George Mason University
Volgenau School of Engineering
Department of Electrical and Computer Engineering

ECE 445: Computer Organization
Syllabus
Spring 2016

Professor:  Dr. Craig Lorie
3221 Nguyen Engineering Bldg.
clorie@gmu.edu
(703) 993 – 9616

Teaching Assistant:

Lecture:  Monday / Wednesday,  1:30 – 2:45 pm  
Blueridge Hall, room 129

Office Hours:  Instructor and TA office hours posted on Blackboard.

Prerequisites:  Grade of C or better in ECE 331 and ECE 332, and in either CS 262 or CS 222.


Hardware:  Digilent Basys2 Board.  
http://www.digilentinc.com/

Software:  Xilinx ISE WebPack  
http://www.xilinx.com
MARS  
http://courses.missouristate.edu/KenVollmar/MARS/
SPIM  
http://spimsimulator.sourceforge.net/

Course Webpages:  https://mymasonportal.gmu.edu/  (Blackboard)

Textbook Website:  http://textbooks.elsevier.com/9780124077263

COURSE DESCRIPTION (FROM GMU COURSE CATALOG)

This course provides a general overview of the operation of a digital computer. Topics include computer arithmetic, the arithmetic and logic unit, hardwired and microprogrammed control, memories, register-to-register data transfer, input-output operations, and behavioral modeling of computer organization using VHDL. The course also provides an introduction to assembly language programming, using the MIPS processor. Credits: 3 (Lecture: 3, Lab: 0).

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 ISE. The processor will be realized using the Basys2 board and programmed using assembly language.
LEARNING OUTCOMES

Following successful completion of ECE 445, the student will be able to:

- Describe an Instruction Set Architecture (ISA)
- Write assembly language programs.
- Convert assembly language to machine language, and vice versa.
- Design the datapath and control unit for a simple processor.
- Design the datapath and control unit for a pipelined processor.
- Evaluate the performance of various processors.
- Understand how exceptions (and interrupts) are handled.
- Understand the need for a hierarchical memory system.
- Describe direct-mapped, set-associative, and fully-associative caches and explain how they work.
- Describe virtual memory.
- Describe the various types of memories and memory technologies.
- Represent real numbers using floating-point notation.
- Understand how arithmetic operations, including addition, subtraction, multiplication, and division are implemented in computer architectures.
- Understand how input and output devices interface to, and interact with, the processor.

A detailed schedule is provided at the end of this document and posted separately on Blackboard.
**CLASS MEETINGS**

This course has been designed to improve learning and retention through active participation. Each class meeting will have the following format:

1. **Class preparation**
   You should review the class materials provided prior to each class meeting. This includes the short presentation (discussed below), the supplemental lecture slides, and any associated reading assignments. The supplemental lecture slides provide greater detail on the topics covered, and should prove to be beneficial when studying for the exams. Proper preparation is essential if you are to be successful in this course.

2. **Short presentation**
   Through a short presentation, I will provide an overview of the material covered (in each class). I will not review the supplemental slides provided in the lecture materials, but will address any questions on this material.

3. **In-class exercises**
   The in-class exercises will provide the practice necessary to learn (and retain) the material. Through these exercises, and the active learning process, you will, hopefully, develop a deeper and more complete understanding of the material.

Each in-class exercise will be assigned a point value based on the level of complexity.

<table>
<thead>
<tr>
<th>Type of Exercise</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Review problems</td>
<td>0.5 pt.</td>
</tr>
<tr>
<td>Simple problems</td>
<td>1 pt.</td>
</tr>
<tr>
<td>Complex problems</td>
<td>2 pts.</td>
</tr>
</tbody>
</table>

All exercises are multiple-choice. Only a correct answer will earn the points. An incorrect response will earn zero (0) points.

To obtain the full class-participation grade of 5 points (see "Course Grade" section below) you will need to earn 10 points on the in-class exercises during each class meeting. Any points earned beyond the needed 10 points will contribute to extra credit for the class participation grade, with a maximum of 1 additional point.
CLICKER DEVICES

To facilitate the in-class exercises, this course will use clicker devices. The clicker2 was chosen because it offers a "self-paced polling" feature which is not available on the other clicker devices, nor on the clicker mobile app. The "self-paced polling" feature allows you to work on the in-class exercises at your own pace and in the order you choose.

