SDP Final Project Report

Poor to Proper Posture

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***Abstract*—The modern world is almost entirely dominated by electronics and many people today find themselves stationary for hours at a time, whether it be sitting behind a monitor at an office or behind a steering wheel. While being stationary, many individuals inherently suffer from poor posture which can cause many long lasting negative effects for overall health, being detrimental both mentally and physically. To solve this epidemic problem, our group has designed a wearable system that will detect when a user hunches and then notify them through a small, continuous vibration that will stop once the user goes back to proper posture. As a result, the user is able to target their posture habits directly. Our product will be entirely battery powered and last at least 20 hours as well as have wirelessly charging, and users will be able to connect with the device over bluetooth to view progress.**

I. Introduction

About 80% of the American population has suffered from some sort of back posture issue [11]. As a technological driven society we spend more and more time on our devices. As more office jobs become more prevalent, back and posture issues start to arise.

A. Problem

When sitting at a non optimal desk for a user's height, people tend to slouch which can cause a series of issues [2]. Being misaligned puts a lot of stress on your body and your body will compensate for those changes such as rounding of the shoulder or having your head positioned forward. These stresses can add unnecessary pounds to your body. Other than the obvious effects of poor posture, there are other side effects such as headaches, heaving breathing, fatigue and multitudes of issues that can arise from poor posture [1].

B. Existing Products

Many products have been invented to fulfill the same role as ours, though they mainly consist of strap-on braces that forcefully correct the user's back. There have been positive results where it has helped people fix their back issues. However there have been negative reviews and results with the back braces. One of the issues of wearing a back brace is that it is not a permanent fix and people cannot wear it for too long because the user's body will get adjusted to it and it will defeat the purpose of the product trying to correct the user's posture [4]. Other issues are that it is not a one size fix-all which means that some back braces are not meant to fit for your body type because of the way how our spine curves and everyone's spine curves differently. In addition, not everyone is at the same stages with their slouching issues. With our product, it will be a device that can be put on and off on different clothings that will also be comfortable and non-forceful. Along with comfortability, people can adjust the threshold of curvature that the device monitors and notify the user to stand up straight when the threshold is passed. That way people can slowly work your way up to a proper posture than rush the process that may cause other issues for your back.

The other product is an electronic device that can measure the posture of your back. The device can measure the angle that your back is at and has a buzzer that reminds the user to stand up straight. The sensors that the product uses are accelerometers and gyroscopes [5]. Some issues with using these sensors that in certain cases it may not work because of the limitations on the sensors. For example, if the user were to be on a rollercoaster while wearing the device, the gyroscope will most likely be going off constantly or if the user is playing a sport that involves a lot of jumping that may also affect the gyroscope and accelerometer readings. Even though there have been many positive reviews with these devices on Amazon [6]. The product still comes with bad reviews and issues that can occur from using the device. One of the biggest issues is putting the device on the user's back which is one of the crucial parts of the design. People have complained that the adhesive does not stick the device and the user's back together and sometimes the device falls off or needs to be readjusted. Also the user will need to buy new packs of adhesive every time they run out. With our product the user will not need to buy new packs of adhesive packs nor need to stick something directly onto their backs. They will have the device be connected to an undergarment such as a T-shirt. Since we will be using a curvature sensor, limitations that come from a gyroscope will not be an issue for our product. In addition we will be focusing on the lower back which the other device does not consider. We will have two sensors that will be measuring the lower back and the upper back to help the user have proper posture.

C. Societal Impacts

The people who will benefit from our back posture product are people with poor back postures and people who have back issues. Our product will help them build healthy habits that support proper posture in a non forceful way. There will be a setting that allows different levels of hunching which will help ease people with severe back problems to a better back. This solution will be used instead of having the user to start standing up straight from day one to prevent back strain. When the user has always had poor posture, standing straight all the time immediately can strain the back without the proper muscle support that has to be built over time. Since we want this system to be convenient and user friendly, we have added the functionality of changing the levels of hunching before the device reminds the user. In addition, we added a tracker of how many times the user has hunched on that day to create a reward system so the user is more inclined to stand up straight throughout the day.

