

ECSE-4790: MICROPROCESSOR SYSTEMS

Course Catalog Description: Hardware and software for real-time microprocessor based digital systems. Basic concepts and operations of on-chip components related to digital system functionality. Architectures, instructions sets, and interfacing with peripherals through serial or parallel ports. Introduction to 32-bit machines with in-depth treatment of 16- and 8- bit machines. Emphasis on C language cross-compilers. Laboratory exercises are included to demonstrate hardware and software development techniques practiced in industry. Pre-requisites: ECSE-2610 and ENGR-2350. Fall term annually. *3 credit hours*

Pre-Requisite Courses: ECSE-2610 Computer Components and Operations and ENGR-2350 Embedded Control

Co-Requisite Courses: None, but need senior standing

Pre-Requisites by Topic: 1. Fundamentals of logic design 2. Digital & analog circuit theory
3. Computer programming 4. Computer instruction sets and microcontroller operations

Textbook: None

References: Silicon Laboratories C8051F120 Technical Summary
Gene H. Miller, *Microcomputer Engineering*, 3rd Edition, Prentice Hall, Englewood Cliffs, NJ 2003. (Any Edition is fine)
Alan Clements, *Microprocessor Systems Design*, 3rd Edition, PWS Publishing Company, Boston, MA, 1992
Kim R. Fowler, *Electronic Instrument Design*, Oxford University Press, New York, NY 1996
Online: www.ecse.rpi.edu/Courses/CStudio, www.rpi.edu/dept/ecse/mps, or <http://rpilms.rpi.edu/>, log in & pick "Microprocessor Systems"

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Overall Educational Objective: To provide fourth year ECSE students with a hands-on laboratory experience with more advanced features of state-of-the-art microprocessor systems and to enhance their written communication skills through exploratory lab exercises and reports.

Course Learning Outcomes: Students will be able to: 1. Write a program to display messages on an ANSI terminal with attributes for position, color, background color, and animation. 2. Create a service routine that performs a function on the occurrence of an IRQ hardware interrupt and use a counter to control the accurate timing of a stopwatch display. 3. Connect RS-232 and SPI devices to the 8051 processor and write programs to pass data to and from them. 4. Develop a routine to read an analog input on an ADC port, use a MAC to implement a 2nd order digital filter, and output the resultant analog voltage. 5. Interface a static RAM memory chip to the 8051 processor at a given address and write a program to verify operation. 6. Interface the Hitachi HD44780 LCD panel to the 8051 and write a program to display a message on it or develop software to create message frames to be sent on a CAN network.

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Syllabus, Schedule & Course Project

How Course Objectives are Assessed: Part of each grade will be determined by the team effort and part by individual effort. For the lab exercise reports, individual responses to TA questions while verifying the exercise results determines 20% of the grade while 80% is determined by the team. A more detailed breakdown of the team vs. individual grading on the semester project is given in the course project description handout. (5 pts/day late penalty on all reports)

Teams of 2 students

67% 6 C8051 exercises (not uniformly weighted - breakdown below),
of this, 80% is based on group effort & 20% on individual effort

Teams of 2 [or 4 students]

33% Student selected final project
Post-project and general course clean up, mini-quiz, TA
evaluation of student lab performance and participation

100% TOTAL

NOTE: The six exercises are not weighted equally in adding up to the 72% of your overall course grade. The weights are:

SiLabs IDE/ANSI Terminal	6%
Interrupts	4%
Serial Communications	17%
Analog Conversions/MAC	14%
Memory Interfacing	9%
Magic 8-Ball or CAN device control	17%
TOTAL	67%

Relations to CSE Outcomes:

Outcome	Level	Demonstrate Proficiency
	N, M, H	e.g. Exams, projects, HW
Mathematics, science and engineering	N	
Basic disciplines in Electrical Engineering	N	
Depth in Electrical Engineering	M	Lab ex. & Project
Basic disciplines in Computer & Sys. Eng.	M	Lab ex. & Project
Depth in Computer and Systems Eng.	M	Lab ex. & Project
Electromagnetics, electromechanics, power semiconductors	N	
Power system behavior	N	
Electrical energy conversion	N	
Conduct experiments and interpret data	M	Lab ex. & Project
Identify, formulate and solve problems	N	
Design a system, component or process	H	Lab ex. & Project
Communicate in written and oral form	M	Exercise rpt & presentation
Function as part of a multi-disciplinary team	N	
Preparation for life-long learning	M	Lab ex. & Project
Ethical issues; safety, health, public welfare	N	
Humanities and social sciences	N	
Laboratory equipment and software tools	H	Lab ex. & Project
Variety of instruction formats	N	

