EEL 3744C: MICROPROCESSOR APPLICATIONS

http://mil.ufl.edu/3744/  @eel3744  UF’s Canvas

INSTRUCTORS  Dr. Eric M. Schwartz  MAEB 321  392-2541  ems@ufl.edu  Office Hours:

LECTURES  Tues 5th – 6th (12:50-2:45pm) in LIT 109 & Thur 8th (3:00-3:50pm) in MAEA 303

LAB SECTIONS  (NEB 281)

* Honors Section

CATALOG DESCRIPTION
Elements of microprocessor-based systems; hardware interfacing and software design for their application. Laboratory.

COURSE OBJECTIVES (ABET Design Content 50%) [Lab fee: $198.20]
The student will learn the functional and technological characteristics of microprocessor structures, memory components, peripheral support devices, and interface logic. Through laboratory experiments and textbook examples the student will learn how to integrate and apply microcomputer subsystems and components to common interfacing problems. The Atmel ATxmega128A1U microcontroller will serve as the vehicle for exploring these topics.

TEXTBOOKS

REFERENCES

OFFICE HOURS
You may go to any TA available, not just the one teaching your lab section. The instructors will hold office hours (as shown above) or by appointment. If you come by at any other time, I reserve the right to say, “I’m busy,” although I rarely say this (even though it’s invariably true). You are encouraged to use e-mail to communicate with the instructor and TAs.

TA Office hours in NEB 281 (or NEB 222, when not)

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<thead>
<tr>
<th>TA name</th>
<th>Office Hour</th>
<th>Khaled Hassan</th>
<th>Rachel Johnson</th>
<th>Mason Turner</th>
<th>Austin Baylis</th>
<th>Ian Van Stralen</th>
<th>Madison Emas</th>
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MULTIMEDIA CLASS/AUDIENCE NOTES
Audience notes are normally posted on the class web site every week or so for the subsequent week or more of classes. The notes consist of pdf versions of the class PowerPoint slides with some space for note taking. These notes are not required but are highly recommended. Check the class web site for information on exactly when the notes are available. For optimal performance, read the notes and examples for a class before that class and bring the printed class notes and examples to class to augment the printed material with your own notes. Notes will be removed shortly after they are covered in class.

EXAM SCHEDULE
All exams (except exam 3a) will be given outside of regular class time.

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HARDWARE PURCHASES

- The Digtalent Analog Discovery (DAD) board is required for this course (and many other ECE courses). Board ordering information can be found at this link: [http://tinyurl.com/discov-ufl](http://tinyurl.com/discov-ufl). The discount price for students is $159 (no tax for Florida addresses), with a shipping price of $11-$13 for slowest shipping. Check your 3744 tweets (or email) to find the code necessary to get the Analog Parts Kit (with list price of $49.99) for free with the purchase of a DAD! If you are an EE student, I also recommend that you buy the NI Multisim & Ultiboard software (for analog circuit design and simulation) for $9.95. The UF bookstore *MAY* have the Analog Discovery ($28132) and the BNC Adapter ($23132) for those that want to use financial aid or want it right away.

- Soldering Iron [purchases optional, but recommended]. We will have soldering irons in our lab.

- Wire cutters and needle-nosed pliers [purchases optional, but recommended]. A few of each may be available in lab.

- UF 3744 (AVR XMEGA) board kit [required] was designed by *Out of the Box: Electronics and Robotics*, [http://ootbrobotics.com/](http://ootbrobotics.com/). The 3744-board kit is now included in your lab fees. Your parts kit comes with two printed circuit boards (PCBs) – the uPAD (with a ATxmega128A1U already mounted on the board ) and the uPAD Proto Base (with a large prototyping area). You will get dozens of parts including RAM, 2 USB cables, LCD Panel, and many sockets and other components. You probably **cannot** buy the kits separately, so please be careful as you design and construct your circuits this semester.

Radio Shack, Lowes, and Home Depot all sell soldering irons. Radio Shack has several cheap and adequate soldering irons, for example part numbers 640-2055, 640-2051, and 640-0094 (for $12.99, $8.99, and $22.99, respectively). Jameco.com also has many soldering irons, starting at $19 when shipping is included. Weller makes the recognized best soldering irons, e.g., WLC100 is a very good iron available for about $45.

