CSE/EEE 230 Computer Organization and Assembly Language

Spring 2015 — Course Information

Lecture Section	11697 (CSE230), 11885 (EEE230)
Date & Time	MWF 1:30–2:20
Location	CAVC 351
TA	Bernard Ngabonziza
Lecture Section	11784 (CSE230), 11886 (EEE230)
Date & Time	MW 4:30 –5:45
Location	PSF 101
TA	Mahesh Balasubramanian

Catalog Course Description

Register-level computer organization. Instruction set architecture. Assembly language. Processor organization and design. Memory organization. IO programming, Exception/interrupt handling. Prerequisite: CSE 120 or EEE 120 with C or better; CSE 100, 110 or 200 with C or better OR Computer Science or Computer Systems Engineering Graduate student; Credit is allowed for only CSE 230 or EEE 230. Three (3) credit hours. Lecture/No lab.

Course Objectives

At the end of the course the student shall be able to:

1. Explain how programs written in high-level languages are executed by a computer system.
2. Write relatively simple assembly language programs employing flow of control constructs and procedures.
3. Explain what hardware factors impact program performance and how to write programs for performance.
4. Explain techniques used by computer hardware designers to improve performance.
5. Explain the reasons for the ongoing transition to multiprocessor architectures.
6. Explain data representation, instruction sets, and addressing modes.
7. Explain how a datapath can be implemented as a single-cycle or pipelined design.
8. Explain how the memory hierarchy impacts performance.

Major Topics

The material to be covered in this course will be drawn from Chapters 1-6 of the textbook, although not necessarily in the order listed here. We will also not cover all of the material in the textbook as there is too much to be discussed in a one semester course.

Chapter 1: Computer Abstractions and Technology

- What is "computer organization?"
- The five classic components of a computer system.
- Defining performance.
- Measuring performance.
- The classic CPU performance equation.
- Performance and the power consumption wall.
- Multiprocessors and parallel computing.

Chapter 2: Instructions: Language of the Computer

- Instructions and instruction sets. Instruction set architecture (ISA).
- Operations and operands.
- Representing signed and unsigned integers.
- Encoding instructions.
- MIPS logical instructions.
- MIPS instructions for making decisions.
- Supporting procedures in computer hardware.
- Representing characters and strings.
- MIPS addressing modes.
- Instruction decoding.
- MIPS assembly language examples.

Chapter 3: Arithmetic for Computers

- MIPS signed and unsigned arithmetic instructions.
- Fixed point representation of real numbers.
- IEEE 754 single and double precision floating point formats.

Chapter 4: The Processor

- The basic MIPS implementation instruction set.
- Review of digital logic design conventions.
- Building the single cycle datapath.
- Adding the control to the single cycle datapath.
- An overview of pipelining.
- Pipeline hazards.
- The MIPS pipelined datapath and control.
- Detecting and handling data and control hazards.

Chapter 5: Large and Fast: Exploiting the Memory Hierarchy

- Memory hierarchy and the principle of locality.
- Memory technologies: RAM (SRAM and DRAM), ROM (Flash).
- Cache basics. Direct mapped caches.
- Measuring and improving cache performance.
- Set and fully associative caches.
- Reducing the miss penalty using multilevel caches.
- Virtual memory and implementing protection with virtual memory.

Chapter 6: Parallel Processors from Client to Cloud

- Parallel programming, the speed-up problem, and Amdahl's Law.
- SISD, SIMD, MISD, and MIMD architectures.
- Hardware multithreading.
- Shared memory processors.

Office Hours & Support

The instructor will be available during his office hours to answer any questions you may have about the course, the material, or the assignments. I'm a friendly guy (except when I'm not), and willing to talk with you and help you as much as I can, so stop by if you want, but please be aware that I also teach other courses and have other duties as well, so I am quite busy. When you come in for help, please be prepared to ask pointed and specific questions about what you do not understand or are having difficulty with. It is next to impossible for me to help you if you come in and say, "I don't understand anything." Also, a final word of advice. I may not be available as much as you would like the day before or the day an assignment is due. I will give you plenty of time to complete the assignments as long as you start working on them well before the deadline. This will give you ample time to meet with me or the TA to discuss your questions as you are working on the assignment. Start early!