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Syllabus, Schedule & Course Project

Topics Covered: The most advantageous use of the C8051F120 microcontroller evaluation board in the course project requires a broad understanding of its features and options. These topics have been selected to facilitate the comprehension of the general functions most widely used in real-time controllers and are accompanied by lab exercises: 1. Brief overview of available development environment tools (cross-assembler, C cross-compiler, & simulator/debugger) and other platforms (MC6812 microcontrollers) 2. Hardware & software development techniques 3. ANSI terminal escape sequences 4. Interrupts & timers 5. Synchronous & asynchronous serial communications 6. A/D conversion 7. Multiply Accumulate (MAC) operation 8. Memory bus interfacing 9. I/O interfacing of a keypad & LCD panel 10. CAN network communication and control

Computer Usage: All exercises and the enhancements integrally use microcomputers.

Laboratory Experiences: 1. C8051 IDE environment & ANSI terminal programming, 2. Interrupts and timers programming, 3. Serial communications, 4. Analog conversions & MAC, 5. Interfacing memory to the microprocessor, 6. I/O programming with an LCD panel & keypad and Project (Magic 8-Ball or CAN device control)

Design Experiences: The small design effort as part of the final exercise allows students to pursue individual interests. All involve: 1. Determining a design and method to implement it, 2. Building, troubleshooting, & possible re-engineering, 3. Finalization of completed design and documentation & analysis

Independent Learning Experiences: Although students work in teams, they are assigned individual tasks for the exercises and project which require: 1. Research of solutions, 2. Determining S/W & H/W requirements, 3. Purchasing components 4. Reading data sheets, 5. Troubleshooting/Determining how to achieve correctly functioning subsystems

Class/Lab Schedule: ~1.5 hr/wk of lecture, ~4.5 hrs/wk of laboratory (See following page)

Contribution to the Professional Component:

- (a) College-level mathematics and basic sciences: 0 credit hours
- (b) Engineering Topics (Science and/or Design): 3 credit hours
- (c) General Education: 0 credit hours

Prepared by:	Russell P. Kraft
Date:	August 22, 2012

Laboratory exercises are included to facilitate hardware and software development techniques practiced in industry. Evaluation is based on individual and team performance.

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Syllabus, Schedule & Course Project

Academic Integrity: Academic dishonesty is a very serious matter, and we suggest that you read the remainder of this statement carefully:

Student-teacher relationships are built upon trust. For example, students must trust that teachers have made appropriate decisions about the structure and content of the courses they teach, and teachers must trust that the assignments, which students turn in, are their own. Acts that violate this trust undermine the educational process.

The Rensselaer Handbook defines various forms of Academic Dishonesty and procedures for responding to them. All forms are violations of the trust between students and teachers. Students should familiarize themselves with this portion of the Rensselaer Handbook and should note that the penalties for plagiarism and other forms of cheating can be quite harsh.

Any portion of work handed in that is not your own, should cite the author. Just as you would not write a history paper by copying text from the encyclopedia, you should not take credit for another person's engineering work. Reference should also be made to any personal communications you have had with anyone outside your group that contributed substantially to the successful completion of an assignment. (Please read the IEEE Code of Ethics, especially item number 7. http://www.ieee.org/web/membership/ethics/code_ethics.html The ASME has a similar code. <http://files.asme.org/ASMEORG/Governance/3675.pdf>)

Collaboration on assignments is encouraged, in fact essential, between lab partners. However, having one partner always work on hardware aspects and the other on the software or data analysis or report writing will be detrimental to all partners. All partners should understand and participate in all aspects of the lab exercises in order to learn the necessary topics addressed in lab write-ups and covered on the exams. While you may discuss your classwork with anyone, collaboration on assignments is not allowed between lab groups, either within or between lab sections. Turning in similar out-of-class assignments, which suggest that copying (in part or in total) has taken place, will be considered as academic dishonesty.

Cheating on an exam will be considered as academic dishonesty and will result in a failing grade for the course.

At all times, we reserve the right to take formal action against anyone engaging in academic dishonesty. This action may range from failing an assignment to failing the course, or to being reported to the Dean of Students. If you have any questions about these rules or how they apply to any specific assignment or exam, discuss it with one of the instructors or course administrators.

