15-447: Introduction to Computer Architecture

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1 Organization

Instructors:

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M1007, 454-8625	M1017, 454-8631
Tue, 10-12pm	Thu, 10-12pm

TA:

Adnan Majeed
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454-xxxx
Sun, 3-4pm; Mon, Wed, 4:30-5:30pm; Tue, Thu, 1-3pm
Please see the class Web page for up-to-date office hours.

Lecture:

Mon and Wed, 2:30–3:50pm, M1030

Recitations:

Tue 2-2:50pm, M1032, Adnan Majeed

Class Web Page:

`http://www.qatar.cmu.edu/~msakr/15447-f08`

Class Message Board:

`http://blackboard.qatar.cmu.edu/`

Note: This is the only message board your instructors will be monitoring. We will not be using the Andrew or Blackboard message boards for this class.

2 Objectives

Computer architecture is the science and art of selecting and interconnecting hardware components to create a computer that meets functional, performance and cost goals. This course introduces the basic principles and hardware structures of a modern programmable computer. We will introduce the Von-Neuman architecture and understand the primitives of a programmable processor. We will learn how to design the control and datapath for a pipelined RISC processor and how to design fast memory and storage systems. We will also learn how to quantitatively evaluate the cost and performance of various designs. The principles presented in lecture are reinforced through projects involving the design and simulation of a RISC processor pipeline.

3 Learning Outcomes

- Understand computer arithmetic and be able to perform basic arithmetic operations using ones complement and twos complement representation. (Assessed in a number of homework problems, quizzes and exams)
- Understand the concept of Instruction Set Architecture (ISA) and develop the ability to design an ISA given design considerations. (Assessed in quizzes, home works, exams and project 2)
- Understand performance metrics and learn how to analytically evaluate the performance of a computer system. (Assessed by evaluation of alternate designs in project 4)
- Understand single-cycle data-paths and learn how to design and evaluate them. (Assessed in Project 3 and in home works and quizzes)
- Understand multi-cycle data-paths and learn how to design and evaluate them. (Assessed in home works and quizzes and to some extent in project 3)
- Consider the various trade-offs between using a single-cycle and multi-cycle data-path and their effect on cost, die area and performance.
- Understand the concept of pipelining and its impact on performance. Recognize the additional hardware required to enable pipelining. Additionally, understand how to overcome data and control hazards in a pipelined system. (Assessed in quizzes, home works, exams and project 3)
- Understand the memory hierarchy and the cost-performance trade-offs of using multiple levels of memory and different memory technologies. Additionally, understand the concept of locality and how it is exploited by the memory hierarchy to bridge the processor-memory gap. (Assessed in home works and quizzes and in project 4)
- Design and evaluate cache systems and understand different cache organizations.
- Understand the operation of a virtual memory system. (Assessed in exams)
- Understand super-scalar computer systems at a high level. (Assessed in exams)
- Understand I/O and storage devices such as disks and RAID. (Assessed in exams)

4 Textbook

The primary textbook for the course is

> Patterson and Hennessy, *Computer Organization and Design: The Hardware/Software Interface, Third Edition*, Morgan Kaufmann/Elsvier.

5 Course Organization

Your participation in the course will involve five forms of activity:

1. Attending the lectures.
2. Preparing for and participating in the recitations.
3. Homework assignments.
4. Projects.
5. Reading the text.
6. Exams

Attendance will be taken at the lectures and recitations; it will be worth 5% of your grade. You will be considered responsible for all material presented at the lectures and recitations.

Lectures will cover higher-level concepts. Recitations will be more applied, covering important "how-to's", especially in using tools that will help you do the labs. In addition, the recitations will help clarify lecture topics and describe exam coverage.

The textbook contains *homework questions* at the end of each chapter. The intention is that you work on the practice problems right as you are reading the book. Our experience has been that trying out the concepts on simple examples helps make the ideas more concrete. In addition, the schedule (at the end of this document and on the class web page) shows specific chapter sections with each lecture topic. The intention is that you read these sections prior to lecture. You will find that you will get much more out of the lectures if you have done some advance preparation.

