Syllabus For Engineering 1650
Embedded Microprocessor System Design, Fall 2010

Catalog Description: This is a combined lecture and design project course offering experience in the open-ended design of an electronic product or system employing an embedded microprocessor by small-group design teams. Activity includes product specification, circuit design, programming, printed circuit layout, construction, packaging, and economic assessment. Teams are expected to produce functional products. Lecture topics will be adjusted to reflect the design problems chosen. Emphasis is placed on the criteria for choosing processors and on the interfaces and programming requirements of the system. Assessment is based on the quality of the product and on a final portfolio documenting the design. Primarily for senior concentrators. Experience with C programming is helpful but not required. Prerequisite ENGN1630 or permission of the instructor.

Professors: The principal professor for this course will be William R. Patterson but Professors Harvey Silverman and Kenneth Silverman may also participate.

Contact Information:

Wm. R. Patterson, Room 449, ext. 3-1449, patterson@engin.brown.edu.
Harvey Silverman, Room 324, ext. 3-1433, hfs@lems.brown.edu.
Ken Silverman, Room 325, ext. 3-3918, kjs@lems.brown.edu

Office Hours: I do not schedule regular office hours. Instead I am prepared to answer questions or deal with problems as they arise. I am available at any time you can find me in Barus & Holley (or *Au Bon Pain*). A list of my haunts and the phone numbers thereof is posted on my office door. If it is inconvenient to see you then, I will tell you so and arrange an alternate time. Otherwise, feel free to take advantage of my availability – the offer is genuine. I am especially available after class and am willing to make appointments, at least for a day or two ahead, either after class or by email.

Web Site: I hope to have a class web site at `www.engin.brown.edu/courses/engn1650` for class handouts. The details of the site are TBD.

Goals: All courses in our ABET accredited programs need explicit goals, and at the end of the course, you will be asked to evaluate how well we have met those goals. The information you supply on how we have done helps us improve the course and is part of our evaluation by the Division. Here is what I hope may be accomplished:

1. To learn the basics of designing systems, such as cameras, cell phones, mice, etc., which have one or more microprocessors dedicated to controlling the information flow. Generally such systems also have high-speed logic, sensors, ADC and DAC converters, etc. and an interface to more general-purpose computers, to a computer network, or to their human owners by video, audio, or other display. Any design of such a system must simultaneously address a number of interacting factors including:

- Electrical circuit requirements, especially bus interfaces
- Mechanical packaging needs
- Software programming, particularly real-time programming and the need for code efficiency to minimize the required processor size
- Economic constraints
- Safety and standards compliance issues

2. To learn to present engineering reports, data, and calculations while developing the habit of making and preserving such records

3. To relate the content of core and specialized introductory courses to the practical implementation of products.

4. To gain an appreciation of the need for and the pleasures of constantly learning new material needed to do innovative design.

Organization: The course will be organized primarily around your designing, building, programming, and estimating the cost of an embedded system. This will be a group project and we hope to organize it so that everyone gets some exposure to most of the system. We particularly urge that you choose how you participate so you maximize your exposure to what you don't know much about at the start of the course. For example someone who has done summer work on PCB design should decide to do circuit design or programming or some other such task but be available to his or her team's layout artist for consultation. Depending on the size of the class there may be more than one project. We find that teams of three are the ideal size, and we are averse to more than four. There will also be lectures on related topics and you will present formal status reports on and schedules of your work on a weekly basis.

For a project to succeed, the system itself has to be chosen early and a rough decision made as to how to implement it. I prefer to give you a chance to select a project of your own, but experience suggests that without some constraint this selection process can take too long. On the first day of class, there will be a list of possible projects that Prof. Silverman and I have thought of. You have one week to decide on a project or accept one from that list. You may also suggest variants from the list. The projects must also have target prices.

Previous offerings of the course have included projects to build:

- A 3-D Mouse based on ultrasound pulses
- A 3-D Mouse based on crossed orthogonal low-frequency (10 - 12 KHz) magnetic fields
- A GPS system in a battery-operated USB dongle for use as a pedometer or trip recorder
- Battery-powered pair of accelerometers in a package attached to your foot and connected by Bluetooth wireless to a PC for use as a gaming sensor
- An attachment for an LCD monitor to convert a standard monitor into a multi-finger touch screen. (This was the only one fully functional at the end of the

course. We hope this marks an upwards trajectory of accomplishment and that you will finish faster with a more polished product.)

- LED panels to attach to a bicycle wheel producing a stationary image of slow animation as the bike is driven at 8 mph or higher.

Although your project will probably use only relatively low-speed electronics, I will spend a substantial portion of the class talking about high-speed signal propagation and the electromechanical limitations that imposes on systems. Other lecture topics will include microprocessor types and their selection (Digital Signal Processors, microcontrollers, small general-purpose computers, FPGA and ASIC implementations, etc.), printed circuit design and fabrication including IPC standards, power conditioning and regulation circuits, the USB bus interface, and advanced packaging solutions (stacking chips, flip-chip bonding, etc.). I will have at least one demonstration session for the PCB layout software. (I have set documentation standards for schematics and board design that you must comply with.)

I have noticed that sometimes students do not make the connection between mathematical principles learned in classes and the calculations to design a system. For that reason, I may assign an occasional homework assignment to make such calculations.

