

EMCH 367 Fundamentals of Microcontrollers

SYLLABUS

GENERAL INFORMATION

- Credit: 3 hours
- Prerequisites: EECE 221 Basic Electric Circuits,
EMCH 361 Measurements and Instrumentation
- Description: Study of microcontrollers and their applications as measurement and control devices in mechanical systems
- Textbooks: Giurgiutiu, V. and Lyshevski, S. E. "Micromechatronics." 2nd ed., CRC Press 2009
M68HC11 Reference manual; MC68HC11A8 programming reference guide,
- References: Motorola, Inc. + additional references.
Basic Science: 20%, Engineering Science 80%
- Coordinator: Dr. Victor Giurgiutiu; email: giurgiut@cec.sc.edu
Office Location: 300 Main St.; Room A222
Office Hours: 10:00 am - 11:00 am Monday – Friday and when door is open
- TA's: Head TA, Section 3 (M 9:05-12:05): Patrick Pollock pollocpj@cec.sc.edu, A237
Section 1 (M 1:25-4:25): Matthew Presson, pressonm@mailbox.sc.edu, A237
Section 2 (W 1:25-4:25): Bin Lin, linbin@cec.sc.edu, A237
Section 4 (W 9:05-12:05): Giola Bottai, bottai@cec.sc.edu, A236
Section 5 (M 4:30-7:30): Lingyu (Lucy) Yu, yu3@cec.sc.edu, A236
Section 6 (W 4:30-7:30): Nathan Dyer, nathand@controlmanagement.com, A236
- Required tools: PC with THRSim11 installed (the USC computers in rooms B202 and A235, 300 Main St. have it.)
Pocket calculator with Hex, Bin, and Oct, and logics operators (e.g., TI-34)
- Website: <http://www.me.sc.edu/courses/emch367>: handouts and important information related to labs and project can be found on the website.

INSTRUCTIONAL OBJECTIVES

During the course:

1. The student will gain knowledge about the microcontroller and how it can be used in modern machinery.
2. The student will achieve comprehension of the microcontroller principles, functions, and its interaction with the rest of the world via sensors, actuators, and programming.
3. The student will gain hands-on experience through lab work and course project.
4. The student will develop analysis, synthesis, and communication skills through the course project.

After the course [Dept. Objectives and Outcomes] (Assessment method)

1. Students will be able to demonstrate knowledge and comprehension of the microcontroller and of its use for sensing and actuation control of engineering systems, and of its role in modern society [1.1, 1.2, 5.1] (1, 2, 3, 4)
2. Students will be able to demonstrate application ability by programming the microcontroller to perform sensing and actuation control functions [1.2] (1, 2, 3, 4)
3. Students will be able to demonstrate application ability by performing laboratory experiments for demonstrating the sensing and actuation control functions of the microcontroller [1.3] (2, 4).
4. Students will be able to demonstrate synthesis ability by designing, constructing and testing, in a teamwork environment, proof-of-concept demonstrations of the microcontroller sensing and actuation control functions in solving practical engineering problems [1.3, 3.1, 3.2, 4.3] (4)
5. Students will be able to demonstrate communication ability by presenting in written and oral format, in a teamwork environment, the project development and results, and by performing hand-on demonstrations [4.1, 4.3] (4)
6. The student will be better prepared for the job market.

COURSE DESCRIPTION

This course is designed to give mechanical engineers a basic understanding of microcontrollers and their use in a mechanical engineering environment. This study of microcontrollers will consist of the following main parts:

1. Review of circuits and semiconductor devices
2. Digital logic and arithmetic; Boolean algebra; Logic gates.
3. Basic microcontroller architecture; internal data handling and control, arithmetic-logic unit (ALU), input-output.
4. Microcontroller programming language and opcodes (Assembly).
5. Digital sensing and control through input and output parallel communication
6. Control through asynchronous serial communication
7. Sensing and control through timer input capture and output compare functions
8. Actuation control via digital to analog conversion; digital control of DC motor actuation
9. Direct digital control of stepper motor actuators
10. Sensing of sensor signals through analog to digital conversion; sampling theory.