You **MUST** have and use your own laptop for this course, since there are no computers available in the 3744 lab. You will be given your UF 3744 board kit in your first lab meeting (Lab 0). This kit contains most of the additional hardware that you will add to your boards over the course of the semester. (You may also need to purchase some additional ICs or other components as the semester progresses.) Starting with lab 1, you will need to wire-wrap.

CLASS ATTENDANCE AND BEHAVIOR

Class attendance is not **YET** mandatory; but all classes are important. At any point, if I think it is necessary, I may start taking class roll. You will be notified by a tweet at least one day in advance. There will be pop (unannounced) quizzes. A missed class/quiz cannot be made up. (See Course Requirements below for policy on missed quizzes.)

Turn off all cell phones, beepers, laptop sound effects, and other noise making devices before entering our classroom. If a noise-making device goes off during class, I reserve the right to lower your course grade. If a noise-making device goes off during an exam, your will lose a significant number of points on this exam.

SOFTWARE REQUIREMENTS

Atmel Studio, an integrated development environment (IDE) for developing and debugging Atmel ARM® Cortex™-M processor-based and Atmel AVR® microcontroller applications (including our XMEGA), will be utilized in our course.

Quartus (from Altera) has been now required for *EEL 3701C* and *EEL 4712C*, so many of you already have copies. Quartus Web Edition Version 9.1, Service Pack 2 is available to download, free of charge from Altera's website and our website. Some *EEL 3744C* homework and laboratory assignments will require the drawing or simulation of logic circuits. This program greatly simplifies such assignments. Since Quartus programs will be useful in other ECE courses (*EEL 4712, EEL 4713 and Senior Design*), we recommended that you obtain a copy if you have not already done so. If you have an old version of Quartus, it should work fine. Newest versions have restored the built-in simulator. You will need tour Altera USB Blaster from 3701 in order to program a CPLD on the UF 3744 (uPAD Proto Base) PCB.

REFERENCE MANUALS (available on our class website)

- XMEGA AU Manual (Atmel doc8331)
- XMEGA128A1U Manual (Atmel doc08385)
- Instruction Set (Atmel doc0856)
- and others

Do **NOT** printout these entire documents. Selected pages should be printed and brought to class, lab, and exams. Other documents are available on the class website ([http://mil.ufl.edu/3744/software.html](http://mil.ufl.edu/3744/software.html)) and on the Atmel website ([http://www.atmel.com/devices/ATXMEGA128A1U.aspx?tab=documents](http://www.atmel.com/devices/ATXMEGA128A1U.aspx?tab=documents)).
COURSE GRADE DETERMINATION

I have found that attendance is directly correlated to grades. But I assume that students in 3744 have learned this already. Therefore, attendance is not **required** but may become **required** in the future. If I start requiring attendance, it will **NOT** be worth positive points. Each missed class results in a deduction of X points, with deduction of maximum point loss of 10 points (out of 100) from your overall course total, where the loss for each miss class will be 0.5 points. If I take roll, there are no excuses for missed classes, but two classes can be missed without penalty.

3 Midterm Exams 62–73% (Exams are equally weighted)
Laboratory 25% (Some labs will count as less than 1 lab, some as a 1 lab, and some as more than 1 lab)
Homework 2–3% (4–10 homework)
(Pop) Quizzes 0–5% (0–10 quizzes)
Total 100% (90+ on exam 3 results in 5% grade bonus, e.g., 86% ⇒ 91%)

* A grade of 65% or better in Lab is **required** in order to obtain a passing grade. Your lowest lab will be dropped. But use this drop wisely, i.e., do **not** just skip a lab since all labs are important and your next missed lab may be unavoidable. If you need to miss a single lab, it’s ok; you can **not** make up the missed lab. (You should do this lab on your own.) **If you have a valid reason for missing this lab, get documentation from your first missed lab and hold on to it.** If you miss a second lab, you must show the professor (not the TA) written documentation for BOTH your first and your second missed labs. This documentation should be **official**, i.e., from a doctor, judge, etc., so that a make-up can be arranged. You must notify the professor **prior** to your scheduled second missed lab or **as soon as possible** after your second missed lab. There is no excuse that will allow you to reschedule your first missed lab other than an **assembly exam** in another course. You must notify the professor at least 8 days prior to your assembly exam.

† Although HW does not count much toward your grade, **not** doing it will likely have an effect on your quiz and exam scores.