D. Requirements Analysis and Specifications

We want our product to vibrate every time the user is hunching and be able to function for a whole day without recharging. Also there will be bluetooth that will interface between the posture device and a smartphone so the user can calibrate proper posture, hunching and the level of hunching that is acceptable. As we can see in Table 1. we have our system specifications and requirements. We want our system to be light and power efficient which can last for about 20 hours, which is more than enough for an average working day. In addition, we want the battery to be conveniently charged without a usb but instead with an inductive coil. Once the system detects hunching it will vibrate a motor within 5 seconds, giving the user a 5 second leeway before it vibrates because the user may be picking up an object off the floor which can trigger the system. To prevent the system from short circuiting from sweat or rain water we will make it have an IPX grade 4.

Requirement	Specification	Value
portable	weight	<.5lbs
	size	<10cm2
	battery powered	<lasts 20 hours
	inductive Charging	<charges in 5 hours
responsive	latency	<every .5 sec sample
safety	sweatproof	IPX 4

Table 1: Requirements and Specifications

II. Design

A. Overview

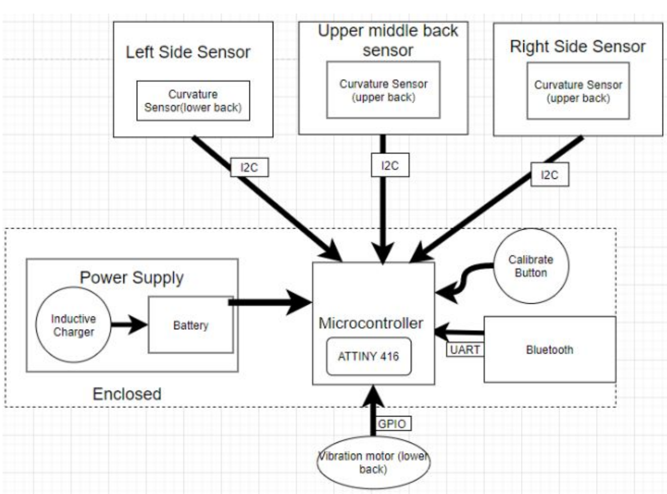

Figure 1: Block Diagram of our device

We will develop a product that uses vibration to notify the user when he is in a bad posture. We are going to use a capacitive curvature sensor, small vibration motor, and power efficient microcontroller. See the block diagram in Figure 1. We will use the capacitive curvature sensor to measure the angle of the user's back. As you can see in the block diagram of Figure 1 the sensor uses I2C protocol to communicate with the microprocessor. The sensor is very accurate, the error is half a degree in curvature[10]. We need the precision because the curvature sensor is only about 10cm long and the curve on the back in 10cm is very small. With a sensor that's less precise, we wouldn't be able to notify the user hunching in a timely manner. We also considered a resistive curvature sensor. See Appendix A for details.

The curvature sensor needs to measure the curvature accurately, we have conducted tests to guarantee that. See Appendix B for detailed test procedure.

After detecting the hunch of the user, the microcontroller will send a signal through the GPIO pin to tell the vibration motor to start vibrating while the curvature sensor is continuously feeding angle data to the microprocessor. After the user has stopped hunching and the curvature sensor has sent in the information to the microprocessor, the processor will signal the vibration motor to stop running.

In order for the product to be portable, we had made the whole system rely on battery power. In addition, we have added the feature of inductive charging to make it even more convenient. We will collect data on the system current and use that to calculate the battery life and ensure that it lasts 20 hours.

Overall, with the specifications of each component in the block diagram. The system will be a wearable battery powered device that will remind the user every time they start hunching. If one of the components of the block diagram is not working properly, it will affect the product. If the battery is not working then the system will not be powered. Angle sensor not working then the vibration motor will not run even if the user is hunching drastically or if the vibration motor is not working, then the user will not get the response if they were hunching. Everything must work for the product to work successfully as intended.

As we were designing our product, we needed to balance between responsiveness and the power consumption. Because more responsive means we need a higher sample rate which means more power consumption. And high power consumption means a bigger battery which will affect the weight, size, and battery life. In the end, we decided half a second per sample is satisfiable while meeting other specifications.

