Senior Design Report
for
ECE 477 – Spring 2011

submitted by
Prof. David G. Meyer

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School of Electrical & Computer Engineering

Contents

Course Description

Digital Systems Senior Design Project (ECE 477) is 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, telecommunications, intelligent devices, etc.). The primary objective is to provide practical experience developing integrated hardware and software for embedded microcontroller systems in an environment that models one which students will most likely encounter in industry.

One of the unique features of this course 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.

Course web site: https://engineering.purdue.edu/ece477

Course Staff

Name	*Title / Role*	*E-mail Address*
Prof. David Meyer	Faculty / Project Advisor	meyer@purdue.edu
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Lecture Schedule / Course Calendar

Monday	Tuesday	Wednesday	Thursday	Friday
Jan 10	Jan 11 Course Introduction 1:30-2:20 EE 117	Jan 12 Module 1 Doc/Prop/TC 11:30-1:20 GRIS 280	Jan 13 Module 2 Digital Design 1:30-2:20 EE 117	Jan 14 Preliminary Proposal Due
Jan 17 MLK Day	Jan 18 Module 3 Packaging 1:30-2:20 EE 117	Jan 19 **TCSP** PSSCs 11:30-1:20 GRIS 280	Jan 20 Module 4 uC survey 1:30-2:20 EE 117	Jan 21 Final Proposal Due
Jan 24	Jan 25 Module 5 Emb Sys I/F 1:30-2:20 EE 117	Jan 26 Module 6 Pow Sup Des 11:30-1:20 GRIS 280	Jan 27 Module 6 Pow Sup Desl 1:30-2:20 EE 117	Jan 28
Jan 31	Feb 1 Module 7 Pass Cmp Sel 1:30-2:20 EE 117	Feb 2 **TCSP** Constr Anal 11:30-1:20 GRIS 280	Feb 3 Module 8 Doc Stnds 1:30-2:20 EE 117	Feb 4 Design Constraint Analysis Due
Feb 7	Feb 8 Module 9 PCB Design 1:30-2:20 EE 117	Feb 9 **TCSP** Packaging 11:30-1:20 GRIS 280	Feb 10 Module 10 Assem/Solder 1:30-2:20 EE 117	Feb 11 Packaging Design Due
Feb 14 Lab Notebook Evaluation	Feb 15 Module 11 Debugging 1:30-2:20 EE 117	Feb 16 **TCSP** Schematic 11:30-1:20 GRIS 280	Feb 17 Prep for Design Revs 1:30-2:20 EE 117	Feb 18 Preliminary Schematic and Design Narrative Due
Feb 21	Feb 22	Feb 23 **TCSP** PCB Design 11:30-1:20 GRIS 280	Feb 24	Feb 25 Preliminary PCB Layout and Design Narrative Due
Feb 28	Mar 1 Formal Design Reviews	Mar 2 Formal Design Reviews	Mar 3 Formal Design Reviews	Mar 4

Monday	Tuesday	Wednesday	Thursday	Friday
Mar 7	Mar 8 Module 12 Software Des 1:30-2:20 EE 117	Mar 9 Progress Briefings 11:30-1:20 EE 063	Mar 10	Mar 11 **Proof-of-Parts** **Final Schematic** **Final PCB Due**
Mar 14 Spring Break	Mar 15 Spring Break	Mar 16 Spring Break	Mar 17 Spring Break	Mar 18 Spring Break
Mar 21 Midterm Peer Evaluation Due	Mar 22 Module 13 Patent Liab 1:30-2:20 EE 117	Mar 23 **TCSP** Software 11:30-1:20 GRIS 280	Mar 24 Module 13 Patent Liab 1:30-2:20 EE 117	Mar 25 Software Design Narrative Due
Mar 28 Lab Notebook Evaluation	Mar 29 Module 14 Rel/Safe Anal 1:30-2:20 EE 117	Mar 30 **TCSP** Patent Liability 11:30-1:20 GRIS 280	Mar 31 Module 14 Rel/Safe Anal 1:30-2:20 EE 117	Apr 1 Patent Liability Analysis Due
Apr 4	Apr 5 Module 15 Eth/Env Imp 1:30-2:20 EE 117	Apr 6 **TCSP** Reli & Safety 11:30-1:20 GRIS 280	Apr 7 Module 15 Eth/Env Imp 1:30-2:20 EE 117	Apr 8 Reliability and Safety Analysis Due
Apr 11	Apr 12 Prep for Final Presentations 1:30-2:20 EE 117	Apr 13 **TCSP** Eth/Env Imp 11:30-1:20 GRIS 280	Apr 14	Apr 15 Ethical and Enviro Impact Analysis Due
Apr 18	Apr 19 Exam Review 1:30-2:20 EE 117	Apr 20 Desgn & Prof Attrib Exam 11:30-1:20 GRIS 280	Apr 21	Apr 22 User Manual Due
Apr 25	Apr 26 Progress Briefings 1:30-2:20 EE 063	Apr 27 **TCSP** **PSSC Demos** 11:30-1:20 GRIS 280	Apr 28	Apr 29 ECE 270/362 Bonus Credit Presentations (by invitation)

Formal Design Reviews will be individually scheduled on March 1, 2, and 3 Final Presentation Session will be on May 4, 8:00 AM – 12:00 PM in EE 170

Final Lab Notebook Evaluation, Confidential Peer Review, User Manual, Final Report, Poster, and Senior Design Report submitted on-line by **5:00 PM May 2**

Design Project Specifications / Requirements

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:

- **Microcontroller:** To help make the project tractable, recommended microcontroller choices include Freescale, PIC, 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. Optionally, auxiliary processing can be accomplished using a "motherboard". Examples of these directly supported are Intel Atom and ARM-based platforms.
- **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 printed circuit board will be created. Board etching will be processed by the ECE Department (the first one is "free", but any subsequent iterations are the team's responsibility). 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 two team members:** 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 surface mount components.
- **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 and software.

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 **five significant** *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.

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 website will be archived on the course website.

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.

Design Project 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.* With proper budgeting, senior design can be a very rewarding and pleasant experience.

See course schedule for homework due dates.

Week	*Milestone*
1	Formulate project ideas Preliminary project proposal due
2	Research parts, create initial block diagram and initial BOM Final project proposal due
3	Order/sample parts, review/learn OrCad *Capture* and *Layout*
4	Create detailed BOM (including resistors, capacitors, etc.)
5	Draw preliminary schematic Prototype interface circuits
6	Finalize schematic Begin PCB layout Begin prototyping software with EVB/prototype
7	Finalize PCB layout for Design Review Continue software development Prepare for Design Review
8	Continue software development **DESIGN REVIEWS**
9	Incorporate changes/comments from Design Review **Proof-of-Parts due** **Final schematic due** **PCB file submission due**
10	Continue software development on EVB
11	PCBs arrive - begin populating/testing
11-15	Test PCB section-by-section as parts are added, porting software as you go - *add functions one-by-one so you know what it was that "broke" your code or your board when things stop working*
16	**PSSC Demos** Prepare for Final Presentation
Finals	**FINAL PRESENTATIONS**

Course Outcomes and Assessment Procedures

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
(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

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
(iii)	Success Criteria Satisfaction (general *and* project-specific)
(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 of **60%** will be required to establish basic competency. Demonstration of Outcome (iii) will be based on satisfaction of the **100%** of the general success criteria and a minimum of **60%** (3 out of 5) of the project-specific success criteria (PSSC). Note: If a "motherboard" is used, at least 2 of the 3 "passing PSSC" must involve functions implemented on the custom PCB. 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.

Since *senior design* is essentially a "mastery" style course, students who fail to satisfy all outcomes but who are otherwise passing (based on their NWP) will be given a grade of "I" (incomplete). The grade of "I" may subsequently be improved upon successful satisfaction of all outcome deficiencies. If outcome deficiencies are not satisfied by the prescribed deadline, the grade of "I" will revert to a grade of "F".

Course Grade Determination

Several “homeworks” will be assigned related to key stages of the design project. Some of the assignments will be completed as a team (1, 2, 7, 13, 15, 16, 17), two will be completed individually (8 and 14), and some will be completed by a selected team member (one from the set {4, 5, 6, 9} and one from the set {3, 10, 11, 12}).

1. Team Building and Project Idea
2. Project Proposal
3. Design Constraint Analysis and Component Selection Rationale
4. Packaging Specifications and Design
5. Hardware Design Narrative/Preliminary Schematic
6. PCB Design Narrative/Preliminary PCB Layout
7. PCB Submission, Final Schematic, and Parts Acquisition/Fit
8. Peer Review – Midterm
9. Software Design Narrative, and Documentation
10. Patent Liability Analysis
11. Reliability and Safety Analysis
12. Ethical/Environmental Impact Analysis
13. User Manual
14. Peer Review – Final
15. Senior Design Report
16. Final Report & Archive CD
17. Poster

Grade Determination: Your course grade will be based on team effort and your contributions:

TEAM COMPONENTS (40% of total) distribution of team component:		**INDIVIDUAL COMPONENTS (60% of tot.) distribution of individual component**	
Project Success Criteria Satisfaction*	20%	Laboratory Design Notebook*	20%
Design Review*	15%	Design Component Report*	15%
Final Presentation*	15%	Professional Component Report*	15%
Final Report*	15%	Significance of Individual Contribution	15%
Final PCB, Schematic, and Parts Fit	10%	Design and Professional Attribute Exam	15%
System Integration and Packaging	10%	Class Participation / Clicker Exercises	10%
User Manual	5%	Peer Evaluations of Presentations (2)	5%
Senior Design Report	5%	Confidential Peer Reviews (2)	5%
Poster	5%	* items directly related to outcome assessment	

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 must be demonstrated in order to receive a passing grade for the course.

Course Assessment Report

Course: ECE 477 **Submitted by:** D. G . Meyer
Term: Spring 2011 **Course PIC:** D. G. Meyer

1. **Did all students who received a passing grade demonstrate achievement of each course outcome? If not, why not and what actions do you recommend to remedy this problem in future offerings of this course? (Attach additional sheets as necessary)**

   Yes

   a. **How many course outcomes are there for this course?** 5

   b. **On a scale from 0 – 4 (0=not at all, 1=marginal, 2=adequate, 3=good, 4=very good), please rate, on average, the overall degree to which the students in this course achieved each of the course outcomes.**

Outcome 1	4	Outcome 5	4	Outcome 9		Outcome 13	
Outcome 2	4	Outcome 6		Outcome 10		Outcome 14	
Outcome 3	4	Outcome 7		Outcome 11		Outcome 15	
Outcome 4	4	Outcome 8		Outcome 12		Outcome 16	

2. **Are the course outcomes appropriate? If not, explain. (Attach additional sheets as necessary)**

   Yes – they are the standard "senior design" outcomes

3. **Are the students adequately prepared for this course and are the course prerequisites and corequisites appropriate? If not, explain. (Attach additional sheets as necessary)**

   Yes

4. **Do you have any suggestions for improving this course? If so, explain. (Attach additional sheets as necessary)** Tweaks in lecture content (additional material on interfacing, embedded software development, new references for ethical and environmental lifecycle considerations), additional equipment for lab, larger quantities of standard supplies, purchase of a professional software package for maintenance of electronic lab notebooks – e.g. LabTrack (still looking for funds).

Appendix A:

Senior Design Reports

Purdue ECE Senior Design Semester Report

Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Semester / Year	Spring 2011
Advisors	Prof. Meyer and Dr. Johnson
Team Number	1
Project Title	GHUD

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Ryan McLean	CmpE	Software Development	May 2011
Joe Perrin	CmpE	HW Skills / Micro Devel	May 2011
John-Michael Mulesa	CmpE	Linux Expertise	May 2011
Zach Schoenberger	CmpE	Micro Development	May 2011

Project Description: Provide a brief (2-3 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 GHUD project aimed to be a general-purpose vehicle heads up display that projected speed, elevation, acceleration, compass, and position information directly onto a user's windshield so that the information would be available in a distraction-free location.

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

We gained useful skills from ECE 270 and ECE 362. We used careful parts placement, how to read datasheets, how to set up and use a power supply, and using an oscilloscope from ECE 270. We used various skills related to microcontrollers such as programming and debugging, peripheral usage, and external device control from ECE 362.

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

We gained better insight into the design process of developing a viable printed circuit board. We also learned some new soldering skills as well as properly packaging the device. Finally we learned some valuable new troubleshooting/debugging techniques for both the microcontroller and for an embedded linux platform.

(d) Description of how the engineering design process was incorporated into the project. Reference must be made to the following fundamental steps of the design process: establishment of objectives and criteria, analysis, synthesis, construction, testing, and evaluation.

In our initial planning of the GHUD project, we discussed what the initial functionality of the project was to be. It included the ability to display information directly on a windshield and show speed, elevation, compass, and acceleration data. We then analyzed what parts would be necessary to achieve the device's functionality. Once we had a solid parts list we then started creating a block diagram for the overall device and a schematic and a PCB layout for the microcontroller board.

(e) Summary of how realistic design constraints were incorporated into the project (consideration of most of the following is required: economic, environmental, ethical, health & safety, social, political, sustainability, and manufacturability constraints).

Economic: The GHUD is a relatively economical device, either on its own or produced on a large scale. Thanks to being sourced from common parts, once the microcontroller PCB is produced, the rest of the items that make up the GHUD are relatively low cost due to their commercial nature. The ARM board came out of a Seagate Dockstar and the projector is easily available online. This allows for a relatively low cost device even when not produced on a large scale.

Environmental: We aimed to make the GHUD as environmentally friendly as possible, within our project constraints. As a result, the only environmental issue the GHUD may cause is if it is not disposed of properly. The microcontroller PCB uses leaded solder since the soldering job was done by hand and the projector uses a lithium ion battery, both of which will have a negative environmental impact unless disposed of properly. Everything else meets environmental standards.

Ethical: The largest ethical challenge of the GHUD is the potential for giving the driver inaccurate information due to device malfunction or failure to obtain satellite signal. In order to remedy this, if we brought the GHUD to market there would be a disclaimer screen to not rely on the GHUD as one's only means of navigation.

Health & Safety: The two main safety issues associated with the GHUD are the fact we use a laser projector, which if the light is not properly diffused, can cause a distraction to the driver or other drivers. We would remedy this issue by including a piece of transparent plastic designed to filter a certain color such as green to make the GHUD more visible and less distracting. The second issue is if the GHUD slides off the dash and hits someone. To remedy this we attached a weighted stand to the GHUD to keep it securely on the dash.

Sustainability: The GHUD is a very sustainable device. Once it is produced commercially we can switch to lead-free solder. We also may be able to directly wire the projector's battery leads to a regulated 5v power supply so that we can eliminate all batteries from the device entirely. As long as the GHUD is properly recycled at the end of its life, it will be a very sustainable and environmentally friendly device, granted electronics manufacturing stays a viable operation.

