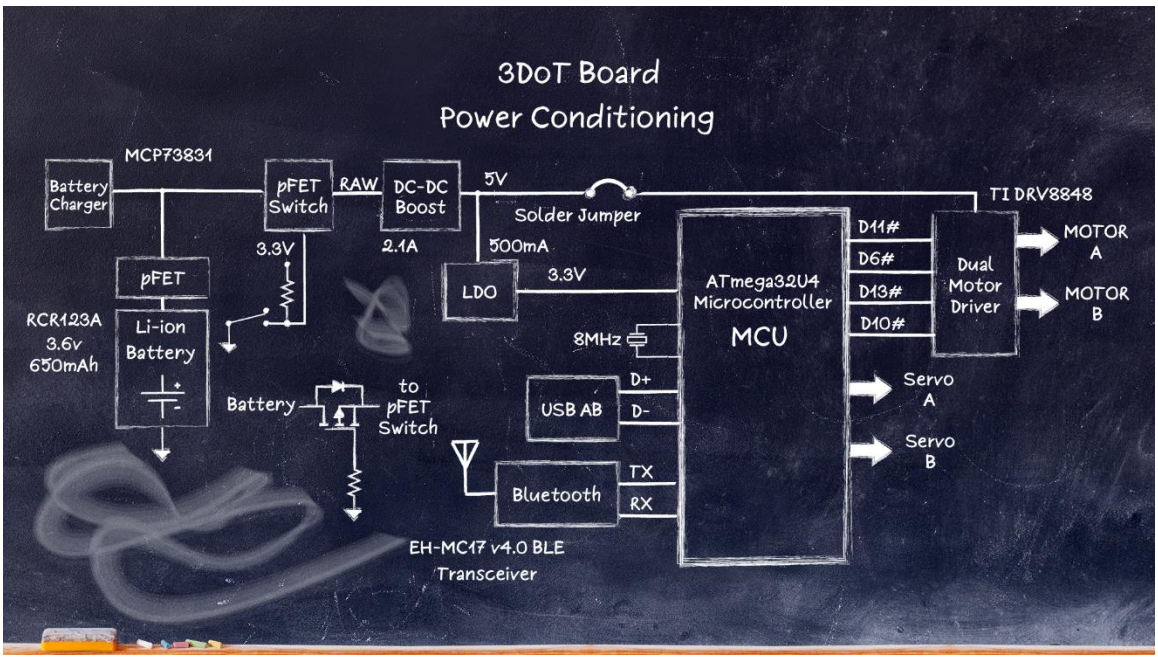
EE 444

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 learn how to design, build, and program a modern RISC microcontroller-based robot.



Course Outline

The focus of the first few lectures is on hardware design. Next up, is a discussion of why programming a microcontroller is different from programming a computer. Based on the prerequisites for this course, the student should have an introductory knowledge of writing in a high-level language like C++. The course now goes into greater detail on both the hardware and programming of real-world embedded systems, in most cases using your 3DoT Robot as a case study. For example, new to this semester is a special lecture on how the 3DoT Battery Powers its suite of Robots.

1. System Engineering Your Robot

- MCU Based Interface Design
- Allocating MCU Resources

2. Robot Sensors and Actuators

- Interfacing Sensors and Actuators
- Digital and Analog Sensors
- Digital and Analog (PWM) Actuators
- Serial Interface Protocols

3. C++ Types of Data & Playing with Bits

- Assemblers, Compilers, and Interpreters
- Scope and Data Types
- The Arduino Scripting Language
- Working with Bits in C++

4. General Purpose I/O Ports

- Pin Description of the ATmega32U4
- GPIO Port pin as an Output and Input.
- 3DoT Board Design Example

5. Pulse Width Modulation (PWM)

- Motor Direction and Speed Control
- ATmega32U4 10-bit Timer/Counter 4
- PWM Motor Speed Control Example

5. C++ Structured Data Types

- Declaring an Array
- Accessing Array Elements
- Passing & Returning Arrays in a Function
- Structured Data Types in Program Memory (PROGMEM)
- Data Structures

6. Analog-to-Digital Conversion

- MCU ADC Subsystem Features
- How it Works
- How to make an Analog to Digital conversion within the Arduino IDE

7. Serial Communication

- Serial Peripheral Interface (SPI)
- 74HC595 Code Example
- Inter-Integrated Circuit (I2C)
- C++ Code Example

Special Topic

- How the 3DoT Battery Powers its Robots (Article by Jaap de Dood)
- PID Controllers (PowerPoint by Jordon)
- Watchdog Timers

