E-SKATE

Cesar Romero, Oscar Cedeno, Camilo Romero

University of Central Florida, Department of Computer and Electrical Engineering, Orlando, Florida, 32816, U.S.A

***Abstract* — This paper presents the design and methodology utilized in the creation of an electric skateboard. The main objective of the E-Skate is to transport a person from one point to another using a DC motor, powered by a rechargeable battery, which will be controlled wirelessly using Zigbee technology. The user uses a hand on controller while riding the E-Skate. The E-skate uses a microcontroller with analog to digital conversion, motor controller and GPS module. It provides fast transportation and easy portability. In addition it shows the actual location of speed in a LCD display mounted on the remote controller.**

***Index Terms* — Microcontroller, analog to digital conversion, Zigbee, DC motor, battery, LCD, GPS.**

I. Introduction

Electric skateboards are a new and promising alternative form of urban transportation. They provide all the advantages of a regular bicycle: fun exercise, free parking, zero emissions, and freedom from gridlock. Imagine skateboarding up a hill as comfortably as riding down, that's what the E-skate experience is all about. In most situations in the city, riding an electric skateboard will be faster and cheaper than either car or public transit.

Fundamentally, the E-skate is just a regular skateboard with an electric motor to provide additional assistance. You can skate normally and just use the motor to help out on hills and headwinds, or use the motor all the time just to make riding easier. The experience is entirely different from riding say a gas scooter or motorbike. Here the electric assistance is perfectly smooth and it complements rather than supplants human power.

E-Skate is born from the idea of simplifying the methods of transportation inside university campus. Throughout the years, many students have used simple methods of transportation along far distance buildings inside campus. Many students have use bicycles, skateboards, or just walking. We noticed that sometimes we need to travel long distances inside the university area; the idea of having a portable and fast transportation, which people don't have to use physical force, came to our mind while we saw a student skating and paddling constantly because he was late for class.

A. Goals and Objectives

The main goal of this project is to successfully complete a working electric skateboard, along with the ability to be controlled wirelessly with a remote controller while skating. The objectives of the E-Skate are the most influential criteria when it comes to final design. It is important to make the necessary adjustments and testing so the user would not have any injuries.

B. Requirements and Specifications

The E-Skate has certain requirements that must be met in order to work. The E-Skate is for cruising in clear weather conditions and it cannot be used off road. The wireless range of the controller should be 10 feet while you are skating on top of E-Skate. It can handle a maximum weight of 200 pounds. The battery must be charged 2 hours so it can acquire 80 percent charge, and you must take in consideration that the faster you go, the faster the battery dies.

II. Hardware Design

The overall design of the E-Skate is shown in Figure 1. There will be three processing units. Two located on the hands on remote controller and the other one located on the bottom of the skateboard. The first control unit is called Wireless Control, which is in charge of sending a wireless signal from the user through a transmitter located on the remote controller. It has a potentiometer which is used for controlling the speed and sending the analog data. The Second control unit is called Motor Control. It will be integrated by the processor, the battery and the receiver module. This unit is in charge of receiving the data from the user and controls the speed of the motor. The receiver, which will receive the signal, process it and output it to the DC motor data and also sends the signal to the battery so it gives power to the DC motor. The last control unit is called Data Control, which will provide actual localization and speed through a display mounted on the controller. In addition, it will provide the actual battery life of the E-Skate and will have an accelerometer which will stop the motor if the user encounters an accident. The direction in which the user will want to go will be controlled by the user himself using his legs and weight to control which way he/she would like to go.