Manufacturability: The majority of the parts used in the construction of the GHUD are available for purchase by the consumer. The PCB is the only part not publicly available to the consumer and would require mass production. The parts that could cause a halt in production are the GSM unit and the pico laser projector. Both of these parts are expensive and hard to find in large quantities. The pico laser projector would have to be specially ordered in mass quantities, as would the GSM unit.

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

The GHUD project utilized multiples areas of expertise in order to complete the design. In addition to typical ECE knowledge, we had to use new knowledge to solder various components onto our PCB and to construct our package to fit our various components.

(g) Description of project deliverables and their final status.

The GHUD package was completed with all components in the package and full functionality was demonstrated at various points. The final result was a bit hard to see on the windshield due to no color filter on the glass, but it still worked as expected. The GHUD updated the compass, accelerometers, speed, and elevation in real-time. We had some issues with the Google Maps functionality, but we did successfully demonstrate that functionality at a preliminary PSSC check off.

Purdue ECE Senior Design Semester Report

Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Semester / Year	Spring 2011
Advisors	Prof. Meyer and Dr. Johnson
Team Number	2
Project Title	HOARD Robotics

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Jay Zifer	CompE	Coding, Debugging	May 2011
Jamis Martin	CompE	Micros, Coding, PBC	May 2011
TJ Andres	EE	Chassis, RF, Batteries	December 2011
Brad Newark	EE	Schematics, Coding	May 2011

Project Description: Provide a brief (2-3 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 HOARD (Horde Of Autonomous Robotic Devices) is to develop a team of eight robots that work together to accomplish tasks. Each robot is equipped with an array of six IR LEDs and corresponding IR sensors for both object avoidance and proximity detection to other robots. They are fitted with an RF module to enable wireless commands to be sent from a main controller as well as communication between the robots. They also utilize two ambient light sensors, which simulate chemical detection. The chemical detection mode causes the robots to spread out and seek a chemical spill, which is simulated by a concentrated bright light. When one robot finds the “chemical spill”, it then assists the other robots to navigate towards it. This mode is practical for commercial use, such as detecting chemical spills in a factory, or for military use. The second function is predator avoidance, which is demonstrated in a “Humans vs. Zombies” mode. Initially, one human is infected with a virus to turn it into a zombie. The humans then avoid the zombies, but are transformed into one when caught. This mode is useful for predator vs. prey studies as well as entertainment purposes. We approached this project with a “divide and conquer” mentality. Large, complicated tasks are split up among simple robots that can cover a lot more area and work together to accomplish tasks.

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

This project draws heavily on knowledge and skills we have learned in our ECE coursework. On the basic level, we utilized skills from all the circuit design and analysis classes for all the analog components. Our skills in microcontroller interfacing came directly from ECE 362 and were used almost constantly. Our robots were coded in embedded C, which we had experience with from ECE 362, but the knowledge of algorithms and the C language came from ECE 264 and ECE 368. In order to communicate between robots, with used an RF module. This required knowledge of serial communications, something we experienced in ECE 337.

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

Over the course of the semester, there are a number of new skills we had to develop for the sake of our project. None of us had any experience with wireless communications prior to this project, so it was necessary to do a lot of research and experimentation in order to understand both the process of how to send and receive packets, and how to design our own protocol. We had had little experience with PCB layouts, and spent a substantial amount of time both learning the software and carefully planning how to best layout our PCB. There was also a lot of battery management needed for this project that we had little prior knowledge of. Finally, the fact that we built eight robots introduced a lot of mechanical design challenges we had not previously faced with chassis design and working with motors.

(d) Description of how the engineering design process was incorporated into the project. Reference must be made to the following fundamental steps of the design process: establishment of objectives and criteria, analysis, synthesis, construction, testing, and evaluation.

Before the semester even began, our group had been meeting to talk about what we wanted our project to be. The ideas drifted from a single robot with object recognition, to a team of robots. From there, we eagerly began to set objectives for what we wanted our robots to be able to do. We came up with a number of different programs, but settled that there were two base functions that they should exhibit, a collective search, and collective avoidance. From there, we examine what functionality the robots would need in order to accomplish these behaviors. We would need to be able to communicate relative distance, as well as information about the particular robot's status. It was determined that IR and RF synchronization would accomplish this well. The robots needed to be very agile and able to turn in place, so a two wheel approach was decided on. All parts of the robot were prototyped before committing to a design so that all testing was done before PCBs were sent out. This also enabled us to create "heartbeat" programs for fast assembly and initial software to be developed before the final product came in. Two final robots were then analyzed and specific components evaluated before building the remaining robots.

(e) Summary of how realistic design constraints were incorporated into the project (consideration of most of the following is required: economic, environmental, ethical, health & safety, social, political, sustainability, and manufacturability constraints).

Economic: Most of the functionality of the robots is accomplished through the software. This allowed for the robots to be individually simple and cost effective. This is especially important because the functionality of HOARD robotics requires multiple robots, so the overall cost has been kept to a minimum.

Environmental: With multiple robots needed for this project, environmental concerns were taken into account not only for disposal, but also manufacturing. A simple aluminum chassis was designed for fast manufacturing and ease of dismantling so it could be recycled after project termination. Rechargeable NiMH batteries, which are better for the environment than other rechargeable options, were used to cut down on the number of batteries thrown away. Software was also written with energy conservation in mind so that the robots could run as long as possible before having to charge again.

Ethical: Since one of the functions of the robots is to find a chemical spill, if they malfunction and do not detect hazardous chemicals then people could get hurt. To ensure proper function, every possible corner case we could think of was tested and addressed in the software to get bugs out. If we are sending out a project that customers are relying on for safety, then we needed to make sure it works in every scenario.

Health & Safety: HOARD robots are very small and have little potential of causing harm to a user. Each robot is equipped with bright indication LEDs so that no one will accidentally step on them. The battery has a three pin connector so that it cannot be plugged in backwards and is placed on the bottom of the robot to protect the components and the user if there are any complications. They are also designed to be remotely controlled so that they can replace humans in hazardous situations.

Sustainability: The robots were built to last with time tested components and circuitry that does not strain them to the limits. Also, if one robot is destroyed it has little effect on the project goal. The horde was designed to be resilient towards adding and removing robots.

Manufacturability: Manufacturing of the robots was designed as a simple process. Once the PCBs are manufactured, all that needs to be done is screw it onto the chassis, attach the motors and battery, and plug in the RF module.

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

This project incorporates aspects of electrical engineering, computer engineering, and even some mechanical engineering. The coding of the behaviors and the wireless communications interfacing are both computer engineering skills. Our PCB layout as well as the careful selection of parts and the design of our control unit involve electrical engineering skills. The crafting of the chaises and the movement system were derived from mechanical engineering.

(g) Description of project deliverables and their final status.

We are delivering eight robots, each complete with an RF communication module, IR LEDs and IR sensors and ambient light sensors. Each robot's mobility is accomplished by means of two motors on the rear sides and a ball castor to balance on the front. The robots each have three dip switches to assign roles in certain programs, a programming header, indication LEDs, as well as a power switch. We are also delivering a handheld control module with an LCD screen and control buttons. The control module is used to send commands wirelessly to the robots such as start/stop and changing modes. The robots have achieved all intended functionality, including the ability to avoid obstacles autonomously, the ability to utilize swarm behavior to find a simulated chemical spill, and the ability to utilize swarm behavior to avoid predators.

Purdue ECE Senior Design Semester Report

Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Semester / Year	Spring 2011
Advisors	Prof. Meyer and Dr. Johnson
Team Number	3
Project Title	Autonomous Targeting Vehicle

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Daniel Barrett	CompE	Software/Power Systems	May 2011
Sebastian Hening	CompE	Hardware	May 2011
Sandunmalee Abeyratne	CompE	Hardware (PCB)	May 2011
Anthony Myers	CompE	Embedded Software	May 2011

Project Description: Provide a brief (2-3 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 Autonomous Targeting Vehicle is designed to autonomously navigate to designated GPS waypoints and to visually locate and follow targets. Our motivation for creating the ATV was to allow the user to remotely track objects for surveillance purposes. The ATV uses two microcontrollers to interface with sensors and to control its speed and direction of the robot and of the camera turret. The on-board Intel Atom processor parses GPS and sensor data to accurately determine location of the robot and of detected obstacles. It then dynamically finds a path around the obstacles to a designated waypoint. The Atom also processes images from the webcam to facilitate visually tracking a target. Integrating an Atom processor allowed us to create a hands-free, user-friendly interface through a wireless network to facilitate the operation of the device.

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

Several aspects of our project relied on information that was obtained through work in previous courses. Knowledge of basic circuit design was heavily utilized in the creating the custom fabricated PCB. From ECE 270, we utilized binary and decimal to hexadecimal conversions, gate level logic ICs for the battery charging circuitry, and two's complement notation for reading negative values from the compass module. From ECE 362, we used two Freescale MC9S12C32 microcontrollers. On these microcontrollers, we utilized the PWM, ATD, SCI, TIM, and RTI modules. The programs were written in Embedded C, and were implemented using a hybrid of interrupt-driven and flag-driven operation. We also implemented our own custom handshaking routines for communicating with the compass module. Several datasheets were analyzed to determine timing characteristics, voltage/current specifications, etc. Along with the digital logic, we used our knowledge gained from ECE 255 to integrate transistors and diodes into our project for use with the battery charging circuit and the h-bridge. Experience with programming graphical user interfaces in ECE 364 was used for the display and control GUI. ECE 368 provided a background in algorithms and data structures which facilitated the creation of the obstacle mapping and path-finding systems.

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

Throughout of the course of the project, we acquired knowledge of writing code for complex embedded systems. This included the use of several timer functions for controlling the precise movements for the robot's wheels, along with coordinating events between reading values from sensors and sending the appropriate data when necessary. We also gained the knowledge for creating a custom PCB, which includes the specifications for trace widths, pad sizes, producing gerber files, creating multi-layer boards, and layout design issues to reduce noise in the circuit. Learning to use the PADS program for creating the PCB involved drawing detailed schematics, custom creation and placing of components, and manually laying out traces between components while taking care to reduce noise. While populating the PCB, we learned techniques for soldering surface-mount package. In the process of creating the software, we learned about a number of advanced algorithms, such as using a Kalman filter to perform sensor fusion and state estimation.

(d) Description of how the engineering design process was incorporated into the project. Reference must be made to the following fundamental steps of the design process: establishment of objectives and criteria, analysis, synthesis, construction, testing, and evaluation.

At project conception, we established five goals for the completion of our project, which included the ability to interpret GPS data, control the robot's motors for movement, visually follow a target via webcam, and interpret sensor data for various purposes. To tackle these issues, we analyzed the available parts that would suit our needs, and began integrating them to design a fully functional system. We obtained several range finders for determining the presence of objects, a compass for determining orientation, and a GPS for determining location. Using an Atom board for path finding algorithms and image processing, we integrated the system as a communication network between the two microcontrollers and the Atom board using the PCB. We constructed the PCB to include sockets for the two microcontrollers, an h-bridge circuitry system, and a battery charging system. We built a 3-shelf tiered package to allow for sufficient air to circulate around the heat sensitive electronics and for easy access to components. When the PCB arrived, we populated one subsystem at a time, verifying the proper functionality of each before adding new components. For verifying functionality of the system as a whole, we tested the code to ensure the proper functioning of all peripherals, which include the range finders, compass, GPS, and communication routines between the Atom board and microcontrollers. Modifications were made as necessary to make the robot function as we had intended it to. We were able to demonstrate all five goals that were established for the project.

(e) Summary of how realistic design constraints were incorporated into the project (consideration of <u>most</u> of the following is required: economic, environmental, ethical, health & safety, social, political, sustainability, and manufacturability constraints).

Economic: The goal was to keep the cost of the ATV under $800. The final cost came to just under $750, which was below the project budget. Because this is more of a specialty item for those interested in surveillance or for use by industries, the $750 cost is not considered especially high.

Environmental: The ATV contains components consisting of harmful chemicals. The PCB is especially environmentally unfriendly because both fabrication and disposal of it can release hazardous materials such as copper and lead into the environment. The NiMH battery, though usually environmentally friendly, could be considered hazardous as ten NiMH batteries are used in our device; thus, the battery pack requires proper disposal at a secure landfill. Most of our larger components such as the chassis body, tires, and camera can be recycled for use in new products.

Ethical: The ATV contains video capabilities which can be used maliciously to spy on innocent persons. Anybody with WiFi capabilities could gain access into our product and manipulate it to navigate into restricted areas if the login password were stolen or cracked.

Health & Safety: The ATV is quite bulky and heavy, which might damage another person, object, or itself if the software or sensors malfunction. The open-packaging leaves many wires exposed, causing potential harm if proper care is not taken when handling the device. Also, the open packaging prohibits the operation of the device under wet conditions. Coming into contact with water will damage the device and render it inoperable.

Social: The ATV can interact with targets using its webcam. This feature can be socially friendly if used to intentionally interact with the user; for instance, following the user. It can also be a non-social feature if used for spying or surveillance purposes.

Sustainability: Based on very conservative calculations, the MTTF of the ATV robot is 27.4 years. Because the microcontroller is the component most likely to fail, it was mounted on the PCB using a 40-pin Dip Socket, which makes replacing it very easy. The range sensors, motors, GPS, and compass can also be replaced very easily as they are connected with headers to the PCB. This design enables for easy and cost-effective maintenance of the robot.

Manufacturability: the manufacturability of the ATV can be significantly improved in several ways. The PCB can be designed using more surface mount components and smaller footprints. The Atom could be replaced with an application specific processing chip that is specifically designed to processes images, GPS data, and compute path-finding algorithms. Reducing the size the ATV will allow a closed-packaging design, as well as an easier assembly and integration process.

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

The construction of the PCB required knowledge from the field of Electrical Engineering. The other aspects of the project, which include coding the microcontrollers with Embedded C and coding the Atom board with C++, required extensive programming and algorithm knowledge from the field of Computer Engineering. As a team of four Computer Engineers, we relied heavily on knowledge from ECE 201 to complete the PCB fabrication process, and relied on our coding backgrounds from the Computer Engineering curriculum to complete the software aspects of the project. We also used knowledge of basic physics and mathematics in the creation of a kinematic model of the system for use by the Kalman filter.

(g) Description of project deliverables and their final status.

At the completion of the semester, we have successfully created a fully functional robot that satisfies all the criteria we established for the project. The robot is fully capable of (1) Determining its current location within 10 meters based on GPS data, (2) controlling the speed and direction of the motors in order to turn left, turn right, move backward, and move forward, (3) visually tracking and following a target via webcam, (4) detecting obstacles using several range finders and avoiding collisions, (5) determining changes of position using wheel encoders and a compass. The finished product is also capable of working wirelessly over WiFi to achieve all of the five goals stated above. The product includes a user-friendly GUI for controlling the actions of the robot. We were also able to successfully demonstrate autonomous obstacle mapping and path-finding, which were beyond the requirements set out at the start.