B. Embedded System

The brain of the whole system is the microprocessor that deals with the sensor data and triggers the vibration motor at the correct time. At first, we implemented an Arduino UNO microcontroller [13]. The reason is that the manufacturer of the curvature sensor has wrote a driver targeting Arduino. It makes it very easy to set up and have the prototype working. We just need to make the correct pin connection and upload the program. Unfortunately the Arduino consumes a lot of power, so we carefully chose the low power 8 bit microprocessor - ATTINY 416 [14] as the replacement used on the demo. Using Atmel Studio Integrated Development Environment, we programmed it to communicate with the curvature sensor using I2C protocol. The chip has I2C hardware built in, so we need to read the datasheet and use different registers to control the I2C component. The curvature sensor has a driver code written for Arduino Platform using the wire library. Since there is no wire library for ATTINY 416, we wrote our own I2C communication code. There are still problems with the code as it requires manual reset to reestablish connection. We will keep working on improving the code during the next semester.

C. Power and Charging

As a portable system our product will be powered by a small rechargeable lithium ion battery. After power consumption was tested to be 30mA@4V while passive and 72.5mA@4V while active a 1200mAh 3.7-4.2V Li-Ion battery [12] was chosen. This battery fulfills the requirement for a 20hr use with overhead. With a battery powered device we introduced a to charge it. Due to the desire to create a completely enclosed, water resistant device, inductive charging was implemented. The inductive charger [9] we chooses uses 2 coils with inner diameter 29.9mm outer diameter 38.7mm in conjunction with a rectifier and oscillator to transmit power wirelessly. This induction charger provides 5V DC with a maximum of 500mA current draw, dependent on coil distance. In our design the coils will be 2-3mms apart with 200mA draw. To charge the battery from the inductive charger we are using a board [8] that keeps the battery topped off by dynamically changing the current based on the batteries current capacity. As the battery gets closer to capacity the current is reduced till it is trickle charging to keep the battery topped off. Using skills learned in our electronics class and lab we must test this circuit to determine many of its parameters. To determine proper charge time we must test their current draw of circuit from the output of the charging circuit at carrying induction coil distances. In testing the efficiency of the inductive charger we tested the output current at the rectifier against varying input currents.

D. Curvature Sensor

The most important and most expensive part of our product is the curvature sensor. Since the data from the sensor needs to be accurate, precise, and reliable, we decided on using the Bend Labs [7] single axis flex sensor. According to Bend Labs, the single axis sensor has very low power consumption (78 uA active run current), zero drift, and a repeatability of 0.18°. Not only this, but it is also water and weather resistant, made with a flexible silicon elastomer which allows for unrestricted bending and stretching. As something that needs to be strapped up along a user's spine, the qualities of the Bend Labs sensor lead us to pick it over other less accurate sensors.

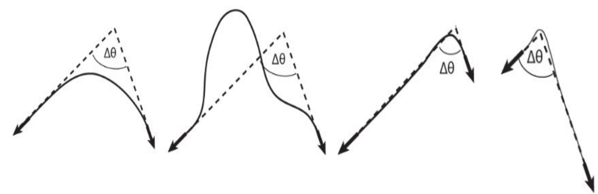

Figure 2: Path independence demonstration of flex sensor

Observing Figure 2 above shows one of the unique properties of the sensor, in which regardless of the path the sensor takes, the angular displacement is independent, thus all four paths of the figure above will theoretically yield the same result. As all humans have different curves to their spines, this path independence quality of the flex sensor is an important part of our product and will allow it to be used on nearly every person. To correctly make use of the single axis sensor, we must use data and signal processing techniques from our Hardware and Signals and Systems classes to manipulate the I2C protocol that the sensor is based off of. Since we aim to use multiple sensors in parallel, we must also learn how to manipulate the parallel I2C bus to get accurate and noiseless data from each sensor. To test out the accuracy of the sensor we will conduct various angular measurements to simulate the precision of the sensor at various set angles, making sure to power cycle the sensor as to simulate its on and off states. This test will demonstrate the precision of the sensor as well as the repeatability of our product as a whole.

III. The Product

A. Overview

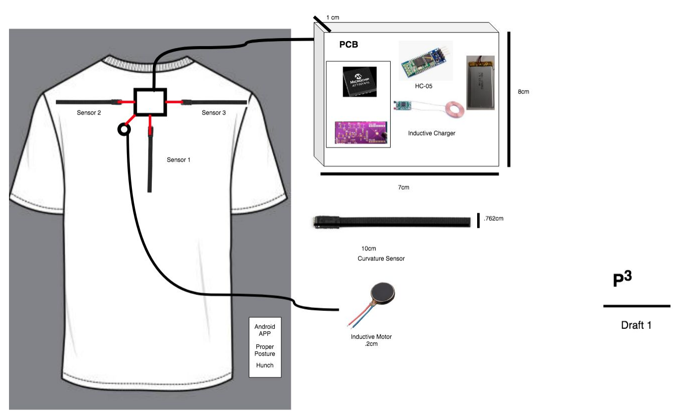

Figure 3: Product sketch

In the product we have three curvature sensors and one vibration motor. The curvature sensors are arranged in the shape of a "T" on the back of the shirt. At the center of the "T", we have our PCB which has microcontroller, blue-tooth, battery, and inductive charging integrated into one. The product is intended to attach to the shirt via velcro, so the shirt can be washed separately.