ECSE-4790 Microprocessor Systems

Fall 2012 Schedule

WEEK	TOPICS (to support lab exercises & team project)	READING 8051 man./notes	8051 LAB EXERCISES	DUE DATE
1 8/27	Introduction Resources (S/W, WebCT, CStudio), ANSI escape sequences	Chapters 1, (2, 3, 4), 14,	Lab tools: HyperTerm, ProComm, ANSI Display	
2 9/3	Instruction Set, Assembler/C Compiler, Parallel I/O, [Labor Day, no class Mon]	Chapters (11), 18	IDE & ANSI Display	9/17
3 9/10	Interrupts & Timers	Chapters 23, 24	Interrupts & Timers	9/24
4 9/17	Serial I/O	Chapters 21, 22, 20	Serial Communications	10/15
5 9/24	CONFIG2 (Configuration Wizard 2) program		Serial Communications (cont.)	
6 10/1			Serial Communications (cont.)	
7 10/8	Analog Conversion & MAC [Columbus Day Vacation, Tues is Mon]	Chapters 5, 7, 8, 9, 12	Analog Conversion & MAC	10/29
8 10/15			Analog Conversion & MAC (cont.)	
9 10/22			Analog Conversion & MAC (cont.)	
10 10/29	Bus Interfacing	Chapters 15, 17	Interfacing Memory	11/12
11 11/5			Interfacing Memory	
12 11/12	LCD Screen, Keypad, Key Wakeup Interrupts Augmentations description	LCD handout User Man. handout	Magic 8-Ball Lab or CAN	12/10
13 11/19	CAN Controller Bus [Thanksgiving Vacation]	Ch. 18 in F040 & CAN info on web	Magic 8-Ball Lab or CAN (cont.)	
14 11/26			Project	12/10
15 12/3	[Last week of class]		Demonstrations	(All Rpts 12/10)

NOTE: dates may be subject to change, check the course WebCT calendar for actual due dates.

Requirements and Format for Lab Exercise Reports.

Goal

The objective of the Lab Exercise Report is to have you document what you did, how you did it, and what you learned.

Requirements

You are required to write a brief team Lab Report for each exercise. Details should document what you did and the observed results. Use titles and headings to separate sections for easier reading. Use paragraphs and write in complete sentences. The following sections should be included, but renamed appropriately, depending on the experiment and results and the style of your report. These reports are not expected to be as detailed as your project report, but will be graded on accuracy and completeness along with your performance of the exercise.

Format of the Report

Front Matter

Title Section

Place the title at the top of the page.

Authors' names go under the title with class designation and date in the title section

Report Body

Introduction/Background Information

A description of the objective and purpose of the exercise goes here. Keep this section brief (no more than half a page).

Materials and Methods/Procedure (with Calculations)

What did you do to develop a solution to the problem? What methods did you use? Describe the way you got to your final configuration. Write this so that one of your classmates could duplicate your work based on your report alone.

Results/Analysis (Highlight special features)

What did you accomplish? Take care to state your result precisely. State all significant results. Use data, figures, tables, etc, to support your claims.

Discussion/Conclusions/Evaluations/Observations

This is the section where you can explain why your final result was different from your initial goal. Or you can point out where you might take the project given more time, resources, etc.

Back Material

Appendices

This is the appropriate place for details such as testing procedures, all software source code listings, flow charts, hardware drawings and electrical schematics.

References

List any sources of information you referred to in the report.

Requirements and Procedures for the Final Exercise Augmentation

Goal

The objective of the augmentation is to have you design an add-on feature that you select. Whenever possible, the functionality of the product should be demonstrated both in simulation and in a working, physical mock-up.

Writing requirements

The written requirements include documentation in the Final Exercise Report. Details for this are given on below.

Important Dates

- Magic 8-Ball and CAN projects start the week of **Nov. 26** (all sections)
- Demonstrations on **Dec. 6**
- Final Reports due Monday, **Dec. 10** in my office, JEC-6028, by 4:00pm

Opportunity

This is your opportunity to propose and implement a project of your own design. Your project should be based on a Silicon Labs microcontroller (C8051F120 or C8051F040). Your project should use some of the on-chip capabilities of a microcontroller. The project should not be all software or hardware but, rather, a comfortable mixture of both. There should be a requirement for real-time control and digital and/or analog I/O. Avoid projects that could be developed on a standard PC.