Purdue ECE Senior Design Semester Report

Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Semester / Year	Spring 2011
Advisors	Prof. Meyer and Dr. Johnson
Team Number	4
Project Title	3MS

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Alex Buschkoetter	CompE	PCB Design, Hardware Dev	Dec 2011
Alex Glenn	CompE	Software Architecture	May 2011
Kimberly Soong	EE	Hardware Dev, Power	May 2011
Petra Mustafa	CompE	PCB Design, Packaging	Dec 2011

Project Description: Provide a brief (2-3 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.

3MS is short for Mobile Multi-Person Monitoring System. It is intended as an electronic method for parents and pet-owners to be able to keep track of their children or pet within a certain radius. This radius is adjustable by the parent or pet-owner, and violation of this radius is reported on all devices. 3MS also has peripheral tampering, should the module placed on the child or pet come off due to the wristband being cut or pulled apart.

The proximity detection is executed with Received Signal Strength Indicator (RSSI) on the Zigbee modules. The peripheral wristband tampering is detected with a port pin on the microcontroller that detects when the connection in the wristband severs – that is, when the pin transitions from high to low.

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

ECE201 and ECE255 were applied to a lot of the circuit design, especially when it came to determining component values with voltage drop considerations. ECE264 provided the C skills to program the microcontroller. ECE270 and ECE362 provided the knowledge about embedded and digital systems, including what voltages read as logic high and logic low. ECE437 helped with basic processor structure and enforced what was learned in ECE362.

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

The PIC24FJ microcontroller used was new to the team, so the software and in-circuit debugging had to be familiarized with. Working with the wireless modules was a new experience as well, especially the (RSSI) and audio transmission and sampling over wireless. The PADS software was also very new to the team, and none had any experience making a PCB layout. Some of the CompE members had little to no soldering experience, and learned a lot in that department even if it was only practice.

(d) Description of how the engineering design process was incorporated into the project. Reference must be made to the following fundamental steps of the design process: establishment of objectives and criteria, analysis, synthesis, construction, testing, and evaluation.

The main objective for this project was to have each sub-section of it (proximity sensing, wireless audio transmission and tamper detection) perform a function that has been successfully done on various commercial products. The idea was inspired by a baby monitor and virtual leash technology. Upon analysis of the design, it was believed that it would be completely achievable within the given time constraints and the appropriate parts easily acquired. After the system was worked out on a schematic and the PCB layout finalized, the team was able to connect the three boards (base and two peripherals) and develop the software to control the various functions. The development of the PCB was ongoing from fabrication, and testing helped find problems to fix. The team also spent a lot of time reevaluating some design and component choices.

(e) Summary of how realistic design constraints were incorporated into the project (consideration of <u>most</u> of the following is required: economic, environmental, ethical, health & safety, social, political, sustainability, and manufacturability constraints).

Economic: The cost of production was set relatively low, accounting for shipping and damage costs. Most of the ICs, including the microcontroller, were sampled at little to no cost. This allows an affordable amount of financial contribution per team member.

Environmental: The chemicals used to fabricate the PCBs are hazardous and detrimental to the environment. The batteries used are lithium-ion and environmental concerns associated with them include method of charging (which may draw energy from non-renewable sources) and disposal (non-biodegradable components and heavy metals).

Ethical: The project utilizes proximity sensing, and is intended for parents and pet-owners. This intended consumer group places trust that the product will always be able to track their children and pets, so reliability is of utmost importance.

Health & Safety: The project is neither detrimental to health nor a serious safety risk. The main safety concern would be the possibility of overcharging the lithium-ion batteries, as this can result in dangerous reactions – the batteries are prone to exploding if overcharged, and this is extremely undesirable in a product intended for use with children and pets.

Social: The project could be used as a listening device by unsavory individuals, as it looks like an innocent game console (base control) or a basic display module with speakers (peripherals).

Political: The project does not violate any government laws.

Sustainability: The project does not run on a lot of power, and with the rechargeable batteries, it could last hours. Chip components have low failure rates and will most likely not need to be replaced until the end of the product's lifespan – which could be a few years.

The programming on the microcontroller is stable and reliable to not require any maintenance.

Manufacturability: Both the base control and peripherals' PCB is simple, with only a few ICs including the microcontroller onboard each one. The parts are open and available for purchase from various online vendors. The only suggestion one would have for the peripheral modules would be to decrease the size of them further.

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

The entire project required a substantial knowledge base in electrical and computer engineering. Most of the team members were computer engineers, and the project required a lot more electrical engineering knowledge than computer engineering. The team partitioned the workload according to capability, and the computer engineers were exposed to the electrical engineering side of things – mainly, the schematics and PCB design but also the packaging engineering. Amplifiers, a fair share of hardware debugging and soldering were mostly left to the electrical engineer in the team. There was no area, aside from the PCB design, that the team was not able to cover well and with that, managed to overcome the multidisciplinary nature of the project.

(g) Description of project deliverables and their final status.

The final project deliverables are a base control with D-pad and select button with a graphic display LCD, and two peripheral modules with wristbands. The project is able to detect and display proximity of the peripherals, report proximity violation on all devices, and detect peripheral wristband tampering.

Purdue ECE Senior Design Semester Report

Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Semester / Year	Spring 2011
Advisors	Prof. Meyer and Dr. Johnson
Team Number	5
Project Title	We are Wireless Audio (WaWA)

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Aarthi Balachander	ECE	Hardware, software integration	May 2011
Ryne Rayburn	ECE	Hardware, PCB layout	May 2011
Daniel Jiang	ECE	Hardware, software integration	May 2011
Drew Schuster	ECE	Software	December 2011

Project Description: Provide a brief (2-3 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.

We are Wireless Audio (WaWA) is a wireless audio system designed for people who like to listen to music on a speaker system. WaWA aims to play high-quality audio for the user from his/her portable music device on a speaker system. It gives the user more control over the speaker system with the use of voice recognition commands to increase, decrease, or mute the volume. It is composed of a base station, in which the user can interface his/her portable audio device with. It also contains the voice recognition microphone as well as manual controls for the volume. The OLED on the base station displays the volume. The receiving station has a switch that allows the user to choose if the audio is to be played on internal or external speakers.

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

The introductory courses of ECE 201, 202, and 255 taught us how to design circuits and use power supplies and this knowledge was applied in the design of our PCB. ECE 270 allowed us to become more adept at constructing these circuits physically and reading datasheets to obtain important information. ECE 362 taught us embedded systems programming which was the basis of our senior design project. The mini-project from ECE 362 was a sample of the project for ECE 477. Classes like ECE 264 and ECE 368 sharpened our C programming skills. This was important for our project as the microcontrollers were programmed in C. The skills acquired from all of these classes allowed us to design and implement WaWA.

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

None of the team members had prior experience in designing a printed circuit board (PCB). Our team had to learn how to layout, route, and fabricate a PCB for this project. We also had to choose the correct components and make sure the placements of those components on the PCB prevent unwanted interference amongst each other. After the completion of the PCB, our team had to learn how to assemble the board with soldering techniques. We also acquired hardware debugging skills, as the JTAG for our LPC2377 was not functional for a long time. This problem required extensive work and was finally fixed after reading the LPC2377 errata online. The importance of documentation was learned through the completion of this project. Regarding the software side, our team had to learn how to program a microcontroller in C as we have only had previous experience in assembly.

(d) Description of how the engineering design process was incorporated into the project. Reference must be made to the following fundamental steps of the design process: establishment of objectives and criteria, analysis, synthesis, construction, testing, and evaluation.

The initial idea for WaWA was to be a wireless audio system that responds to “clapping” sounds. The course staff, however, gave a better suggestion of having WaWA respond to voice commands by the user. Based on this concept, our team devised five project specific success criteria to measure the success of our project. We began to search for suitable components for this project. We had some constraints in our design, like finding a microcontroller that uses I2S, which would allow us to interface with audio codecs. We also needed a microcontroller that we could develop code for. The voice recognition component needed an accurate voice recognition chip. After selecting the parts based on these constraints, functionality, cost, and ease of use, we were able to construct a schematic. We then incorporated our schematic into our PCB design. We made sure to separate analog and digital components, check that the parts aren’t interfering amongst each other, and design the PCB so that debugging wasn’t difficult. Once the PCB arrived, we assembled the board methodically, testing each part as it was assembled. This is when we discovered the JTAG header would not allow us to program our microcontroller. After fly-wiring and cutting traces, we realized a new PCB would be needed to fully incorporate all of these changes. We assembled the new PCB like the old PCB, one part at a time. As the hardware was assembled, software was simultaneously being written and debugged using a prototype circuit of the base and remote stations. Once the hardware was fully assembled, we proceeded to integrate the software to our hardware. After correcting a few minor errors, we arrived at our final project, which was then packaged.

(e) Summary of how realistic design constraints were incorporated into the project (consideration of most of the following is required: economic, environmental, ethical, health & safety, social, political, sustainability, and manufacturability constraints).

Economic: WaWA attempted to be an economical project as there are wireless speaker systems on the consumer market for less than a $100. We used as few components as necessary for the full functionality achieved. The cost of our construction of WaWA is approximately $300. This is higher than an average user will pay for a speaker system, even though it has voice command recognition. Mass manufacturing the product will definitely decrease the cost as the voice recognition chip was the most expensive part of our product, but is cheaper when bought in large quantities.

Environmental: The environmental impact from WaWA was attempted to be minimal by making the hardware layout compact and ensuring that the majority of the components used on the PCB are also RoHS compliant. WaWA is a fairly low-power device, which is beneficial to the environment. WaWA also uses an OLED, which is more environmentally friendly than a regular LCD. The packaging used for WaWA can be recycled as well. As a result, the environmental impact from the manufacture and use of WaWA is minimized.

Ethical: An ethical concern regarding WaWA rises from the use of the XBee wireless modules. As audio is being transmitted wirelessly from the base station to the receiving station, an external user could interfere with the integrity of the audio. The external user could even steal the audio being transmitted. Fortunately, a software mechanism can allow only the base station's Xbee and the receiving station's Xbee to only interact with each other. Another ethical concern is the possibility that repetitive exposure to loud audio can damage hearing. A safety mechanism in software only allows the volume to reach a certain level to limit the volume.

Health & Safety: Health and safety of the WaWA design are of critical importance to the product. We analyzed four components of the design: the microcontroller, the speech recognition chip, the audio codec, and the audio amplifier. From the analysis, we learned that the two primary safety concerns for WaWA are overheating and accidental over amplification (occurs if already amplified external speakers are connected to a WaWA system that has failed volume controls). In order to increase the reliability of the design so that these problems become as rare as possible, in future iterations of WaWA, it is recommended that an air-cooling system be implemented to control the temperature. High temperatures are not only a safety concern in itself, but can cause other components to fail, thereby creating the possibility of more safety concerns (such as the over amplification).

Social: With today's fast paced media world, WaWA attempts to be flexible in the way the users can use its features. WaWA first makes the user experience better by allowing the speaker and base station separable. The speaker can be set in place while you move around the base station. This is great for social settings when more than one person wants to control the audio. Another great feature is the voice commands. With today's media, users are constantly multitasking, so being able to control WaWA volume hands-free helps when with others at a social setting. The voice commands also allow you to set the base station in a specific place and still be able to control WaWA from a distance.

Political: WaWA is not expected to have a political impact other than any concerns with patent infringement if the product is to be manufactured.

Sustainability: WaWA is dependent on the success of many components working together such as the OLED, HM2007, microcontrollers, amplifier, Xbee's, etc. If one of the devices fails, it may be difficult to just replace that component, especially as the product is tightly packaged. Depending on the part that is not functioning, the PCB may need to be replaced. If WaWA is to be manufactured, the packaging should be made to allow damaged parts to be replaced easily.

Manufacturability: WaWA would be easy to manufacture. The base station consists of an OLED, four pushbuttons, an audio in jack, a microphone input, and a place for the power cord to come out. The remote station consists of an internal speaker, audio out jack, and a speaker switch. With both stations not having a great deal of components, the manufacturing line would be simple. The manufacturing of the PCBs would be simple as well. Each PCB has a microcontroller, audio codec and headers to control special components specific to the station it will be put in. With all the mechanical and electrical components being physically small and in small quantities, the manufacturing is completely feasible.

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

During the semester long design process; we had to incorporate a wide variety of skills both from within ECE and other disciplines as well. First and foremost, these include hardware design, PCB design, and software interfacing. To accomplish these tasks, we needed to have a deep understanding of electrical engineering concepts (for hardware and PCB design), while also understanding computer science/engineering to successfully implement the software. In order to successfully package our design, our team needed to learn skills not typical of an ECE student, such as drilling and cutting. In addition, from the weekly homework assignments that we completed, we were able to get a glimpse of many other areas that we would otherwise be unfamiliar with—these include environmental impact, safety and reliability, ethics and even patent law.

(g) Description of project deliverables and their final status.

The final project deliverables include a base station, a remote station, and a microphone. The base station provides an audio input jack and a microphone input jack and the remote station provides the audio out jack (in addition, it includes internal speakers). Both stations are packaged with power supplies. Our Project Specific Success Criteria (PSSC) were an ability to encode and decode an audio stream, an ability to control volume by way of user controls on the main station, an ability to interpret audio-based volume regulation commands, an ability to display system status on a LCD, and an ability to play audio from an external media device using a wireless protocol to a remote speaker setup. The status of the project is complete; all of the Project Specific Success Criteria (PSSC's) were completed satisfactorily.

Purdue ECE Senior Design Semester Report

Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Semester / Year	Spring 2011
Advisors	Prof. Meyer and Dr. Johnson
Team Number	6
Project Title	Defender

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Stephen Wolf	EE, Physics	Circuit Design, PCB Layout, Packaging	May 2011
Kirk Iler	EE	Image Processing, Visual Studio C++	May 2011
Fuhe Xu	CmpE	Network Communications, Java, C++, Embedded C	May 2011
Brian Bentz	EE	Analog Circuitry, Hardware Design	May 2011

Project Description: Provide a brief (2-3 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 Defender project consists of a coilgun mounted on a turret featuring target recognition abilities. A Java user interface communicates over an Ethernet connection with an Atom processor, where the image processing occurs. The Atom processor then communicates the results over USB with a microcontroller, which then communicates with the individual circuit devices over Inter-Integrated Circuit protocol. The project was divided into subsystems by implementing two printed circuit boards, one for high voltage, and the other for communication and low voltage components. The software was also divided into the Java user interface, the C++ image processing, the network communication, and the Embedded C microcontroller code. Each subsystem was built with standalone functionality and then integrated piece by piece with the rest of the project.

Defender consists of a manual and automatic mode for varying functional purposes. The system features commands to charge capacitors to a variable voltage up to 400 volts, discharge the capacitors slowly through a high resistance, or generate a large current pulse through a coil to propel a projectile. The user can also manually control the turret rotation in two planes. The automatic mode features camera based target recognition and the ability for the motors to automatically turn towards an object.