The clicker2 device can be purchased from the Bookstore or from the clicker website:

https://www1.iclicker.com/products/iclicker-2/

The clicker device must be registered at the clicker website:

https://www1.iclicker.com/register-clicker/

If you do not register your clicker device, your responses will not be properly recorded, and you will not get credit for your participation.

Important information when registering your clicker device:

- GMU uses a Learning Management System (Blackboard)
- Your student ID is the prefix of your email address
  (for example, if your email address is xyz@gmu.edu, then your student ID is xyz).
HOMEWORK ASSIGNMENTS

Homework is an essential part of the learning process. Each homework assignment will be composed of:

1. Reading assignment
   The reading assignment will be from the course textbook and/or from supplemental reading sources. The reading will provide greater depth and breadth than can be provided in class. You are expected to complete the assigned reading prior to each class meeting (and before attempting any of the homework problems).

2. Problem set
   The problem set will provide (additional) practice needed to develop a more comprehensive understanding of the material. You are expected to complete, to the best of your ability, all of the assigned problems.

Homework is assigned on a weekly basis (on Blackboard). It will cover the material discussed in class and in the associated reading assignment.

Homework solutions must be submitted via Blackboard. Solutions must be submitted as a single PDF file. You may generate the PDF file directly from a wordprocessor or spreadsheet. Or you may scan your written solutions using a conventional scanner or a scanner app (e.g. Camscan) for your smartphone or tablet. You may not submit pictures of your homework solutions. You are responsible for ensuring that your homework solutions are readable. If the grader cannot read your solutions, they will not be graded and you will receive a zero for your submission.

Homework solutions must be submitted by 5:00pm on the specified due date. Late submissions will be assessed the following penalty:

<table>
<thead>
<tr>
<th>Number of days late:</th>
<th>Penalty</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5 %</td>
</tr>
<tr>
<td>2</td>
<td>10 %</td>
</tr>
<tr>
<td>3</td>
<td>15 %</td>
</tr>
</tbody>
</table>

Homework solutions will not be accepted more than 3 days late.

You are encouraged to work together on the homework assignments. However, you must submit your own work. Copying any or all of the homework solutions of another student is considered plagiarism and is strictly prohibited. Cheating on a homework assignment will result in a zero (0) for that assignment.

Homework solutions will be graded as follows:

- Two selected problems graded for correctness. 10 pts.
- Remaining problems graded for completeness. 1 pt. each

The lowest homework grade will be dropped at the end of the semester.
Homework solutions must be formatted as follows:

1. Your name should appear at the top-left on all pages of your solutions.
2. The class number (ie. ECE 331) and the assignment number should appear below your name.
3. All pages should be numbered at the top-right.
4. All solutions should be written neatly and clearly.
5. Each problem should be started on a new page (front and back are considered separate pages).
   (Multiple-choice problems may all be included on the same page).

Additional "practice" problems may be included on each homework assignment. These problems do not need to be submitted and will not be graded.
EXAMS

This course includes two Midterm exams and a Final exam. Exam dates are specified in the course schedule. Each exam will consist of: (1) a set of multiple-choice questions; and (2) several long-answer questions. You must provide a Scantron form for each exam. The specific Scantron form is specified on Blackboard.

The final exam is cumulative.

All exams are closed book. I will provide any necessary reference materials and scrap paper as needed.

If you cannot make one of the scheduled exams, you must speak with me in advance to arrange for an alternate time to take the exam.

DISCUSSION BOARD

All questions about the material covered in this course, including questions about the class, homework assignments, exams, and projects, will be addressed using the discussion board on Blackboard (https://mymasonportal.gmu.edu/). Four forums have been created on the discussion board:

1. General questions
2. Homework assignments
3. Exams
4. Labs

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.

I will do my 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. I will review all answers posted by other students to confirm their correctness.

Any questions or concerns regarding a personal matter should be emailed to me directly. Do not post such comments on the discussion board.
MACHINE PROJECTS

The machines projects 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 ISE design tool.

The processor will be developed in stages. At each stage, the design will be realized using the Digilent Basys2 board, and tested using sample assembly language programs.