Every project must include analysis aspects of reliability, maintenance, awareness of safety issues along with the application of previous mathematics, science, and engineering. This analysis must be completed by the end of the project and discussed in the report. In general, the engineering sciences have their roots in mathematics and basic sciences but carry knowledge further toward creative application. These projects provide a bridge between mathematics and basic sciences on the one hand and engineering practice on the other. Engineering design is the process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative), in which the basic sciences, mathematics, and the engineering sciences are applied to convert resources optimally to meet stated needs.

Some suggestions

- A temperature controller satisfying more than one criterion or intelligent thermometer
- A waveform generator with amplitude & frequency control
- A pulse counter or frequency measurement meter, or fancy alarm clock
- An animated message board using the LCD panel and/or interfaced to a sound chip
- A Morse code interface (sending and receiving)
- A computer controlled chain of robots

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Syllabus, Schedule & Course Project

In addition to the standard kind of project, you might elect to develop several introductory lab exercises for the C8051F120 microcontroller. These would build upon preceding C8051F020 lab exercises in Embedded Control and emphasize what is new and different.

Constraints

It is strongly suggested that all ideas for augmentations be passed by the TAs or course instructor for feasibility and possible complications. To eliminate possible problems in implementation due to misunderstandings, teams should consider writing up their ideas in a paragraph or two for review by the teaching staff.

The microcontrollers are available for you to use in the lab. You have been assigned a protoboard for your use in the lab, also. These can only be taken from the lab between lab sessions with prior special arrangements.

The lab does not have a budget for special parts. So, if you need anything not in the lab, you will have to get it yourself. If parts are not available locally, several weeks can elapse between the time you order the parts and when they arrive. This can happen even when you have been told the parts are in stock.

The TAs will do what they can to help you with your project; but they aren't guaranteed to be an expert on your specific project.

Grading

The augmentation contributes another 18% to the course grade. The components are as follows:

- | | | |
|---|-----|-----------------|
| • Project Demonstration & Report | 18% | team/individual |
| • Post-project clean up, Quiz, Preparation, Attendance & Teamwork | 15% | team/individual |

Post-project clean up

Disassemble all components and wires on the protoboard. **Return them to where they belong.** Be sure to get checked off.

Late Reports

Any late progress reports should be given to the secretary in JEC 6012. A received date stamp will be put on it. A lateness penalty of 5% per day will be assessed against the report grade. Final project reports must be turned in by the drop-dead due date of the last day before final exams begin to receive any credit.

Project Demonstration

This is the functional day of reckoning. Your product should meet your (revised) objectives. The audience for this demonstration is the TAs and/or instructor. You should prepare a brief oral presentation to explain the features of your project. (You may be evaluated by your peers for a portion of your total points.)

Your project design should be frozen at this point. Any improvement can be suggested in the report, but not implemented. (You must stop changing things at some point in time. This is it.)

All members of the project team are expected to participate in the demonstration.

Your grade here will be an accumulation of points based on:

1. Your general effort level and laboratory techniques
2. Degree of difficulty of the project
3. Amount of work actually completed and demonstrated to function as proposed
4. Neatness of the project (wiring, mechanical components, etc.) and quality of the presentation

Final Project Report & Demonstration (18%)

The format of your Augmentation Report depends a lot on the type of project and how it was developed. This report is separate from the Magic 8-Ball or CAN report. Much of the grade will depend on how well it is formatted and organized for ease of comprehension. It is your responsibility to figure out how to fully document your work and highlight the main features.

Post-project clean up, Preparation, Attendance & Teamwork (15%)

This is the last part of your course grade. Please help get the lab ready for the students who follow. Let's leave the lab and the equipment in it as tidy as we would like to find it. At the end of the semester your protoboard must be stripped down and all components returned to parts drawers or plastic bags issued with the protoboards at the beginning of the semester.

Part of your project grade is based on evaluation by TAs of augmentation performance, originality, and complexity as well as student attendance, preparation, participation, and performance. Your final clean up points will be for having cleaned up your protoboard, work space, and properly returned all parts to the parts bins.

Project Hardware Available in the Studio

A number of processors, including DSPs, are available in the lab for use with projects. Additionally, a number of peripherals and systems are available such as simple robots, a magnetic stripe card reader, and a barcode reader. The devices and specific details are listed below.

