Senior Design Report for ECE 477 – Spring 2003

submitted by

Prof. David G. Meyer

May 10, 2003

School of Electrical & Computer Engineering
Purdue University

Contents

Overview

One of the unique features of ECE 477, *Digital Systems Senior Design Project*, is that each team gets to choose their own specific project (subject to some general constraints) and define specific success criteria germane to that project. In general, this approach to senior design provides students with a sense of project ownership as well as heightened motivation to achieve functionality. All project teams this semester successfully designed and built a printed circuit board, achieved at least basic functionality of their microcontroller-based hardware, and successfully integrated their application software. Some groups, in fact, continued to work on their projects *after* the semester was over ("just for fun"), to add features and/or obtain a higher degree of functionality. In short, students not only devoted a lot of time to this course, but they also learned a lot – in the words of several students, "more than in all their other ECE courses combined." The complete set of Senior Design Reports is included as Appendix A.

Self-Evaluation

A major change was put into effect this semester, which provided specific, quantitative evaluation of each team member's professional and design contributions. A series of four "design component" assignments along with four "professional component" assignments were defined, where each team member was required to complete one assignment from each group. Further, these assignments represented the "first draft" of corresponding sections of the team's final report, which enabled the course staff to give detailed feedback toward improving the quality of the final reports. The significant weight of these assignments allowed us to adopt a "50-50" grading scheme (i.e., course grade based on 50% individual contribution, with the other 50% based on the team component).

The high degree of success achieved by each team was a direct result of the availability of the course staff to spend a significant amount of time consulting with each team. Another reason for the high degree of success attained was the incredible effort put forth by our outstanding teaching assistants, John Leimgruber and Jeffrey Jackson.

A problem inherent in all "open-ended" project courses is the tractability of the student-chosen design projects. The staff needs to be more "forceful" in suggesting alternative ideas and in rejecting project proposals that are too ambitious.

Also, the course and instructor evaluation forms used by the senior design courses (in particular, ECE 402 and ECE 477) need to be revamped. (The forms developed for EPICS were used by "default" until they no longer were made available to us). I have developed an alternative form compatible with the University's PICES system, and used it on an experimental basis in ECE477 for several semesters. I will once again attempt to present the idea of a "universal senior design evaluation form" to the ECE Senior Design Committee at its next meeting.

Finally, the ECE Administration is encouraged to remain cognizant of the fact that ECE 477 is not a "standard 3-credit hour" load – the amount of evaluation and consultation required is *several times* that of a "normal" course. Increasing the enrollment to 48 (12 teams) this semester has stretched the limits of the lab and staff capacity. At least two faculty (along with two half-time teaching assistants) need to be assigned to this course if the enrollment remains at 48.

Course Policies and Procedures

Course Description: A structured approach to the development and integration of embedded microcontroller hardware and software that provides senior-level students with significant design experience applying microcontrollers to a wide range of embedded systems (e.g., instrumentation, process control, telecommunication, intelligent devices, etc.).

Objective: To provide practical experience developing integrated hardware and software for an embedded microcontroller system in an environment that models one which students will most likely encounter in industry.

Instructors: Prof. D. G. Meyer, meyer@purdue.edu, Office: MSEE 238, Phone: 494-3476; and Prof. T. M. Talavage, tmt@purdue.edu, Office: EE 336, Phone: 494-5475.

Course Teaching Assistants: John Leimgruber (leimgrub) and Jeffrey Jackson (jhjackso) will be available at scheduled (or arranged) times in lab for consultation.

Course web site: http://shay.ecn.purdue.edu/~dsml/ece477

Course E-mail address: ece477@ecn.purdue.edu

Office Hours: Scheduled office hours will be posted on the course web site; other times may be arranged by E-mail appointment. Please make use of the "live" consultation hours available rather than E-mailing "long" or detailed questions specific to your project.

Open Shop Lab: Room EE 069 is the laboratory for this course; students enrolled in ECE 477 will be given a key code that will provide them with 24-hour access. This facility is equipped with expensive, state-of-the-art instrumentation; students are expected to treat the equipment and furnishings with respect. There will be a "zero tolerance" policy for abuse/misuse of this lab: anyone who does so will be unceremoniously dropped from the course, receive a failing grade, and be prohibited from re-registering for the course. Theft will be prosecuted.

Design Project: Of utmost importance in the "real world" is the ability to document and present technical information in a clear, organized, succinct, and well-illustrated fashion. In microprocessor-based designs, the ability to integrate hardware and software is a fundamental skill that should be possessed by all Computer Engineering graduates. The design project, formal written report, and videotaped presentation will give each student in this course the opportunity to develop these skills. Students will work on their design in teams of *four*. Detailed project specifications are provided on page 4 of this document.

Lab Notebook: Developing good design documentation skills is an important part of this course. A significant part of your grade (10%) will be based on the individual lab notebook you maintain throughout the design and development process.

Weekly Meetings: During a scheduled (20-minute) portion of the weekly lab period for this course (8:00-10:00 AM on Wednesdays), each team will meet with a course staff member to discuss progress on the design project. Each team member will be expected to post a completed weekly progress report on their team's project web site in advance of these meetings.

Group Account and Team Webpage: Each team will be assigned an ECN group account to use as a repository for all their project documentation and for hosting a password-protected team web page. The team web page should contain datasheets for all components utilized, the schematic, board layout, software listings, interim reports, presentation slides, etc. It should also contain the individual lab notebooks for each team member as well as the progress reports (prepared in advance of the weekly progress briefings) for each team member. At the end of the semester, each team must submit a CD-ROM containing the complete image of the webpage.

Homework: Several "homeworks" will be assigned related to key stages of the design project. Some of the assignments will be completed as a team (1, 3, 12, 14), some will be completed individually (2, 13), and some will be completed by a selected team member (one from the set {5, 6, 7, 10} and one from the set {4, 8, 9, 11}).

1. Preliminary Design Project Proposal
2. OrCAD Exercise
3. Final Design Project Proposal
4. Design Constraint Analysis and Component Selection Rationale/Parts List
5. Packaging Specifications and Design
6. Schematic and Hardware Design Narrative/Theory of Operation
7. Board Layout
8. Patent Liability Analysis
9. Reliability and Safety Analysis
10. Firmware Listing and Software Narrative
11. Social/Political/Environmental Analysis
12. User Manual
13. Confidential Peer Review
14. Senior Design Report/Project Summary

Grade Determination

Your course grade will be based on both team effort (50%) and individual contributions (50%):

TEAM COMPONENTS		INDIVIDUAL COMPONENTS	
Project Proposal {1 and 3}	3%	Significance of Individual Contribution	10%
User Manual {12}	4%	Laboratory Notebook	10%
Senior Design Report {14}	3%	Design Component {5, 6, 7, or 10}	10%
Design Review	10%	Professional Component {4, 8, 9, or 11}	10%
Final Video Presentation	10%	OrCAD Exercise {2}	2%
Final Written Report & Archive CD	10%	Peer Review {DR + 13 + FP}	6%
Project Success Criteria Satisfaction	10%	Weekly Progress Briefings/Attendance	2%

Your **R**aw **W**eighted **P**ercentage (RWP) will be calculated based on the weights, above, and then "curved" (i.e., mean-shifted) with respect to the upper percentile of the class to obtain a **N**ormalized **W**eighted **P**ercentage (NWP). Equal-width cutoffs will then be applied based on the **W**indowed **S**tandard **D**eviation (WSD) of the raw class scores; the minimum **C**utoff **W**idth **F**actor (CWF) used will be 10 (i.e., the nominal cutoffs for A-B-C-D will be 90-80-70-60, respectively). Before final grades are assigned, the course instructor will carefully examine all "borderline" cases (i.e., NWP within 0.5% of cutoff). Once grades are assigned, they are **FINAL** and WILL NOT be changed. Note that all course outcomes (listed on page 7 of this document) must be demonstrated in order to receive a passing grade for the course.