GRADING POLICY

UF grades are often distributed according to the following **rough** distribution: A: 10% B: 35% C: 45% D&E: 10%. This usually works out to mean that if you make class average you will earn close to a “C+” or “B-”. If you score 10 percent above the class average, you will probably earn a “B.” If you score 20 percent above class average, you will probably earn an “A.” **This is not a contract on grading.** Rather, this information serves to provide you a rough understanding of your academic standing at any time during the semester. Grades are periodically posted on the class web site. **It is your responsibility to check your grades regularly** since mistakes often happen when dealing with a large number of students and TAs. **All grades are final one week after posting.** After curving exams as needed, course grades are assigned using the [86.6 ⇒ 89.9 (A-), 83.3 ⇒ 86.6 (B+), 76.6 ⇒ 79.9 (B-), 73.3 ⇒ 76.6 (C+), 66.6 ⇒ 69.9 (C-), 63.3 ⇒ 66.6 (D+), 0<59.9 (E)].

Part of your grade on tests, quizzes, labs, etc. is based not only on solving the problem you are presented with, but the manner in which you solve it. For example, there is a difference between two programs that meet the given specifications, but one is an elegant, extensible 20-line solution, while the other is an obfuscated 100-line program that also meets the specifications but would be difficult to extend later. Just as your future employer would value the latter program less than the first, so will I in grading your assignments.

The UF grading policies for assigning grade points can be found on the following undergraduate catalog web page: [https://catalog.ufl.edu/ugrad/current/regulations/info/grades.aspx](https://catalog.ufl.edu/ugrad/current/regulations/info/grades.aspx).

**COURSE REQUIREMENTS**

1. It is recommended that you bring your printed notes to each class, since you may need it for a pop quiz.
2. Perform all laboratory experiments. A grade of 65% or better in Lab is **required** in order to obtain a passing grade. Your lowest lab will be dropped. But use this drop wisely, i.e., do **not** just skip a lab since all labs are important and your next missed lab may be unavoidable. If you need to miss a single lab, it’s ok; you **cannot** make up the missed lab. (You should do this lab on your own.) **If you have a valid reason for missing this lab, get documentation from your first missed lab and hold on to it.** If you miss a second lab, you must show the professor (not the TA) written documentation for BOTH your first and your second missed labs. This documentation should be **official**, i.e., from a doctor, judge, etc., so that a make-up can be arranged. You must notify the professor **prior** to your scheduled second missed lab or **as soon as possible** after your second missed lab. There is **no excuse** that will allow you to reschedule your first missed lab other than an **assembly exam** in another course. You must notify the Dr. Schwartz at least 8 days prior to your assembly exam so that an alternate lab time can be arranged.
3. Labs **must** be done at scheduled times.
   - An average lab grade of **65% or higher** is required to be **eligible** to **pass** the class!
4. Do all homework assignments and turn them in **by the posted deadline**.
   - **Late homework will not be accepted.**
   - Homework will be collected, but will be “Zen” graded. The grade book will reflect submission and level of effort.
5. A quiz can happen at any time, during any class, i.e., quizzes are generally not announced ahead of time. You should therefore not miss class.
   - Missed quizzes cannot be made up.
6. Take 3 during-term exams.
   - No makeup exams or test will be given except in cases of a medically documented incapacity or family emergency.

STUDENTS WITH DISABILITIES
Students requesting classroom, laboratory or exam accommodations must first register with the Dean of Students Office. The Dean of Students Office will provide documentation to the student who must then provide this documentation to the instructor when requesting accommodation. For optimal consideration, you must see the professor during the first week of classes.

UF COUNSELING SERVICES
Resources are available on-campus for students having personal problems or lacking clear career and academic goals. The resources include:
- University Counseling & Wellness Center, http://www.counseling.ufl.edu, 3190 Radio Road, (352) 392-1575.
- SHCC mental Health, Student Health Care Center, http://shcc.ufl.edu/, Infirmary Building, 1 Fletcher Drive, 392-1161.
- Center for Sexual Assault/Abuse Recovery and Education (CARE), Student Health Care Center, 392-1161.

STUDENT PRIVACY
There are federal laws protecting your privacy with regards to grades earned in courses and on individual assignments.