Lab Schedule

Lab	Subject	Pre-lab /Due	Lab	Due /Signoff	Weeks
Zero	Build the Robot	Tutorial(s)[1]	Jan 19[2] to 28[3]	Feb 2nd	2
One	Line Follower		Feb 2nd to 11th	Feb 11	2
Two	Motor Control and Fast Pulse Width Modulation (PWM)		Feb 16th and 18th		1
Three	Sensor Data as an Analog Input		Feb 23rd and 25th	Feb 25	1
Four	Take A Step		Mar 2nd to 11th	Mar 11	2
Five	Turning		Mar 16th and 18th	Mar 18	1
Six	Arrays and Data Structures	Mar 23	Mar 23rd to Apr 8th	Apr 8	2
Seven	Navigating the Maze	Apr 13	Apr 13th to Apr 22nd	Apr 22	2
	Research / The Mission		Apr 27th to May 6th	May 11[4]	2

Research Options

- Arxterra Gallery of Previous Research Projects
- Pre-Arxterra Research Projects
- RoboRally Board Game, including RoboRuckus
- LDC Shield to Replace IR Sensor Shield
- *Your Idea Here*

[1] See Detours in Lab 1
[2] Order
[3] Build and Test
[4] Day of the final.

General Class Information

Contact Information

Instructor — G. C. Hill

Office — ECS-519

Hours[5] — Monday to Thursday from 3:00 p.m. to 4:00 p.m.
Zoom by Appointment: https://csulb.zoom.us/j/81453706383

E-mail — hellogaryhill@gmail.com

Website(s) — https://www.arxterra.com/getting-started/, lectures and labs

Class Prerequisites

- Microprocessor Principles and Applications (EE346)

Class Meetings

Lecture — Tuesday and Thursday from 9:30 to 10:20 a.m. ~~in ECS 316~~

Lab — Tuesday and Thursday from 11:00 to 12:15 p.m. ~~in ECS 316~~

Use Zoom ID for both lecture and lab sections.

Zoom: https://csulb.zoom.us/j/87478686235

Preliminary Grading Procedure[6]

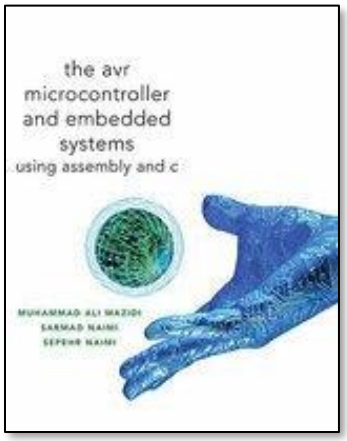
Category	**Total %**
Miscellaneous - Attendance, Class Participation, ...	5
Exams / Quizzes	45
Labs / Worksheet(s)	30
Research **or** Lab Challenges	10
The Mission	10

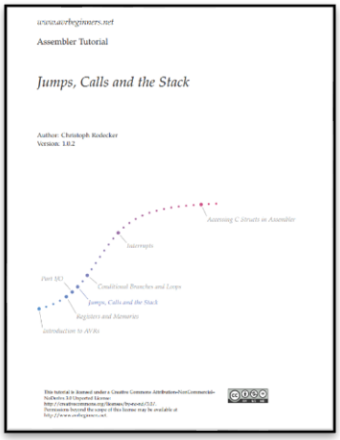
The Mission

10:15 AM to 12:15 PM	Tuesday, May 11th
Zoom ID	https://csulb.zoom.us/j/84591259550

[5] ~~If I am not in my office, look for me in ECS-316 and VEC-425~~ Please request an appointment during these hours.
[6] 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 ATmega32U4 Datasheet

Reference — Atmel 8-bit AVR Microcontroller ATmega32U4 Summary

Atmel 8-bit AVR Instruction Set doc0856.pdf

AVRBeginners.Net by Christoph Redecker

Arduino in a Nutshell by Jan Borchers

Atmel AVR Assembler User Guide doc1022.pdf

Arxterra - Getting Started

Help — Humans for Robots Discord Channel

AVR Freaks

Lab Supplies — Humans For Robots Maze Kit

Software — AVR Studio 4 (**Recommended**) or ATMEL Studio 7.

Independent of which Studio version you download, you will also need WinAVR, and the Arduino IDE.

All download software is **FREE**. Labs assume AVR Studio 4.

Fun Stuff

C++ to Assembly — Compiler Explorer https://godbolt.org/ Select Arduino Uno from drop-down menu.

Videos — Arduino the Documentary

The Game Boy, a hardware autopsy - Part 1: the CPU

The Game Boy, a hardware autopsy - Part 1.5: a few mistakes and register F

The Game Boy, a hardware autopsy - Part 2: memory mapping

Game — Tessellated Intelligence System TIS100

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

Computers and Mobile Devices

While the following material was written for in-class lectures, it remains true for zoom meetings.

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 tabletop, 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 quizzes and exams may be taken if you received my permission prior to the test date. Makeup tests 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.