The graduate TA's are listed below. Each TA will hold four weekly office hours in CTRPT 114 where he will be available to help you with the homework assignments and answer any questions about the material. The TA's will also perform some of the grading.

Section	TA's Name	Email	Office Location	Office Hours
MWF 1:30–2:20	Bernard Ngabonziza	bngabonz@asu.edu	BYENG 469AC	TuTh 11:00-1:00
MW 4:30–5:45	Mahesh Balasubramanian	mbalasu2@asu.edu	CTRPT 114	TuTh 10:00-12:00

We have two graders, listed below. Brandon will grade homework assignments and exams for the MWF 1:30 section and Yi for the MW 4:30 section. Each grader will hold one office hour per week in CTRPT 114 where he will be available to answer any questions you may have about the grading of a homework assignment or exam. If you have questions about the grading of an assignment or exam it will be best to meet with the TA or grader who graded it.

Section	Grader's Name	Email	Office Location	Office Hours
MWF 1:30–2:20	Brandon Kral	brandon.kral@asu.edu	CTRPT 114	We 11:00-12:00
MW 4:30–5:45	Yi Shan	yi.shan@asu.edu	CTRPT 114	Fr 3:30-4:30

The School of Computing, Informatics, and Decision Systems Engineering (CIDSE) provides free tutoring in the CIDSE Tutoring Center, which is located in CTRPT 114, Mon through Fri 9:00am to 6:00pm.

Course Materials & Resources

- *Computer Organization and Design, 5th Ed*, David Patterson and John Hennessey, 2013, Morgan Kaufman, ISBN: 978-0-12-407726-3.
- Textbook Green Card.
- My ASU Courses (Blackboard)

MIPS Simulators

- SPIM: A MIPS32 Simulator
- MARS: MIPS Assembler and Runtime Simulator (Recommended)

MIPS Documentation

- MIPS Architecture Volume I-A: Introduction to the MIPS32 Architecture
- MIPS Architecture Volume II-A: The MIPS32 Instruction Set
- MIPS32 Instruction Set Quick Reference
- MIPS Assembly Language Programmer's Guide

Intel Documentation

- Intel 64 and IA-32 Architectures Software Developers Manual: Vols. 1, 2A-2C, 3A-3C

The website you are currently viewing is the main website for this course (I will refer to it as the course website), and most course information will be available here. I only use Blackboard for: (1) posting important announcements; (2) student submission of assignment files; (3) posting assignment and exam solution and grading rubrics; and (4) posting scores in the Blackboard Grade Center.

Assessment

Various methods will be used to present the material and assess the student's understanding and comprehension.

Homework Assignments

There will be n homework assignments, each consisting of short-answer type exercises and MIPS assembly language programming exercises. Each homework assignment will be published on the course website at least one week before the assignment deadline and are accepted for grading on a variable deadline (except for the final homework assignment which will be due shortly before the final exam).

Submitted	Bonus/Penalty
$>$ 48 hrs before the deadline	Bonus of 20% of earned pts.
$>$ 24 hrs and $\leq$ 48 hrs before the deadline	Bonus of 10% of earned pts.
$\leq$ 24 hrs before the deadline	Accepted for grading with no bonus/no penalty.
$<$ 24 hrs after the deadline	Penalty of 10% of assignment pts.
$\geq$ 24 hrs and $<$ 48 hrs after the deadline	Penalty of 20% of assignment pts.
$\geq$ 48 hrs after the deadline	Not accepted for grading. Score will be 0 pts.