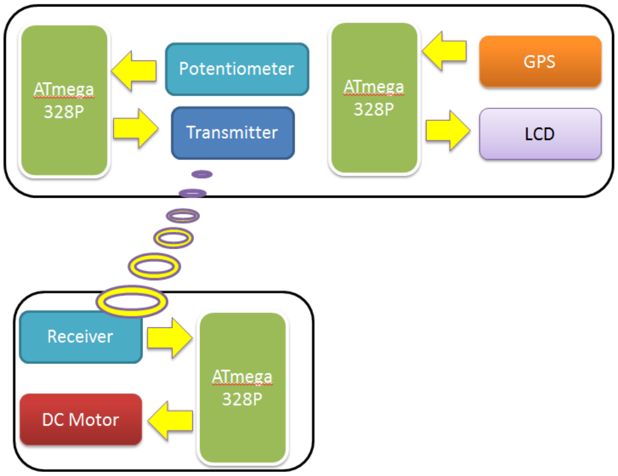

Figure 1 – Hardware Design

Specifications	**Atmega328p**
Pins	32
I/O pins	23
EEProm	1K
Program Memory	32K
SPI	Yes
USART	1
Timers 8/16 bit	2/1
PWM pins	6
ADC channels	8
Programming Language	C, Arduino
Max Clock Rate	20 MHz
Voltage	1.8-5.5V
Price	$5

Table 1 – Atmega 328p Specifications

A. Micro Controller

After researching various microcontrollers, our group decided to go with the Atmega 328p from AVR. The reasons why we selected the Atmega 328pover other microcontrollers like the Pics were that it had more programmable memory than similar ones we looked. In addition, we already had some precious experience working with the Atmega 8 and the Atmega 168. The only thing we needed to get was the programming device. We chose the Arduino UNO in order to program and test our microcontroller. Another reason we selected this microcontroller was that it is supported by many libraries that simplify the programming process. Some of the advantages that this microcontroller possesses are that it has 23 I/O pins and 32K of programmable memory. In addition, the Atmega 328p has 3 timers and 6OWM capable pins as well as 8 ADC channels. The following chart, Table 1 shows some specifications of the Atmega 328p microcontroller. Figure 2 shows the atmega 328p.

Figure 2 – Atmega328p Microcontroller

III. Wireless Control

One of the goals of the E-Skate is to be controlled wirelessly while skating. The First control unit is the Wireless Control. It will consist in a single atmega 328p, which will have four components. The first component is the Xbee module, which will be connected using the RX and TX pins as well as 5V DC power and ground. The second component is the LCD screen. It will display the latitude, altitude and longitude of the E-Skate. In addition, we created code so the GPS could calculate actual speed and show it to the LCD screen. The LCD screen is connected to I2C which is a simple connection that only uses two of the digital pins on the microprocessor as well as power and ground. Also, the third component, which is a potentiometer, will be connected to the microcontroller using only one PWM pin. The potentiometer will be in charge of sending the analog data to through the xbee to the other xbee connected in the microcontroller on the skateboard. This willallow us to control the speed as we like.We should not forget about the last important component, which is how all this components will be powered. We use a standard 9V lithium Ion rechargeable battery, which will give us 4 hours of continuous battery life for all components. All of these components will be mounted on the user's remote controller.

A. Xbee

The wireless module the group decided to use was the XBee OEM RF 802.15.4 as shown in figure 3. The range was good enough for the group having a max range of 100ft (30m). While 250kbps might seem small for a commercial product, for a simple project like the power units with the central unit, it will be sufficient to work properly. The only distance that we need is the one from the skateboard to the user standing on top of it, so this module is good enough for our design. We purchased this kit that consisted of two Xbee modules, which would run up the price to $76.00 total for just the radio chips.

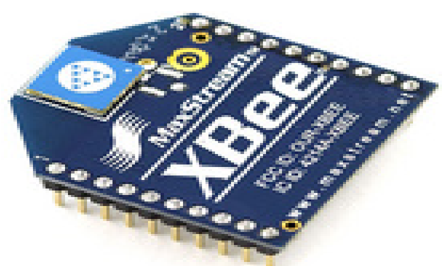

Figure 3- XBee Module

After weeks of research, trying to find a good adapter for the XBee, an adapter from sparkfun was the one chosen costing $13 per unit. The adapter kit will look like figure 2, shown below. The kit includes a 3.3V regulator board, a level shifting chip that drops the input voltage that is 5V and drops it to 3.3V, activity LED, a power LED, pins to represent ten of the most useful pins and 20 pin holes to place the XBee in. Also, the Xbee Explorer Regulated allows the XBee to be easily programmed using a cord that connects to the important six pins stated above and any computer. X-CTU was the program used to program the XBee radio chips. This allows you to manipulate the chips for things like sleep time, baud rate and giving it a network ID so only other XBees with the same network ID can communicate to each other. Also, this allows for a basic test to see if the chip responds to basic commands.