The only graded assignments in this class will be a set of homework assignments and four projects. Some of these are fairly short, requiring just one week, while others are more ambitious, requiring several weeks.

6 Getting Help

For urgent communication with the teaching staff, it is best to send electronic mail (preferred) or to phone.

If you want to talk to a staff member in person, remember that our posted office hours are merely nominal times when we guarantee that we will be in our offices. You are always welcome to visit

us outside of office hours if you need help or want to talk about the course. However, we ask that you follow a few simple guidelines:

- Prof. Sakr normally works with his office door open and welcomes visits from students whenever his doors are open. However, if his door is closed, he is busy with a meeting or a phone call and should not be disturbed.

- Prof. Abu-Ghazaleh is glad to meet with students. The best way to meet with him is during his office hours or set up an appointment by email.

- Please send mail to arrange a meeting with your TA outside of office hours.

We will use the Web as the central repository for all information about the class. The class home page is at

`http://www.qatar.cmu.edu/~msakr/15447-f08/`

Using the Blackboard, you can:

- Obtain copies of any handouts or assignments. This is especially useful if you miss class or you lose your copy.

- Find links to any electronic data you need for your assignments

- Read clarifications and changes made to any assignments, schedules, or policies.

- Post messages to make queries about the course, specific labs, or exams.

7 Policies

Working Alone on Assignments

You will work on all assignments by yourself.

Handing in Assignments

All assignments are due at 11:59pm (one minute before midnight) on the specified due date. All handins are electronic.

Handing in Late Assignments

Each student will receive a budget of three *grace days* for the course. Here is how grace days work:

- If you hand in an assignment k days late, then you receive full credit for the lab, but you will have spent k of your grace days. For example, if an assignment is due at 11:59pm on Thursday and you hand it in at noon on Saturday, then you will have spent 2 grace days. If you hand it in at 9am on Friday, then you will have spent 1 grace day.

- When you are out of grace days, you can no longer hand in late assignments, and must make special arrangements with your professor, as described in the "Making up Exams and Assignments" section.

- Regardless of the number of grace days you have remaining, handins will not be accepted after the *end date* of the lab, which is typically 2 days after the due date.

Grace days are a tool to help you manage your time and to help smooth out burstiness in assignment due dates. We recommend that you conserve your grace days, saving them for the end of the term when things get most hectic.

Making up Exams and Assignments

Missed exams and assignments more than 2 days late can be made up on a case by case basis, but only if you make prior arrangements with Prof. Sakr. However you should have a good reason for doing so. It is your responsibility to get your assignments done on time. Be sure to work far enough in advance to avoid unexpected problems, such as illness, unreliable or overloaded computer systems, etc.

Appealing Grades

After each exam and lab assignment is graded you have seven calendar days to appeal your grade.

The TA in 15-447 has the authority to unilaterally change your homework or project grade, without permission from the professors. So if you have questions about the grade you received on a project or an assignment, please talk first to the TA.

If you are still not satisfied, please come and visit Prof. Sakr. If you have questions about an exam grade, please visit Prof. Sakr directly.

Final Grade Assignment

Each student will receive a numeric score for the course, based on a weighted average of the following:

- **Attendance:** Attendance and participation will count 5% of your score.

- **Homework assignments & Quizzes:** The assignments and quizzes will count a combined total of 15% of your score.

- **Projects:** The projects will count a combined total of 40% of your score. The exact weighting of the different assignments will be determined near the end of the course based on our perception of the relative effort required. In any case, each project will count 6–12% of your score. Since small differences in scores can make the difference between two letter grades, you'll want to make a serious effort on each assignment.

- **Exams:** There will be two in-class exams, each counting 10%, plus a final counting 20%.