While the overall implementation of the device is not the most practical implementation for a real world application, the various skills required to implement the device in this form provide invaluable design experience to the team. The functionality of the project implements knowledge in a wide array of important engineering topics that can be applied to future engineering design. If the product was to be formalized into a commercial product, the customer this device would likely be the military or a government security organization.

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

Kirk was able to expand on his undergraduate research where he learned to use Visual Studio C++ while assisting a professor in creating an experimental course in the area of image processing and mobile robotics (ECE495). As an electrical engineer, he was also able to implement his programming knowledge gained in data structures (ECE368). Brian's high voltage circuit design expanded on his previous experience in analog integrated circuit design (ECE455). Fuhe was able to apply his previous use of Java, specifically in the swing GUI libraries as well as general programming approaches learned throughout the computer engineering curriculum to coordinate the software on all the devices. Stephen utilized his previous knowledge through summer work experience of PCB design, power supply design, experience with PIC micros and I2C. He also utilized previous course and project related knowledge of motors (ECE321), IGBTs, optical isolators, and transformers to successfully develop and implement the overall scheme of the project. All team members built upon their previous circuit design knowledge gained from the ECE core curriculum and also the microcontroller design knowledge gained in ECE362.

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

Topics learned by the team include high voltage power system design, coilgun design, printed circuit board design, soldering techniques, Ethernet packet transfer, USB microcontroller communication, further Microsoft Visual Studio utilization, and numerous methods of debugging the aforementioned. Some useful technical bits of knowledge learned throughout the project include the importance of wiring all reset and shutdown pins, being aware of the configuration hassle associated with choosing to use Visual Studio to integrate a project, knowing not to trust sample codes to be implemented correctly, and learning just how many design flaws can be fixed through flywiring.

(d) Description of how the engineering design process was incorporated into the project. Reference must be made to the following fundamental steps of the design process: establishment of objectives and criteria, analysis, synthesis, construction, testing, and evaluation.

The team established the project conception before the semester started, and then formalized the goals into five project criteria as required by the course. As the schematics were constructed, the project realization was continually updated to better allow the functional requirements to be implemented into the design. Functions of the project were implemented individually where applicable and then integrated piece by piece in order to produce the final system. Throughout this process, various changes in the design were necessary to allow appropriate integration of various functions.

(e) Summary of how realistic design constraints were incorporated into the project (consideration of <u>most</u> of the following is required: economic, environmental, ethical, health & safety, social, political, sustainability, and manufacturability constraints).

Economic: The project was constructed within a price reasonable enough to ensure safety, reliability, and functionality. The cost of production of the prototype was around $1,100, though the cost of commercial production would be around $500. As most similar products on the market are multifunctional devices designed for the military, our product satisfies a niche in the market for a low cost automated defense system.

Environmental: Defender poses several challenging environmental concerns throughout the course of its life-cycle. During the manufacture phase, the printed circuit boards and various integrated circuits must be synthesized. As such, an emphasis was placed on minimizing the areas of the printed circuit boards and the amount of integrated circuit chips. During the disposal phase, many of the parts on Defender can be easily recycled, while others must be properly disposed of. All of these concerns must be addressed to assure minimal environmental impact during Defender's life-cycle. The product was constructed with these constraints in mind in order to minimize environmental impact.

Ethical: Ethical concerns arise from the production of the Defender system. User safety was of major concern when producing this product. The high voltages, moving parts, and high projectile velocities are all able to lead to user injury. In order to protect the user, there are many safety precautions that were implemented to protect against these dangers. Physical warnings placed on the product, audio warnings, and barrel rotation stoppers were implemented in order to make the product safer for the user. If this product were to be commercialized, a background check would be required in order to purchase the Defender system. As the project can be dangerous if used improperly, a user should be both reputable and knowledgeable to be allowed to obtain a product of this nature. The user assumes certain liabilities related to the use of the product.

Health & Safety: User safety was highly considered when constructing this project. Various safety mechanisms were integrated into the system including audio warnings and user interface updates of capacitor voltages. When implemented as a deterrence system, steps must be taken to ensure that the user appropriately implements and utilizes the system in a safe manner.

Social: The project is designed to be a weapon, therefore its distribution and availability would be restricted to individuals or organizations with proper licensing. Precautions must be implemented to ensure that the user will implement the system in a lawful manner. Furthermore, the system itself uses components that are potentially lethal to a careless or untrained user.

Political: As this device is a weapon, it could be utilized by the government to further a political agenda. The political implications of Defender are largely limited to its military applications.

Sustainability: The project is sustainable over the life of the circuit components. As the capacitors are constantly being charged and discharged from high voltages, they will need to be replaced as they age over time.

Manufacturability: Several natural resources are involved in the manufacture of the turret. These natural resources are used to create the base of the turret, the coil, the barrel, and the rotator arm. To create the base of the turret, wide sheets of eighth-inch aluminum are used. The coil is constructed from over 100 feet of 18 gauge magnet wire. An additional amount of brass and aluminum is needed for the barrel and rotator arm. All of these metals are in limited supply, though they are recyclable at the end of the product life cycle.

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

The project expanded largely upon previous coursework in electrical and computer engineering. Each member of the team was able to implement a portion of the project according to his specialization. The team successfully integrated knowledge of high voltage circuit design, electromagnetics, packaging design, image processing, microcontroller design, software user interfacing, communication protocols, and general programming approaches.

(g) Description of project deliverables and their final status.

The project deliverable is a fully functional coilgun system accomplishing the intended tasks of having a computer based user interface for entering commands and displaying system information, charging capacitors to a variable voltage, aiming the projectile with two degrees of freedom, and performing image processing to locate targets. The software network, which consists of a Java user interface connected through Ethernet to a C++ program performing image processing, connected by USB to a microcontroller communicating over I^2C, was fully implemented.

The ability to fire a projectile using electromagnetic force is fully implemented, and the team has no reason to believe that it would be unable to expel a projectile at a high speed. 500 amps were successfully pulsed through a coil during a high voltage test. Due to time and safety constraints, the firing of the projectile was delayed to a later date. As of the time of the writing of this report, the team has not attempted to expel a projectile with the current through the coil.

Purdue ECE Senior Design Semester Report

Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Semester / Year	Spring 2011
Advisors	Prof. Meyer and Dr. Johnson
Team Number	7
Project Title	Digijock Home Security

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Will Granger	CmpE	Software, Hardware, Language	May 2011
Stuart Pulliam	CmpE	Software, Hardware	December 2011
Zach Smith	CmpE	Software, Hardware, Networking	May 2011
Linda Stefanutti	CmpE	Software, Hardware	May 2011

Project Description: Provide a brief (2-3 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 Digijock Home Security (DHS) system provides security for home owners and owners of small businesses. The DHS consists of multiple remote sensor units (RSU) wirelessly relaying updates and alerts to a web server in the Central Monitoring Station (CMS). The RSU's detect threats in the form of motion, noise, and smoke. The RSU's can also measure temperature. This information is displayed on local LCD's on all of the devices and remotely displayed on a website hosted by the CMS. If an alert is detected, not only will all of the devices sound an alarm, but the CMS will also notify the customer in real-time via text messaging, email, and a website. The website allows the user not only real-time but also the ability to control the system remotely.

The RSU's monitor threats using a built-in motion detector, microphone, smoke detector, and a temperature sensor. The information from these devices is handled by a microcontroller whose software is written in Embedded C. Wireless communication between the RSU's and the CMS is handled by the Xbee wireless modules. A peripheral box contains a keypad and an LCD that handles user I/O for the CMS. The peripherals in the peripheral box connect to an Atom board via USB. Windows XP runs in the Atom board and hosts a MySQL database and a web server. The software handling input and output is written in C#. The user can arm the system changing the LED from green to red indicating all threats are being monitored or disarm which just leaves the smoke detector monitoring. When threats are detected, all devices activate their alarm system: the LCD's display threat information and the sirens emit sound. The user can also test the alarm system or change the CMS password. The web server on the CMS handles sending alerts via text messaging and email as well as updating and receiving commands from the website.

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

This project was developed using knowledge from several Electrical and Computer Engineering courses. ECE362 was primarily the most useful class since we utilized the same Freescale microcontroller in our design. We were able to expand upon our knowledge of interfacing with embedded systems by writing the software for the microcontroller in Embedded C. Using this language over pure Assembly allowed us to utilize our skills from ECE264 - Advanced C Programming. Programming in an embedded system was a new frontier for us, but it turned out to be very similar to what we already knew and knowing this will be very useful in the future. Most of our circuit debugging skills from classes such as ECE207 and ECE208 as well as the lab portion of ECE270 were given more practice with this project. Utilization of a wireless network expanded upon knowledge obtained in ECE463 giving us real world experience with packets and protocols. Senior design primarily gave us a reason to pool several skills together and in doing so made us see how everything is connected.

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

The Digijock Home Security system could be described as a “bigger” ECE362 mini-project, but the extra requirements needed to finish the project demanded new technical skills and knowledge. With regards to embedded systems, technical skills such as soldering surface mount components to a PCB board were new to the group. Also vital was using the PADS software in order to design our PCB. The greatest learning curve, however, came with interfacing the embedded system with a more complex system like an Atom board. Only one of our group members had any experience with web servers and databases. We all had to learn how to obtain data from an Xbee wireless module, format it, and place it in a MySQL database, so that it could be displayed on not only a web server but also an LCD.

(d) Description of how the engineering design process was incorporated into the project. Reference must be made to the following fundamental steps of the design process: establishment of objectives and criteria, analysis, synthesis, construction, testing, and evaluation.

Wanting to build something practical that everyone could use was the motivation behind the DHS. When we decided upon a home security system, the next decisions revolved around what this would protect against and how it would alert the customer. A wide variety of features could have been deployed, but our objective was to tackle the most common threats to a small home or business. Through some basic analysis of common home security systems, we decided to monitor motion, noise, smoke, and temperature. Next we figured that the best way to handle a threat would be to sound an alarm and also notify the customer of the threat via email, text messaging, and a website. Once the security situations to detect and the handling was figured out, our biggest task was finding the best and preferably most affordable parts and combining them into the DHS. What resulted was a design for a remote sensor unit controlled by a microcontroller and a central monitoring station controlled by an Atom board which would communicate using Xbee wireless modules. Construction and testing happened simultaneously. We were able to create the circuits on breadboards while the PCB’s were being designed and fabricated. Once construction of the PCB’s was complete, the breadboard circuits were moved to the PCB’s and testing with the PCB circuits began. Once we were able to simulate every kind of threat, and the system handled it appropriately, we considered the project completed.

(e) Summary of how realistic design constraints were incorporated into the project (consideration of most of the following is required: economic, environmental, ethical, health & safety, social, political, sustainability, and manufacturability constraints).

Economic: While also intended to be easy on our own pockets, we wanted the most affordable components in our design. The main reason behind this was that we later found out after the initial inception of our project that there were similar commercial products compared to ours. In order to be competitive, the overall cost of the DHS needed to be less than $200.

Environmental: Alternatives could be used if the DHS ever became a commercial product but since PCB's were being offered for free, we had to use PCB's that contain lead which is harmful to the environment. Our LCD's also contain mercury that is harmful as well. The containers for the devices use ASB plastic which is recyclable, but if not recycled, it will take up landfill space for a long time. We decided that we will have to use these, but we will have proper notifications on how to recycle the product properly in order to limit its impact on the environment.

Ethical: The DHS's main ethical concern is protecting the customer and his personal information. Since a customer will depend on this system for security, it was a top priority to make sure the customer knows how to use the product properly. Protecting the customer's personal information was a huge concern, and for that reason MySQL was chosen since it does encrypt the customer's passwords.

Health & Safety: Health and safety closely related to our ethical concerns. Since the health and safety of our customer is the purpose of this product, it was paramount to make sure the customer knew how to use and maintain the product correctly.

Social: The only social constraint for the product was to allow multiple users monitor be able to monitor the DHS on the website.

Political: Monitoring capabilities were chosen that couldn't potentially violate the fourth amendment of the Bill of Rights since this product was designed for small businesses too.

Sustainability: Packaging was chosen, so that the RSU's and CMS could withstand concussive blows and heat.

Manufacturability: The size of the PCB's for the RSU's was designed not to exceed the maximum 60 square inches. Also cheap and easy to use peripherals connected via headers make manufacturing fairly easy.

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

All aspects of this product fall into the realm of electrical and computer engineering.

(g) Description of project deliverables and their final status.

The project deliverables are two remote sensor units and a central monitoring station. The two remote sensor units are packaged in their plastic covers painted white with appropriate labels. They are able to perform all functions. For the central monitoring station, the user and system interfaces are located within a plastic box with appropriate labels on it. These interfaces allow both the user to interact with the system and the RSU's to communicate with the CMS. The CMS is able to perform all functionality. The website hosted by the CMS is able to perform all functions too; however, we could not obtain a dedicated IP address for it to use. Regardless all members of the Digijock Home Security system are fully functional and in their final packaging.

Purdue ECE Senior Design Semester Report

Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Semester / Year	Spring 2011
Advisors	Prof. Meyer and Dr. Johnson
Team Number	8
Project Title	Recon Robot

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Arjun Bajaj	CmpE	Hardware and software development	May 2011
Aabhas Sharma	CmpE	GPS Systems	May 2011
Abhinav Valluru	EE	Circuit Design and Debug	May 2011
Vinit Bhamburdekar	CmpE	Wireless communications and software development	Dec 2011

Project Description: Provide a brief (2-3 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.

Recon Robot is an unmanned land vehicle intended for military applications. The vehicles is capable of traveling to programmed way points and provide live video feed back to the base station while doing so. It also has the capability to be manually controlled by the user as and when required

Since the vehicle has military applications, the vehicle is small unobtrusive as possible.It is build on chassis which runs on motors with high torque and hence has the capability to handle rough terrains. It is also equipped with ultrasonic and IR sensors which allow it to detect any obstacles and potholes in its way and has the ability to move around them. It has an onboard camera which provides live video feed back to the base station and is also equipped with the capability of being manually controlled by the base station using just a laptop.

The Recon Robot was designed keeping reliability in mind. Since the vehicle is to be used for recon missions, it should be able to have autonomous and manual control providing the user with complete access to dangerous and volatile territory. It should be able to navigate potentially difficult terrain and provide live video feed back to the base station.

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

Recon Robot's design and architecture relied heavily on the principles learnt in ECE 362. Even thought the component selection, PCB design and architecture related characteristics were all learnt over the period of the 477 course, the basic understanding of microcontrollers and embedded system architecture was from 362.

The software for the Recon Robot was developed in Embedded C which requires specific consideration not always present in general purpose system development. Even though 362 was taught in assembly language, the basic concepts and understanding of how registers of a micro work and the relation with clock speeds , all very basis for coding in embedded C.

Other courses like ece 201 and ece 202 also came to great help when electrical circuits were to be designed.

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

The project has taught us the important lesson of planning ahead of time and knowing in the early stages of development what exactly is required in the future. The decision of using a different and more reliable base which has motors on two sides and not front and back so as to have in place turning for the robot when required.