Lecture Schedule (Tentative):

Week 1	Tu – course and project overview, team formation
	Th – project proposal guidelines and documentation requirements
Week 2	Tu – PCB layout basics, OrCAD demo, packaging specifications
	Th – technical writing guidelines, real-world design constraints
Week 3	Tu – microcontroller survey - PIC
	Th – microcontroller survey - Rabbit
Week 4	Tu – microcontroller survey - Atmel
	Th – interfacing: D.C. and A.C. loads, optical isolation
Week 5	Tu – interfacing: keypad encoding, switch debouncing, RPGs
	Th – interfacing: PWM applications, position control, steppers, LCDs
Week 6	Tu – power supply design – basic considerations, linear regulators
	Th – power supply design – switching regulators, DC-DC converters
Week 7	Tu – capacitor and resistor selection guidelines
	Th – patent infringement liability
Week 8	Tu – (no class – Design Reviews individually scheduled this week)
	Th – (no class – Design Reviews individually scheduled this week)
Week 9	Tu – design for reliability, maintainability, and safety
	Th – FMECA worksheet
Week 10	Tu – soldering issues and techniques, board construction tips
	Th – embedded software organization and development tools
Week 11	Tu – interactive “broken board” debugging
	Th – interactive “broken board” debugging
Week 12	Tu – social/political/environmental considerations
	Th – user manual, final report, and final presentation guidelines
Week 13	Tu – current embedded system topics
	Th – current embedded system topics
Week 14	Tu – current embedded system topics
	Th – course summary and evaluation
Week 15	Tu – (no class – Project Presentations individually scheduled this week)
	Th – (no class – Project Presentations individually scheduled this week)

Design Project Specifications

Work on the design project is to be completed in teams of four students. The design project topic is flexible, and each group is encouraged to pick a product that uses the strengths and interest areas of their group members. The design must have the following components:

- **Microprocessor:** To help make the project tractable, microprocessor choices will be limited to 68HC12, PIC, Rabbit, and Atmel variants. Development tools are readily available in lab to support these devices. Further, the devices themselves are relatively low cost and readily available.
- **Interface to Something:** Your embedded system must interface to some other device or devices. It could be a computer, or it could be some embedded device such as a Palm Pilot, telephone line, TV, etc. Some interface standards that could be used are: serial to a computer, parallel to a computer, Universal Serial Bus (USB), Firewire, Ethernet, Infrared (IR), Radio Frequency (RF), etc. This requirement has a large amount of freedom. To help with some of the more complex interfaces such as Ethernet, USB, or Firewire there are dedicated chips which encapsulate the lowest layers of the interface. This makes using these interfaces easier to handle but not necessarily trivial. Be sure to investigate the interface(s) you wish to utilize and make a reasonable choice. (NOTE: *Interfaces involving A.C. line current require special permission – see the instructor for details.*)
- **Custom printed circuit board:** Through the process of the design, each group will be required to draw a detailed schematic. From the schematic, a two-layer (maximum) printed circuit board will be created. The board will etched by a local board house. The team is then responsible for populating the board (solder the parts on the board), and for completing the final stages of debugging and testing on their custom board.
- **Be of personal interest to at least one team member:** It is very difficult to devote the time and energy required to successfully complete a major design project in which you and/or your team members have no personal interest. There are *lots* of possibilities, ranging from toys and games to “useful and socially redeeming” household items, like audio signal processors and security systems.
- **Be tractable:** You should have a “basic idea” of how to implement your project, and the relative hardware/software complexity involved. For example, you should not design an “internet appliance” if you have no idea how TCP/IP works. Also, plan to use parts that are reasonably priced, have reasonable footprints, and are *readily available*. Be cognizant of the prototyping limitations associated with most flash-memory-based microcontrollers (like the 68HC912B32 and most PIC microcontrollers, for example).
- **Be neatly packaged:** The finished project should be packaged in a reasonably neat, physical sound, environmentally safe fashion. Complete specification and CAD layout of the packaging represents one of the project design components.
- **Not involve a significant amount of “physical” construction:** The primary objective of the project is to learn more about *digital system* design, not mechanical engineering! Therefore, most of the design work for this project should involve digital hardware.

Project Proposal

Each group should submit a proposal outlining their design project idea. This proposal should not be wordy or lengthy. It should include your design objectives, design/functionality overview, and project success criteria. The five success criteria common to all projects include the following:

- Create a bill of materials and order/sample all parts needed for the design
- Develop a complete, accurate, readable schematic of the design
- Complete a layout and etch a printed circuit board
- Populate and debug the design on a custom printed circuit board
- Package the finished product and demonstrate its functionality

In addition to the success criteria listed above, a set of *project-specific* success criteria should be specified. The degree to which these success criteria are achieved will constitute one component of your team's grade.

Forms for the preliminary and final versions of your team's project proposal are available on the course web site. Use these skeleton files to create your own proposal. Note that the proposal should also include assignment of each team member to one of the design components as well as to one of the professional components of the project.

Design Review

Part way through the design process, there will be a formal design review. This is a critical part of the design process. In industry, this phase of the design process can often make or break your project. A good design review is one where a design is actively discussed and engineers present concur with the current or amended design. The design review is in some cases the last chance to catch errors before the design is frozen, boards are etched, and hardware is purchased. *A friend is not someone who rubber-stamps a design, but rather one who actively challenges the design to confirm the design is correct.*

Approach the design review from a top-down, bottom-up perspective. First, present a block diagram of your design and explain the functional units. Then drop to the bottom level and explain your design at a schematic level. Be prepared to justify every piece of the design; a perfectly valid answer, however, is applying the recommended circuit from an application note. If you do use a circuit from an application note, have the documentation on hand and be able to produce it. *Your grade for the design review will not be based on the number of errors identified in your design.* The best engineers make mistakes, and the purpose of the design review is to *catch them* rather than spend *hours of debugging later* to find them. The design review will be graded primarily on how well the group understands their design and the professionalism with which they present it.

To facilitate the design review process, the class will be split into subgroups that will meet at individually scheduled times. Both the presenters and the assigned reviewers will be evaluated.

Milestones

Each group is responsible for setting and adhering to their own schedule; however, there are several important milestones, as listed in the table below. Always "expect the unexpected" and allow for some buffer in your schedule. *Budget your time.*

<table>
<tr><td>Week 1</td><td>Jan 13 – Jan 17</td><td>Formulate Group and Project Ideas</td></tr>
<tr><td>Week 2</td><td>Jan 20 – Jan 24</td><td>Preliminary Project Proposal Due</td></tr>
<tr><td>Week 3</td><td>Jan 27 – Jan 31</td><td>• Research Parts
• Create Block Diagram</td></tr>
<tr><td>Week 4</td><td>Feb 3 – Feb 7</td><td>Final Project Proposal Due</td></tr>
<tr><td>Week 5</td><td>Feb 10 – Feb 14</td><td rowspan="2">• Draw Schematic
• Construct Prototype
• Begin Software Development
• Create Bill of Materials
• Begin Ordering/Sampling Parts</td></tr>
<tr><td rowspan="2">Week 6</td><td rowspan="2">Feb 17 – Feb 21</td></tr>
<tr><td>Schematic and Parts List Due</td></tr>
<tr><td>Week 7</td><td>Feb 24 – Feb 28</td><td>• Prepare for Design Review</td></tr>
<tr><td>Week 8</td><td>Mar 3 – Mar 7</td><td>Design Reviews</td></tr>
<tr><td>Week 9</td><td>Mar 10 – Mar 14</td><td>Board Layout Due</td></tr>
<tr><td>Week 10</td><td>Mar 24 – Mar 28</td><td rowspan="2">• Continue Software Development
• Populate Circuit Board</td></tr>
<tr><td>Week 11</td><td>Mar 31 – Apr 4</td></tr>
<tr><td>Week 12</td><td>Apr 7 – Apr 11</td><td>Firmware Listing Due</td></tr>
<tr><td>Week 13</td><td>Apr 14 – Apr 18</td><td rowspan="2">• Debug Hardware on Printed Circuit Board
• Hardware/Software Integration and Testing
• Write Report and Prepare Presentation</td></tr>
<tr><td>Week 14</td><td>Apr 21 – Apr 25</td></tr>
<tr><td>Week 15</td><td>Apr 28 – May 2</td><td>Project Demonstrations and Final Presentations</td></tr>
<tr><td>Week 16</td><td>May 5 – May 9</td><td>Archive CD, Peer Review, Final Report, and Senior Design Report due May 7 at 5:00 PM</td></tr>
</table>

Outcome Assessment

In order to successfully fulfill the course requirements and receive a passing grade, each student is expected to demonstrate the following outcomes:

(i) an ability to apply knowledge obtained in earlier coursework and to obtain new knowledge necessary to design and test a microcontroller-based digital system [1, 2, 3, 4, 5; a, b, c, e, i, j, k]
(ii) an understanding of the engineering design process [4, 6, 7; b, c, e, f, h]
(iii) an ability to function on a multidisciplinary team [6, 7; d, h, j]
(iv) an awareness of professional and ethical responsibility [6, 7; f, h, j]
(v) an ability to communicate effectively, in both oral and written form [6; g]

The following instruments will be used to assess the extent to which these outcomes are demonstrated (the forms used to "score" each item are available on the course web site):

Outcome	*Evaluation Instruments Used*
(i)	Design Component Homework
(ii)	Individual Lab Notebooks (two separate evaluations)
(iii)	Project Success Criteria Satisfaction
(iv)	Professional Component Homework
(v)	Formal Design Review, Final Presentation, and Final Report

Students must demonstrate basic competency in ***all*** the course outcomes, listed above, in order to receive a passing grade. Demonstration of Outcome (i) will be based on the satisfaction of the design component homework, for which a minimum score of **60%** will be required to establish basic competency. Demonstration of Outcome (ii) will be based on the individual lab notebook, for which a minimum score (average of two separate evaluations) of **60%** will be required to establish basic competency. Demonstration of Outcome (iii) will be based on satisfaction of the project success criteria, for which a minimum score of **60%** will be required to establish basic competency. Demonstration of Outcome (iv) will be based on the professional component homework, for which a minimum score of **60%** will be required to establish basic competency. Demonstration of Outcome (v) will be based on the Design Review, the Final Presentation, and the Final Report. A minimum score of **60%** on the Design Review and a minimum score of **60%** on the Final Report and a minimum score of **60%** on the Final Presentation will be required to establish basic competency.

Students who fail to satisfy all outcomes but who are otherwise above the "passing threshold" (based on their NWP) will be given a grade of "E" (conditional failure). The grade of "E" may subsequently be improved to a grade of "D" upon successful satisfaction of all outcome deficiencies. If outcome deficiencies are not satisfied within one week from the receipt of final course grades, the grade of "E" will revert to a grade of "F".