SOFTWARE USE
All faculty, staff and student of the University are required and expected to obey the laws and legal agreements governing software use. Failure to do so can lead to monetary damages and/or criminal penalties for the individual violator. Because such violations are also against University policies and rules, disciplinary action will be taken as appropriate. We, the members of the University of Florida community, pledge to uphold ourselves and our peers to the highest standards of honesty and integrity.

TECHNOLOGY
The use of cell phones and every other technology device is strictly prohibited during exams. All use of an electronic devices during an exam will be considered a violation of the student honor code (i.e., cheating). See the Cheating section below for the minimum penalties that are incurred for all cases of cheating in our course. Laptop computer and tablets are welcome in class as long as they are used for class-related work. Surfing the web, checking email, making Facebook posts, etc., is strictly prohibited (if distracting to others) and will result in course grade deductions.

COMMUNICATION
You are responsible for checking announcements and course-related postings on the class website and Canvas. Twitter is utilized for announcements, so you are also responsible for getting this information (either with a Twitter account or with software that creates and email or text message from tweets). You are also responsible for checking your UF email daily.

EXTRA CREDIT
Extra credit is sometimes offered during class (or on the web, by tweet, or by email). The amount of extra credit given is at the discretion of the faculty member unless specifically stated with the extra credit opportunity.

CHEATING
The following pledge is required for all work submitted for credit by University of Florida students: “On my honor, I have neither given nor received unauthorized aid in doing this assignment.” **CHEATING WILL NOT BE TOLERATED.** We will actively search for cheaters. If you are caught, there will be no negotiations. You will fail the course and get reported to the honor court. There are **no excuses and no exceptions.** You may talk to other students about homework and lab assignments, but the final work **must** be your own. If you are caught cheating on any assignment (homework, lab, quiz, or exam, etc.), the **smallest** penalty possible is failure for the course. During a recent semester several students were caught with partly copied lab assignments. All of these guilty students earned an “E” in the course. A meeting with the instructor (and, possibly, the UF honor court) will determine **additional penalties,** none of which are desirable or pleasant (i.e., cheating in this course will result in a failing grade in the course, initiation of honor court charges, and possibly expulsion from the university). If you know someone is cheating, **it is your responsibility to report it.** We have and will continue to prosecute cheaters by turning them over to the office of Student Judicial Affairs. For more information about cheating, the UF Honor code, and the consequences of academic dishonesty, please refer to https://www.dso.ufl.edu/sccr/process/student-conduct-honor-code/ and https://www.dso.ufl.edu/sccr/process/incident-report/. See https://www.dso.ufl.edu/sccr/sccr-forms/
WORKING TOGETHER
You are encouraged to work with other students on homework assignments (absolutely forbidden on labs) in a professional manner. Each person in the group should attempt to solve all problems independently and only then discuss the results with one's partner(s) to correct errors and resolve differences. Copying your partner's work without a serious attempt on your part constitutes cheating and should not be permitted by your partner(s). Matching your solution to your partner's, however, is acceptable, if, after independent study and work you are convinced your partner's solution is correct. All solutions should reflect your style of problem solving, even those you have changed to match your partner's solution. In other words, verbatim copying or simple paraphrasing of your partner's solution is not an acceptable form of cooperative study. Your name and your partner's name(s) must be on your homework. You may not copy and submit old or new posted solutions as if they were your own.

You must do independent work on labs. Although you may consult with other students, TAs, or Professors, you must do independent work. Consulting means "seeking opinions or advice," not getting working programs or designs, understanding them, and then modifying them to make them your own. The latter constitutes cheating (see above section). Working side-by-side to construct a program or design in a group constitutes cheating. (Solving labs is good practice for solving quizzes and exams, which are also not group activities.)

EXAM RE-GRADE POLICY
If you believe an error has been made on an exam score, you must make a written request to the instructor explaining where the misgrading or error occurred and why you think more credit is deserved. This request must be submitted immediately at the end of the class in which the exam is returned. If you do resubmit an exam, the instructor reserves the right to scrutinize and grade the entire exam more closely. This definitely places your current score at risk. Consequently, it is not advisable to resubmit an exam for re-grade unless a blatant grading error has been made. You must make it clear what writing you added to the exam (by clear indication, e.g., use a different color pen or pencil) after it was returned to you.