M68HC11 EVB

M68HC12 EVB

M68332 Processor System

Several DSP boards from Analog Devices and Motorola

Two STA013 EVB: STMicroelectronics MP3 development systems with PC interface (limited H/W & S/W driver documentation) user guide on the studio web site and online from www.eetasia.com/ARTICLES/2000MAR/2000MAR15_AMD_MSD_AN.PDF, more information also at <http://www.st.com> (ST Microelectronics web page): search for 'STA013'

CompactFlash/IDE interface connector for adding CFDISK/IDE hardware to the M68HC12 EVB (limited S/W driver documentation)

TeachMover MICROBOT Computer Controlled Robot

Shadow Boxes for shape recognition

American Magnetics Magstripe Card Reader

Hewlett Packard HEDS-300 Digital Bar Code Wand

Fuzzy Logic Controller (available on the 68HC12 through fuzzy logic instructions)

Temperature Sensitive Transistors,

MC146818 Real Time Clock/Calendar chip

Misc. Components (op amps, discrete logic, solid-state relays, small motors, stepper motors,

+5 V, ±12 V Power Supplies

References

"Microcomputer Engineering" by Gene H. Miller, Prentice-Hall (1993).

"Lab Manual for Single- and Multiple-Chip Microcomputer Interfacing" by Peter Song and G.J. Lipovski Prentice-Hall (1988); a copy is available in the CML TA cabinet.

"Operation Manual of the Five-Axis Robot Model TCM" by Microbot Inc., Edition 2, (1982). All the information you need to check out the robot and to interface using the serial port connection for the robot's 6502 microprocessor. A copy is available in the studio TA cabinet.

Microprocessor, Microcontroller, and Peripheral Data, Volume II, available in the lab, on pp. 3-1653 to 3-1672. (information about the MC146818)

Course Handouts (available on the web)

All the course handouts are on the web at http://www.rpi.edu/dept/ecse/mps/mps_handouts.html. Unless noted otherwise, all are available in both MSWord DOC and PDF files. These are the files referred to most frequently and for which printed copies would be used regularly. Other reference material is available on the web but is not listed here.

Course & Lab Exercise Handouts	Course Project Handouts
MPS_Intro.ppt (only PPT)	[Loose guidelines for small course project]
MPS_Sched,Syll&Project.doc – this file	ECSE_Guidelines_for_Design_Lab_Notebooks.doc
Student-Guide.doc – compile and EVB download instructions	Guidelines_Proj_proposal_Fall_03.doc
IDE&SDCC_C_Compiler.doc – compiler hints, port & control register device definitions, interrupt program example, ASCII character table	Guidelines_Final_Report.pdf (only PDF)
M6812_Users_Man.doc – summary of all HC12 peripherals & 16-button keypad (comparative reference)	RPI_Technical_Writing_Manual.ppt (only PPT)
Appendix_A_ver_9_7.pdf - F020 guide (abridged) w/ C Programming (Ch 6)	ECSE_Guidelines_Final_Oral_Presentation.doc
LCD_Screen-8051.doc – H/W & S/W guide for LCD panel	Studio-AV-Manual.doc – guide to using the studio podium A/V equipment for project presentations
MPS_Lab_Ex1-IDE_ANSI.doc	Supplementary Course Handouts
ANSI ESC codes, SFR list, LED & Potentiometer Ccts	MPS_60-pin_Bus.docx: 60-pin header assignments
MPS_Lab_Ex2-Intrpt.doc	DEBUGGING-Understand_Analog-Mixed-Signal_Design_In_The_Analog_And_Digital_Domains.pdf
ISR Priority Order table	SPI.pdf: SPI introduction (M68HC12)
MPS_Lab_Ex3-Serial.doc	Coding_SPI_sw.pdf
RS232 DB-9 pin numbering	MPS_Timer_modes.doc
MPS_Lab_Ex4-ADC.doc	SYCLK_Clock_Frequencies.doc
MPS_Lab_Ex5-Memory.doc	MPS_UART_conf.doc
MPS_Lab_Ex6-Magic8Ball.doc	MPS_SPI_conf.doc
Keypad data sheet & wiring diagram	VREF_Reference_Voltage.doc
MPS_Lab_Ex7-CAN.doc	ADC-DAC_Summary.doc
CAN pseudocode, RC Car CAN ID specs	2s_comp_converters.doc
NI_User_Manual.docx	MAC_Summary.doc
CAN_Theory&Case_Study.docx	
sloa101.pdf: TI CAN overview	6399-STA013_MPEG.pdf
Microcontrollers Tackle Networking Chores.pdf	6526-STA013_AppNote.pdf
xc_autobus48(CAN).pdf	HID_How_Card_Is_Read.pdf: HID card reader info
CAN_lecture.ppt	thinlineii_ds_en.pdf: HID ThinLine II data sheet
	Fuzzy Logic.ppt (and PDF)