Appendix A:

Senior Design Reports

Purdue ECE Senior Design Semester Report

Semester / Year	Spring 2003
Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Team Name	Group 1
Advisors	Prof. Meyer and Prof. Talavage
Project Title	Autonomous Robot

Senior Design Students			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Matt Seeds	EE	Controls, Digital and Analog Circuits, Software Debugging	May 2003
Robert Gorgol	CmpE	C Programming, HTML	May 2003
Tarun Shivlani	EE	Controls, Analog and Digital Circuits	August 2003
Derick Winston	EE	Controls, Digital and Analog Circuits	December 2003

Project Description: Provide a brief (one or two page) technical description of the design project, as outlined below:

(a) Summary of the project, including customer, purpose, specifications, and a summary of the approach.

This project was designed to be an interactive demonstration of various electrical and computer engineering disciplines for HKN to use to generate interest in the school. HKN wanted something that was portable, easy to setup, and could run on battery power. The result of these criteria was our autonomous maze robot. The basic idea was to develop a robot that could find its way through a maze that may be changed at the start of the robot's run. The robot would then move through the maze using infrared sensors to detect the openings in the maze walls and optical encoders placed on the wheels to monitor the distanced moved and the speed of the robot. The end of the maze is marked by a magnet, which is placed in an accessible grid space by the user and is detected by the robot using a reed sensor.

(b) Description of how the project built upon the knowledge and skills acquired in earlier ECE coursework.

The project required the team to learn more about interfacing various types of digital and analog hardware with a microcontroller in an embedded system and utilized skills and knowledge acquired in EE 270: Digital Logic Design as well as EE 362: Microcontroller Design. The software was written in C, and utilized skills developed in EE 264: Advanced C Programming, such as file I/O in the maze simulator and the use of pointers as function parameters.

(c) Description of what new technical knowledge and skills, if any, were acquired in doing the project.

The project provided allowed us to learn the process of designing an embedded system from the ground up. We developed new technical abilities through the use of new tools. For example, the project required that all the team members learn ORCAD Capture and Layout. At the start of the semester none of us had used any of these tools. New techniques for troubleshooting and soldering were also acquired. An understanding of the professional aspects of designing a safe and reliable product and bringing it to market were acquired in addition to new technical skills.

(d) Description of how the engineering design process was incorporated into the project.

The project idea was selected and similar types of robots were studied to see what kinds of features would be good for our robot and what we thought we could improve. Parts were researched to see what would be the best to perform certain tasks, such as wall detection and motor control. The parts were ordered and tested individually to verify their ability to interface with the microcontroller and function properly. Individual circuits were verified through testing, and an initial board schematic was laid out. After the design review, changes were made to the schematic, and the PCB was designed and constructed. The parts were then soldered to the board and individual blocks were tested. Once we were satisfied with the testing, we tested overall software functionality in the microcontroller. The rest of the project involved testing and debugging.

(e) Description of the multidisciplinary nature of the project.

The project had both electrical and computer engineering aspects. The robot required knowledge of motors, sensors, and controls, which are all EE disciplines. The robot also required the use of a microcontroller and therefore needed a fair amount of embedded software. The packaging of the robot required a slight amount of mechanical knowledge.

(f) Summary of how realistic design constraints were incorporated into the project (where appropriate, include economic, environmental, ethical, health & safety, social, and political constraints as well as considerations related to sustainability and manufacturability)

The process of selecting components for the design was divided equally among all members of the group. We searched for components that could be sampled to reduce overall cost and analyzed data sheets for components that would function properly under expected testing conditions (operating currents, temperature, etc). The professional lectures and homework assignments provided us with the knowledge necessary to analyze our components (albeit, after we already had most of them) and determine the considerations that should be taken in order for our product to be manufactured, used, and disposed of safely.

Purdue ECE Senior Design Semester Report

Semester / Year	Spring 2003
Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Team Name	Group 2
Advisors	Prof. Meyer and Prof. Talavage
Project Title	Boilermixer

Senior Design Students			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
David Reiner	CmpE	µC & C Programming	Dec. 2003
Tracy Wells	CmpE	Hardware dsn & debug	May 2003
Ed Maia	CmpE	Website & hardware	May 2003
Jim Marsh	CmpE	Feasibility,Construction	May 2003

Project Description: Provide a brief (one or two page) technical description of the design project, as outlined below:

(a) Summary of the project, including customer, purpose, specifications, and a summary of the approach.

The Boilermixer is an automated drink mixing machine. Its purpose is to make the task of mixing ingredients and remembering recipes easier. The target customer would be middle class young people, ages 21 through 25, although it can easily be used by anyone 21 or older.

It is capable of creating a number of drinks from the ingredients located in its 6 cylindrical containers. These cylinders are supported by a wooden structure which also has a 4 x 20 LCD panel, and a 4 x 3 keypad for easy user interface. A microcontroller controls all of the functionality of the machine, including opening and closing the valves for the containers. There are also separate LEDs for each container, which light up both when that ingredient is in use as well as after a drink has been made, in case the drink uses that ingredient.

(b) Description of how the project built upon the knowledge and skills acquired in earlier ECE coursework.

This project required knowledge and skills from several different earlier ECE classes. First on the circuit side of the project most of the knowledge had been acquired in ECE 201 and ECE 255 which included knowledge about transistors, voltages, currents, construction of circuits, current limiting resistors, and AC to DC wave rectification. Picking out and interfacing the microcontroller pulled knowledge from ECE 270 (fanouts, noise margins) and ECE 362. The software for the project also pulled knowledge from ECE 264 (C programming), ECE 270 (state machines), ECE 362 (microcontroller specific considerations), and ECE 495A (uC architecture effects on software, including database optimization).

(c) Description of what new technical knowledge and skills, if any, were acquired in doing the project.

There was actually quite a bit of new technical knowledge acquired during ECE 477 that either was not taught in previous courses, or which was not remembered due to large amounts of time between that class and ECE 477. The main technical thing learned was how to create schematics and layouts in Orcad which was a major part of the design process. A lot of little new things were learned on the circuit side, which included how to design power circuitry, what wattage resistors were needed in certain applications, and the different voltage capacitors. In addition to all these skills there were more general skills that were acquired such as how to use the knowledge used in classes to solve real world problems, and how to combine topics used in different parts of the curriculum correctly.

(d) Description of how the engineering design process was incorporated into the project.

A very strict engineering design process was used during the creation of The Boilermixer. It started with constructing a team made of members who were reliable and who worked well together. At the beginning stages of the process, each team member was assigned a role to play throughout the semester. This helped to keep the team organized and establish responsibilities. Throughout the semester, weekly meetings took place among the team members, and at these weekly meetings, the most current issues concerning the project were discussed. All tasks at hand were prioritized in order to make sure everyone was on the same page and the most important tasks were completed first. Through the use of an excellent online documentation system created by Jim and Ed, we were able to fully document all work that was done individually, and it was very simple for any member to quickly see what other members had accomplished.

When designing the hardware, we used a top-down specification, bottom-up implementation procedure. A plan was followed in which each part of the circuitry was fully tested and prototyped before finalizing it into the overall design. In this way, it was ensured that the circuitry would work. After the PCB was made, a process was followed in that each part of the circuit that was added to the board was tested before adding anything else. This proved to be very useful because as we went along, there were some resistors that were damaged during soldering but they were found right away because of our bottom-up testing.

Through these design processes, the hardware worked very quickly without any major problems. We were able to incorporate the software very seamlessly and obtain great results from the functionality of The Boilermixer.

(e) Description of the multidisciplinary nature of the project.

This project required that all team members have some areas of specialization, and that they make full use of those skills. Because each team member did have important unique multidisciplinary skills, our project became a great success. Skills were utilized that involved knowledge in areas such as fluid dynamics, woodworking, soldering, and systems testing. Of course skills were also utilized from our computer and electrical engineering classes. But even specialization was necessary within our majors. For instance, specific knowledge about microcontrollers and software was necessary to properly program and interface the ATmega32L microcontroller. Extensive knowledge about circuit design was needed in creating useful circuits. Also a general knowledge for user interfacing was useful when designing the look and feel of the project. The culmination of all of these skills made the plans for the Boilermixer a reality.

(f) Summary of how realistic design constraints were incorporated into the project (where appropriate, include economic, environmental, ethical, health & safety, social, and political constraints as well as considerations related to sustainability and manufacturability)

There were many realistic design constraints which were incorporated into The Boilermixer. The first realization was that we were using both water and electricity, which meant that there was a potential fire hazard. With this in mind, we planned on isolating all of the electrical components from any areas where water might be. This was done both by mounting the PCB inside a plastic Tupperware dish, and also by inserting rubber rings around all of the containers so that if any spills occurred on the outside, the water would not be able to seep into the box.

For user convenience, we included an option in the menus called "clean". This allows the user to completely flush out all of the liquid that is contained in the selected container. In this way, cleaning is easy because the user never has the need for removing the containers from the apparatus.

We believe that we have made The Boilermixer as low-cost as possible. When selecting parts to use, cost played a major role. However, we did not sacrifice cost for quality in any way. The Boilermixer is a cost-effective, reliable product.