EXAM SOLUTIONS, HW SOLUTIONS AND LAB SHELLS
We will post homework, lab, lab program shells and other class material on our class web site at: http://mil.ufl.edu/3744/, along with periodic postings of your grades and the class grade book statistics. Previous exams on the course material are also posted on our web site. Current exam solutions will be discussed and shown in class on the day the graded exam is returned to class, but will not be posted.

HOMEWORK GRADING
Homework is assigned periodically. Homework is submitted through Canvas by the assigned deadline. Unless other specified, a single pdf document should be submitted for each homework. (Sometimes additional files will be requested.) Scans are acceptable, but must be compressed and in a single document. Fast Scanner (available for Android and iPhone) is a cell phone app that works well. Homework solutions are sometimes posted on our class web-site before they are due. It is not appropriate to copy the supplied solutions verbatim; this constitutes cheating. Homework will only be graded in a cursory fashion, i.e. Zen grading is used. The grades will be entered into the grade book as 0 (no significant effort or not submitted), 1 (half-hearted attempt) or 2 (significant attempt). The final course grades will be assigned with strict cuts between grades, but HW could push you above a cut. Also, the (pop) quizzes will come from the class material, the labs, and the homework. In addition, the exams will be partly based on the assigned homework. Late homework will not be accepted.

LABORATORY GRADING
You will not be admitted to the lab without a Summary document, as described in the Lab Rules and Policies. Homework is due through Canvas submission by the assigned deadline. Unless other specified, a single pdf document should be submitted for each homework. (Sometimes additional files will be requested.) Scans are acceptable, but must be compressed and in a single document. Fast Scanner (available for Android and iPhone) is a cell phone app that works well. The Summary document and other files also must be submitted through Canvas before the start of your lab.

Each circuit diagram, VHDL file, and assembly language program, and list file must have your name included at the top. All Quartus simulations should be clearly annotated. Quartus files should be sent in a Quartus archive file.

Some labs will count more than other labs. Grading emphasis will be placed upon your producing well documented, well-structured programs and hardware designs that realize the functional requirements specified by the lab handout and the lab instructor. The remaining portion of your grade will result from observations by your lab instructor on such matters as your understanding of the lab, your lab techniques, your pre-lab preparation, your lab reports and your cooperation and compliance with the rules. Having your design perform properly does not guarantee a grade of 100, but makes a 100 grade possible. Lab designs and/or software that are similar and/or identical to other student’s work constitute cheating (see above) and result in you failing the course, honor court charges, and possibly expulsion from UF. We have software that will be used to look
for plagiarized software. There may be a quiz at the beginning of some labs. If you are late for a lab, you will get a zero for the quiz.

**HANDOUTS**

Most handouts are supplied on-line and can be downloaded from the class web site: http://mil.ufl.edu/3744/. Old graded non-lab assignments not picked up in class can be picked up from Dr. Schwartz for a few days, then they will be recycled.

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**LABORATORY GUIDELINES**

**LABORATORY OBJECTIVES**

The purpose of this laboratory is to teach students hardware and software development of microprocessor based applications. The laboratory complements the lectures by providing hands-on experience with microprocessors, peripheral devices and the required hardware and software development tools.

**EQUIPMENT REQUIRED**

1. UF 3744 board kit including the USB cables.
2. In your first lab (lab 0) you will also be given a “bag of goodies,” i.e., parts that you will use during the semester, including the UF 3744 board kit.
3. Wirewrap tool. **REQUIRED** for lab 0.

**LABORATORY PREPARATION**

All of the lab experiments require advanced preparation in the form of assembly language coding, simulation, computations, circuit diagrams and, of course, reading and understanding the lab handout itself! These preparations **must** be finished before admittance to the lab for that experiment. For your own benefit, you should attempt to have logically correct programs before lab as well as syntactically correct code.

**Note:** The best students have everything working **BEFORE** coming to lab.

If any of your lab designs are essentially identical to another student’s work, this constitutes cheating. If you are caught cheating, you will fail the course, be brought up on honor court charges, and possibly expelled from UF.