You will have access to the computer lab in the Nguyen Engineering Building (room 3208), where the required design software has been installed. In addition, you may use your personal computer, assuming the proper software has been installed.

The simple processor to be implemented in these projects is the 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).

A list of the projects is given below:

0. Introduction to the Xilinx ISE
1. The MIPS Arithmetic and Logic Unit (ALU)
2. The MIPS Datapath and Control Unit to implement R-type Instructions.
3. Realization of the Datapath and Control Unit for R-type instructions using the Basys2 board.
4. The MIPS Datapath and Control Unit to implement R- and I-type Instructions.
5. The MIPS Datapath and Control Unit to implement R-type, I-type, and Jump Instructions.
6. Connection of simple I/O devices to the MIPS processor.

Late submissions will NOT BE ACCEPTED!

Details of the machine projects will be provided by the TA, and will be posted on Blackboard.

PROJECT GRADING:

The machine projects will be scored as follows:

P.1 4
P.2 7
P.3 3
P.4 7
P.5 7
P.6 7
Total 35 points
ATTENDANCE

You are expected to attend class, however attendance will not be formally recorded. Failure to attend class does not excuse you from the material covered. If you miss class you must consult with one of your classmates to obtain the notes and/or problem solutions that were presented. Furthermore, you will receive a zero for the in-class exercises that were missed.

COURSE GRADE

The final grade for the course is based on my best assessment of your understanding of the material and your participation in the class during the semester. The exams, projects, and homework assignments will be used to determine your final grade according to the following weighting:

<table>
<thead>
<tr>
<th>Component</th>
<th>Weighting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homework</td>
<td>10%</td>
</tr>
<tr>
<td>In-class Exercises</td>
<td>5%</td>
</tr>
<tr>
<td>Machine Projects</td>
<td>35%</td>
</tr>
<tr>
<td>Midterm Exam #1</td>
<td>15%</td>
</tr>
<tr>
<td>Midterm Exam #2</td>
<td>15%</td>
</tr>
<tr>
<td>Final Exam</td>
<td>20%</td>
</tr>
</tbody>
</table>

The final letter grade will be assigned accordingly.

ACADEMIC INTEGRITY

The George Mason University Honor Code is stated as follows:

"To promote a stronger sense of mutual responsibility, respect, trust, and fairness among all members of the George Mason University community and with the desire for greater academic and personal achievement, we, the student members of the University Community have set for this:

Student members of the George Mason University community pledge not to cheat, plagiarize, steal, and/or lie in matters related to academic work."

You are expected to abide by the Mason Honor Code. Violations of the Honor Code are taken very seriously and will be prosecuted to the fullest extent. This includes, but is not limited to, cheating on homework assignments, quizzes, projects, labs, and exams.

As indicated above, you are encouraged to work together on assessments, and share ideas about solutions to problems. However, you must submit your own work. Copy the solution from another student, or from the author's solution manual, is considered cheating and is a violation of the Honor Code.

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

Classroom Etiquette

Cellphones are to be turned off during class; minimally they must be silenced. Emergency calls may be taken, but must be taken outside of the classroom.

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.

Office of Disability Services (ODS)

If you are a student with a disability and require special accommodations, please contact me 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; http://ods.gmu.edu