Purdue ECE Senior Design Semester Report

Semester / Year	Spring 2003
Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Team Name	Group 3
Advisors	Prof. Meyer and Prof. Talavage
Project Title	Bus Tracking System

Senior Design Students			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Rio Lopa	CMPE	Rabbit Hardware and Software	May 2003
Ricky Riyadi	EE	Atmel Hardware and Software	May 2003
Evie Salim	CMPE	Atmel Hardware and Software	May 2003
Olinka Utomo	CMPE	Rabbit Hardware and Software	May 2003

Project Description: Provide a brief (one or two page) technical description of the design project, as outlined below:

(a) Summary of the project, including customer, purpose, specifications, and a summary of the approach.

The customer of this product is transportation system. The main customers are all bus transportation companies who want to make their passengers more satisfies, the bus passengers and the bus driver. The purpose of this project is to inform the bus passengers waiting in the bus stop whether they miss the bus or not. Another purpose of this project is to inform the bus driver if the bus is full or not.

The Bus Tracking system is a system which informs passengers in every bus stop about the last bus stop where each bus was seen. The bus will send the Bus ID continuously through an RF transmitter in each bus. When the RF receiver in a bus stop receives the signal, that bus stop will update the position of the bus in its system by showing it in the LCD, and also informs all other bus stops to update the information about that bus. In addition, the position information will also be displayed on the website. The bus tracking system also informs the driver in the corresponding bus about the number of people inside the bus. This helps the driver to determine if the bus is already full or not. This can be done by utilizing 3 IR sensors installed on the front door and the back door.

(b) Description of how the project built upon the knowledge and skills acquired in earlier ECE coursework.

We use a lot of stuff from Circuit analysis class, and EE255, EE270 to figure out how the IR works, all capacitor, resistor values and all of circuit analysis. We also utilized the skill from EE264 about C programming.EE362 also helps us a lot in the microcontroller interfacing.

(c) Description of what new technical knowledge and skills, if any, were acquired in doing the project.

RF, IR, LCD, ATMEL, and RABBIT microcontroller.

(d) Description of how the engineering design process was incorporated into the project.

All of the homework assigned can be illustrated as the design process. For example, we have to decide our design. After that, we need to choose components. After choosing the component, we need to think about our product packaging. Next, we have to try to build and test hardware and software design of our project in the prototyping board. Then, we have to start producing the schematic, and layout of our project. After we received the board, we start to populate the board while we are thinking about reliability and ethical issues. After everything is done, our product is again tested to see if it is going to work in the PCB board. After testing it, we have our product ready to be promoted to our customers which in this case are our teachers.

(e) Description of the multidisciplinary nature of the project.

The disciplinary of this project utilized are EE, Computer Engineering, and social science. In the ECE, we use C programming language, microcontroller, and circuit analysis. In the social disciplinary, we realized that people need a device that can inform them about the bus position in order to smooth their activities.

(f) Summary of how realistic design constraints were incorporated into the project (where appropriate, include economic, environmental, ethical, health & safety, social, and political constraints as well as considerations related to sustainability and manufacturability)

Since our customer will be bus companies, the cost of our products which are about 300-400$ will not be a huge expense for them. The social part which we want our customer to have all information updates about the bus location. Therefore, besides looking at the LCD in each bus stop, we add website interfacing so that the users can check the bus position from their home.

Purdue ECE Senior Design Semester Report

Semester / Year	Spring 2003
Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Team Name	Group 4
Advisors	Prof. Meyer and Prof. Talavage
Project Title	Digi-YALi

Senior Design Students			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Abhishek Gupta	CmpE	AI, Digital Systems, Software	May 2003
Jalaj Chotani	CmpE	AI, Digital Systems, Software Engineering	May 2003
Nitin Jethanandani	CmpE	Software Engineering, Digital Systems	May2003
Charles Raley	CmpE	Digital Systems, Software	May2003

Project Description: Provide a brief (one or two page) technical description of the design project, as outlined below:

(a) Summary of the project, including customer, purpose, specifications, and a summary of the approach.

The idea was to create a YALi game with enhanced features that helped the player and also made the game allot easier for beginners and more enjoyable. The features that we wanted incorporated were:

1. Displaying different possible moves for a given game piece.
2. Displaying the best possible move for a given game piece
3. Displaying player turn and side move information
4. Displaying the number of turns remaining for a player

For this purpose we created a plastic 9 by 6 game board with 40 locations. The game would be played with 12 pieces, 6 a side. The help features would be incorporated using a LCD display, sound chip and a motor. The LCD was used to display game board updated with the current state at all times. Player pieces were represented on the LCD as 1 or 2 respectively for player one and player two. A diamond denoted a blank spot. Places where the player could move and the best move were represented by "X" and "B" respectively. Player turn and side move information was show using left and right indicators. And the number of turns left was represented as a number on the bottom left of the LCD.

The sound chip incorporated different messages that also helped a player and acted as reminders. 9 messages were recorded and would be played-back, depending on player turn, availability of side moves and incase of a player win or error condition. The motor added the ability for our game board to tilt left or right depending on player turn. A microcontroller would handle and integrate the working of all these components together.

(b) Description of how the project built upon the knowledge and skills acquired in earlier ECE coursework.

The project required the combination of the knowledge gained throughout our undergraduate years. The design was heavily based on digital systems and most important component of our project was the interfacing of the different components with the microcontroller. This required the extensive use of knowledge and skills we learnt in ECE270/362. Among others, we also used this knowledge when we worked with hexadecimal values, built a 3:8 decoder on a PALCE16V8, used DCNM to decide whether connections between components in our circuit would work or did we need to boost the output through a level transceiver, read data-sheets and timing diagram.

The microcontroller was programmed in C and required the use of software skills and data structures that we had learnt in ECE264/368, e.g., efficient use of memory using malloc and free functions, usage of linked lists for our list of possible moves.

The power circuit requires knowledge of ohms law and circuitry using capacitors and diodes. The knowledge gained in ECE201/255 was used in this part of the project.

(c) Description of what new technical knowledge and skills, if any, were acquired in doing the project.

We acquired new knowledge through the different approaches we used while getting our components to work. Because of the use of so many contact sensors in our design, we learnt more efficient ways of reading these inputs by learning about how a key-pad works and incorporated it in our design, instead of reading each value on by one. We learnt about different motors like the servo motor, stepper motor when we tried to incorporate the tilt mechanism in our game board. We learnt and used the OrCad software to create schematics and the PCB layout.

(d) Description of how the engineering design process was incorporated into the project.

Once we had decided on the idea of Digi-YALi, we had to start finding components that suited our needs. We had to try out different approaches and see the ones that fit best with our design and within our constraints. Also a side by side prototyping of the parts was done to see if the part worked as well as we had expected or if improvements were to be made. Once we had everything prototyped, the schematic and layout of the design was created. The components were populated on the PCB and debugged.

(e) Description of the multidisciplinary nature of the project.

The use of microcontrollers, LCD screens power supply all required knowledge of electronics. The plastic game board and packaging required mechanical labor. The use of the motor to tilt the board required understanding of physics (gravity and torque).

(f) Summary of how realistic design constraints were incorporated into the project (where appropriate, include economic, environmental, ethical, health & safety, social, and political constraints as well as considerations related to sustainability and manufacturability).

We reduced the size of the game to half (40 locations) so as to be easily able to prototype, since the wiring involved with the original board (80 locations) was too tedious and cumbersome.

YALi being a game marketed towards age group 8 and above was required to be kept enjoyable, easy and low cost. The original game cost 25 dollars, while our enhanced version of the game cost 160 dollars to prototype. This value will reduce once the unit is mass produced, but this required us to keep the cost of the parts for our design low.

Use of a larger LCD screen would make the number of turns remaining indicator and error indicator much clearer, which at present is cramped on the same line at present along with other vital information.

Our product being targeted towards kids possess a health hazard for young kids who might swallow the game pieces, thus requiring adult supervision. The motor had to be turned slowly, so as not to throw away the game pieces.

Ethics required us to create a bug-free design and software code.

Purdue ECE Senior Design Semester Report

Semester / Year	Spring 2003
Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Team Name	Group 5
Advisors	Prof. Meyer and Prof. Talavage
Project Title	Fembot5

Senior Design Students			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Quinn Kirsch	CmpE	Embedded Software	May 2003
Jeremy Brodt	CmpE	Power Systems	May 2003
Daniel Lenz	CmpE	Circuit Design	May 2003
Jeffrey Wigh	CmpE	Embedded Software	May 2003

Project Description: Provide a brief (one or two page) technical description of the design project, as outlined below:

(a) Summary of the project, including customer, purpose, specifications, and a summary of the approach.

The "FemBot5" is a voice-controlled tank that allows the user to be in command of the direction and speed of the vehicle. The user is also in control of the tank's turret movement. The vehicle is controlled by a separate device that takes voice commands, and transmits them via an FM broadcast to an FM receiver on the tank. A voice recognition chip interprets the designated voice commands and issues commands to the microcontroller, which then interfaces to all the motors of the tank. The microcontroller is also required to monitor a sonar sensor on the front of the vehicle to determine if an object is in the forward path of the tank.

(b) Description of how the project built upon the knowledge and skills acquired in earlier ECE coursework.