B. Electronic Hardware Component

A PCB was designed, with the Altium design software, to replace all previous breakout boards. There are two major groups of components for the PCB, the microcontroller and the inductive charging. The curvature sensors, inductive coil, and the vibration motor are able to connect directly to the PCB. We encountered issues opulating the SMT devices due to the small footprints. With the technology at hand, it was difficult to prevent short circuits. After populating the microprocessor, we still had the difficulty programming the microprocessor. We had intended to disconnect the microprocessor on the breakout board and connect our PCB to the breakout board programmer. After, resolving these issues we would have been left with a pcb that reduced the size of our design substantially.

C. Functionality

By the time of CDR, the inductive charging, vibration motor and one curvature sensor was working together. We connected a LED to determine if current was going through when we were inductive charging which lit up. We tested the curvature sensor to cause the vibration motor to run when the demonstration hunched which showed that the single curvature sensor and vibration worked.

However, some of the intended components did not work by CDR, such as the bluetooth and three curvature sensors working together. Both ran successfully on the Arduino, but importing the code was difficult since there was the challenge of learning the ATTiny416 library and the different protocols which were required from the curvature sensors and the bluetooth chip.

D. Performance

After putting the main components in the enclosure we were able to measure the area that the case took and it was less than 10 cm^2 .

The estimated average power used for 20 hours was 620mAh at 4V and the selected battery which was 1200 mAh at 4V (was the next smallest battery that could power our device for at least 20hours) which shows that the device will definitely last for 20 hours and longer. The inductive charger had a charging current about 300 mA and this would fulfill our specification because in less than 5 hours the battery will be charged.

Another specification that was met was the latency. We measured and set a timer for the latency and it was able to produce a result in half a second which barely met the specification.

One specification that was not met was the weight of the device. Since we had multiple components added to the enclosed case and used a bigger battery that had more power than needed, they all increased the weight of the product. The product weighed around .7 lbs, which should not affect the user's experience too much.

IV. Conclusion

For CDR we were able to show that our product was working with one curvature sensor. The curvature sensor would be sending in data to the ATTiny416 to process. Once the user reached the hunching mark, the vibration motor would run. We were also able to calibrate the hunching and proper posture with buttons. In addition the team was able to produce a PCB, have three sensors work on the Arduino and bluetooth to work on the Arduino.

There were many goals needed to be accomplished to have a working product that met specifications by FPR. One was having the three curvature sensors using I2C to communicate with the ATTiny416. So when the user has improper posture on his shoulders or back, the system should buzz the user that they have improper posture. Another goal that needed to be accomplished was the bluetooth component. This would allow the user to calibrate the hunching and proper posture data on their phone instead of pressing buttons on their back. In addition, they would be able to see their progress on the app as they continue to improve their posture. Lastly, we want to put nail polish on the electrical components to make the product sweatproof which is a rating of IPX 4 and put it all in a custom designed enclosed case.

Acknowledgment

Thank you to Prof. Wolf for advising and guiding the team along the way. Thank you Francis Caron for ordering the different components for our senior design project, without him we would have no hardware to use. Special thanks to Chuck Malloch for helping the team come up with the idea of a posture sensing system that uses a curvature sensing device.

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Appendix

A. Design Alternatives

We could have used a resistive curvature sensor, but the capacitive sensor is more accurate and doesn't have any drift in measurement data[10].

We have considered different Microprocessors and ATTINY416 seems to be the most power efficient and reliable one.

B. Technical Standards

We used an off-the-shelf Bluetooth module to let the user monitor the posture condition throughout the day. The Bluetooth module adheres to the IEEE 802.15.1 : WPAN / Bluetooth standards.