11. Design project.
12. Assessment Methods:
 - Homework
 - Labwork
 - Tests
 - Project

GRADING POLICY

The final grade consists of grades from homework two tests, laboratory experiments and a final project:

Homework	20%
Labs	25%
Circuit practice	5%
Tests (2 x 10% each)	20%
Project	25%
In-class attendance and Project progress	5%

Homework, labs, tests, and project must be completely submitted, and borrowed items must be returned before final grade can be calculated. (Else, a grade of INCOMPLETE will be assigned.) Any missed item will also result in an INCOMPLETE grade.

Note: *instructor bonus* based on individual performance may be used in determining the final grade.

Guidelines for letter grade assignment of the final grades are:

94%-100%	A
88%-93%	B+
82%-87%	B
76%-81%	C+
70%-75%	C
65%-69%	D+
60%-64%	D
≤ 60%	F

HOMEWORK REQUIREMENTS

1. Homework, as assigned in the Schedule, is due on the day shown in the schedule, before the class starts.
2. Homework should be submitted to your section TA for grading.
3. Printed paper of Homework is preferred.
4. Homework should be completed independently. Copied homework will be dealt with in accordance to the Honor Code of the University of South Carolina.
5. If the homework is not handed on time, it is late, and the following penalty system applies:
 - Up to 3 days from the due date, 10 points
 - After 3 days from the due date, 50 points
 - After one week, ALL points will be penalized.

LABORATORY REQUIREMENTS

All students are required to attend their laboratory sections. Labs meet once a week, three hours a session. Students are encouraged to do the labs in groups of two students. Students should bring corresponding lab pages of the course package and homework to the labs. Other lab policies will be announced on the day of lab orientation.

PROJECT REQUIREMENTS

All students will be required to complete a practical project for this course. In addition to this final deadline, several other intermediate "milestones" are required. For in-depth information on the specific project requirements see the project section.

ELECTRONIC FILES REQUIREMENTS

LASTNAME_Firstname_Hmwk_X_Y.doc for Word doc homework files, where X is the homework number and Y is the exercise number or name

LASTNAME1_LASTNAME2_Proj.doc for Word doc project report files

LASTNAME1_LASTNAME2_Proj.ppt for PowerPoint project presentation files

Hw_X_Y.asm for .asm lab files, where X is the homework number and Y is the item number.

Lab_X_Y.asm for .asm lab files, where X is the lab number and Y is the item number in that lab.

To write the .asm Assembler file, use the template available on the web site. Before using the template, personalize it by substituting LASTNAME, Firstname with your actual last name and first name. (This is necessary because the .asm file names have to stay within the standard file name length and hence cannot be personalized with your name.)

ADDITIONAL REFERENCES

1. Engineer's Mini Notebook Series, Radio Shack, Inc.

Radio Shack publishes a series of simple and easy to understand electronics manuals. Most are written by Forrest M. Mims, III. They are easy to read and come with many basic descriptions of electronics concepts and components. In addition, they usually contain complete circuit diagrams that can come handy in projects.

Title	Catalog #	Price
Schematic Symbols, Device Packages, Design And Testing	276-5017	\$1.99
Formulas, Tables, and Basic Circuits	62-5016	\$1.99
Basic Semiconductor Circuits	62-5013	\$1.99
Op Amp IC Circuits	62-5011	\$1.99
Digital Logic Circuits	62-5014	\$1.99

555 Timer Circuits	62-5010	\$1.99
Communication Projects	62-5015	\$1.99
Environmental Projects	62-5019	\$1.99
Optoelectronics Circuits	276-5012A (*)	\$1.99
Science Projects	62-5018	\$1.99
Sensor Projects	62-5026	\$1.99
	TOTAL	\$21.89

NOTE: (*) It may no longer be available in some stores since Radio Shack is updating this item.

- National Semiconductor Databooks
Found in the lab, these books contain all the technical specifications of the electronic devices we will use. They are generally called "The Blue Books."
- Stiffler, A. K., "Design with Microcontrollers for Mechanical Engineers", McGraw Hill, 1992, ISBN 0-07-061374-5
- Histand, M. B. and Aciatore, D. G., "Introduction to Mechatronics and Measurement Systems", WCB McGraw Hill, 1999, ISBN 0-07-029089-X
- The Engineering Handbook. Richard C. Dorf (Ed), CRC Press, 1995, ISBN 0-8493-8344-7.
- Mark's Standard Handbook of Mechanical Engineers, E. A. Avallone and T. Baumeister III, 9th Edition, McGraw Hill, 1987.
- The Way Things Work. David Macaulay
An easy-to-understand and sometimes humorous explanation of many of the electro-mechanical elements discussed in this course. (Transistors, microcontrollers, logic gates, etc. can be found in this enjoyable book.)

