15-447: Introduction to Computer Architecture

Majd F. Sakr (*) and Kareem A. Sakallah(**)

(*) Computer Science
Carnegie Mellon University

(**) Electrical Engineering and Computer Science
University of Michigan, Ann Arbor

Fall 2007

1 Organization

Instructors:

Majd F. Sakr  
msakr@qatar.cmu.edu  
LAS A134, 454-8625  
Tue, 10-12pm

Kareem A. Sakallah  
ksakalla@qatar.cmu.edu  
LAS A146A, 454-8649  
Thu, 10-12pm

TA:

Zaher Andraus  
zandraus@qatar.cmu.edu  
LAS A136, 454-8546

Office Hours:

Sunday 1:30-3:30
Tuesday 2:30-3:30
Wednesday 3:00-3:30
Thursday 9:30-11:30

Lecture:

Mon and Wed, 10–11:20pm, LAS CO 08

Recitations:

Tue 9:30–10:20am, LAS A0 41, Zaher Andraus

Class Web Page:

http://www.qatar.cmu.edu/~msakr/15447-f07/

Class Message Board:

We will be using blackboard (http://blackboard.qatar.cmu.edu/) to post messages and for students to upload assignments and projects.
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 learn, for example, how to design the control and datapath for a pipelined RISC processor and how to design fast memory and storage systems. The principles presented in lecture are reinforced through projects involving the design and simulation of a RISC processor pipeline.

3 Textbook

The primary textbook for the course is


4 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 the projects are fairly short, requiring just one week, while others are more ambitious, requiring several weeks.

5 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. Sakallah is glad to meet with students, but he’s also got a lot of other meetings. 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-f07/

Using the Web, 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.
6 Policies

Working Alone on Assignments
You will work on all assignments by yourself.

Handing in Assignments
All assignments are due in class or at recitation. Projects are due at 11:59pm (one minute before midnight) on the specified due date. All handins are electronic.

Handing in Late Projects
Each student will receive a budget of five grace days for the course. Here is how grace days work:

- If you hand in a project \( k \) days late, then you receive full credit for the project, 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.

- 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.

Appealing Grades
After each exam and lab assignment is graded, Prof. Sakr will send each of you a personalized email with your grade (as well as all of your previous grades). You have seven calendar days from the date he sends the email 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 lab assignment, please talk first to the person in charge of the assignment, who will be clearly identified in the writeup.

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.
7 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.

8 Class Schedule

Figure 1 shows the tentative schedule for the class. The reading assignments are all from the book. The schedule also indicates the project activities. Any changes will be announced on the class message board. An updated schedule will be maintained on the class Web page.

Figure 1: CS 447 Class Schedule

<table>
<thead>
<tr>
<th>Class</th>
<th>Date</th>
<th>Day</th>
<th>Topic</th>
<th>Reading</th>
<th>Projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>27-Aug</td>
<td>Mon</td>
<td>Overview</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>29-Aug</td>
<td>Wed</td>
<td>Computer Arithmetic</td>
<td>3.1-3.3</td>
<td>P1 Out</td>
</tr>
<tr>
<td></td>
<td>3-Sep</td>
<td>Mon</td>
<td>Qatar Independence Day - No Classes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>5-Sep</td>
<td>Wed</td>
<td>Computer Arithmetic</td>
<td>3.4–3.5</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>10-Sep</td>
<td>Mon</td>
<td>Floating Point</td>
<td>3.6</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>12-Sep</td>
<td>Wed</td>
<td>ISA Design</td>
<td>2.1–2.4</td>
<td>P1 Due, P2 Out</td>
</tr>
<tr>
<td>6</td>
<td>17-Sep</td>
<td>Mon</td>
<td>ISA Design</td>
<td>2.5–2.6</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>19-Sep</td>
<td>Wed</td>
<td>Performance and Cost</td>
<td>4.1-4.3</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>24-Sep</td>
<td>Mon</td>
<td>Slack &amp; Review</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>26-Sep</td>
<td>Wed</td>
<td>Exam 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>1-Oct</td>
<td>Mon</td>
<td>Single-Cycle Implementation</td>
<td>5.1–5.4</td>
<td>P2 Due</td>
</tr>
<tr>
<td>11</td>
<td>3-Oct</td>
<td>Wed</td>
<td>Register File and ALU</td>
<td></td>
<td>P3 Out</td>
</tr>
<tr>
<td>12</td>
<td>8-Oct</td>
<td>Mon</td>
<td>Multi-Cycle Implementation</td>
<td>5.5, 5.6</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>10-Oct</td>
<td>Wed</td>
<td>Pipelining</td>
<td>6.1-6.3</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>15-Oct</td>
<td>Mon</td>
<td>Eid Al Fitr - No Classes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>17-Oct</td>
<td>Wed</td>
<td>Eid Al Fitr - No Classes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>22-Oct</td>
<td>Mon</td>
<td>Pipelining: Data Hazard and Resolution</td>
<td>6.4,6.5</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>24-Oct</td>
<td>Wed</td>
<td>Pipelining: Control Hazard and Resolution</td>
<td>6.6</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>29-Oct</td>
<td>Mon</td>
<td>Modern CPU Design</td>
<td></td>
<td>P3 Due</td>
</tr>
<tr>
<td>17</td>
<td>31-Oct</td>
<td>Wed</td>
<td>Slack &amp; Review</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>5-Nov</td>
<td>Mon</td>
<td>Exam 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>7-Nov</td>
<td>Wed</td>
<td>Memory Hierarchy</td>
<td>7.1</td>
<td>P4 Out</td>
</tr>
<tr>
<td>20</td>
<td>12-Nov</td>
<td>Mon</td>
<td>Caches</td>
<td>7.2</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>14-Nov</td>
<td>Wed</td>
<td>More Caches</td>
<td>7.3</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>19-Nov</td>
<td>Mon</td>
<td>And More Caches</td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>21-Nov</td>
<td>Wed</td>
<td>VM</td>
<td>7.4</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>26-Nov</td>
<td>Mon</td>
<td>Disks &amp; RAID</td>
<td>8.1,8.2</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>28-Nov</td>
<td>Wed</td>
<td>Busses &amp; I/O</td>
<td>8.4, 8.5</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>3-Dec</td>
<td>Mon</td>
<td>Multicore</td>
<td></td>
<td>P4 Due</td>
</tr>
<tr>
<td>27</td>
<td>5-Dec</td>
<td>Wed</td>
<td>Exam review</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>