Grades for the course will be determined by a method that combines both curving and absolute standards. The total score will be plotted as a histogram. Cutoff points are determined by examining the quality of work by students on the borderlines. Individual cases, especially those near the cutoff points may be adjusted upward or downward based on factors such as attendance, class participation, improvement throughout the course, final exam performance, and special circumstances.

Cheating

Each lab assignment must be the sole work of the student turning it in. Assignments will be closely monitored by automatic cheat checkers, and students may be asked to explain any suspicious similarities. The following are guidelines on what collaboration is authorized and what is not:

What is Cheating?

- *Sharing code or other electronic files*: either by copying, retyping, looking at, or supplying a copy of a file.
- *Sharing written assignments*: Looking at, copying, or supplying an assignment.

What is NOT Cheating?

- Clarifying ambiguities or vague points in class handouts or textbooks.
- Helping others use the computer systems, networks, compilers, debuggers, profilers, or other system facilities.
- Helping others with high-level design issues.
- Helping others debug their code.

Be sure to store your work in protected directories.

The usual penalty for cheating is to be removed from the course with a failing grade. We also place a record of the incident in the student's permanent record.

8 Facilities: Computer Systems Cluster

We have Linux-based 32-bit Xeon that we will use for all labs and assignments. The class Web page has details.

9 Class Schedule

Figure 1 shows the tentative schedule for the class. The reading assignments are all from the book. The schedule also indicates suggested homework problems, the lab activities, and the lecturer for each class. Any changes will be announced on the class message board. An updated schedule will be maintained on the class Web page.

Class	Date	Day	Topic	Reading	Projects	Lecturer
1	18-Aug	Mon	Overview	1		Both
2	20-Aug	Wed	Digital Logic		P1 Out	NBA
3	25-Aug	Mon	Computer Arithmetic	3.1–3.5		NBA
4	27-Aug	Wed	Floating Point	3.6		NBA
5	1-Sep	Mon	ISA Design	2.1–2.4	P1 Due, P2 Out	MFS
6	3-Sep	Wed	ISA Design	2.5–2.6		MFS
7	8-Sep	Mon	Performance and Cost	4.1-4.3		MFS
8	10-Sep	Wed	Slack & Review		P2 Due	MFS
9	15-Sep	Mon	Exam 1			n/a
10	17-Sep	Wed	Register File and ALU		P3 Out	MFS
11	22-Sep	Mon	Single-Cycle Implementation	5.1–5.4		MFS
12	24-Sep	Wed	Multi-Cycle Implementation	5.5, 5.6		NBA
	29-Sep	Mon	Eid Al Fitr - No Classes			n/a
	1-Oct	Wed	Eid Al Fitr - No Classes			n/a
13	6-Oct	Mon	Pipelining	6.1-6.3		MFS
14	8-Oct	Wed	Pipelining: Data Hazard and Resolution	6.4,6.5		MFS
15	13-Oct	Mon	Pipelining: Control Hazard and Resolution	6.6		MFS
16	15-Oct	Wed	Modern CPU Design		P3 Due	NBA
17	20-Oct	Mon	Slack & Review			NBA
18	22-Oct	Wed	Exam 2			n/a
19	27-Oct	Mon	Memory Hierarchy	7.1	P4 Out	MFS
20	29-Oct	Wed	Caches	7.2		MFS
21	3-Nov	Mon	More Caches	7.3		MFS
22	5-Nov	Wed	Virtual Memory			NBA
23	10-Nov	Mon	More Virtual Memory	7.4		NBA
24	12-Nov	Wed	Disks & RAID	8.1,8.2		NBA
25	17-Nov	Mon	Buses & I/O	8.4, 8.5		NBA
26	19-Nov	Wed	Emerging Architectures		P4 Due	NBA
27	24-Nov	Mon	Power-Aware Architectures			NBA
28	26-Nov	Wed	Slack and Review			Both

Figure 1: CS 447 Class Schedule