The ability to design a PCB using PADS and the importance of component placement on the circuit board so as to minimize any electrostatic interference between traces and components is another important technical skill that has been acquired during the course of this project. It has provided us with a good knowledge of how electrical circuits work and what possible things can go wrong during the development phase.

The technical skill of soldering different kinds of components on a PCB and also how to disorder them is a skill that all of us have greatly acquired

The importance of component selection is something else that we've learned during this project. Components that have development kits or breakout boards available with them is something that should be considered heavily when deciding which parts to use for a project as they make the development process easier.

(d) Description of how the engineering design process was incorporated into the project. Reference must be made to the following fundamental steps of the design process: establishment of objectives and criteria, analysis, synthesis, construction, testing, and evaluation.

The course structure of ECE 477 has been extremely helpful in applying the engineering process to the development of our project. The homework deadlines that were given to us forced us to work ahead of time and stay on track during the early stages of the project. The homework assignments guided us to keep track for completion of the project by the end of the semester.
The homework assignments given to us during the initial stages helped us it refining our objectives in detail and gave us the ability to constantly evaluate their ability though out the development phase of the project. The feedback from course staff helped us in improving our ideas and approach to construction of the actual vehicle during the synthesis of the project.

As we approached the last few weeks of the semester, the closely approaching deadlines helped us speed up our design process. The final product headed more towards completion as we tested the vehicle for different functionalities and also improved on some features. We were able to get a good evaluation of our earlier design choices and see how they were affecting our final product.

(e) Summary of how realistic design constraints were incorporated into the project (consideration of most of the following is required: economic, environmental, ethical, health & safety, social, political, sustainability, and manufacturability constraints).

Economic: The Recon Robot is a military based project and hence need to be economically feasible. For the military to have many Recon Robot's to be manufactured and deployed in the field , they need to have the least manufacturing cost without comprising on stealth and stability. Our prototype cost about $400 to develop and could be resold in the market for around $ 800. With higher-quality materials used and a better operating system, a single Recon Robot would definitely be within military budget.

Environmental: Since the Recon Robot is battery operated, its environmental impact is minimal since it has no emission of harmful chemicals during operation like a general internal combustion engine would have. However it does contain a NiCd cattery and an outer plastic covering which both require proper disposal methods when the vehicle is disposed of. To reduce the environmental impact of the product, a Lithium Ion battery could be used in a revised version.

Ethical: Recon Robot is a vehicle capable of transmitting live video feed and also has the capability of entering private or restricted territory. These abilities have certain ethical ramifications and if used in a civilian environment, can cause violation of privacy and trespassing.

Health & Safety: Recon Robot's safety issues are to a minimal, and can mainly arise from its battery exploding in cases of unregulated voltage while charging or due to its mechanical drive system where the gears used to rotate the wheels can pose a hazard to fingers or small animals. This is also to a minimal due to the light weight and slow speed of the robot.

Social & Political: Due to Recon Robot's military applications, there is a possibility of a major political and social conflict if it was misused. It could be used to spy in allies, foreign powers and enemies. Can also be used for terrorist activities if it were to be discovered in the wrong hands.

Sustainability: The chassis of the robot has very few moving parts in it, essentially the wheels, gears, motor and the camera. But since it is built for military applications and should be capable of traveling through hazardous terrain during wartimes, it should be able to survive enemy fire which includes bullets and explosions, something that the prototype would not be able to survive.

Manufacturability: Since the Recon Robot is essentially a small vehicle, there are no special parts that are needed to be manufactured for it. It would need a custom designed chassis, but all other parts should be easily available and be within the normal parameters of typical manufacturing processes.

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

The Recon Robot in many ways was a multidisciplinary platform. The PCB and supporting hardware required the integration of concepts from electromagnetic, circuit theory and effective mechanical placement. The packaging and enclosure design was completed with mechanical dynamics in mind. The GPS system uses data from a variety of physical sensors and was implemented in software. The wireless chip uses an adhoc network and hence a good knowledge of TTL sockets and other communication protocols was required. Overall the completion of the project required the developers to extend their minds and use more than the core principles of electrical and computer engineering.

(g) Description of project deliverables and their final status.

The Recon Robot prototype is only partially built and not all functionality has been achieved to accomplish the original goals set out in the beginning of the semester. The autonomous motion of the robot is incomplete as it still unable to navigate to a set of programmed waypoints from its initial position. More work is required to be done on the navigation of the robot.

The robot currently has the ability to have its motion and its camera remotely controlled by a user using a laptop and also detect any obstacles or potholes it faces when it is not in manual mode. It also has the ability to have its battery life monitored on the base station using a laptop.

Purdue ECE Senior Design Semester Report

Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Semester / Year	Spring 2011
Advisors	Prof. Meyer and Dr. Johnson
Team Number	9
Project Title	MRAV

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Vinayak Gokhale	EE	PCB design/Software	May 2011
Nicholas Gentry	EE	Hardware/Control System/Software	May 2011
Vineet Ahuja	EE	Software	May 2011
Oliver Staton	EE	Control System/Software	May 2011

Project Description: Provide a brief (2-3 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 consists of constructing a quad-rotor helicopter and designing the control systems that govern its stability in flight. The quad-rotor (or MRAV – multi rotor autonomous vehicle) has a square central frame that has four arms extending outwards from it, with each arm at an angle of ninety degree to the adjacent arms. The arms exist to support motors that turn propellers. Each arm has one motor attached to it. The arms provide no aerodynamic lift and as such, the MRAV is considered a “rotary wing” aircraft.

Our customers would mainly consist of RC hobbyists. Many RC hobbyists modify existing commercially available products to make their own modified RC aircraft. Since our software is open source, research groups, such as that of Prof. Bouman (Purdue ECE) could also use it.

This projects purpose was to mainly design a stable control algorithm for this type of vehicle. This platform is inherently extremely unstable and designing a stable control system is a challenge.

The stability algorithm was designed using a PID controller at its core. The microcontroller was chosen keeping in mind that the PID controller and the other operating blocks would require a lot of clock cycles and memory. Once the PID algorithm was in place, we designed an algorithm that would let us tune the PID values wirelessly while operating the vehicle. This was very helpful as we could see which values worked the best in real time without having to reprogram the microcontroller every time. This also saved us a lot of time.

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

The microcontroller selection was based on criteria such as memory, clock speed, and peripheral availability. These concepts were taught in ECE 362. The software design, understanding of datasheets and implementation of debugging techniques are all skills acquired from ECE-362. The code was written in C and C++ which were learnt in courses such as VIP, CS-159, etc.

While the PCB design was learnt this semester, the reasoning behind the implementation of the various components was learnt in previous courses such as ECE 201, 202, 255, 270 and 362.

To design the control system, ECE 382 and ECE 483 were critical as they enabled the team to understand PID controllers.

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

The team learned to design and implement a PID controller. PID controllers are very important in control systems and are widely used in the industry. Variables such as temperature, pressure, flow rate, chemical composition and speed are generally controlled using PID controllers. As such, they are a very important class of controllers.

Another important skill learned was the programming language C++. The entire project was implemented in C++. C++ is different from C in that it uses classes and is used widely in the industry. Everything from device drivers to video games involves C++.

(d) Description of how the engineering design process was incorporated into the project. Reference must be made to the following fundamental steps of the design process: establishment of objectives and criteria, analysis, synthesis, construction, testing, and evaluation.

Description of how the engineering design process was incorporated into the project. Reference must be made to the following fundamental steps of the design process: establishment of objectives and criteria, analysis, synthesis, construction, testing, and evaluation.

This project was oriented around the engineering design process, which helped our project to continuously progress throughout the semester. At the beginning of the semester when we were working to establish objectives and criteria we, first evaluated what exactly we wanted to get out of this project. There was talk of making a tri-rotor helicopter but since this would require much more mechanical engineering oriented work, we stuck with the quad-rotor helicopter, which in return is much more electrically and program oriented. Obviously the most ideal result for this project for us would be a flying helicopter. After confirming this, we created PSSCs that revolved around this.

Deep analysis into which components we need for functionality (includes not purchasing something that is more than we need), cost effectiveness, availability, ease of integration with other components, and processing speed (for electrical components). We made several bill of materials until we decided on components that were the best for our specific circumstance.

Synthesis of components was quite difficult because keeping so many things in mind at the same time was difficult. When creating the PCBs, we had to take into account the current size for trace creation, component pins and dimensions for their holes, having the right pins go to the right components, and taking into account the possibility of changes in the future. One of the troubles we had was realizing that the current microcontroller was not the best for our use for two reasons: (1) we were having trouble integrating the I2C peripheral to the microcontroller, and (2) there was no floating point capability on the microcontroller. To account for this we switched hardware. Although it was unfortunate to do this because we lost our ability to use the PCB, this "work-around" is very realistic to what would happen in the real world. We used what knowledge we had and what supplies we could afford and open sourced material there was to get a working prototype for demonstration purposes.

After creating a solid blueprint with our well set objectives, a deep analysis on components and structure, and a detailed consideration to the synthesis of said components, the construction was second nature. The actual construction of the MRAV quad-rotor is actually quite simple: a frame, hardware, and motors. The difficulty in construction came in constructing the software (in other words how to organize all the component communication and PID filter loops so that memory is efficiently used and things occur in a fast enough fashion for proper functionality). Working with material from our control feedback classes, and working hand in hand with a master level aeronautical engineer with experience in control theory, we were able to create a structure that worked. In the end it was a result of pulling together the appropriate resources (students, professors, literature, open source code, open source hardware).

Testing was necessary to perfect the PID values and code for functionality. Observing bode diagrams and nyquist plots we established a base of PID values. Theory is not enough to establish success because variables such as weight differences, external disturbances, and a lack in processing speed, EMI, or wireless interference. Numerous iterations with numerous adjustments took place.

Evaluation of our entire project was one of the biggest sources of learned material. Seeing how much time we spent on the individual responsibilities and how much we should have spent were not always equal in quantity. Planning on exactly what is needed for the project in long term is just as, if not more, important than the short term necessities. Also, the idea of setting deadlines a bit further off than what might initially seem appropriate is a good idea because complications and unforeseen difficulties are a common occurrence. The careful evaluation of this project will make for better engineering processes in the future.

(e) Summary of how realistic design constraints were incorporated into the project (consideration of <u>most</u> of the following is required: economic, environmental, ethical, health & safety, social, political, sustainability, and manufacturability constraints).

Economic: Components were chosen to design a low cost system. However, care was taken to ensure that user safety is not compromised. Competitors' products include the Parrot Drone and DraganFlyer UAVs. While the Parrot Drone is cheaper, it has a much lower payload capacity. Also, its components are mainly plastic while our project uses reinforced aluminum. DraganFlyer's UAVs are much more robust and give better performance but are much more expensive ($8000 - $40000).

Environmental: While most of the components of the MRAV are RoHS compliant, reusable or recyclable, there are certain components that could potentially pose as an environmental hazard. The PCB is not RoHS compliant because it isn't built for lead-free parts; this can be corrected by buying a more expensive PCB and components that can withstand the higher temperatures needed to melt lead-free solder.

The LiPo battery can be safely discarded along with regular trash as long as certain procedures are adhered to. To minimize the environmental impact of the MRAV, several procedures have been implemented to increase its life span. For example, battery monitoring has been added so that the user doesn't spoil the battery by over-discharging it. Warnings have been placed in the battery's user manual so that the user doesn't over-charge the battery either.

Ethical: Since the MRAV is a potentially dangerous project, it will be rigorously tested before it is deemed safe. The user manual will emphasize the need for precaution on the user's behalf by placing warning and caution statements.

The user manual will also convey the importance of adhering to FAA regulations while flying the MRAV so that it doesn't pose a threat to other aircrafts.

Health & Safety: The MRAV can be a hazardous device if misused. To ensure the safety of the user and the vehicle itself, the user must follow the instructions laid out in the user's manual. In handling the MRAV, there are three major sections of safety: being aware of the rotors during operation, connecting all of the wiring in the set-up stage, and adjusting the code for customized stability.

The rotors are made out of carbon sheet and can be very sharp. When any power is applied to the motors, the user must keep all objects away from the moving rotors. Failure to do so will bring severe damage to the object and the vehicle. Maintenance and upkeep of quality rotors is integral to the expected level of safety. Replace any damaged parts immediately (refer to the user's manual).

The user should not attempt to handle the MRAV until (s)he understands the use and underlying connections involved in setting up. Giving power to components in the wrong order can severely damage the hardware. A rule of thumb is to start small and work up in power supply (i.e. start all smaller components first).

The code can be adjusted to update features (mainly the PID filter values of the quad-rotor). The PID values will vary with every quad-rotor (with size, center of mass). When adjusting these values, software simulations should be used if possible. At minimum, PID calculations should be made using feedback system theory.

Social: Socially, the MRAV could prove to be a hazard but as mentioned earlier it will be rigorously tested before it can be put on the market. Also, it will be marketed primarily to the adult population and will come with instructions on how to exercise caution while operating the vehicle.

Political: The only politically oriented criteria of the MRAV project was to NOT infringe on any existing patents. This was done by using as much open source material as possible.

Sustainability: Sustainability was important while designing the MRAV. The vehicle can crash very easily and care had to be taken that the user could not bank the vehicle enough to crash it. Reinforced aluminum was used for the body and the propellers were made of carbon fiber. Also, the batteries used are LiPo batteries that cannot be drained below a certain minimum voltage. LiPos can source a very steady current while dropping voltage. In other words, their performance and rate of discharge does not decrease with voltage. However, they can be damaged if dropped below a certain voltage and that means that a safe upper limit for minimum voltage had to be decided so the user would not drop below that value.

Manufacturability: The potential manufacturability of the MRAV is very high and as such our criteria was based on the hypothetical scenario of realistic manufacturability. The components can be broken down into several major categories: the platform frame, the electronic hardware, the battery, and the motors and rotors. The frame is a simple assembly of four rods and two square discs. The electronic hardware is mostly located in the center of the MRAV platform, except for the ESCs that are attached around the square. This portion of the setup is quite variable and the user can adjust and place to the components relatively freely (the center of mass must stay in the center). The battery must be placed underneath the center (this is the biggest contributor to the center of mass). The trickiest set up is threading the motor wiring (that connects to the ESCs) through the platform rods.

When manufacturing this product, the manufacturer can simply assemble the rods with the motors wiring going through the rods, and include all necessary parts for the purchaser to finish the assembly. This will keep costs at a very low amount because almost all of the costs will go to the physical parts themselves. The most complicated part of this project, the stability algorithm and general working code, is the cheapest most easily distributable part of this project. A hardware debugger will be included to load any updated code onto the hardware during the life of the MRAV. Instructions on how to do this will also be included.

To keep reliability high and costs low, the code will be open sourced and accessible so that the user will always have the most up to date version of the MRAV code. Since the package is a kit that comes in parts, the user has the ability to update and adjust as desired.