Class: The initial class schedule is for two 1.5 hour classes. This is not my preferred arrangement, so we will probably reschedule the class. I want three 50-minute classes a week and we will arrange times to maximize participation. In two classes each week, I will present regular lectures and in the third will ask you to report on the status of the projects. Status reports should be formal with appropriate use of PowerPoint and I have a handout for you on the requirements for these reports.

Reviews of this kind are a normal part of industrial and even academic activity. Everyone is expected to contribute to these presentations regularly and I will weigh these talks in the final grading scheme.

Text: This course is unusual in having no required or recommended textbook nor is there any required reading. It is not, however, a course for illiterates. As the course has two distinct parts – lecture and projects – the written materials to support it pose two separate problems. There is no textbook that covers the rather heterogeneous set of topics I will cover in lecture. Instead I will refer to individual books, application notes, and papers as I change topics. I will try to put some materials on library reserve and to have handouts or web references for other things. While I hope the lectures will have a logical progression of topics, I will adapt them to support your project work as we go along. Gaps and jumps are unavoidable. There is a tentative list of references at the end of the syllabus for some of the topics I have covered in the past.

Part of your project is finding written materials for each aspect of it (fairly easy) and learning to extract what you need from more pages than you want to deal with (rather harder). The typical datasheet for even a small microprocessor runs to well over a hundred pages. The documentation for a Windows API interface is well nigh incomprehensible at first sight. One of the talents of a good engineer is the ability to extract all of what is needed from this wealth of material that usually is far more than is required for any one project. It also frequently requires spotting the subtle point in a technical description that is the difference between what works and what doesn't in a particular situation. You need to develop what our friends in the Humanities call an ability to do "close reading."

Assessment: Assessment is the *au courant* term for how you learn how well you have mastered the course and how I give the grade that the Registrar records. I have found assessment in this course difficult and would frankly prefer to teach the course on an S/NC basis but understand that is not the preference of our students. Instead I try to measure your participation in all aspects of the course. As many of you know, I prefer a style of teaching that allows me to ask you questions as lecture goes along. A small portion of the grade will depend on your being both courageous and awake at such moments. Obviously your weekly status presentations give me an impression of how hard and efficiently you are working. I may ask that these talks sometimes include short tutorials for your classmates on the technical principles exploited by your product.

Finally, at the end of the course I require that each group turn in a paper or portfolio, *i.e.*, a collection of short papers and supporting materials, describing your work. Only one such set of data is needed for each group, but the section on schedules and responsibilities should address each person's activities. Based on earlier versions of the course, I expect this package to run some 50 to 60 pages exclusive of schematics, blueprints, and programs. The latter are part of the requirements but are delivered separately in electronic form. The principal issues to be covered in this documentation are:

1. Specifications for product performance and the calculations to back these up. Any safety issues, packaging durability issues or standards compliance should be explained.

2. Sufficient documentation, files, program source code, explanatory notes, etc. so that someone else might be able to either reproduce what you have done or continue on with its debugging or enhancement.

3. Schedules and commentary about how long each phase of the project took, how schedules were originally envisioned versus how they actually worked out.

4. Economic analysis of the product. This should include some estimate of what you think the product might sell for, how many you think you might sell, and how much it might cost to manufacture.

I will give you more guidance on the materials to be included as the course nears its end. In particular, I will give you some rough rules by which to do the required simple economic analysis. In all likelihood, I will give a grade for the course soon after reading your papers. At that point I have no further leverage to oblige you to do anything, but I will rely on your sense of duty to make corrections to the documentation for any major technical or stylistic errors.

Reference Reading List:

Howard Johnson and Martin Graham, "*High-Speed Digital Design – A Handbook of Black Magic*", Prentice-Hall PTR, Upper Saddle River, New Jersey, 1993.

Howard W. Johnson, "*High Speed Signal Propagation: Advanced Black Magic*," Prentice-Hall PTR, Upper Saddle River, New Jersey, 2003.

Sanjaya Maniktala, "*Switching power supply design & optimization*," New York, McGraw-Hill, c2005.

Jan Axelson, "*USB Complete, Third Edition*," Madison, WI, Lakeview Research, c2005.

John Hyde, "*USB Design by Example, Second Edition*", Intel Press, 2001.

Richard Gerber, "*The Software Optimization Cookbook – High-Performance Recipes for the Intel Architecture*", Intel Press, 2002.

Walter Oney, "*Programming the Microsoft Windows Driver Model- Second Edition*", Microsoft Press, Redmond, Washington, 2003.

Robert Angus, Norman Gunderson and Thomas Cullinane, "*Planning, Performing and Controlling Projects – Third Edition*", Prentice-Hall, Upper Saddle River, NJ, 2003.

Mark I. Montrose, "*Printed Circuit Board Design Techniques for EMC Compliance—Second Edition*", IEEE/Wiley-Interscience, 2000.

Patrick H. Garrett, "*Advanced Instrumentation and Computer I/O Design – Real-Time Computer Interface Engineering*," IEEE Press, 1994.

Phillip A. Laplante, "*Real-Time Systems Design and Analysis – An Engineer's Handbook*", IEEE Press, 1997.