We used I2C protocol to communicate between the curvature sensor and the microprocessor. The protocol was designed by Philips Semiconductor in 1982.

We used the international standard IEC 60529 to convey how waterproof our product is to the customer.

C. Testing Methods

So far our group has only executed precision testing for the curvature sensor to demonstrate its repeatability. For this test our sensor was set up to simulate 0 degrees and 90 degrees, in which we measured with a protractor to make sure we were as accurate as we could be. Since we had the baseline for what was theoretically 90 degrees, we then proceeded to take the sensor reading at 90 degrees, resetting the sensor back to 0 degrees after taking the reading. We took 40 samples in total following this procedure and plotted each iteration.

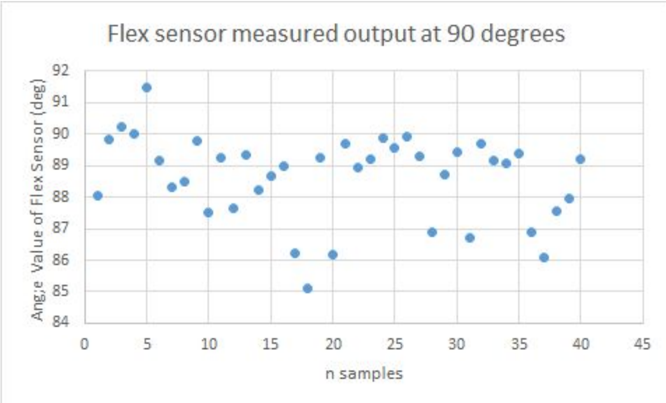

Figure 4: Sensor readings of 90 degrees conducted with 40 samples to demonstrate accuracy and precision

Observing Figure 3, the flex sensor output generally comes short of 90 degrees, with a sample mean of 88.6 degrees and a standard deviation of 1.335. By assuming that the sensor output was purely Gaussian, we were able to conclude with 95% confidence that the true mean of our output is 88.6265 ∓ 0.413661 degrees. This data shows the flex sensor to be very reliable and repeatable regardless of what state the sensor is in.

Although this test shows the precision and accuracy of the flex sensor, we only conducted it at 90 degrees. Since the change in angle of the back when someone hunches versus when they have good posture is small, we need to be able to demonstrate that the sensor is able to discern smaller angles as well as smaller changes in angles.

To meet our design specification of a battery lasting at least 20 hours, we would need to take various current draw measurements for each of the blocks of our product. Since the flex sensor has extremely low current draw, the only component that will determine how big of a battery we need is the microprocessor. To meet our design specifications of users being notified of their hunch within 5 seconds, we would need to take various measurements to see how long it takes our system to respond.

D. Team Organization

We divided our work and each member of the team was given work that matches his expertise. Kiet worked on hardware, in particular the soldering, battery and inductive charging. O-Dom worked on hardware, on curvature sensor, making sure it works and soldering the curvature sensor circuit. Karl worked on the Arduino prototype which we then used to measure the accuracy of the curvature sensor. Tong worked on ATTINY 416 prototype which we used to put on a shirt as the demo. Each lead work in their corresponding fields through starting discussions, problem solving when a bug arrose, or assigning parts to team members.

Karl was able to come up with the posture system idea and build the basic block diagram for it. When we were looking at different microprocessors, Tong was able to determine which one to buy based on the specs that were given in the datasheets. Kiet came up with the inductive charging addition to make the product convenient for the user. Initially, the team wanted to have two curvature sensors for the upper and lower back, however there was an issue with the I2C protocol with the second curvature sensor, O-Dom was able to make the assessment that we should focus on the first curvature sensor based on the time constraint. In addition, to increase testing to make sure that the curvature sensor and system will work.

On the night before the MDR demo, we worked together to create and debug the prototype and test the prototype. After four hours of debugging and testing, we finally found the solution to stabilize the sensor output - decrease the sampling rate of the sensor.

Throughout the semester, we increased workflow and productivity by assigning team members to their appropriate field of study within the project and separating tasks to individuals or small groups. The team coordinated two or more full team meetings throughout the week as well as several small team meetings spread intermittently. This provided an optimal progression of ideas. During large team meetings discussions were held for basic ideas and goals to be bounced around and analyzed. Sometimes the team meetings did not work out because of classes or exams season, to make sure that we would be continuously communicating with each other, we created a group chat on messenger. Sometimes if the situation was urgent and we couldn't meet up physically, we would use video call.