The most influential course to our project had to be EE362, where we learned many things about digital circuit design. The chip we used for our project was also similar to the one used in EE362 in many ways. Other courses used were EE201 and EE255. We used the EE201 to do some of our simple circuit design for things like equivalent resistance, voltage dividers, and for our power systems. We also used EE255 to design some amplifier circuits to drive motors using transistors.

(c) Description of what new technical knowledge and skills, if any, were acquired in doing the project.

The most obvious technical skill that we learned was probably the use of the OrCAD development suite in order to create a circuit and printed circuit board layout. This was all new to the entire group. Since we are all computer engineers, we also learned a lot about power circuits. Another interesting problem that we had to tackle late in the project concerned electro-magnetic forces, which showed up when our circuit was powered up. Also our embedded programming experience was greatly increased due to the breadth of our project and the lack of professor provided specifications as in previous coursework.

(d) Description of how the engineering design process was incorporated into the project.

Due to the nature of our task being a design assignment, we had to incorporate and develop our engineering skills from the beginning. At the beginning of the project, we had a rough idea of what we needed done. However, we needed to simply start specifying out all the things we thought it would require. Then we had to go through the process of picking components that would fit our needs along with all the compromises that goes with that process. Real world constraints like size and cost came into scope during this process. It became imperative that the correct components were selected in order for the project to become a success.

(e) Description of the multidisciplinary nature of the project.

Our project consisted of a moving tank, which required many moving components. This brought about the need for mechanical engineering concepts. Motors and gearing systems were used in order to move the tank in a controlled manor. Also a sonar sensor was used, which used the physics concept of sound waves. The project also had a variety of electrical and computer engineering concepts. It required power systems, embedded programming, motor controls, and general circuit design.

(f) Summary of how realistic design constraints were incorporated into the project (where appropriate, include economic, environmental, ethical, health & safety, social, and political constraints as well as considerations related to sustainability and manufacturability)

The project did contain some realistic design constraints. As the tank was battery powered, the engineer must be partly responsible for trying to ensure that the battery was either environmentally sound or disposed of in a proper manor. As a toy tank, the engineer of a commercial product like this would have to make sure that it is safe for children in the designated age group and for younger children who may stumble upon the toy. The product should be reliable to a certain degree and take reasonable to ensure its users are not injured as a result of a failure. The toy also uses radio band electromagnetic waves, which are regulated by the government, but a suitable frequency outside of the provided range could be select to avoid interference with those issues.

Purdue ECE Senior Design Semester Report

Semester / Year	Spring 2003
Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Team Name	Group 6
Advisors	Prof. Meyer and Prof. Talavage
Project Title	SWiMP: Streaming Wireless Media Player

Senior Design Students			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Michael Arens	EE	Layout Design	May 2003
Themen Danielson	CmpE	Microcontrollers	May 2003
Hai Nguyen	CmpE	Microcontrollers	May 2003
Siddarth Raghunathan	CmpE	Various Programming	May 2003

Project Description: Provide a brief (one or two page) technical description of the design project, as outlined below:

(a) Summary of the project, including customer, purpose, specifications, and a summary of the approach.

This project was designed to provide a means of listening to digital music (stored on a home PC) in the living room. Previously, the only solutions were expensive or inconvenient. The SWiMP provides a low cost and low-impact (no running wires, drilling holes, etc.) solution to this problem. It is designed with the average user in mind: it should be easy to install and easy to use. The approach that we used that allowed this device to be inexpensive was to stream music from a PC over an existing wireless network such that we minimize the amount of expensive memory on the device.

(b) Description of how the project built upon the knowledge and skills acquired in earlier ECE coursework.

This project built heavily upon ECE362: Microprocessor Systems. Our design was microprocessor-centric and required prior knowledge of C-programming as well as an understanding of the logistics involved in interfacing. It was also heavily involved in content such as networking and TCP/IP programming. Digital logic was a necessity in order to complete this project. Some aspects of the design even required high and low frequency filtering knowledge. Concepts from ECE495R (Network Programming), ECE364 (Software Tools), ECE368 (Data Structures), ECE495A (Computer Architecture), ECE469 (Operating Systems) etc were also used at varied times in the project.

(c) Description of what new technical knowledge and skills, if any, were acquired in doing the project.

We each learned very valuable skills such as microcontroller selection and justification, as well as other component selection. We each learned a great deal about creating schematics and layouts in order to fabricate a printed circuit board. The most important experience we all took from this course was first-hand knowledge of the design process and what it takes to create a prototype.

(d) Description of how the engineering design process was incorporated into the project.

The engineering design process was the backbone of our system. We first specified the requirements we needed to ensure a working final product. We then acquired the parts and began creating prototypes to test them. Once the prototypes were completed, we were able to fabricate a circuit board to integrate all the modules together. Finally, we were able to test each module with each other and ensure perfect operation.

(e) Description of the multidisciplinary nature of the project.

This project involved many aspects of Systems Engineering, Electrical Engineering, Computer Engineering, Mechanical Engineering, product reliability and even law. Each of these disciplines played a valuable role in the success of our project and was absolutely necessary. The project began with Systems: specifying requirements and deadlines. It also involved Electrical Engineering to design the layout and schematic. Vast amounts of Computer Engineering went into the software and a small amount of Mechanical Engineering into the packaging design. Finally, such non-technical disciplines such as reliability analysis and law went into evaluating the final product and its manufacturability.

(f) Summary of how realistic design constraints were incorporated into the project (where appropriate, include economic, environmental, ethical, health & safety, social, and political constraints as well as considerations related to sustainability and manufacturability)

Besides the obvious fact that this product was merely a prototype, real-world design constraints were taken into account. We analyzed the product from a manufacturing perspective to determine what components we could remove what features we could add, and what costs we could cut. We determined such things as safety; what would we need to do to the project to make sure someone doesn't misuse it and cause injury to person or property. We also analyzed our product to see what impact on society it could cause. Does it infringe on the rights of recording artists to have their music available in the living room from a PC that could have illegal copies on it? These are just some of the constraints we addressed as a group.

Purdue ECE Senior Design Semester Report

Semester / Year	Spring 2003
Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Team Name	Group 7
Advisors	Prof. Meyer and Prof. Talavage
Project Title	OBD-II

Senior Design Students			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Jason Ridenour	CmpE	Hardware/Software interface & debug & Leadership	May 2003
Brian Dunn	EE	Hardware development PCB pop. & debug	May 2003
Brian Todd Thrall	CmpE	Embedded Software Automotive Comm.	December 2003
Namit Prasad	CmpE	Embedded Software	May 2003

Project Description: Provide a brief (one or two page) technical description of the design project, as outlined below:

(a) Summary of the project, including customer, purpose, specifications, and a summary of the approach.

The system is a handheld automotive diagnostic device. The system will be capable of communicating with all automobiles made after 1996 which adhere to the SAE 1979 OBD-II standard for diagnostics communications. The user will interface with the device using a menu system displayed on an LCD which will be navigated using a 16 button keypad. The system will have access to all the diagnostics that SAE 1979 provides for and will provide a method for periodic logging and ultimately dumping diagnostic information from several different diagnostics onto a compact flash memory.

It is meant for car owners, automobile technicians and performance technicians for reading and recording the car sensor data which would eventually save costs and effort in identifying engine problems.

(b) Description of how the project built upon the knowledge and skills acquired in earlier ECE coursework.

The project built upon almost every class we attended here at Purdue. Brian Dunn relied heavily on ECE445 modern filter design in which he learned about building circuits. Jason Ridenour has a great deal of work experience in ECE291, 292, and 393 where he worked for United Technologies Electronic Controls and Thompson Consumer Electronics. While in the class he learned about printed circuit boards and using layout. Also in his time working as a COOP Jason learned about being a leader and how to cultivate a successful engineering team. For the software, Brian Thrall used information such as basic C programming skills learned in ECE264 as well as more advanced data structure skills learned in ECE368. When interfacing with the micro-controller's on-board peripherals Brian utilized his time in ECE362 and even used Dr. Meyer's lectures from time to time. Brian also used his knowledge of micro-processors gained from ECE495A micro-processor design to interface with the microcontroller also. Namit called upon knowledge imparted in EE 264 (Advanced C Programming) and EE 362 (Microprocessor Systems and Interfacing). We all drew upon COM114 in preparation for and in giving our design reviews.

(c) Description of what new technical knowledge and skills, if any, were acquired in doing the project.

Brian Thrall learned how to use the cad tools Layout and Capture. He also acquired his first experiences with a soldering iron. Never before had Brian Thrall relied on an oscilloscope for debugging his software and has become quite proficient. Brian Thrall learned all about Atmel micro-processors and their on-board peripherals. He also spent a great deal of time learning how to read ISO and SAE standards documents which will make future projects easier.

Jason Ridenour: I learned some valuable leadership techniques. I also learned the importance of planning ahead for project deadlines. I learned the difficulties of trying to keep several people working productively at the same time. I was already familiar with hardware layout and PCB population, but my skills definitely improved by working on this project. I learned how to use a C-based programming suite to program a microcontroller. I also learned how to debug a circuit and its software while it is in its operational phase.

Brian Dunn: Although my main contributions were on the hardware side of things, I learned the most when working with software development. Coming into this class I had taken only an introductory course in C, which had been long since forgotten. I am now confident I could develop firmware in a C environment for embedded systems design. This is something I value greatly, as it's a useful skill to have, but something I did not develop until this course.

