer simulation package to investigate assembly language programming.
11. Design the datapath and control unit for a simple processor.
12. Design the datapath and control unit for a pipelined processor.
13. Compare alternative implementations of datapaths.
14. Understand how control signals are generated using hardwired or microprogrammed control units.

15. Explain basic instruction level parallelism (ILP) using pipelining.
16. Understand the effects of resource, data, and control hazards on processor functionality.
17. Explain what can be done to overcome the effects of hazards, including the use of branch prediction.
18. Understand the factors that contribute to computer performance.
19. Understand the effect of a processor's arithmetic and logic unit (ALU) on its overall performance.
20. Understand how each of the functional units of a computer affects its overall performance.
21. Estimate the effect on system performance of a change to a functional unit.
22. Describe the various types of memories and memory technologies.
23. Explain the effect of memory latency and bandwidth on performance.
24. Explain the use of memory hierarchy to reduce the effect memory access time (EMAT).
25. Describe direct-mapped, set-associative, and fully-associative caches and explain how they work.
26. Describe virtual memory.
27. Understand how interrupts, exceptions, and traps are handled.
28. Understand how input and output devices interface to, and interact with, the processor.
29. Explain how to use interrupts to implement I/O control and data transfer.
30. Describe data access from magnetic and optical disk drives.
31. Design an interface to memory.
32. Understand how integers and real numbers are represented in digital computers.
33. Understand how arithmetic operations, including addition, subtraction, multiplication, and division are implemented in computer architectures.

Course Materials and Student Privacy

All course materials posted to Canvas or other course site are private to this class and must not be shared with anyone not enrolled in this class. That applies to lecture slides, homework, quizzes, exams, labs as well as to material posted by students.

Videorecordings – whether made by instructors or students – of class meetings that include audio, visual, or textual information from other students are private and must not be shared outside the class.

Live video conference meetings (e.g. Collaborate or Zoom) that include audio, textual, or visual information from other students must be viewed privately and not shared with others in your household or recorded and shared outside the class.

Honor Code

All rules of the GMU Honor Code system will be in effect. You must review the rules and be familiar with them. You are encouraged to discuss homework problems and labs with other students and/or obtain the assistance of the instructor. Nevertheless, you must write down your own homework

solutions which represent your understanding of the material. Labs must be completed individually. No part of a lab submission can be copied from another person of the class or any other source. Duplicating someone else's work such as but not limited to quiz solutions, hard-ware/software designs, diagrams, source code, lab reports, and exam notes, is considered cheating. If you use material from other sources such as but not limited to the web, books, journals, data sheets, etc. you must reference the source. Honor code violations will be followed up with full force.

For more information about the Mason Honor Code and about the Honor Committee, please visit the website for the Office of Academic Integrity (`https://oai.gmu.edu/`).

Classroom Etiquette
Cellphones, pagers have to be put into silent mode. If you have an emergency need to answer a call please quietly leave the room BEFORE answering the call. Lectures may not be recorded without express written permission from the instructor.

Texting, using your laptop for something other than lecture-related work, etc., is considered a distraction to me and to the other students trying to learn in the class, and will not be tolerated.

GMU E-mail Accounts
Students must use their Mason email account to receive important University information, class-related messages, and to communicate with the professor and the teaching assistants. See `http://mail.gmu.edu` for more information.

Students with Disabilities
If you are a student with a disability and require special accommodations, please contact the instructor and the Office of Disability Services as soon as possible. All special accommodations must be arranged through ODS.

Office of Disability Services (ODS): (703) 993-2474; `https://ds.gmu.edu`

Other Useful Campus Resources

- Writing Center: A114 Robinson Hall; (703) 993-1200; `https://writingcenter.gmu.edu`
- University Libraries: "Ask a Librarian" `https://library.gmu.edu/ask`
- Counseling and Psychological Services (CAPS): (703) 993-2380; `https://caps.gmu.edu`
- The University Catalog: `https://catalog.gmu.edu`
- University Policies: `https://universitypolicy.gmu.edu`

Common Policies Affecting All Courses at George Mason University

Please follow this link: `https://stearnscenter.gmu.edu/home/gmu-common-course-policies/` to familiartize yourself with these common policies affecting academic standards, accomodations for students with disabilities, FERPA and use of GMU email addresses for course communication, and title IX resources and required reporting. You can also find this document in the syllabus section of our Canvas page.

The course syllabus is subject to change