Once the idea was thought out, each goal was assigned to a small team or individual. Each individual would then conduct their own research and meet with their small team to discuss more in depth on planning and ordering parts.We had small teams instead of people working on their own parts individually so if one person had a question or needed to bounce ideas, they had a buddy that they could rely on. Once parts were purchased, small teams would complete their components and then it would all be combined and tested in the large team meetings. This process insured everyone had a job at any given time and were contributing towards completing the project as a whole. Everyone worked in parallel and made sure their component functioned properly. Then the team came together to combine the whole system, test and troubleshoot.

E. Beyond the Classroom

Karl - In this project, previous knowledge with embedded systems and how to interface embedded systems with different sensors was helpful. At the same time there are many protocols out there that I have not learned yet, such as I2C. This protocol was important to learn for our project since the curvature sensor uses the I2C protocol to communicate with the microcontroller. In addition to the technical skills, I had to learn communication and time management. Communicating the current progress on my end of the project and making sure that we were making progress was one of the important aspects to this project because without it I do not think we would have had a successful MDR. My advisors and professors in the ECE department have been very helpful because they were able to give me an insight on the project. Overall this project has many connections to the professional world because I want to work in the embedded system industry and working on a project that involves an embedded system is a great way to gain experience. In addition, in the professional world, I know that I will be working in teams all the time. Communication and asking other people for help will be a big part of my professional career.

Tong- This semester was pretty busy for me so I had to improve my time management skills and really block out a chunk of time to work on this project. Especially, I have another course project that is also a time eating monster. No matter how much time I spend, there are always more things to do. Without blocking out time for a specific purpose, I would get distracted by some other tasks and end up missing the deadlines. Scheduling my time for a work day helped me stay on top of my assignments and relieve stress. I also needed to be a better communicator. Before this semester, I do everything on my own, even in a group project. And a lot of the time, I ended up exhausting myself. But this semester, I started to trust other people a lot more and be a team player. Communicating with the team member about the goal and talking with the other members to get their opinions on the approach to solving the problems. Also in this semester, I learned how to modify the driver code written by the sensor manufacturer. Because we used a low power microprocessor instead of a mainstream one. The driver code isn't available. So I looked into the driver code of the mainstream processor, examining which part can be changed and which part can't. In the end, I created a SPI library for the low power microprocessor to replace the SPI library used by the mainstream processor's driver. Those are valuable experiences to prepare me for professional life in the future.

O-Dom- Throughout the semester working on this project, I have had to use a lot of prior knowledge as well as utilize resources to give myself the knowledge needed to create a successful product. Overall, I found myself having to educate myself on what I believe to be one of my weaknesses, which is coding language and protocol. To be able to contribute my portion of the project, I had to have a better understanding of the coding environment as well as how to manipulate the registers of each of our components, and then to be able to identify how and when our components, like the sensor, were able to communicate amongst each other. Along with this was the struggle to manipulate the I2C protocol that our project is based upon. Although still in the dark, I have found myself needing to further understand how the I2C bus functions. Mostly, my resources have mostly come from my teammates, as well as consulting from other friends within the ECE department. Along with this, if I was not able to reach a level of understanding that I wanted, I would shift my questions to the internet, where a lot of info is given. I see this connecting to life as a professional. As a professional, having connections seems to be the best way to learn and obtain information, as the workers around you may have had similar questions or problems.

Kiet - In this project much of my previous knowledge of circuits and electronics were applied and expanded upon. To understand the compatibility between many of the parts ordered I had to test inputs and outputs if each IC along with decipher schematics and learn the underlying technology required for its operation. More so than in class I got to see real applications of IC on a higher level of abstraction and how the abstraction improves workflow on the overall system. I also had to do research to improve my understanding over things such as transformers which were only briefly covered in theory in the classes I have taken. I experimented with the inductive charger and gathered experimental data to help me in my design. This project has taught me to combine and expand upon knowledge learned through my years in college to bring together a cohesive package. Most importantly I believe I've learned to seek out information from various sources that are open to me such as professors or colleagues. Within classes knowledge is contained, all the information to succeed in the courses is within the course, due to this it is never required to seek external information. However in capstone projects, information is not provided to you such as in a real work environment. Information gathering is part of the course itself along with the ability to adapt to the new information you have gathered. This all parallels real work environments.