Assignments that are submitted more than 24 hours early will be awarded bonus points. For example, if the assignment is worth 50 points and you earn 33 points by submitting the assignment 50 hours before the deadline, then you will be awarded $33 \times 20\% = 6.6$ bonus points, for a total assignment score of 39.6 points. Assignments that are submitted less than 48 hrs after the deadline will be penalized points. For example, if the assignment is worth 50 points, and you earn 33 points by submitting your assignment one minute after the deadline, then you will be penalized $50 \times 10\% = 5$ points, for a total assignment score of 28 points. The penalty for 24 to 48 hours after the deadline is 20% of the assignment points. In no case will an assignment be graded when submitted 48 hours or more after the deadline. Assignment solutions must be uploaded to Blackboard for grading; in no case will an emailed assignment be accepted for grading.

Short-answer solutions to homework assignments must be typed using either a text editor or word processor and submitted to Blackboard in PDF. A solution that is submitted in a file format other than PDF will be graded with a 25% penalty if the TA or grader can open the submitted file. If the grader cannot open the submitted file for grading, then the student will be assigned a score of zero. Newer versions of Microsoft Word will export documents in PDF format. If you use Open Office or Libre Office, you can export a document in PDF format using the File | Export as PDF menu item. Otherwise, there are freeware programs that you may download and install which will convert a file into PDF format. One such Windows-based program is named CutePDF; Google it.

At the end of the term a homework assignment percentage, denoted hw in the course percentage formula below, will be calculated as the sum of the points you earned on the homework assignments divided by the number of points that were possible on all assignments. Your assignment percentage—including bonus points—will be limited to a maximum of 100%.

Examinations

There will be two in-class midterm examinations; the exam dates are listed on the monthly calendars in the Schedule section. There will be a noncomprehensive final exam given during the final exam period, see the May calendar.

Only in exceptional, documented cases (exceptional is defined by the instructor and will generally involve something like a note from the neurosurgeon who performed your emergency hemispherectomy on the day of the exam) will an exam be given after the exam date. If you know you are going to be absent on the date of an exam for a good reason (generally only business travel for your job or travel for an approved school function) then you may be permitted to take the exam early.

Note: you will be required to show proper photo identification (a driver's license, military ID card, or ASU Suncard) when handing in your examination for grading. If the instructor or TA does not recognize you, and you cannot produce photo identification, your exam will not be accepted for grading.

Quizzes

From time to time, there may be unannounced open-book extra credit pop quizzes. In no case—never—will a makeup quiz be given if you miss class for any reason. A quiz percentage, denoted q in the course percentage formula below, will be calculated as the sum of your earned quiz points divided by the sum of the quiz points on all of the quizzes and then multiplied by 2.5. The quizzes will be worth up to 2.5% extra credit which will be added to your final course percentage before assigning letter grades. Note that quizzes are designed to be essentially free attendance points.

Calculating Final Letter Grades

Your final letter grade will be based on your final course percentage FCP which is calculated as a weighted sum of your scores on the homework assignments (one-third of your grade) and examinations (two-thirds of your grade):

$$\text{FCP} = \textit{ceiling}(\ (\text{hw} \times 34\%) + (\text{exam}_1 \times 22\%) + (\text{exam}_2 \times 22\%) + (\text{final} \times 22\%) + (\text{q} \times 2.5\%)\ )$$

The *ceiling* of x is the smallest integer that is greater than x. For example, the ceiling of 79.2 is 80 and the ceiling of 89.99999 is 90. Your final letter grade will be based on *FCP*:

FCP	Letter Grade
$\text{FCP} \in [98, 100]$	A+
$\text{FCP} \in [87.5, 98)$	A
$\text{FCP} \in [75, 87.5)$	B
$\text{FCP} \in [62.5, 75)$	C
$\text{FCP} \in [50, 62.5)$	D
$\text{FCP} < 50$	E