Other Useful Campus Resources

- Writing Center: A114 Robinson Hall; (703) 993 – 1200; http://writingcenter.gmu.edu
- University Libraries: “Ask a Librarian” http://library.gmu.edu/mudge/IM/IMRef.html
- Counseling and Psychological Services (CAPS): (703) 993 – 2380; http://caps.gmu.edu
- The University Catalog: http://catalog.gmu.edu
- University Policies: http://universitypolicy.gmu.edu
<table>
<thead>
<tr>
<th>Date</th>
<th>Lec</th>
<th>Topic</th>
<th>Reading</th>
<th>HW due</th>
<th>Lab</th>
</tr>
</thead>
<tbody>
<tr>
<td>M 1/18</td>
<td></td>
<td>No Class (MLK Day)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>W 1/20</td>
<td>1</td>
<td>Course Introduction</td>
<td>H/P: B, 1.1 - 1.5, 1.12</td>
<td>P.1 due</td>
<td></td>
</tr>
<tr>
<td>M 1/25</td>
<td>2</td>
<td>Instruction Set Architecture Program execution</td>
<td>H/P: A.1 - A.5, 2.1 - 2.5</td>
<td>P.1 due</td>
<td>Intro to P.2</td>
</tr>
<tr>
<td>W 1/27</td>
<td>3</td>
<td>Assembly and Machine Language</td>
<td>H/P: A.10, 2.1 - 2.7</td>
<td></td>
<td>P.1 due</td>
</tr>
<tr>
<td>M 2/1</td>
<td>4</td>
<td>Programming in Assembly Language 1</td>
<td>H/P: A.9, 2.1 - 2.7, 2.10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>W 2/3</td>
<td>5</td>
<td>Processor Design 1</td>
<td>H/P: 4.1 - 4.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M 2/8</td>
<td>6</td>
<td>Processor Design 2</td>
<td>A/E: 5.1 - 5.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>W 2/10</td>
<td>7</td>
<td>Processor Design 3</td>
<td>H/P: 4.1 - 4.4; A/E: 5.1 - 5.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M 2/15</td>
<td>8</td>
<td>Function Calls and the Stack</td>
<td>H/P: 2.8</td>
<td></td>
<td>P.3 due</td>
</tr>
<tr>
<td>W 2/17</td>
<td>9</td>
<td>Programming in Assembly Language 2</td>
<td>H/P: A.9, 2.1 - 2.14</td>
<td></td>
<td>Intro to P.3</td>
</tr>
<tr>
<td>M 2/22</td>
<td>10</td>
<td>Performance 1</td>
<td>H/P: 1.6 - 1.10</td>
<td></td>
<td>P.3 due</td>
</tr>
<tr>
<td>W 2/24</td>
<td></td>
<td>Midterm #1 (Lectures 1 - 9)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M 2/29</td>
<td>11</td>
<td>Performance 2</td>
<td>H/P: 1.6 - 1.10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>W 3/2</td>
<td>12</td>
<td>Processor Design 4 (MIPS, pipelined)</td>
<td>H/P: 4.5 - 4.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M 3/7</td>
<td></td>
<td>No Classes (Spring Break)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>W 3/9</td>
<td></td>
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<tr>
<td>M 3/14</td>
<td>13</td>
<td>Pipeline Hazards 1</td>
<td>H/P: 4.7</td>
<td></td>
<td>P.4 due</td>
</tr>
<tr>
<td>W 3/16</td>
<td>14</td>
<td>Pipeline Hazards 2</td>
<td>H/P: 4.7</td>
<td></td>
<td>Intro to P.5</td>
</tr>
<tr>
<td>M 3/21</td>
<td>15</td>
<td>Branch Prediction</td>
<td>H/P: 4.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>W 3/23</td>
<td>16</td>
<td>Computer Arithmetic</td>
<td>H/P: 3.1 - 3.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M 3/28</td>
<td>17</td>
<td>Floating-point Representation</td>
<td>H/P: 3.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>W 3/30</td>
<td>18</td>
<td>Interrupts and Exceptions</td>
<td>H/P: 4.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M 4/4</td>
<td>19</td>
<td>Input / Output</td>
<td>H/P: 1.4</td>
<td></td>
<td>P.5 due</td>
</tr>
<tr>
<td>W 4/6</td>
<td></td>
<td>Midterm #2 (Lectures 10 - 18)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M 4/11</td>
<td>20</td>
<td>Memory Technologies</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>W 4/13</td>
<td>21</td>
<td>The Memory System</td>
<td>H/P: 5.1 - 5.2, 5.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M 4/18</td>
<td>22</td>
<td>Cache 1</td>
<td>H/P: 5.3 - 5.4, 5.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>W 4/20</td>
<td>23</td>
<td>Cache 2</td>
<td>H/P: 5.3 - 5.4, 5.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M 4/25</td>
<td>24</td>
<td>Cache 3</td>
<td>H/P: 5.3 - 5.4, 5.8</td>
<td></td>
<td>P.6 due</td>
</tr>
<tr>
<td>W 4/27</td>
<td>25</td>
<td>Virtual Memory; TLB</td>
<td>H/P: 5.7 - 5.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M 5/2</td>
<td>26</td>
<td>Microcoding</td>
<td>H/P: D.1 - D.5 (online)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>