Namit Prasad: I learned how to use design tools like ORCAD capture/Layout for a design process. In-depth knowledge of a new standard (OBD-II), interfacing a microcontroller with real life peripherals like LCD & Keypad and most importantly the value of team-work are some of the major things I have learned in this class.

(d) Description of how the engineering design process was incorporated into the project.

Virtually all aspects of the engineering design process were incorporated into this project. Beginning with product conception and definition, we saw how any project begins. The product development cycle began with circuit design and prototyping, schematic capture, and PCB layout. Following these elements were board population and debugging along with a second rev to the PCB and then firmware development. Finally, an appropriate packaging scheme and creating a user's manual capped off the development cycle. The only aspect left untouched would be the troubleshooting and revisions after years of use in the real world.

(e) Description of the multidisciplinary nature of the project.

There were many areas of expertise that were utilized in bringing the QuickScanner to fruition. From the obvious technical standpoint; circuit design required knowledge of discrete components and how they interface with other parts of the system. Furthermore, a strong background in programming was required for the development of firmware. A less apparent facet to this design project was the managerial and professional aspects more formally stressed through the 'professional component' design homeworks. These included a patent liability analysis, ethical and environmental concerns, and reliability calculations.

(f) Summary of how realistic design constraints were incorporated into the project (where appropriate, include economic, environmental, ethical, health & safety, social, and political constraints as well as considerations related to sustainability and manufacturability)

Our design constraints were feasibly realistic, but not corporately realistic. If our design was to go into production, the LCD we chose would not be used because it is far too expensive. Environmentally, our design constraints were realistic because if the product went to market we would incorporate certain caveats so that the end user couldn't ignore their check engine light forever or change their fuel to air ratio. Ethically and safety speaking, the final design would certainly require many little yellow flags warning the user not to use the device while driving and not to ignore the EPA standards.

Purdue ECE Senior Design Semester Report

Semester / Year	Spring 2003
Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Team Name	Group 8
Advisors	Prof. Meyer and Prof. Talavage
Project Title	Shadow

Senior Design Students			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Mark Harris	CmpE	Hardware	May 2003
Samir Chopra	CmpE	Software, Hardware	May 2003
Azhar Salim	CmpE	Software	May 2003
Vamsi Vytla	CmpE	Software	May 2003

Project Description: Provide a brief (one or two page) technical description of the design project, as outlined below:

(a) Summary of the project, including customer, purpose, specifications, and a summary of the approach.

The goal of this design project was to create a vision guided robot that follows a brightly colored ball. The resulting product was Shadow. Shadow locates the ball and then attempts to keep it in its field of vision. In addition, Shadow tries to maintain a set distance from the ball by advancing and retreating as necessary.

Shadow is primarily intended to be a toy for children. Amusement is its only true purpose. However, due to its high level of technology and capabilities, it can be altered for other purposes. For instance, it could be modified to respond to voice commands to locate and retrieve a specific object. In this way, it could be used to assist injured and disabled persons.

Shadow consists mainly of a camera, microcontroller, IR range sensor, and control servos. The camera is used to locate the ball. The microcontroller uses the information provided by the camera to adjust the location of the head and the position of the robot body to keep the ball in the field of vision. The IR range sensor is used to determine the distance to the ball and controls when Shadow should move forward or backward.

(b) Description of how the project built upon the knowledge and skills acquired in earlier ECE coursework.

Skills learned in prior ECE classes were very important to this project. Basic circuit analysis skills were obtained in ECE 201 and 202, which allowed us to design and troubleshoot our schematic and board. ECE 255 provided a background in diodes and other semiconductor devices. More importantly, advanced C programming was learned in ECE 264. All of the programming for this project was done in C. ECE 270 provided the basics of digital systems. This included topics such as pull-up resistors and logic states. Finally, ECE 362 was extremely instrumental in this project. It gave us exposure to programming and using a microcontroller. PWM's and ATD's were first learned in 362 and were used extensively in this project.

(c) Description of what new technical knowledge and skills, if any, were acquired in doing the project.

We feel that we have acquired the following technical skills over the semester long project:

1. We learned and implemented I2C protocol, though we did not use it in the final design.
2. We learned how to interface a microprocessor with several devices and get the entire design to function harmoniously.
3. We learned to design a Printed Circuit Board and the rationale for placing various electronic chips and headers on it and by routing the wires on the board.
4. We learned how to simplify our software to fit the constraints of hardware.
5. For many of us it was a first experience with soldering.
6. It was an interesting introduction to Robot Design, as we were successfully able to design and implement a Robot.
7. We learned how servos worked and we also were able to transform them to motors for running our wheels.
8. We learned a rationale for selecting various parts for the design, especially in choosing a micro-controller or a camera or servos or an IR sensor that exactly fit the design criteria.
9. Overall, we learned how to design and implement a full scale project.

(d) Description of how the engineering design process was incorporated into the project.

The design process certainly played an important role helping us pace our project well over the course of the semester. The time given to us to pick the necessary parts for the design helped us do a rational analysis of what we needed and what we did not. The idea of top-down specification helped us to layout our success criteria well and helped us set our goals for the later parts of the semester.

Using the idea of bottom-up implementation we prototyped various parts of the design individually and then we went on interfacing them with each other. This helped us a lot in debugging.

The initial assignments on packaging gave us a rough idea regarding what the final product would look like. This gave us a goal for designing the look of the final product.

(e) Description of the multidisciplinary nature of the project

Our design included knowledge and applications from many disciplines. Digital design was the largest design discipline used. There was also some design work involving physics, law, and ethics. The chassis of the robot demanded that the center of gravity must be low, and towards the front of the robot. This was a design constraint that we had to think about when designing the packaging. Also we had to make sure our design did not infringe on other products that already had patents. Finally we had to make sure that our project can be marketed as a safe product.

(f) Summary of how realistic design constraints were incorporated into the project (where appropriate, include economic, environmental, ethical, health & safety, social, and political constraints as well as considerations related to sustainability and manufacturability)

Our biggest design constraint was the use of batteries to power our robot. In all of the design work we have done in the past, we never had to consider power as a constraint. Since Shadow used three servos, there is quite a bit of power usage, and power conservation is needed. One example of how we tried to limit power consumption is when we removed unnecessary components of our final product. The circuit board inside shadow does not have a MAX202 chip because it is unnecessary. By removing the chip we are able to save a few milliamps of current. Another idea we tried, but did not implement, was to use very small resistors (on the order of a few ohms) to limit the amount of current drawn from the batteries. For example, we measured the CMUcam to have a resistance of about 40 ohms. Since 6 volts will need to be dropped across the CMUcam, and the source voltage is none volts, we could in theory add a resistor to drop the extra three volts and ease the work of the voltage regulator. We tried this but found that the CMUcam became unreliable and the amount of current we were saving did not outweigh the risk we were taking.

Safety measures were also taken into account. We recognized choking hazards, and mentioned them in the user manual. We also analyzed how Shadow would effect the environment. We mentioned noise pollution and danger of contact with the lead solder.

Purdue ECE Senior Design Semester Report

Semester / Year	Spring 2003
Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Team Name	Group 9
Advisors	Prof. Meyer and Prof. Talavage
Project Title	Speedy Gonzales

Senior Design Students			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Pedro De Keratry	CmpE	Computer Engineering	May 2003
Michael Maletich	CmpE	Computer Engineering	May 2003
Kevin Morlock	CmpE	Computer Engineering	May 2003
Erick Sunarto	CmpE	Computer Engineering	May 2003

Project Description: Provide a brief (one or two page) technical description of the design project, as outlined below:

(a) Summary of the project, including customer, purpose, specifications, and a summary of the approach.

The project is a learning tool for young programmers. User will program the mouse via a GUI to move through a maze (forward, left, right). Then download the program to the mouse. The mouse will follow the users program, keeping track of its position by measuring stripes in the maze. If the mouse does not reach the end of the maze by following the user's program, the mouse will hit a push button and drive back to the start to be reprogrammed.

(b) Description of how the project built upon the knowledge and skills acquired in earlier ECE coursework.

1. Linear Circuits
2. Logic
3. Programming
4. Fundamental semiconductor concepts

(c) Description of what new technical knowledge and skills, if any, were acquired in doing the project.

- Team work – reliable and helpful team members are the recipe of success
- New electronics components such as microcontrollers, infrared sensors, switching power supplies
- Robotic control system
- Firmware development
- Practical applications of microcontroller

(d) Description of how the engineering design process was incorporated into the project.

We followed a top down method of designing the project. We implemented a basic block diagram for the project along with constraints to be met. After prototyping each of the major components we made a schematic and layout of the design. The final stage was debugging of the project.

(e) Description of the multidisciplinary nature of the project.

Aesthetic knowledge was needed in the creation of the GUI and the mouse packaging. Basic mechanical skills were needed in the creation of the maze. Soldering skills were required in creating the board as well. General circuit knowledge was needed in the linking of components, headers, and miscellaneous components.

(f) Summary of how realistic design constraints were incorporated into the project (where appropriate, include economic, environmental, ethical, health & safety, social, and political constraints as well as considerations related to sustainability and manufacturability)

Our main priority was to make the robot and maze portable. This meant making the mouse small and the maze collapsible. The mouse needed to be reasonably reliable so that users would be learning about programming and not how to upkeep the robot. To make the robot accessible to large amounts of people it needed to be cheep and vacant of unusual components.