Grade Appeals

If you believe a graded assessment (i.e., a homework assignment or exam) was marked incorrectly, the first step is to meet with the TA or grader who graded the assessment in question and discuss your concerns with him or her. If the TA or grader made an honest mistake, then he or she should correct it and enter the updated score in Blackboard. On the other hand, if the TA or grader correctly marked, or believe they correctly marked, the assessment using the grading rubric the instructor gave them, and after conferring with them, you disagree, then you may file a grade appeal with the instructor using this form. Please read the form instructions carefully. Basically, you have one week from the date the assignment or exam was graded to file your grade appeal. No appeals will be accepted after the one week period for any reason. You must submit the original assignment or exam along with your grade appeal form in person to the instructor; emailed forms will be discarded. Grade appeals are considered by the instructor at the end of the semester before calculating your final course percentage and letter grade (the reason is, that in most cases, whether the appeal is successful or not, it will not affect a student's course percentage enough to change the student's letter grade). At that time, I will regrade your assessment only if giving you the points in question would change your final course percentage enough to increase your final letter grade. If your score was changed, the new score will be entered in the Blackboard Grade Center.

Academic Misconduct

In general, the instructor believes learning is a collaborative activity, that students learn best when they work together, and that students should be encouraged to learn from and teach each other. These activities would include discussing solutions to homework exercises and jointly studying for exams. In completing homework assignments, student-pair collaboration is encouraged and will be permitted as long as each member of the pair contributes equally to the work. Collaboration is only acceptable between members of the same pair-team; inter-team collaboration is forbidden and violators may be sanctioned. Collaboration on examinations is not permitted; each exam must be completed by the individual student. Failure to abide by these rules on a homework assignment will result in a score of zero being assigned to one or both members of the team (e.g., if I have a reasonable hunch that one student did all of the work on an assignment and the other student simply put his/her name on it, then the student who did all of the work will receive the assignment score and the other student will be given a score of zero). Any student caught cheating on an exam will be given a score of 0 and will be reported to the Fulton Schools of Engineering Dean's Office for disciplinary action.

You are encouraged to acquaint yourself with the ASU Academic Integrity Policy

Classroom Behavior

The ASU Student Services Manual (SSM 201-10) permits the instructor to withdraw a student from a course for disruptive behavior with a mark of W or E. Note that "disruptive behavior" is defined by the instructor, not by the University or the student. Violation of conventional and acceptable classroom behavior will result in the offender being asked to exit the classroom and notification of the offense to the Fulton Schools of Engineering's Dean's Office. A warning may or may not be provided.

Attendance Policy

There is a strong and well-established correlation between class attendance, learning, and performance; therefore, regular class attendance and participation is expected. I intend to begin class each day on time and I expect you to be present and ready at that time. However, you are adults, and you (or someone who may or may not love you) are paying for your education, and ultimately, it is your education. If you want to squander this opportunity, then no gimmick I devise to try to get you to come to class and participate will be successful, so lecture attendance will not count toward your final course grade. That said, any extra credit quiz points you earn may alter your final letter grade if your course percentage lies on the border between two letter grades.

Requirements for Success in this Course

The instructor assumes that you are mature and responsible adults, that you are enrolled in this course because you wish to learn the material, that you will read any assigned readings before class begins, that you will come to class prepared to discuss the reading and ask questions, that you will complete the assignments to the best of your ability on time, that you will actively participate in class discussions, and that you will ask questions about material you find confusing. The instructor believes that college students must be actively involved in their own learning process, that they cannot just sit and listen to lectures and expect to learn the material, that one of the purposes of college education and the Arizona State University mission is for the student to self-develop skills such as problem solving, independent learning, critical thinking, and effective written and spoken communication. To succeed in this course you must:

- Be prepared for every class, attend every class, and pay attention.
- Read the textbook and other assigned readings prior to class.
- Begin and complete the assignments well before the due date.
- Prepare thoroughly for and complete every exam.
- Do any additional exercises you must to understand the material.
- Work with a partner if you wish or if it helps you.