TEST FORMAT

There are two open-book open-note tests in total and the dates are listed in the class schedule. All students are required to attend the tests. The tests will be held in a computer lab and students need to finish the problems in 60 minutes. Test papers and floppy disks containing the test document are given to students. Students can write answers on either of them and are required to turn in both when the test is finished. The test problems will include questions, choices, and programming. Please be aware that the tests are "open book, open notes". I hope this is good news to you! However, be warned that PAST TESTS ARE NOT INCLUDED IN THE "OPEN BOOK, OPEN NOTES" CATEGORY AND HENCE ARE NOT PERMITTED DURING TESTS.

EMCH 367 LAB

Lab Objective

This lab will give you hands-on experience with the MC6811 microcontroller and its interfacing with other electro-mechanical devices. You will work in teams. However, the grading will be individual, based on pre-lab quiz, your performance, and lab report. The principles learned during the lab will be applied during the course project period.

Lab 1	Basic Programming
Lab 2a	Parallel Communication
Lab 2b	Serial Communication
Lab 3	Timer Functions

Lab 4	DC Motor Tachometer
Lab 5	Stepper Motors and AD conversion

It should be noted that the successful completion of the labs is essential to the successful completion of the project. In most cases, 50% - 75% of project code is little more than lab code. As such, you have a personal stake in the successful completion of the labs.

Lab location

A235 – Door key will be assigned during final project period.

LAB GRADING POLICIES

Individual lab grades will be made up of the following components.

1. Pre-Lab points: 50% of the individual lab grade will be based on the preparation work done before the lab. There will be a pre-lab quiz (10%) which will be counted in the pre-lab points: .
2. 25% of the individual lab grade will be based on in lab participation: TA points.
3. 25% of the individual lab grade will be based on the level of success in completing the lab goals: In-Lab points.

LAB POLICIES

1. Attendance is mandatory! If you miss a lab and do not make it up you will receive 0% for the total lab grade!
2. The completion of the pre-lab assignment is vital to the success of the laboratories. There will be a 50% penalty for anyone not prepared for the day's lab. Address all questions and prepare all
3. Programs (write, type, save on floppy disk) before coming to the lab. A printed copy of all codes with annotations is required.
4. The following must be completed before the lab:
 - a) All written questions, predictions, or problems not requiring lab hardware.
 - b) Program flowcharts
 - c) A printout of all program code for the lab
 - d) The programs saved on a floppy disk
5. If you do not complete a lab, you may choose to hand it late. Labs will be accepted up to 1 week after your normal laboratory class, in consultation with your lab TA. You must arrange with your TA a time outside the normal lab hours when you will show the TA your completed lab. This time cannot be the next lab period!
6. If you leave the lab prior to the end of the lab period without successfully completing the lab goals, you will receive no credit for that lab.
7. If a student needs to change a laboratory section due to an unexpected conflict (i.e. interview, illness, etc.) and go to a different section, both TA's must agree to the rescheduling. Due to the limited availability of supplies, labs are limited to a maximum of 9 students.

EMCH 367 PROJECT

One of the best learning experiences that a student can have is to work, HANDS-ON, with tools, computers, and other devices. For this reason, the EMCH 367 course has a cumulative final project. This project will involve a team of two students developing a microcontroller-controlled application.

PROJECT OBJECTIVE

Throughout the labs, you have been learning how to apply microcontroller functions to various electro-mechanical systems. The project will be the application of all of these skills and the culmination of your efforts. You will work in team, just like in the lab. This will strengthen your team-working aptitudes, since the grade will be shared equally by the team partners. You and your partner(s) will develop the project idea and submit a brief proposal prior to the start of the project period to the assigned project TA.

The TA and students will iterate on the project idea until a suitable project is obtained.

HOW THE PROJECT WILL WORK

First, you must develop an idea. The idea can come as an improvement to an existing device through the use of microcontrollers (I'm sure that you can think of a few) or a process which may not have been able to be done before microcontrollers. Some examples from previous semester projects are available on the course website. For each idea, there are four conceptual aspects that must be specified:

- How can a process be controlled (using a microcontroller)?
- What makes the use of a microcontroller better than that of a physical system?
- How can this process be SIMULATED, and
- IN WHAT WAY DOES THE MICROCONTROLLER THINK?

