Microprocessor Based System Design

Study of RISC microprocessor based systems and their integration with peripheral devices.

**Learning Objectives**

Study of microprocessor based systems and their integration with peripheral devices including sensors, actuators, and serial communications. Programming problems will be completed in C++, using the basic problem solving techniques learned in EE186 and EE346. Following a progressive lab sequence, over the semester the student will design and construct a modern RISC microcontroller based system.

*Figure 5.1: ATmega328P block diagram, adapted from ATMEL (2009).*
Course Outline

1. The Mission
   - Mission Objectives
   - How to Build, Wire, and Test Your Rover

2. Microprocessor Based System Design
   - Introduction to Microcontroller Programming in C++
   - Compiler Explorer
   - General-Purpose Input/Output Ports
   - Arduino the Documentary
   - Introduction to Microcontrollers – \texttt{328P}/\texttt{32U4}/\texttt{3DoT}
   - Microcontroller Based System Interface Design - \texttt{328P}/\texttt{32U4}/\texttt{3DoT}

3. Serial Communication (SPI, I2C) and the Adafruit Motor Shield - Part 1
   - Serial Peripheral Interface (SPI)
   - Two-wire Interface (I2C)
   - Universal Synchronous/Asynchronous Receiver/Transmitter (USART)
   - Adafruit Motor Shield v1 Software Serial Peripheral Interface

4. Motors and Actuators
   - DC and Stepper Motor Control (includes Shaft Encoders)
   - Servos and the Scan and Tilt Platform
   - Pulse Width Modulation and the Adafruit Motor Shield - Part 2
     - ATmega Timers and Fast Pulse Width Modulation
     - Adafruit Motor Shield v1 Basic DC Motor Control

5. Sensors and Signals
   - Analog / Digital sensors
   - ATmega Analog-to-Digital Converter
   - ATmega Analog Comparator (Section 22 Analog Comparator)

6. MCU Instructions
   - Sleep
   - Watchdog Timer
   - In-Circuit Emulation (ICE)

7. C++ Programming
   - Arrays
   - Interrupts – Part One and Two
   - AVR Studio Blink
   - PID Control Software
## Lab Series

<table>
<thead>
<tr>
<th>Lab</th>
<th>Subject</th>
<th>Pre-lab /Due</th>
<th>Lab</th>
<th>Due /Signoff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zero</td>
<td>QRE1113 Reflectance Sensor</td>
<td></td>
<td>Aug 30, Sept 6</td>
<td>Sept 13</td>
</tr>
<tr>
<td>One</td>
<td>An Introduction to 3DoT and C++</td>
<td>Sept 13</td>
<td>Sept 13</td>
<td>Sept 20</td>
</tr>
<tr>
<td>Two</td>
<td>Motor Control and Fast Pulse Width Modulation (PWM)</td>
<td>Sept 20</td>
<td>Sept 20, 27</td>
<td>Oct 4</td>
</tr>
<tr>
<td>Three</td>
<td>Sensors and How to Make a Turn</td>
<td>Oct 4</td>
<td>Oct 4, Oct 11</td>
<td>Oct 18</td>
</tr>
<tr>
<td>Four</td>
<td>Working with Arrays</td>
<td>Oct 18</td>
<td>Oct 18, 25</td>
<td>Nov 1</td>
</tr>
<tr>
<td>Five</td>
<td>Subroutines as Building Blocks</td>
<td>Nov 1</td>
<td>Nov 1</td>
<td>Nov 8</td>
</tr>
<tr>
<td>Six</td>
<td>aMazing Solution</td>
<td>Nov 8</td>
<td>Nov 8, Nov 15</td>
<td>Nov 29</td>
</tr>
<tr>
<td></td>
<td>Research Lab</td>
<td>Nov 29</td>
<td>Nov 29, Dec 6</td>
<td>Dec 11</td>
</tr>
</tbody>
</table>

1 Lab due dates are to be determined.
General Class Information

Contact Information

Instructor — G. C. Hill
Office — ECS-519
Hours — Monday and Wednesday from 12:20 p.m. to 1:20 p.m. and Friday from 11:00 a.m. to 1:00 p.m.
E-mail — hellogaryhill@gmail.com
Website — http://www.csulb.edu/~hill/ee444/

Class Prerequisites

- Critical Thinking in the Digital Information Age (CECS 100) or equivalent
- Digital Logic Design (EE 201)
- Microprocessor Principles and Applications (EE346)

Class Meetings

Lecture — Monday and Wednesday from 10:00 to 10:50 p.m. in ECS 314
Lab — Monday and Wednesday from 11:00 to 12:15 p.m. in ECS 314

Preliminary Grading Procedure

<table>
<thead>
<tr>
<th>Category</th>
<th>Total %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miscellaneous - Attendance, Class Participation, ...</td>
<td>10</td>
</tr>
<tr>
<td>Worksheet(s) / Labs / Mission Objectives</td>
<td>35</td>
</tr>
<tr>
<td>Exams/Quizzes</td>
<td>35</td>
</tr>
<tr>
<td>Research</td>
<td>10</td>
</tr>
<tr>
<td>The Mission</td>
<td>10</td>
</tr>
</tbody>
</table>

The Mission

10:15 AM to 12:15 PM  Wednesday, December 13

---

2 If I am not in my office, look for me in ECS-314 or ECS-316
3 See University, College and Department rules for information on withdrawing from the class. I do not give incomplete (I) grades. The percentages allocated to each category may change over the course of the semester.
Materials

Textbooks — The AVR Microcontroller and Embedded Systems using Assembly and C) by Muhammad Ali Mazidi, Sarmad Naimi, and Sepehr Naimi

Atmel 8-bit AVR Microcontroller (ATmega328P) datasheet

Reference —

Arduino in a Nutshell
http://hci.rwth-aachen.de/arduino

Compiler Explorer
https://godbolt.org/

Atmel 8-bit AVR Microcontroller (ATmega328P) Summary

MITMECHE 2.017 Design of Electromechanical Robot Systems, by Dr. Harrison H. Chin

Atmel 8-bit AVR Microcontroller (ATmega328P) Summary

Plagiarism

COE has a zero-tolerance policy for cheating or plagiarism. Note: Any time another person’s work is used without giving them proper credit, it is considered plagiarism and cheating. Any individual caught cheating on quizzes, exams, homework, or lab projects will be punished. At the instructor’s sole discretion one or more of the following actions may be taken.

- A requirement that the work be repeated;
- Assignment of a score of zero (0) for the specific demonstration of competence, resulting in the proportional reduction of final course grade;
- A reduction of one letter grade from your final course grade
- Assignment of a failing final grade;
- Referral to the Office of Judicial Affairs for possible probation, suspension, or expulsion.
The official CSULB Policy on Cheating and Plagiarism can be found here: [http://web.csulb.edu/divisions/aa/catalog/current/academic_information/cheating_plagiarism.html](http://web.csulb.edu/divisions/aa/catalog/current/academic_information/cheating_plagiarism.html)

## Computers and Mobile Devices

During the lecture, the computers in lab and any laptop or tablet should be used for looking at the lecture material and/or to take notes only. These devices may not be used for browsing the web or linking to any social media sites. These devices may be taken offline at the instructor’s discretion.

During class, cell phones should be muted and put away (i.e., not on the table top, lap, floor, etc.). During quizzes and exams students will not have access to these devices.

Please ask the instructor before recording audio or taking any pictures or videos in class/lab.

## DO NOT FORGET

Makeup exams may be taken if you received my permission prior to the exam. Makeup exams will not be the same ones taken by the class; however, grading will be on the same curve. Absent students should notify instructors prior to each missed class by email.