Purdue ECE Senior Design Semester Report

Semester / Year	Spring 2003
Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Team Name	Group 10
Advisors	Prof. Meyer and Prof. Talavage
Project Title	RF Model Train Kit

Senior Design Students			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Bill Nagel	CmpE	3D graphics, communications	May 2003
Dave Lukach	CmpE	Microchip programming, debugging	May 2003
Shahid Manzur	CmpE	RF, communications protocol	May 2003
Josh Allen	EE	Sensors, interfacing	May 2003

Project Description: Provide a brief (one or two page) technical description of the design project, as outlined below:

(a) Summary of the project, including customer, purpose, specifications, and a summary of the approach.

Our project was to design a model train system using RF communications. Our product is unique by providing a bi-directional communications system and a graphical interface to control the trains. Our trains are also capable of collision detection and taking appropriate measures to avoid such collisions. A checkpoint calibration system was added to provide accurate location feedback to the graphical display. We took existing HO scale model trains and adding a PCB with microcontroller interfaced to RF transmitters as well as the train motor and collisions and location sensors. Our product was designed with model train enthusiasts in mind.

(b) Description of how the project built upon the knowledge and skills acquired in earlier ECE coursework.

The use of microcontroller programming and interfacing learned from EE362 as well as use of our C programming skills were widely used in this project. General circuit design skills were utilized as learned in the general EE200 level classes. Debugging was a major aspect which we used and was learned every step of the way especially in EE495. We ran into interference from EM emissions of the DC motor in our signal wires, which was taught in our EE311 class. Basic networking and data transmission skills were used, as well as CRC implementations.

(c) Description of what new technical knowledge and skills, if any, were acquired in doing the project.

Several things were learned in the process of the project, such as schematic captures and layout using Orcad. IR detection, usage and interfacing to a microcontroller. We learned that a simple UART can be used for transmitting data over RF. We also became familiar with basic soldering techniques. Hands-on debugging experience with real circuits (not just programs or specifically designed labs) was also useful.

(d) Description of how the engineering design process was incorporated into the project.

The engineering design process was important in all steps of the project. First, we had to design a project and come up with realistic goals. Next, we had to identify what kinds of modifications were necessary to the train without destroying it. Then we acquired the appropriate parts and tested them separately, before designing a circuit board and finally soldering it together.

(e) Description of the multidisciplinary nature of the project.

The project included both Computer Engineers and an Electrical Engineer, but it was mainly an ECE project. Some mechanical engineering was required to come up with ways to meet space requirements, but for the most part, the project consisted of designing a circuit board, interfacing hardware to a microcontroller, and programming that microcontroller and a host computer.

(f) Summary of how realistic design constraints were incorporated into the project (where appropriate, include economic, environmental, ethical, health & safety, social, and political constraints as well as considerations related to sustainability and manufacturability)

Our main constraint involved working with the very rigid size requirements of the existing model trains. There was only a small amount of space inside the casing, and all the parts needed for our functionality had to share this area. Circuit board design was especially tricky, as we had to minimize excess board space and sand down the sides just to fit it inside. Also, we tried to use as short and small of wires as possible for other connections. Another constraint we had came from the fact that we were only running the train off the 12 volt DC track, so all components needing a different source voltage had to be run through regulators.

Purdue ECE Senior Design Semester Report

Semester / Year	Spring 2003
Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Team Name	Group 11
Advisors	Prof. Meyer and Prof. Talavage
Project Title	Weather Satellite Demodulator

Senior Design Students

Name	Major	Area(s) of Expertise Utilized in Project	Expected Graduation Date
David Alan Schick	EE	RF Design, Circuit Design, Layout Design, Software, Circuit Troubleshooting	May 2003
David Lloyd Selke	EE	Circuit Design, Constraint Analysis, Circuit Construction	May 2003
Aaron Keith Massey	CmpE	Software Design, Web Page	May 2003
Nicholas Anderson	EE	Layout Design, Circuit Construction, Circuit Troubleshooting	May 2003

Project Description: Provide a brief (one or two page) technical description of the design project, as outlined below:

(a) Summary of the project, including customer, purpose, specifications, and a summary of the approach.

The project designed is a weather satellite demodulator system. The customer is any interested party who wishes to see an image from a weather satellite. The purpose of this project is to create a weather satellite demodulator that is able to display the images from weather satellites. The specification of the project is that the project must be capable of displaying data from a weather satellite. The approach used was to design a schematic of the circuit, design a layout from that schematic, fabricate the layout, solder the components onto the board, and to test the final circuit.

(b) Description of how the project built upon the knowledge and skills acquired in earlier ECE coursework.

The project built upon knowledge and skills acquired in earlier ECE coursework primarily through two channels. The first was the knowledge of signals and systems, and communications systems which I learned in EE 301, EE 302, and EE 440, along with the knowledge of filters I acquired in ECE 445. These helped me in the design of the front-end. The other channel was the digital skills, which I learned through ECE 362 and ECE 364.

(c) Description of what new technical knowledge and skills, if any, were acquired in doing the project.

The new technical skills that I learned for this project include the use of Orcad in circuit design and layout, the process required for transferring a design from an Orcad layout to a physical implementation, and the skills gained in more deeply understanding the issues surrounding the RF implementation of a receiver.

(d) Description of how the engineering design process was incorporated into the project.

The engineering design process was incorporated into the project in the manner in which we set about designing the system. The first step was the design of the system and the discovery of which specifications that had to be met. The second step was the design of components that meet those specifications. The third step was the integration of these components to each other.

(e) Description of the multidisciplinary nature of the project.

The multidisciplinary nature of the project was evident in the skills learned to realize a circuit layout. Once the layout was completed in Orcad, it had to be constructed by the company Advanced Circuits. Once the layout was constructed, the components had to be soldered on, and this required the surface mount soldering lab of the EET department. Professor Blackwell did an excellent job of teaching us how to solder and assemble the components of the circuit. Professor Chappell enlightened us on different aspects of implementing the antenna that we finally choose to implement, and told us about design considerations with it.

(f) Summary of how realistic design constraints were incorporated into the project (where appropriate, include economic, environmental, ethical, health & safety, social, and political constraints as well as considerations related to sustainability and manufacturability)

Realistic design constraints were included in the project in the area of antenna design. The antennas are collapsible, so that they are able to be more feasible for portability, and they are capped at the ends for safety. The project design worksheets describe packaging that the project will be packaged in which allows for the safety of the user.

Environmentally, our project has little impact, except for the many toxic materials from which the circuits are constructed. The consequences of using such materials is a well known problem for the electronics industry, and new technology and techniques may be able to solve these problems soon.

The manufacturability of these boards is excellent due to the circuit manufacturers available on the web which will be used for any further production.

Purdue ECE Senior Design Semester Report

Semester / Year	Spring 2003
Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Team Name	Group 12
Advisors	Prof. Meyer and Prof. Talavage
Project Title	Bluetalk

Senior Design Students			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
David Anderson	ECE	Hardware Design	May 2003
Nikhil Bhogal	ECE	Software – Web Development	Fall 2003
Hoi Ho Chan	ECE	Bluetooth Software	May 2003
Ade Sun-Basorun	ECE	Software	Fall 2003

Project Description: Provide a brief (one or two page) technical description of the design project, as outlined below:

(a) Summary of the project, including customer, purpose, specifications, and a summary of the approach.

The goal of the Bluetalk project was develop a pair of devices, respectively referred to as the master and slave, utilizing bluetooth transceivers that could transmit and receive and analog audio signal from a portable audio device (CD, MP3, or MD player). In essence the idea behind the Bluetalk system was to prove the concept of a wireless, distributed audio system. The master device is the only static element of the whole system. It provides the ability to tie the Bluetalk system into a home theater or automotive audio network via wired RCA audio output jacks.

The purpose of the project was to utilize the mobility and portability that a bluetooth wireless network can provide. Bluetooth has a major advantage in that its transmission is respectively secure. Device communication must be authenticated with a pass-key and transmission and acceptance of each individual and unique bluetooth address. Major advantages for utilization of Bluetooth technology were discovered using the bluetooth specification located on the Bluetooth Sig website.

In an ever increasing wireless world customers are clamoring for way to make things even more “wire free.” A demand to have audio products become wireless was a major motivating factor behind the design of the Blue talk system. Additionally, the automotive industry is always seeking to make systems that are more easily customized and tailored to customer’s demands. The Bluetalk system could be come the standard base system that enables unlimited customization.

The Bluetalk system is based upon Ericsson’s ROK 100 007 Bluetooth transceiver chipset. In essence the system was built around establishing a Bluetooth connection. Each microcontroller was selected to interface to the ROK based upon required data rates.

(b) Description of how the project built upon the knowledge and skills acquired in earlier ECE coursework.

Senior design, ECE477, has greatly utilized the material learned in classes studied earlier in the ECE curriculum. First, senior design draws on all the basic material covered in ECE270. For example, skills such as reading and interpreting a data sheet, using a digital oscilloscope, and creating basic logical elements with discrete parts were invaluable skills to have for our project. Following the basic topics covered in ECE270, ECE362 was also tremendously useful. In ECE362 we examined timing diagrams, and how to understand gate and port delays. The ability to set a logic analyzer up to watch logic levels was crucial to debugging the CODEC in our project. Lastly, ECE255 with its basic instruction in amplifier and transistor circuits was incredible helpful.