Description of these aspects follows.

1. HOW CAN A PROCESS BE CONTROLLED USING A MICROCONTROLLER?

Microcontrollers have a large amount of control capability. Most processes can be controlled through a combination of a microcontroller and external circuitry. The essential aspect in relation to the project is to figure out how it should be done. Two steps must be considered: measuring external events, and acting on the judgments of the microcontroller to reach the project objective. During the course of the class and lab experience, you will learn many aspects of data acquisition and communication. These include time measurement (using the input capture functions), time scheduling (output compare function), parallel communication, serial communication, and measurement of analog signals (A/D converter). By using a combination of these tools, the microcontroller can determine a lot about its environment. Similarly, the output compare, parallel communication, and serial communication can output different signals. These signals, through the proper use of circuitry, can be translated to useful control over external devices such as motors, magnets, pumps, etc. In this manner, the microcontroller can become a valuable measuring and control tool. Discussing potential project ideas with your TA will help.

2. WHAT MAKES THE USE OF A MICROCONTROLLER BETTER THAN THAT OF A PHYSICAL SYSTEM?

Now that you have determined that a microcontroller can control your desired system, the following question arises: why would someone want to use a microcontroller for your system? Some things can be performed very well using only physical mechanisms (door handles, for example). Why would someone want to improve upon that by using a computer control? (This is done in a variety of places....) What benefit does the use of the microcontroller bring? The answer can be rather complex. A few examples are:

Rapid learning -- smart machinery can learn a new process by being shown once

Record keeping -- how many candy bars were bought? when do we run out?

Fast response -- try making anti-lock braking without a microcontroller

Discussion about the system qualities that can be improved by using a microcontroller will be also emphasized in the course. Do not hesitate to talk to the instructor and TA's about this.

3. HOW CAN THIS PROCESS BE SIMULATED?

We have very few external resources for this lab. We can't buy a car because someone wants to do an anti-lock braking system. Moreover, this is a microcontroller project, NOT A PROJECT INVOLVING THE UNIVERSITY OF SOUTH CAROLINA MACHINE SHOP. We have a number of simulation tools including Lego, Erector Sets, etc. to model physical systems. We have a number of pumps, motors (stepper and DC), digital display chips, LED's, IR emitter-detectors, potentiometers, cermets, etc. Using some combination of these tools, you should be able to simulate the process. **YOU ARE REQUIRED TO BUILD ALL CIRCUITRY ASSOCIATED WITH YOUR PROJECT.** A brief list of available circuitry and other parts is shown below:

Breadboards

Various PINs

Various connectors

BNC miscellaneous

LED's

Buffers

7-Segment Displays

IR Emitter-Detectors

Piston Pumps

Logic Gates

Capacitors

Comparators

Potentiometers

DC Motors

Servo Motors

Various Sensors, including magnetic sensors, motion sensors, E/D, pressure sensors, temperature sensors, thermocouple, etc

Speakers

Latch

Decade counters

Decoders

Solders

Power Adaptors

Voltage Regulators

Voltage Meters

Solenoids

Wire
Resistors
Miscellaneous Chips
Stepper Motors
MOSFET transistors
Linear transistors

You will be building the external circuitry to the microcontroller. OPTOISOLATOR, 8-PIN LED DISPLAYS, AND ANY OTHER PROTECTION CIRCUITRY ARE REQUIRED TO STAY IN THE LAB. If you let the instructor know of a desired part that is not available early enough, there is a possibility that it can be ordered or purchased through a local distributor. Don't hesitate to discuss simulation ideas with your TA.