**LABORATORY ENTRY**

The TA’s will let you in at the start of your lab period. Your TA has the right to kick you out of the lab if you are not prepared, i.e., you do not submit the required Canvas submissions and turned in the required hardcopy document. You may also be removed from lab if you are uncooperative or disruptive. You must be able to demonstrate your understanding of the code you submitted and the lab topics in general. If you are not properly prepared, you will get a zero for the lab and will be asked to leave. You may **not** make-up this lab later. Therefore, it **is imperative that you come to lab prepared!**

**LABORATORY RULES**

1. Lab safety is rule #1. Please play close attention to TA instructions about lab safety, which will occur during your first laboratory.
2. No food, no drinks, and no smoking inside the Lab!
3. Keep your work area neat and clean it before you leave.
4. Students must attend labs during their assigned time.
5. Quizzes might take as long as 1 hour (but could be shorter). Quizzes will be graded on a quaternary (also known as a quinary) scale of 0, 1, 2 or 3. This will translate into values of 0%, 15%, 20%, or 30%, respectively to account for up to 30% of the lab grade. Quizzes will cover information from the pre-lab material and previous labs and course work.
6. Labs are precisely 2.75 hours long (**not** 3 hours) long. You will be assigned no extra time.
7. **You must show up within 30 minutes of the lab starting time for check-in.** (See above for check-in information.) If you are more than 10 minutes late, you will get a zero for the lab quiz.
8. Students **must** be prepared to demo their lab when they enter. Students will be randomly selected for their demonstration times during their lab period.
9. The last 30 minutes of the lab is a time for student check-off and grading only, i.e., no questions for the TA.

**LABORATORY ATTENDANCE**

Laboratory attendance during scheduled times is mandatory. **Documented** personal or family emergency will be accepted as an excuse for absence for a **second** missed lab if documentation for a **first** missed lab is **also provided**. In such cases, consult your **instructor** (not your TA) about a make-up lab **as soon as possible**. See **Course Requirements** for more details. Students should make serious attempts on **all** labs. Grades less than 50% may be interpreted as not a serious attempt and may be scaled to 0.

All grades are **non-negotiable one week** after the grade is assigned. Please don’t come to me after the final grades have been posted with a hard-luck story.
You will not officially makeup your first missed lab. You should do this missed lab at home (or, if necessary, during a TA office hour) to be sure you understand the required material.

If you cannot finish the laboratory during the allotted time, you will lose at least 10% to 30% off your final score. You are expected to finish the labs on time. The most successful students generally get their labs to work at home before their lab begins.

LABORATORY PREPARATION LIST

1. Always compose, edit, assemble, and print your programs before your scheduled lab.
   - This will save you considerable time and frustration and will improve your performance. In addition, you will have a legible working document.

2. Structure your program into functional modules and comment the modules as part of the coding.
   - Each subroutine should perform just one function. If a subroutine extends beyond 40 instructions, it is probably doing more than one function and should be split into two or more smaller subroutines.

3. Devise means for testing each subroutine separately so that problem isolation (debugging) is easily accomplished.
   - Assemble the entire program using our assembler.
   - These tests should be made as part of your pre-lab preparation.
   - Simulate your program with the simulator or debug it on your board before coming to Lab. Bring to your lab your working assembly code and circuit diagram file (if any) on your laptop. Bring a printout of the list file to the lab and circuit diagrams (if any). You will not be allowed in the Lab without a commented listing of your code and a circuit diagram (when relevant).

4. Arrive at the lab on time to give yourself adequate time.

EEL 3744 LABORATORY SCHEDULE

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<th>Lab</th>
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<th>Tentative Lab Topics (Lab in NEB 281)</th>
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<tr>
<td>0</td>
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<td>Circuit board construction. Simulate program. Download code.</td>
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<tr>
<td>1</td>
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<td>Write program; simulate and emulate.</td>
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<tr>
<td>2</td>
<td></td>
<td>Board expansion. Add LED and switch circuits. Write program to utilize input and output ports.</td>
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<tr>
<td>3</td>
<td></td>
<td>I/O Port Expansion</td>
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<tr>
<td>4</td>
<td></td>
<td>Memory (SRAM), Keypad, Bus Timing using LSA</td>
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<tr>
<td>5</td>
<td></td>
<td>External Interrupt, Asynchronous Serial Communication (SCI) with Interrupts</td>
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<tr>
<td>6</td>
<td></td>
<td>A-to-D Conversion (for voltmeter with LCD)</td>
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<tr>
<td>7</td>
<td></td>
<td>Output Compare (making music)</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>Signal Timing: Input Capture (using remote controls)</td>
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