(c) Description of what new technical knowledge and skills, if any, were acquired in doing the project.

The new skills that we have learned are centered on the development of Bluetooth interfaces. We now understand many of the variables and issues (e.g. timing, power, etc.) related to the implementation of a Bluetooth chipset. Additionally, many skills related to board design have also been developed. Primarily, we have discovered the need to correlate a bill of materials with the correct footprints of the parts.

(d) Description of how the engineering design process was incorporated into the project.

The project fundamentally demonstrates the engineering design process by providing the ability to walk a design from concept, to experimentation, to design, to implementation, to manufacturing, and finally testing and product delivery. In the beginning of our project the task of creating an idea and establishing a series of success criterion was the first step. Then we discovered how to implement those criterions by finding parts that could fulfill the requirements. We prototyped the ideas, and then froze the design when were satisfied with its performance. At the midterm, we presented our ideas and work to a peer review group, taking feedback to improve our design. We made modifications to the design based upon the feedback, and then froze our design for the final time with the creation of the PCB. Once PCBs were obtained we populated parts and began to test our design. The final step was the presentation of the completed product.

(e) Description of the multidisciplinary nature of the project.

In the project the ability to perform a variety of multi disciplinary tasks was crucial. Additionally, the ability to see the project from a variety of perspectives also served to foster the project. Understanding the impact that the design could have, and understanding our end application with the customer in mind were the greatest use of our multi disciplinary backgrounds. One skill, which was utilized the most, was our ability for public speaking. Internally we held design meetings where each person would have to present their ideas. Externally, we gave design reviews where each person would have to present the project. Project presentation also draws on our verbal communication skills as well as our graphical design skills for visual aids.

(f) Summary of how realistic design constraints were incorporated into the project (where appropriate, include economic, environmental, ethical, health & safety, social, and political constraints as well as considerations related to sustainability and manufacturability)

General background research was performed to asses the environmental impact that our device could cause. It was determined that processes minimizing toxic contamination would be used for the both construction and population of our PCB. At the end of the product's lifetime a reclamation and recycling program will retrieve and process the discarded products. This effort will minimize the waste and potential pollution that our devices could cause.

With regard to health and safety, our product operates at a very low voltage. Really there is no danger of electrical shock. The most important consideration that would need to be accounted would occur if our device was implemented in a vehicle. The cognitive load of operating our device while driving would need to be assessed. Most likely we will need to implement methods of locking out system functionality while the vehicle is in motion.

Appendix B:

Proposed Application Form

ECE 477 Application/Information Form

Name: ____

Student ID: __ __ __ - __ __ - __ __ __

Semester you plan to take ECE 477: ________________

Expected Graduation Date: ________________

Taking ECE 477 to fulfill ECE Senior Design Requirement? __ yes __ no

Degree Program: __ BSEE __ BSCmpE

Participant in Co-Op Program?

__ yes - company: ____

__ no

Areas of expertise (check all that apply):

__ programming

__ software engineering tools

__ digital hardware design

__ computer networking

__ digital signal processing

__ communications

__ analog hardware design

__ control systems

__ fields and optics

__ biomedical

__ other: _____________________________________

Continued on reverse side…

Do you wish to self-select your teammates or be assigned to a team?

__ self-select

__ be assigned to a team

If you wish to self-select your teammates, list the names of the individuals with whom you would like to work (who are also planning to take ECE 477 the same semester as you):

____

____

____

Do you have a project idea in mind, or would you prefer to have a project assigned to you?

__ have the following project in mind (be as specific as possible):

____

____

____

__ would prefer to have a project assigned to me

List the other courses (including those outside ECE) you plan to take concurrently with ECE 477:

ECE: ___________________ Non-ECE: ___________________

___________________ ___________________

___________________ ___________________

___________________ ___________________

List any other known constraints on your time (e.g., employment):

____

____

____

Appendix C:

Proposed Evaluation Form

ECE Senior Design Course/Instructor/Lab/TA Evaluation

Directions: Circle the response that best represents your assessment of each criterion.

Major (SA = CmpE, A = EE, U = other)	SA A U D SD
Hours/week outside class (SA = 1-2, A = 3-4, U = 5-6, D = 7-9, SD = 10 or more)	SA A U D SD
Your current GPA (SA=3.50-4.00, A=3.00-3.49, U=2.50-2.99, D=2.00-2.49, SD=<1.99)	SA A U D SD
COURSE (SA=excellent, A=good, U=average, D=marginal, SD=poor)	
Significance of design experience	SA A U D SD
Specification and clarity of design project requirements	SA A U D SD
Relevance of design experience to your personal career goals and objectives	SA A U D SD
Relevance of lecture topics to course objectives and outcomes	SA A U D SD
Quality and clarity of course documents	SA A U D SD
Clarity of grading standards and methodology	SA A U D SD
Usefulness of feedback provided on graded materials and peer evaluations	SA A U D SD
Effectiveness of homework assignments in pacing the design project	SA A U D SD
Clarity and awareness of course outcomes	SA A U D SD
Course outcome assessment procedures	SA A U D SD
INSTRUCTOR (SA=excellent, A=good, U=average, D=marginal, SD=poor)	
Qualifications of instructor	SA A U D SD
Effort put forth by instructor	SA A U D SD
Instructional techniques used in classroom presentations	SA A U D SD
Effectiveness in answering questions	SA A U D SD
Rapport with students	SA A U D SD
Availability during scheduled office hours	SA A U D SD
Dedication of instructor to helping students learn and grow as professionals	SA A U D SD
LAB (SA=excellent, A=good, U=average, D=marginal, SD=poor)	
Quality of lab facility (space, room, furnishings)	SA A U D SD
Availability of lab facility	SA A U D SD
Quality of lab equipment	SA A U D SD
Maintenance of lab equipment	SA A U D SD
Adequacy of lab space and equipment for current enrollment	SA A U D SD
Overall, I would rate this lab as:	SA A U D SD
T.A. (SA=excellent, A=good, U=average, D=marginal, SD=poor)	
Qualifications of T.A.	SA A U D SD
Effort put forth by T.A.	SA A U D SD
Quality of assistance provided	SA A U D SD
Rapport with students	SA A U D SD
Availability during scheduled office hours	SA A U D SD
Overall, I would rate this T.A. as:	SA A U D SD

UNIVERSITY CORE:

Overall, I would rate this instructor as: ___ Excellent ___ Good ___ Fair ___ Poor ___ Very Poor

Overall, I would rate this course as: ___ Excellent ___ Good ___ Fair ___ Poor ___ Very Poor

Appendix D:

ECE Course Assessment Report

ECE Course Assessment Report

Course: ECE 477 **Submitted by:** D. G . Meyer
Term: Spring 2003 **Course PIC:** D. G. Meyer

1. *Were all course outcomes addressed during the administration of the course? If not, why not and what actions do you recommend to remedy this problem in future offerings of this* course?

The following outcomes must be demonstrated to receive a passing grade in ECE 477:
(i) an ability to apply knowledge obtained in earlier coursework and to obtain new knowledge necessary to design, build, and test a microcontroller-based digital system
(ii) an understanding of the engineering design process
(iii) an ability to function on a multidisciplinary team
(iv) an awareness of professional and ethical responsibility
(v) an ability to communicate effectively, in both oral and written form

All of these outcomes were addressed and, as indicated below, all students enrolled during the Spring 2003 offering of ECE 477 successfully demonstrated each outcome.

```
Average Outcome Scores and Outcome Demonstration Statistics for ECE 477 - Spring 2003

Outcome # 1 Avg Score:   85.5%    Passed:  48/ 48 = 100.00%    Failed:   0/ 48 =   0.00%
Outcome # 2 Avg Score:   72.0%    Passed:  48/ 48 = 100.00%    Failed:   0/ 48 =   0.00%
Outcome # 3 Avg Score:   93.3%    Passed:  48/ 48 = 100.00%    Failed:   0/ 48 =   0.00%
Outcome # 4 Avg Score:   82.1%    Passed:  48/ 48 = 100.00%    Failed:   0/ 48 =   0.00%
Outcome # 5 Avg Score:   85.7%    Passed:  48/ 48 = 100.00%    Failed:   0/ 48 =   0.00%

Demonstrated all five outcomes based on primary assessment:  48/ 48 = 100.00%
```

2. *Are the course outcomes appropriate?* Yes.

3. *Are the students adequately prepared for this course and are the course prerequisites and co-requisites appropriate? If not, explain.*

For the most part, they are adequately prepared – provided they *actually remember* the prerequisite material covered in ECE 270 and ECE 362. I find that I still have to review certain material that is now covered in ECE 270 (there are still a few students in the pipeline that had 266/267 instead).

4. *Do you have any suggestions for improving this course? If so, explain.*

Enrollment of 48, with the newly formulated quantitative evaluation component, has stretched the course staff and lab facilities to the limit. Yet, only about half of the students who would like to take the course are able to enroll. It is frustrating that students not fully motivated to contribute to a rigorous senior design project are able to enroll, while other more highly motivated students are not. It would be helpful to “filter” students based on their motivation/desire to learn.