4. IN WHAT WAY DOES THE MICROCONTROLLER "THINK"?

This is what separates the projects from the labs. In the labs, you develop tools and learn one simple application. In the project, you combine the tools developed in the lab and develop a methodology for the microcontroller to make intelligent decisions. A SWITCH DOES NOT MAKE INTELLIGENT DECISIONS. If I switch on a light switch, that requires very little microcontroller thought. If I switch on a light because I detected motion, and can then follow and more or less predict the direction of the motion, then it is no longer a simple switch, but a complex device making intelligent decisions. After determining the relevant parameters in the environment by making whatever measurements are necessary, the microcontroller must determine the condition of the surroundings. Are the measured parameters within tolerances for whatever process is being controlled? If there is an immediate problem, the microcontroller must act to try to correct the problem immediately. What about the "long term" control? The best way to control a process is to correct for problems before they occur, to react to indications that a process may be heading in the wrong direction, and thus prevent any immediate problems from occurring. The microcontroller is especially adept at performing these predictive activities. With memory to store the results of the past measurement, the microcontroller can quickly compare data points and determine trends. Based on these trends, the microcontroller can predict the state of affairs at a future time. This is often referred to as extrapolation. By extrapolating over very short time periods (the microcontroller can do this on the order of millionths of seconds), the microcontroller can obtain a very good approximation of future behavior. It can then act to maintain the desired external conditions. By comparing the effects of its actions and the behavior of the environment, the microcontroller can gage its progress in maintaining the control of the external system. This is one of the primary reasons that people use microcontrollers. THEY THINK!!!! Your project must think, as well.

PROJECT PROCEDURE

The following are procedural aspects of the project: getting partners, writing a proposal, project presentation, and final report submission.

GETTING PARTNERS:

A project is, by definition, more involved than a laboratory exercise. As such, students will be allowed to work in teams of two to four. In order to ensure that the teams are developed early enough for the students to start discussing the project and developing ideas. The project teams should be emailed to head TA by the deadline shown in the Schedule section of this document.

Any student not able to form a team by the end of class on that date should contact the head TA by email to request the assignment be done by the head TA ex officio.

WRITING THE PROJECT PROPOSAL

Before going into full development work for the project, a proposal is required. A long, drawn out doctoral dissertation is not expected or desired. All that is necessary is a short description of the project idea. Show why a microcontroller would be good for this process, how this project is not a simple “switch”, and how the microcontroller “thinks and takes decisions”. Ideas for simulation are helpful, but not required. The purpose of this is to make sure that you are thinking about the project and doing some background development. In addition, progress reports like this are often useful to organize your thoughts. It will also help you develop the list of hardware necessary for your project. To ensure that you are thinking about the project ahead of time, the project proposal is worth 10% of the project grade. The project proposal, including the hardware list, should be emailed to the instructor by the deadline shown in the Schedule section of this document. It should be noted that that this date leaves you approximately one month to do the rest of the work. It should also be noted that labs are wrapping up at that time.

PROJECT PRESENTATION

Formal project presentations will be organized for each group in the lab on the date shown in the Schedule section of this document. PowerPoint presentations are required. The presentation should be planned to last 20 min, including real-life demonstration in the lab and questions time. Consider that any topics related to your project, even remotely, can be asked by the instructor and the TA's. This includes both hardware and software components of the project, as well as utility, applicability, and commercialization. There is a very basic template available on the EMCH 367 website.

PROJECT REPORT

The Project Report should address everything involved in the project. This includes: circuit diagrams, software flowcharts, a relevant description of your program, the purpose of your project, and why microcontrollers are a good device for this process. These are all things that you should be developing through the course of the project. The preparation required for the project report should be minimal, provided you keep good notes during the project and perform it in an organized way. Examples of past project reports are available. They may be obtained from your TA. These reports must stay in the lab. There is also a template available on the EMCH 367 website.

GUIDANCE ON COST ESTIMATION

In the project report, you will be required to give estimation of the prototype cost and of the cost of producing of 1000 items. Excel spreadsheets are included in the report template to assist you. For the prototype cost estimation, you need to figure out how much time and rates of pay for the design (Engineer), production (Technician) and any other technical support (e.g. from your TAs). The Total Personnel Costs is the sum of the above 3 items. The Total Direct Costs is the sum of Total Personnel Costs and Materials. The Indirect Costs is estimated as 45% of the Total Direct Cost (you may put other values, if you have a good reason). The Total Prototype Costs is the sum of Total Direct Costs and Indirect Costs. For the production of 1000 items, you need to take wholesale into consideration, which helps you save money. In the production case, the time for Engineer, Technician and Others is not simply multiplying the time of prototype by 1000. The reason is that you don't need to design or get help for each item. Hence large production runs need less money per unit (economy of scale!). This also applies to the estimation of Materials. You might pay much less for an item if you buy 1000, compared with the case of one

purchase only. In the example in the project report, the materials cost for prototype is \$100, but \$50 for 1000 purchase (Profit also needs to be considered in production runs). In the end, dividing the Total Factory Price by 1000, you get the Factory Retail Price per Item.