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

The MRAV project can be broken down into its mechanical and electrical sections. The way team 09 handled the mechanical portion was to carefully find and purchase a frame and components that fit together very well. The electrical section involved using knowledge from many of Purdue's ECE classes for chip selection, power requirements, using IDE, programming the microcontroller, adjusting to multiple peripherals, and general hardware selection. The main ones include ECE 270, ECE362, ECE382, and ECE 483 (Digital System Design, Microprocessor Design, Analog Feedback Systems, and Digital Feedback Systems respectively).

(g) Description of project deliverables and their final status.

The project deliverables, also referred to as the project specific success criteria, are as follows:

- An ability to independently control motors via PWM
- An ability to receive and interpret control data
- An ability to interpret sensor data and send to external source
- An ability to autonomously stabilize attitude
- An ability to monitor battery level remotely

The first PSSC is to independently control motors via PWM. The ground control station has the ability to view the ratio of current thrust and total possible thrust of each motor. The motors are controlled by this ratio, the PWM is what dictates this ratio to change, and the controller dictates the PWMs to change. The motor has independent controls for roll, pitch, and yaw. This PSSC was successfully demonstrated. The method that proved it was when adjusting roll on the controller, the left and right motors adjusted oppositely, when pitch was adjusted on the controller, the front and back motors adjusted oppositely, when yaw was adjusted on the controller, the front/back motors adjusted oppositely to the left/right.

The second PSSC is to receive and interpret control data. The quad-rotor was placed on a restrainer and the motors were turned to 50% of full thrust. Initially, the quad-rotor was flying in place. This PSSC was successfully demonstrated. The method that proved it was when the roll was adjusted on the controller to go left, the quad-rotor would lean to the left, and when the roll was adjusted on the controller to go right, the quad-rotor would lean to the right.

The third PSSC is to interpret sensor data and send to external source. The ground control station has several instruments to visualize what is occurring on the quad-rotor. One of the instruments imitates the motion of the quad-rotor (motion being roll, pitch, and yaw). Another instrument is a graphical representation of the total roll, pitch, and or yaw deviation from the original point of reference. This PSSC was successfully demonstrated. The method that proved this was to physically hold the quad-rotor by hand and move it about. When moving it around differences were seen on the computer as well. This was able to be done by hand because the motors did not have to be on to prove this portion of the project.

The fourth PSSC is to autonomously stabilize the attitude. There is a stability algorithm on the hardware on the quad-rotor. The hope is to have the quad-rotor naturally stabilize to reference and also to any adjusted location. This PSSC was successfully demonstrated. The method that proved this criterion was simple. The quad-rotor was mounted on the restraint and the motors turned on. Once this was complete, an interference was introduced (i.e. a human pushed one of the rods up). It was observed that the quad-rotor would take into account the interference and return to a stable reference.

The fifth and final PSSC is to monitor battery level remotely. The ground control station has the ability to view the ratio of current battery and total possible battery left. Resistors were used on the hardware to complete the available battery monitor platform on the hardware. This hardware then communicated with the ground station to view the ratio. This PSSC was successfully demonstrated. The method used to prove this was to observe the battery status at various levels of charge and then to compare that with what the intelligent battery charger would read. These measurements were the same.

Purdue ECE Senior Design Semester Report

Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Semester / Year	Spring 2011
Advisors	Prof. Meyer and Dr. Johnson
Team Number	10
Project Title	Freed of Feedback

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Alyssa Welles	EE	Systems Integration	05/2011
David Wilkes	EE	Audio Electronics	05/2011
Cody Farmer	EE	Hardware Applications	05/2011
Julien Neidballa	CompE	Software Development	05/2011

Project Description: Provide a brief (2-3 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, Freed of Feedback, is an automatic audio feedback eliminator. It utilizes a precision measurement microphone to detect the audible result (known as the Larsen effect) and uses automatic notch filtering to eliminate it. FoF is intended to be used as part of a sound engineer's equipment setup to eliminate the need to manually adjust levels and phase to remove acoustic feedback. The device is housed in a 3U rack-mountable enclosure and weighs approximately 20 pounds. FoF utilizes a pair of microcontrollers and codecs for ADC and DAC purposes in addition to the detection and elimination algorithms. All inputs and outputs from the device are impedance matched and balanced XLR connections.

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

FoF relies heavily on accumulated ECE knowledge in order to function. As the device is inherently software based, ECE courses specializing in programming and digital signal processing have given us invaluable knowledge.

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

Mainly two novel skill sets were required for FoF: printed circuit board design and digital filtering knowledge. The majority of team FoF had no prior PCB layout experience and thus were introduced to it for the first time. Thankfully, as knowledge of the process is useful beyond the scope of this project, the time spent learning layout technique was well used. Digital filtering is the key to the elimination algorithm, so knowledge of FIR and IIR filtering was required. Texts on Z-transforms and digital filter transfer functions were utilized extensively to learn how to create novel filtering techniques.

(d) Description of how the engineering design process was incorporated into the project. Reference must be made to the following fundamental steps of the design process: establishment of objectives and criteria, analysis, synthesis, construction, testing, and evaluation.

As FoF was a completely original design, the engineering design process was the basis of the entire project. We established our objectives, the PSSCs, within the first two weeks of the semester. We realized that we would need to have some flexibility in our design constraints, so consultations with professors yielded valuable information in this regard. After outlining our objectives and design criteria, we analyzed the feasibility of what we had intended to create. Several changes including changes to the fundamental aspects of the design were made after simulations showed that our prior assumptions were invalid. These simulations mostly concerned the physics behind audio feedback, so upon gathering further knowledge, we were able to proceed with a proper set of goals in mind. We synthesized our design using a methodical approach.

FoF uses shelf-available parts in conjunction with custom designed components. Notably, we are utilizing purchased professional microphones and preamplifiers, but our balanced interconnects were synthesized by us. Our PCB was also 100% original in design and synthesis, and although two iterations were required, we ended up having few issues. Construction of the device was very simple thanks to the methodical approach outlined above. We used an ATX rack-mountable case and simply installed our components to the walls of the purchased enclosure. The testing and evaluation phases took the longest and were without question the most frustrating of the entire process. Several PCB issues including short circuited traces and components caused many days of setbacks, but perseverance yielded success in the end.

(e) Summary of how realistic design constraints were incorporated into the project (consideration of <u>most</u> of the following is required: economic, environmental, ethical, health & safety, social, political, sustainability, and manufacturability constraints).

Economic: Our design is economically feasible with a single caveat. The methodical approach taken in design and construction meant that numerous purchased components resulted in a higher than ideal cost. Were the unit to be manufactured, these components would be made in-house and thus this concern would be irrelevant.

Environmental: The FoF device poses minimal environmental concerns. With the exception of the PCB, the entire device is designed to be recyclable. All of our connections are either plastic or aluminum. As the enclosure is also 100% aluminum, it was designed to be recycled at the end of its lifecycle. Fabrication of the PCB is the only hazardous part of the unit, but fortunately environmentally sound methods are available (i.e. PCB milling rather than etching).

Ethical: Minimal ethical concerns are associated with the FoF design. The only potential ethical issue would be outputting a signal which would damage existing audio equipment.

Health & Safety: Related to the ethical considerations, the FoF device is very safe to operate and utilize in practice.

Social: We do not feel that this is relevant to our project.

Political: We do not feel that this is relevant to our project.

Sustainability: The FoF unit is relatively sustainable. As it is meant to be manufactured and then recycled, its life cycle is such that it will not end up being an issue. Premature failure of the device would be associated primarily to components on the PCB which are very simple to replace or repair.

Manufacturability: Due to the methodical approach of our product, the manufacturability of FoF is not much of a concern. Existing components are used and simply compiled to make a cohesive unit.

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

While this project is primarily composed from an ECE related perspective, it could be considered multidisciplinary with physics and mechanical engineering knowledge required to be successful. We utilized the physics aspects to understand how the signals actually are created and sustained during feedback synthesis. Mechanical engineering background was required as knowledge of room acoustics plays a fundamental role in the creation and potential presence of audio feedback.

(g) Description of project deliverables and their final status.

The FoF device was completed physically as intended. The rack-mount enclosure has two aluminum plates on its rear held in place with strengthened cyanoacrylate adhesive. These two plates hold all of the terminals, the LCD, the pushbuttons and the switches required to operate the FoF unit. The device is able to take the incoming microphone signal and apply an appropriate filter on the venue's microphone signal line. Put simply, the project functions as intended and is housed as initially intended.

Purdue ECE Senior Design Semester Report

Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Semester / Year	Spring 2011
Advisors	Prof. Meyer and Dr. Johnson
Team Number	11
Project Title	KartSense

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Ankit Saboo	CmpE	Hardware Integration	Spring 2011
Animesh Grover	CmpE	Testing and Packaging	Fall 2011
Nag Varun Chunduru	CmpE	Software Design	Fall 2011
Riley Zimmerman	CmpE	PCB & Hardware Design	Fall 2011

Project Description: Provide a brief (2-3 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.

KartSense is an electronic control and data logging system designed for the HKN Electric Vehicle Grand Prix team. The system was designed to meet the needs and requirements provided by HKN. The system required several peripheral sensors, including temperature, rotational speed, battery health, GPS and driver communication. The system records the data to an SD card on the vehicle, as well as transmitting the data wirelessly to the pit crew. KartSense also provides the ability to adjust the relational behavior between the pedals and the brake/accelerator. This is done through a series of graph coordinates uploaded from the pit crew. KartSense provides real time speed and lap count monitoring for the driver through an LCD display. The pit crew monitors the incoming data and transmits pedal coordinates through connecting the system to a computer's USB port.

Our approach involved breaking the system into four modules, three on the vehicle and one in the pit. We designed a central hub for the vehicle for connecting and controlling all peripherals. This module also housed the wireless communication and SD card logging. It is connected to the two other vehicle modules, the LCD display and the "Kill-Switch" modules. The "Kill-Switch" was designed to relay all analog pedal response signals, as well as provide the ability to "Kill" the adjusted pedal response in the event of system failure. The Pit Module was designed for USB communication between the system and a computer, as well as wireless communication to the vehicle.

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

Each phase of the project utilized different skills acquired from a wide range of classes. While designing the circuitry we used skills from ECE 201 and ECE 202, calculating voltages, resistances and capacitances on the PCB. Designing the PCB also used knowledge from ECE 270 and ECE 362. These classes taught us what we needed to know about using microcontrollers and interfacing them to peripherals. These classes assisted in the software side of the project and programming the assembled system. Our software was primarily coded using C. We benefited from ECE 264 and ECE 368 for advanced knowledge of programming in C. Pervious mini projects in ECE 337 and ECE 362 gave us a taste of large scale designing, as well as working as a team to accomplish a large goal.

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

Designing a product of this scale from the ground up required new levels of research into a large assortment of components for their compatibility and functionality. The designing of the printed circuit board also required new knowledge. We learned proper board layout techniques and how to use the PADS software to create our boards for fabrication. The final product required assembling the board, which included learning to solder components and other construction techniques. For software, the C code included new libraries for our specific devices which we needed to become familiar with. We learned about a wide range of professional topics, such as ethics, patents and safety.

(d) Description of how the engineering design process was incorporated into the project. Reference must be made to the following fundamental steps of the design process: establishment of objectives and criteria, analysis, synthesis, construction, testing, and evaluation.

Our product was designed within the specific requirements of HKN. This did not limit us, but provided guidelines of what we had to accomplish when planning the product. Our early meetings involved discussing the objectives with HKN. The next phase included investigating how best to meet these requirements. For weeks we researched the best components to use before proceeding. The individual components came together in the designing of the PCBs. The fabricated PCBs were carefully assembled and tested. We began by testing and confirming the power circuitry output. We then added and tested other components individually before proceeding. Some areas required debugging, such as the programming of the microcontroller. We reviewed all connections and re-evaluated our design in the processes of finding the errors. Minor fixes were made in the form of "fly-wiring" two connections and switching to a JTAG power source. After testing each part and function individually, we began to evaluate how well the modules worked together. We tested the wireless communication and the data packets, which is the main end result. The LCD screen and Kill Switch were also tested and debugged till they worked properly with the entire system. We are still in the process of evaluating the functionality on the HKN Go-Kart.

(e) Summary of how realistic design constraints were incorporated into the project (consideration of <u>most</u> of the following is required: economic, environmental, ethical, health & safety, social, political, sustainability, and manufacturability constraints).

Economic: The overall cost of the final product totaled around $700.00. This includes components for all four modules as well as their connectors. The cost of the course provided PCBs could add another $100 to the total. Keeping the cost low was not a priority for the design. As this is a highly customized product, mass production would not be an issue. Instead, we focused on using the best parts and highest quality components to ensure a top quality final product. The largest expenses included the wireless boards, microcontrollers, GPS, LCD.

Environmental: The product uses several parts that would require special disposal, such as the LCD and PCBs. There is also a large amount of plastic casing and wiring with the system. We do use rechargeable batteries and USB power to prevent the use of disposable batteries.

Ethical: It is critical that our product perform properly as a driver in a race depends on it. We have an ethical responsibility to ensure our product does not fail and endanger the driver. We made sure to complete the product early to allow time for testing to find potential errors. Safety measures were added to counter uncontrollable failures.

Health & Safety: As discussed above, our product is used in a dangerous environment. We have implemented safety measure to ensure the driver is not put at risk by our product. The key safety feature is the Kill Switch. In the event that the adjusted output to the brakes and accelerator fail, the driver has the ability to switch the output to the original input from the pedals. This will prevent loss of control during system failure.

Social: The product is specifically made for the HKN electric vehicle for the Grand Prix race. Our constraints were based on the situation the product would be used in, a race. This lead to the selection of features.

Political: The system is specifically for a green electric vehicle. It could easily be converted to work with any gas powered Go-Kart or a similar vehicle.

Sustainability: Our product was not designed with long-term use in mind, as it will only be used a few times for testing and the race. However, all components on the system could be used for an extensive time. The batteries are even rechargeable.

Manufacturability: The product is highly specialized to work with the HKN specifications. It could be modified for mass production, however changes would need to be made to ensure it was compatible with a wider range of vehicles. Manufacturing would require special machinery for cutouts and specially trained employees to assemble the parts.

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

All team members are computer engineers. We were required to utilize our entire breadth of ECE knowledge. This included knowledge of more EE concepts such as analog circuitry design and the power system. Computer engineering was used for the software and microcontroller programming. Working with the components provided a bridge between the two, as many require both digital and analog knowledge. We needed to use physical skills for construction of the products, such as soldering parts and tooling of the packaging.

(g) Description of project deliverables and their final status.

The final product included four modules. The main Kart module, the Pit module, the Kill Switch and the LCD display. We were unable to test our system on the HKN Go-Kart for reasons beyond our control, however all systems work as designed off of the Go-Kart. Each of the following peripherals are communicating with the system and having their data recorded: temperature sensors, battery health signal, rotational speed Hall-Effect sensors, GPS location and speed. The data is being written to the mini SD card, as well as being transmitted to the pit. The LCD display is showing the lap count and MPH or RPS. The system is adjusting the output to the brakes and accelerator. The Kill Switch is properly acting as a safety mechanism by restoring the original pedal input to the output when activated. The Pit module is receiving the data and communication with the PC through USB. It is also transmitting coordinates to the kart to adjust the pedal relationship graph.