- Ask questions in class. If you do not feel comfortable asking the question in class, talk with me outside of class.
- If you do not complete an assignment by the deadline, complete it anyway later.
- If you miss points on an assignment or exam determine why your answer was graded incorrect and learn the correct answers.
- Seek help from the instructor, TA, or the tutoring center before you are too far behind on your understanding of the subject.
- Read your email every day; I often send important announcements via email.
- Check the course website and Blackboard every day for new announcements, material, and updates.

Having said all that, I want you to know that I care about all of my students and their education. I want all of you to succeed, to feel you have gained something from the course, to have some fun in the process, and I will do all I reasonably can to assist you in your efforts!

Statement on Accommodations

The Disability Resource Center (480-965-1234; Matthews Center; email: drc@asu.edu) is the central location for students requiring accommodation. Any student requiring accommodation must contact and register with the Center before any accommodation requests can be granted by the instructor. If you require accommodation, please contact the Center as soon as possible so the instructor can work with you to ensure your success.

Schedule

Week 1 — Intro to computer architecture and computer organization; HLL language, assembly language, machine language; The five class components of all computer systems; Units for measuring information; Moore's law.

Week 2 — Performance: defining performance; Execution time; Throughput; Relative performance; Measuring performance; CPI and IPC; The classic CPU performance equation; Measuring performance in practice; The power wall.

Week 3 — Instruction set; MIPS, RISC, and CISC; Signed and unsigned integers; Converting from binary to decimal and decimal to binary; Operations, mnemonics, labels, assembly language instructions; Register operands; Memory operands; Memory aliment restrictions; Endianness; Immediate operands; MIPS arithmetic instructions; MIPS LW and SW instructions;

Week 4 — MIPS logical instructions; MIPS shifting instructions; Pseudoinstructions; MIPS assembly language programming and MARS; Labels, directives, segments; Defining global data; MARS memory configuration; MARS system services; Example programs.

Week 5 — Representing instructions: R, J, and I format instructions; Instruction encoding; Instruction decoding; MIPS jump and branch instructions; Implementing HLL if statements; Implementing HLL while loops; Implementing HLL for loops.

Week 6 — MIPS example programs involving if statements and loops; Writing and calling procedures; Stack frames; Passing parameters; Allocating local variables on the stack; Returning values from procedures;

Week 7 — Midterm Exam 1. Saving and restoring registers; Simple optimizations; Jump target address calculation and encoding of J instruction; Branch target address calculation and encoding of BEQ and BNE instructions.

Week 8 — Representing very large integers; floating point; IEEE 754 single and double precision floating point formats; Roundoff error; Representing very small real numbers. A basic MIPS implementation; Logic design conventions; Clocking; The single cycle design data path; The machine cycle.

Week 9 — Single cycle design; How various instructions are executed in the single cycle design; Datapath components; The ALU; The single cycle control; Implementing the J instruction. Intro to pipelining; Designing instruction sets for pipelining.

Week 10 — Pipelining speedup; The pipelined datapath; The five pipeline stages; Structural hazards; Data hazards; Stalling; Resolving hazards by forwarding;

Week 11 — Branch control hazards; Pipeline registers; Determining the contents of the pipeline registers; The pipeline control.

Week 12 — Midterm Exam 2. Resolving data hazards by forwarding; Detecting hazards and resolving them in hardware.

Week 13 — Memory bottleneck; Intro to the memory hierarchy; Temporal and spatial locality; Cache hits, misses, hit rate, miss rate; Hit time, miss penalty; Memory technologies; SRAM, DRAM; Busses; ROM, types of ROM; Cache; Direct mapped cache of words.

Week 14 — Direct mapped cache of words; Calculating hit rate, miss rate; Direct mapped cache of blocks; What happens if the block size if made too large or too small; Handling memory inconsistencies and writes; AMAT for a one-level cache; Set associative cache.

Week 15 — Set associative cache; LRU and pseudo-LRU block replacement algorithms; Virtual memory; Mapping virtual memory pages to physical memory page frames; The page table.