ANSWERS TO FREQUENTLY ASKED QUESTIONS

WHERE DO I GET PROJECT IDEAS?

Look all around you. Microcontrollers touch each and every part of your life. Think about processes that you take for granted. Think about topics that may interest you personally, and extend the role of microcontrollers to that topic. Look at some of the suggested readings in the Class Syllabus. Talk with your TA. Talk with the Head TA or the Instructor.

ONCE I HAVE AN IDEA, WHAT DO I DO?

Each group will probably approach their project differently, since each project has different goals and objectives. As such, writing one clear-cut approach to doing a Micro project is not an easy task. The following are guidelines to assist you:

1. List all tasks that need to be done. Many times, it is helpful to make more lists that are detailed, as the problem becomes better defined. This also helps to organize your thought processes and productivity by letting you know where you are in terms of the final project development.
2. Look at software development. Outline all the routines that need to be developed. Write flowcharts for the program as a whole, and for each routine. Without some sort of organization, a code will not function. Once the flowcharts are completed, write the codes for the corresponding program segments. Use the concept of Modular Design for these aspects of the code development. Write the code such that debugging is straightforward.
3. Start with a base code that works. Then add one piece at a time. Test each program segment, debugging as you develop the program.
4. Look at hardware development. Draw circuit diagrams before building your circuits. Make sure that you understand what each component does. If you have questions, ask your TA's for assistance. Then, build the circuits. Using the oscilloscope, check how the circuit responds by itself. If it doesn't work and you are burning out chips, **DON'T JUST KEEP BURNING OUT CHIPS!!!** Ask someone for assistance. Once you know that the hardware is behaving properly, attach the system together.

HOW DO I GET ASSISTANCE FROM MY TA'S?

TA's are a great reference. Typically, they are available right after the laboratory period for questions. They can also be reached through e-mail. Set up an appointment with them. If they can't find the answer to your questions, they can refer you to someone who can help. During project time, each TA has at least four hours a week of office hours. These are hours that they will be actively engaged in helping students in the lab. Although TA's are encouraged to schedule these hours during the scheduled lab times, many offer additional times to assist students. As such, there will be 20+ hours of TA assistance available for the class each week until projects are completed. A complete list of times will be posted in the lab, on lab doors, etc. The obvious implication is that the earlier you get progress made on the project, the more TA help time you will have. You will not be restricted to use only your lab time. You can go to the lab every day if you wish. Project questions take priority over general questions.

WHEN DO I SIGN UP FOR MY PROJECT PRESENTATION?

Sign-up sheets will be made available before the last week of project presentation. There will be a large variety of time slots available. The scheduling is on first come, first serve basis. If a group wishes to reschedule with another, both groups must agree.

WHEN AND HOW DO I GET HARDWARE FOR THE PROJECT?

After you have developed your project proposal, you are ready to get the hardware. Every group that has partners assigned and a project proposal submitted will be issued hardware based on a checkout sheet reflecting the hardware list sent by you with the Project Proposal. After the end of Lab 5, groups may start getting their hardware from their project TA. **YOU ARE RESPONSIBLE FOR THIS HARDWARE AND MAKING SURE THAT IT IS RETURNED TO ITS PROPER LOCATION IN THE LAB ONCE YOUR PROJECT IS COMPLETED. THIS INCLUDES PROPERLY DISASSEMBLING YOUR PROJECT AFTER THE PRESENTATION, UNLESS YOU ARE INSTRUCTED OTHERWISE.** Instructions for proper placement of lab equipment will be provided in the lab during the project time.

WHEN IS THE LAB AVAILABLE FOR PROJECT WORK?

The lab will be available 24 hours a day from project start till project end. You will be issued the lab door access keys. You must also comply with the building access procedures. This open-door policy may be restricted if improper use of lab facilities takes place. **IF YOU ARE UNSURE ABOUT ANY ASPECT OF THE HARDWARE YOU ARE USING, DO NOT USE THE LAB WITHOUT A TA!**