Purdue ECE Senior Design Semester Report

Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Semester / Year	Spring 2011
Advisors	Prof. Meyer and Dr. Johnson
Team Number	12
Project Title	2D-MPR

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Alex Bridge	CmpE	Drivers, Interfacing	May 2011
Sam Mussmann	CmpE	Algorithms, Interfacing	May 2011
Tyler Neuenschwander	CmpE	User Interface Design	May 2011
James Phillips	EE	Hardware Design	May 2011

Project Description: Provide a brief (2-3 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 2D-MPR is a remotely controlled, partially autonomous sensory platform whose primary purpose is to use optical range-finding to detect and map the walls and other obstacles of a room. The project consists of an iRobot Create mobile robot, a Microsoft Kinect sensor suite, and a custom fabricated printed circuit board based around an NXP LPC1769 microprocessor. Additional peripherals include an xBee wireless transceiver for use transmitting data to and receiving commands from a host PC, a debugging LCD, and an inline Intel Atom netbook to interface with the Kinect over USB 2.0 High Speed and transmit that data to the microcontroller over a UART data stream. The primary purpose of this project is to create a research ready unit for use in academics. However, the application of the technology involved in other fields is not inconceivable. Such other fields may include search and rescue, reconnaissance, and home use. While the prototype implementation of the project uses retail components such as the iRobot Create and the Microsoft Kinect, nothing about the project itself requires such a specific or pre-built implementation. The project only specifies that there be a mobile platform, a range-finding apparatus, a high throughput microcontroller, and the correct software algorithms to translate the range-finding data into a two-dimensional map of the robot's surroundings. Our approach in undertaking this project was to focus as much as possible on the acquisition of range-finding data and the transformation of said data into a map. We then bought pre-made systems to accomplish all ancillary goals (such as moving the robot) that are only tangentially related to the primary goal of the project.

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

The software for this project was built upon the foundation of a handful of computer engineering courses, especially the embedded development involved in ECE 362. Beyond that, many of the simpler algorithms and data structures were inspired by studies in ECE

368. Also, much of the simulation and algorithm development was done using Python simulator, something only achievable because of our Python studies from ECE 364.

For the hardware, much of the knowledge required was again from ECE 362. The microcontroller theory and applications that were taught in ECE 362 allowed us to better select parts, design support circuits, and overall design the hardware around the microcontroller we chose. The general digital hardware design education from ECE 270 also helped with the hardware design of the project, especially in the use of the shift register and other low-level logical electronics.

Beyond the application of ECE coursework, three of our team members are former co-op students. Much of our background and skills are also derived from this on the job experience.

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

The most prominent new skill acquired in doing this project was the ability to design a PCB from end to end. This application seems to be very much underemphasized in the current ECE curriculum, leading to a steep learning curve. We also learned quite a bit about interfacing with peripherals in embedded C, something that was partially covered in ECE 362 and further expounded upon in this project. There were also various algorithms that were either synthesized or learned for various functions of the project. Our entire survey toolchain was a group of algorithms that were borrowed and modified for the specified purpose. Some of those algorithms (such as the error correction/toleration on the survey stitching) were synthesized specifically for this project, with no specific underlying algorithm in mind.

(d) Description of how the engineering design process was incorporated into the project. Reference must be made to the following fundamental steps of the design process: establishment of objectives and criteria, analysis, synthesis, construction, testing, and evaluation.

The engineering design process was most obviously used to satisfy the criterion that we needed a mobile system. This criterion was part of our initial design constraints for the projects, and we then analyzed the problem to find the best solution. Our needs included the ability to have a zero turn radius or the ability to simulate a zero turn radius through software, and the ability to interface simply with the drive motors. Due to the nature of our project, the synthesis component of the engineering design process was done in simulation only. We were ordering a premade system for this part of the design, so we used information from the datasheet to construct a simulated model of the iRobot Create and test it. After the simulated model was deemed acceptable, we ordered the hardware and constructed the software interface for controlling it. Once the software interface was done, we tested the calibration of the iRobot for angular and linear precision, and adjusted the software to compensate for errors. We then evaluated the error induced by the iRobot and found that the amount of error was small enough to not wreak havoc in our algorithms further down the tool-chain.

(e) Summary of how realistic design constraints were incorporated into the project (consideration of <u>most</u> of the following is required: economic, environmental, ethical, health & safety, social, political, sustainability, and manufacturability constraints).

Economic: Due to the academic research nature of this project, the economic considerations are generally lessened, the focus was placed on the quality of the product, as similar research products that have come out recently can run in the $1000 range, which would be a reasonable price range if our product were to go to market.

Health & Safety: The health and safety ramifications of this project are minimal, besides a standard shock hazard, a small parts hazard for children, and a tripping hazard, there is no extraordinarily dangerous part to this project.

Sustainability: The current prototype is a very sustainable design. Many of the parts, if failed, can be swapped out through a simple procedure, and the batteries are easily accessible and replaceable. There are only a few IC's that are specifically mounted to the PCB, and are difficult to replace, but the PCB itself is swappable should an IC cease functioning.

Manufacturability: In the current iteration, the project is very manufacturable. The assembly of the project from its component parts takes less than five minutes, and with some optimization could be cut down even shorter than that.

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

As a prototype, there is not very much beyond the electrical and computer engineering portions of the project. This was done by design, as all of the mechanical and other disciplines were specifically abstracted out through the purchase of pre-made parts. If this product were to go to market, there would be a significant need for mechanical and industrial engineers to redesign the parts of the project that are currently retail products.

(g) Description of project deliverables and their final status.

The project has two deliverables, the robotic system, and the PC software package. The robot system consists of the PCB, the Kinect, a netbook, and the iRobot Create. The software package consists of a user interface that is set up to communicate with the robotic system on an xBee link. The software package is currently done and working correctly. The robotic system is not currently working due to electrical issues caused by an electro-static discharge. The robotic system is fully assembled and partially functional on a level below what would be considered "finished". Given another couple weeks, we could easily have another prototype up and running and overcome the obstacle of this electro-static discharge.

Purdue ECE Senior Design Semester Report

Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Semester / Year	Spring 2011
Advisors	Prof. Meyer and Dr. Johnson
Team Number	13
Project Title	Virtual Presence Vehicle

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Jason Giles	CE	Coding	May, 2011
Brian Bell	EE	Hardware Design	May, 2011
John Ashmore	CE	Coding	May, 2011
Jing Li	EE	Hardware Design	May, 2011

Project Description: Provide a brief (2-3 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 was to create a vehicle which could be operated remotely, without line-of-sight, anywhere in a home or outside in the field. The project was designed as more of a research project, created to test the viability of 3D viewing controls. No specific customer is generally in mind for production, but rather would be marketed to hobbyists of RC cars. The specifications of the project were that the vehicle should operate completely on battery power so that it could be totally portable. Furthermore, to enhance the ability to control the vehicle remotely without line-of-sight, the images that the car sees would be transmitted as stereoscopic 3D vision to the user. Finally, the controls should be easy enough to pick up and use without a form of a manual, hence a standard gaming controller would be the only input with classic D-pad and analog joystick controls. The approach was to separate the wireless video signals from the rest of the computational design. The video would be handled separately by its own dedicated transceiver, and only processed in a video decoder at the final stage when it was to be displayed on the pair of LCD screens. All other controls signals going from the user to the car, and navigational information coming from the car to the user would be routed through a pair of microcontrollers and displayed via an on-screen-display in the corner of the LCD screen.

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

This class builds on several distinct topics learned from other classes. First and foremost, the ability to program a microcontroller and interface the microcontroller with a variety of peripherals is at the heart of the design. Such skills learned in ECE270 and ECE362 that are integral to the design are the ability to code a initializations for the microcontroller, timing module, and SPI interface. In order to design a successful power circuit for the project, some knowledge of basic circuit component configurations was needed as well. For example, the remote station uses a shunt resistor design and an ADC module to determine the amount of battery life remaining. Also, several components required a certain amount of capacitance and inductance coupled alongside them to function at the appropriate frequencies. In order to design such systems, knowledge of circuit construction was used from classes such as ECE201 and ECE 202.

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

One of the primary knowledge acquired from this course was the ability to construct a final product from nothing more than a schematic and then PCB. The project was designed, drawn as a schematic, wired in a PCB diagram, fabricated, and then coded. The entire engineering process, from start to finish, is something never encountered in any other class. This experience taught many lessons about proper component selection, trace sizes, capacitor selection, and the importance of redundancies in designs. A major skill obtained from the class is the ability to solder surface mount components to a PCB board in a skillful yet effective manner.

(d) Description of how the engineering design process was incorporated into the project. Reference must be made to the following fundamental steps of the design process: establishment of objectives and criteria, analysis, synthesis, construction, testing, and evaluation.

The class itself is structured to promote the use of the engineering design process. The first two weeks of the class are a solid conglomeration of team meetings, outlining, brainstorming, and the general flushing out of ideas for the project. Immediately in the course, PSSC's or the general objectives of the project are laid out, such as the ability to control the vehicle remotely with a game controller, or the projection of the remote images as stereoscopic 3D displays. From that point on, the project is drawn in mulptiple forms such as flowcharts, block diagrams, schematics, and PCB layouts. Each of these is presented multiple times in the course of the semester and each goes through at least one revision. Once the project has been analyzed, the PCB's are sent out for production. The boards may have been produced by a 3rd party, but the required soldering of all resistors, inductors, capacitors, microcontrollers, and headers to peripherals is done by the students. Further aspects of construction include the packaging of the end product. Once the PCB was fully operational, extensive programming of the microcontrollers is required to operate the wireless module, on screen display, gaming controller, etc. Once each of these components is functioning, the final operation of the product were compared against the original objectives of the design.

(e) Summary of how realistic design constraints were incorporated into the project (consideration of <u>most</u> of the following is required: economic, environmental, ethical, health & safety, social, political, sustainability, and manufacturability constraints).

Economic: The virtual presence vehicle was to be designed, built, and tested entirely by the four students that composed the team. The entire cost of the project would also be paid for by these students. Since none of the members of the team wished to pay more than was necessary, the entire project was designed on a budget. For example, the remote control vehicle would not be built from a kit, but rather a standard remote control car would be used that could be easily interfaced with. The goggles could be purchased separately, but were instead built from separate LCDs to save several hundred dollars. Finally, the entire control interface is a single widely available gaming controller.

Environmental: The project was not built with the explicit purpose of being mass marketed, but rather produced in small quantities and distributed among a small number of specialized hobbyists. The environmental impact of the product would be rather significant if mass marketed since the LCD screens would not be easily recycled. Furthermore, the project uses multiple PCBs, which each require environmentally dangerous chemicals to be produced. The environmental considerations used in this project mostly came in the form of research into appropriate means of recycling. Multiple online websites exist that provide advanced services for recycling electronic devices, that would be used in the case of this project.

Ethical: The ethical considerations used in this project were mostly in the form of misuse of the remote viewing capabilities of the product. For instance, the remote control car could pose a problem as an invasion of privacy used to spy of people where the user would not normally be able to go. Such misuse of the product is not controllable via the product itself, but rather is a factor based on the user; thus, the ethical considerations were negligible.

Health & Safety: The major health and safety factor involves the LCD screens. 3D technology has been shown to cause various problems such as eye strain, headaches, seizures, and dizziness. The purpose of the project itself was to test the viability of 3D control for remote devices, so the 3D could not really be turned off without interfering with the function of the product. Thus, a significant amount of warnings come with the product in the form of stickers on the goggles, warning labels in the user manual, and warning labels on the package itself. Other safety concerns include the overcharging of the Li-ion batteries on the base station and remote station, which could potentially result in a harmful explosion of the batteries. Preventative measures and redundancies were created so that the battery charge circuit ceases to function when the batteries are completely charged, reducing the chance of harm to the user.

Social: Social considerations implemented in the design are represented by the 3D display itself. 3D display is a nascent technology which would be looked favorably on in the modern market as well as among those researching 3D display's potential uses. Completion of the project represents a display of potential innovation for both the 3D technology as well as the remote control car industries. The product itself very nearly represents a test of virtual reality, considering that the 3D display is delivered to the user in a headset which blocks out other visual stimulus.

Political: Political considerations do not play a large role in the design, production, or testing of the project. If the design of the project were altered with a focus on military applications, then the project could hold significant political elements. However, with the virtual presence vehicle being marketed to hobbyists and with no military grade components, the project could be regarded as an expensive toy.

Sustainability: Design considerations for sustainability were involved side by side with cost considerations. The more commonly available and abundant a material is, the more likely it is to be cost effective as well. Therefore, the selection of common components like an ordinary RC car, common gaming controllers, and simple plastic packaging represent sustainability.

Manufacturability: The manufacturability of the product is high since the components chosen are each individually manufactured on large scales. For instance, the PS2 controller, LCD screens, all SOCs used, and the remote control car itself are each commercially available. The project itself does not require any rare custom components, but rather consists of complex interfaces between each of the multiple components selected.

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

The construction of the virtual presence vehicle requires an advanced knowledge of both electrical and computer engineering topics. The project uses a significant array of SOCs which each require specific amounts of resistors, capacitors, and operating voltages to function properly. Furthermore, each chip has a variety of communication protocols ranging from SPI to I2C, which must all be sourced from a custom programmed microcontroller.

(g) Description of project deliverables and their final status.

The final product consists of a remote control car, central processing base station, and goggle headset. The deliverables of the project are all of these, controllable via a single PS2 controller. The functionality achieved at the time of this report is still partial, since the wireless transceivers are the only component yet to become operational. The wireless module is a crux component that is required for any of the "remote" functionality of the device. However, functionality of each separate module has been achieved thus far. The PS2 controller produces movement commands for the cameras and car. The motors on the remote control car pivot the cameras in response to a PWM signal. The remote control car runs from simple signals produced from a microcontroller. The video transmissions are wirelessly displayed on the goggles headset. Finally, the entire project functions from two Li-ion batteries.

Purdue ECE Senior Design Semester Report

Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Semester / Year	Spring 2011
Advisors	Prof. Meyer and Dr. Johnson
Team Number	14
Project Title	Self Balancing Biped Robot

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Seongwoon Ko	EE	Motion Control & Software	May, 2011
Ankith Cherala	EE	Motion Control & Software	May, 2011
Kelton Stefan	EE	Power Supply & PCB Design	May, 2011
Jinliang Wei	CmpE	Wireless section of software & PCB	December, 2011

Project Description: Provide a brief (2-3 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 Self Balancing Biped Robot aims at replicating the movement of a pair of human legs. The project has a range of customers all the way from children (Age above 10 years) to the military. The prime purpose of this project is to achieve navigation remotely which could be advantageous for military uses and also be used as a toy for children. The dimensions of the robot are roughly *"Insert Dimensions here"* and it weighs about *"Insert weight here"*. The light weight as mentioned enables the robot to walk while easily redistributing its weight to compensate for the shift in the center of mass to achieve balance. Also, the robot does not occupy too much space which makes it easier to be manufactured and sold. To summarize the approach used, a graphic user interface would be used to wirelessly transmit commands to the robot (using Wifi). On receiving these commands from an onboard receiver (using SCI), the robot would take the necessary action. With regard to movement, stable states were designed that would be achieved during the path of the robot's motion. It would then be stepped from one stable state to another. Balance was achieved primarily using the ankle to tilt away from the direction of the potential fall. In some cases, motors were used in conjunction with each other to distribute the load evenly. A range sensor would detect an obstacle and stop the robot while an accelerometer would re-align the robot if nudged while standing.

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

During the course of the project, all the members of the team used a good amount of past knowledge learned through our classes taken in the ECE department. At the start of the project, concepts from our semiconductors class (ECE 255) along with basic electronic circuits (ECE 201) were utilized in developing the schematic and the PCB. A graduate-level class (ECE 569) was used as a base for modeling our Robot. This helped us run simulations to familiarize our self with joint movements while our project was in the simulation stage. Next, with respect to software, the wireless control was done based on acquisition of knowledge from object oriented programming (ECE 462). Next, with respect to the actual motion and controlling algorithm, ideas from classes such as (ECE 362, ECE 264 and ECE 368) were utilized. The microcontroller's class (ECE 362) gave us a general idea of the usage of registers, flags, sampling frequencies, interrupt routines, etc. Also, from the mini-project in ECE 362, the group was able to scan through datasheets more efficiently. Finally, knowledge from ECE 264 and ECE 368 were used as a base to write software for controlling the Biped Robot.

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

While ECE classes taken by our group members were indispensible, good amount knowledge was acquired while working on the project. Firstly, this was the first PCB designed for all the members of the group during the course of which the group relied heavily on datasheets and manufacturers' specifications. Next, this was the first time any member of our group used embedded C for programming a microcontroller. Although it seems to be an easy transition from assembly language given the same manufacturer, there were various topics that had to be studied in detail such as the compiler manual, files for declaring segments of flash and RAM for example, optimizations performed by the microcontroller, enabling floating point arithmetic, etc. Next, an extensive amount of soldering was performed on arrival of the PCB. The group had never done this extensive surface mount soldering in the past. Next, while utilizing the limitation of an 8-bit register (considering no concatenation possible), our group was able to effectively come up with a method to utilize the timer module in conjunction with the PWM module to achieve a better steering angle resolution for the servo motor.

(d) Description of how the engineering design process was incorporated into the project. Reference must be made to the following fundamental steps of the design process: establishment of objectives and criteria, analysis, synthesis, construction, testing, and evaluation.

Firstly, the group met to formulate an initial set of ideas and success criteria that would pave the path to starting on the project and be reasonable enough to be finished in 16 weeks at the end of the semester. Given the time constraint of the project, ideas such as walking & turning while maintaining balance, being remotely controlled and being able to stop on viewing an external object were given top consideration. Following this, a design constraint analysis was formulated which included the choice of hardware, a microcontroller that met the needs of our application. Limiting factors such as a requirement for 8 PWM channels and familiarity level with the microcontroller were given importance which helped narrow down the search for a microcontroller. The wireless Wifly module helped reduce cost by eliminating the need for a transmitter. Thus, factors such as cost were taken into account too. The frame for the robot was a standard frame ordered online that would later be adjusted slightly to incorporate a feature our group decided to add. Next, with regard to synthesis, various modular sub-groups such as wireless control, motion controlling algorithm, power supply, hardware on the PCB and simulations were put together to design the Biped Robot. These sub-groups were handled by collaboration between group members to put together the final product. Next, with regard to constructing the Robot, the ordered frame online was assembled in the lab. In addition, the group incorporated a pair of servo brackets to incorporate two different servos to the existing set of servos that would be used for turning and walking. On the arrival of the PCB, it would be mounted to the torso of the frame behind the battery pack. The battery pack would be placed in the aluminum channel centered on the torso. Next, two different broad groups of testing were performed. Firstly, testing the hardware was done on breadboard (prototyping) before developing the PCB. The power supply was tested along with other hardware components. The testing was eventually repeated after soldering parts on the PCB. Software testing was a time consuming process considering the different modular portions of software. Small segments of code were prototyped on a smaller controller (9s12c32) before incorporating it into the main microcontroller (9s12a256). In addition, the wireless module communication and the SCI routine to communicate with the microcontroller were carried out in parallel to the testing mentioned earlier. On assembling the different modular portions of code, further testing was carried out to assure the working of the product as a whole. Finally, with respect to evaluation, the product works as per designed. This was assured by utilizing all the systems designed that worked perfectly in conjunction with each other. The robot on receiving the appropriate command walked, turned, pivot and stopped when it approached an obstacle while balancing itself.

(e) Summary of how realistic design constraints were incorporated into the project (consideration of most of the following is required: economic, environmental, ethical, health & safety, social, political, sustainability, and manufacturability constraints).

Economic: The economic constraints were large concerns for our group members. Initially we were trying to keep the budget under $500 and although the robot was built under that budget, but replacing broken parts and having spare parts that are valuable to failure, the budget spent on this project was rounded up to $700 when the project was finished. The cost for the mechanical parts, encompassing servos and brackets etc., was about the same cost with the electronic parts, such as microcontroller, accelerometer, range sensor, power regulators and the battery pack.

Environmental: The component that could cause potential environmental issue was the $LiFePO_4$ battery and the aluminum chassis. While the $LiFePo_4$ could be considered harmless during the operation, upon its disposal it could be harmful to environment so proper disposal of battery should be notified to the users. Also the Aluminum produces fluorocarbon emissions from aluminum smelting during the aluminum production. To compensate for that issue, we have to notify the user to recycle aluminum used on the chassis upon disposal of this product.

Ethical: The ethical constraints for this project were also concerned throughout this project. To keep our product from violating intellectual property of the other group or person, we searched for potential infringement about similar product or the method and sought corresponding actions. We have found two possible infringements about our motion design under the doctrine of equivalency, but specific description of the patents was different from that of ours so noting had to be done about that. However, we found one literal infringement about the method we used to expand resolution for servo control signal and we could either change the microprocessor or giving them credit for what they have patented.

Health & Safety: The Health & Safety constraints was also a big concern during the packaging, first targeted age groups were age 10+ so had to make sure the screws were tightly fixed in upon the production, also we should notify the users to check the screws before the operation. The malfunction of the servos could jerk the servos and it could harm user in minor way so notifying users to do a test run before each operation.

Political: Politically, the robot would help in navigation in hazardous terrain. This could be useful for research purposes by the government if needed. There is no real political significance considering the fact that the product is primarily for the general population.

Sustainability: The product after testing is sustainable. The product is estimated to run each time for at least an hour and a half after a fully charged battery pack was inserted. The batteries would just have to be replaced after extensive use. In terms of sustainability of the electrical components such as motors, the motors we have right now are not the highest grade servos. Therefore, if the customer requires a long sustainable product and would be willing to spend a little extra, higher grade servos could be used that would provide a larger life time because of the fact that these servos could be subjected to failure if overloaded too much.

Manufacturability: The product was not too hard to manufacture considering the fact that a good portion of its mechanical structure was already commercially available. The addition to the hip utilized components bought from the same manufacturer, therefore implementation was not a concern. Next, with regard to the PCB, reading up on datasheets and simulating the PCB took some time, but now that the design is available and ready, it would just have to be sent out to a PCB vendor to fabricate. Next, with regard to the battery pack, the lithium iron phosphate batteries are commercially available and a serial connection of them would not be a problem. Finally, external components such as the range sensor, wireless Wifly module and the accelerometer are commercially available. Therefore, replacement of these parts when in need would not be an issue of concern.

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

This project was very multidisciplinary in nature. It involved the utilization of knowledge acquired in various fields of electrical engineering, computer engineering as well as mechanical engineering. The PCB was fabricated utilizing knowledge acquired in the field of semiconductors, linear circuits, interfacing with microcontrollers, etc. In the field of computer engineering, we used programming concepts acquired; interrupt handling, timer module handling and elimination of propagation delays. Finally, in the field of mechanical engineering, we used the idea of load-distribution for distributing the load over multiple motors to prevent failure due to overload. Next, we also relied on concepts such as a shifting center of mass/gravity which we had to account for during motion. Therefore, the role of statics in this project was indispensable.

(g) Description of project deliverables and their final status.

The biped robot frame ordered and modified from Lynxmotion was built successfully. The various success criteria for the project were met. In terms of the structure, the robot frame, the lithium iron phosphate battery pack, the PCB along with spare servo motors and spare parts for the frame would be deliverable. To summarize the structural change made on the existing lynxmotion produced frame, we added two servo motors and their associated C-brackets at the hip joints to allow the robot to rotate at the hip. These motors would have a different orientation to the other hip motors right below them. In terms of functionality, the biped robot is successfully able to walk while balancing itself, make unassisted left and right turns without falling as well as detecting an obstacle in its forward path and stopping. The wireless system built for the robot works as expected and the robot can receive its instructions from the GUI.

Purdue ECE Senior Design Semester Report

Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Semester / Year	Spring 2011
Advisors	Prof. Meyer and Dr. Johnson
Team Number	15
Project Title	The Skinny Dipper

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Michael Green	EE	Hardware	May 2011
Franco Blacutt	EE	Software	May 2011
Collin Phillips	CompE	Software	May 2011
Amber McCann	EE	Hardware	May 2011

Project Description:

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

The project is to design an automatic pool chemical regulator. The product gives the owner a “hands-free” system that maintains the chemical and temperature conditions of their pool. It regulates Chlorine, pH, and temperature by using sensors that we built and pumping in chemicals or heating the pool. It has the ability to measure chlorine concentration, water temperature, and pH with an accuracy of 5%, the ability to dispense measured amounts of regulatory chemicals into a pool, the ability to log chlorine concentration, water temperature, and pH data collected over a 30 day period in nonvolatile memory, the ability to display data logs and configure operating parameters, both locally and remotely, and the ability to detect potentially hazardous chemical concentration levels and sound a local alarm in response and send an E-mail alert.

It uses the MC9S12ne64 microcontroller from Freescale as the main controlling unit. The sensors use electrodes to measure the pH and the Chlorine levels. Circuitry is required for the sensor to work properly with the microcontroller. The system controls pumps and an electric heating coil to change the chemical levels and temperature. There are buttons and an LCD which, allow the user to program the unit to their liking. The system uses Ethernet and a web server to allow the user to monitor their pool from the comfort of their home. If the unit fails to regulate the chemicals or temperature then the control unit alerts the owner with emails and an alarm.

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

Our project had roots in several ECE courses such as, Microcontrollers 362, Linear Circuits 201, Digital Circuits 270, C Programming 264, and Chemistry 115. Microcontroller class was most important due to the microcontroller interacting with all of the peripherals. We had to program for the LCD, interrupts, and solid-state relays. We also used linear circuits a lot. When we built our sensors, we had loading effects and a need for amplifiers. Buffers and drivers were needed for running the LCD and relays. 270 was required for knowing how the ICs will operate with or drive each other. C programming was used for all of the software.

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

We learned several area topics such Chemistry, analog circuits, schematic and PCB design. In chemistry, we learned about electrodes in ionic water, molarity, and pool chemistry. Analog circuits really came in where we needed to read low power sensor signals. We learned how to fix loading effects. We learned how to design PCB. The Ethernet, PLL and sensor circuits and layout proved difficult but, now we have learned from our mistakes even if our board does not perform some of these tasks. We learned the nuances of embedded C.

(d) Description of how the engineering design process was incorporated into the project. Reference must be made to the following fundamental steps of the design process: establishment of objectives and criteria, analysis, synthesis, construction, testing, and evaluation.

The engineering design process was used in the design of the sensors. Our need was to measure the Chlorine and the pH values of the pool. We researched ideas of how this could be done automatically. After, finding a method called Amperometric Method to measure the Chlorine and pH. For this technology, we require electrodes. To choose electrodes we did a component comparison among different types of electrodes. Once we selected electrodes, we needed amplifiers to read the signals. We built many different types of circuits and tested them all. We compared the results of each test and selected the best fit solution.

(e) Summary of how realistic design constraints were incorporated into the project (consideration of most of the following is required: economic, environmental, ethical, health & safety, social, political, sustainability, and manufacturability constraints).

Economic: This product would sell for a thousand dollars on the market, with that in mind our economic constraints were limited by this value.

Environmental: This product is built out of a durable chasse and is to last many years without having to replace the entire system. The chemicals used in this product for testing, will be displaced by the chemicals needed to over-treat the pool which, would be un-necessary with our system.

Ethical: If our product were to fail serious injury could occur to our product's users which are liable on us. Realizing this we built in an alarm system that would alert the user if hazardous conditions are present.

Health & Safety: Safety of our product's users is our highest concern. Our system has an alarm and alerting system to detect harmful conditions to preserve the health of our users.

Social: Our product provides our customers with a "hands-free" maintenance of their pools, allowing them to enjoy their pool more effectively.

Political: Some people may be disturbed by our products use of chemicals and energy for heating. However, they would most likely be disturbed by heated chlorine pools in general.

Sustainability: Our product is built to last. Made with a durable chasse it can weather most environments. Future revisions to our product would add functionality to eliminate the need for replacement.

Manufacturability: Our product would be manufactured in two phases: subsystem components and on-site installation. All of the different subsystems would be manufactured separately and then assembled by our technicians on-site.

(f) Description of the multidisciplinary nature of the project.
This product has designs from 4 disciplines: Electrical Hardware, Embedded Software, Chemistry, and Mechanical Engineering. Our engineers had backgrounds in hardware and software. We divided evenly between the two. This left the chemistry and mechanical designs to be more of a whole team role. We faced problems such as, how to fit non-matching parts together, building mechanical components, and chemistry theory.

(g) Description of project deliverables and their final status.

As of today, all the components to the control unit have been separately built. Separately, they have full function as far as voltage readings from the sensors, buffer chemical pumping from the pumps, debugged functionality of the PCB components, and function of the LCD and buttons. They have yet to be integrated physically; however, the integration will be simple as the only electrical integrations are for input pins for the micro controller. With the software, the LCD is able to display parameters to be chosen, as well as data from the last 30 days. It also is able to signal an alarm for dangerous chemical levels.

As far as the dispensing unit goes, all of the dispensing pumps as well as their connections to the PCB are integrated together in one unit. The temperature regulatory subsystem has been tested with the PCB and works however is not integrated in the same packaging as the dispensing pumps. The software can turn the pumps on and off for the required amount of time to dispense a specific amount of chemicals for the pool. As far as the temperature module, the software is still being written.

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