The XBee explorer is a great solution to be able to add wireless communication to the E-Skate. The XBee explorer allows easy access to the pins needed to receive, send, and give power to the XBee module. The controller also has LED’s in order to show if the unit is powered and if it sending and receiving data. This controller allows you to input 5 volts and it will regulate it to the necessary 3.3 volts. The DOUT pin will be directly connected to the RX pin of the microcontroller and the DIN pin will be directly connected to the TX pin of our microcontroller.

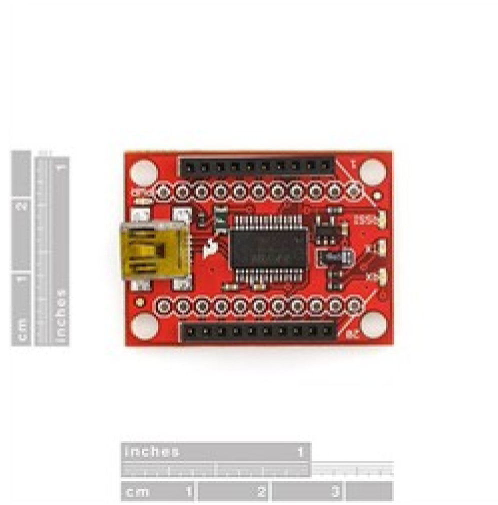

Figure 4- XBee Explorer Regulated

B. Potentiometer

The potentiometer we will use is the analog 2 axis thumb joystick from. This joystick is easy to mount and we will only use one axis of it. It comes with a breakout board for easy connection. Since it is analog, we will need to connect it to analog pins on the ATmega 328. It powers with 5V and has 1ma of current draw. Figure 5 shows the joystick from adafruit.com

Figure 5- 2 axis Joystick

IV. Motor Control

The second control unit is called Motor Control. It will allow us to control the DC motor mounted on the skateboard. It consists of four parts, the Xbee module, the motor controller, the DC motor, and the battery.

A. DC Motor

The motor we are using is a 12Volts DC 100W drive motor. It is 3400 Revolution. Figure 6 shows the DC motor that will be used on the E-Skate.

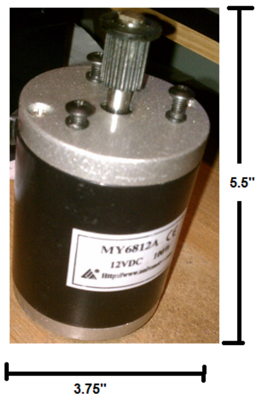

Figure 6- Dc motor

B. Motor Controller

To control the speed and of the E-skate, we are using the BTN7971B high Current PN Half Bridge. This H Bridge can be programmed with pulse width modulation. It was two inputs. One is digital high, and the second one is modulated to change the speed. Another good characteristic is that it has a temperature sensor that will shut down the motor if it overheats. It also input a 50 amps minimum and can input a maximum 70 amps if a heat sink is used. Figure 7 shows the H-Bridge.

Figure 7- Motor control

C. Power Supply

The Power System to be used in the E-Skate design would be the motor MY6812A Heavy Duty, two batteries RITAR RT 1250, and a power adapter from Leadman powmax model KY-05036S-12 3 Whole Female connector. The MY6812A is a 12 Volts 100 watt heavy duty motor. It has enough power to move a scooter; therefore, it is an excellent choice for our E-Skate design. The Two RITAR batteries are going to be connected in parallel to provide more current flow. Each battery has an output of 12 volts and a 5 Amp hours. It is also rechargeable and need a minimum input of 1.5 amps to be recharge. It was a great battery life and need to be constant recharge after use to maintain battery life longer. The purpose of the charger is to power up the battery. The charger that is going to be used is manufacture by Leadman model KY-05036S-12 Powmax. It has an input of 100 ~240 Volts per 1 amp and an output of 12Volts / 1.5 Amps. Because it dissipated 1.5 amps it is a great used for the battery. The block diagram of how does the motor is attached to the battery and is shown in Figure 8.

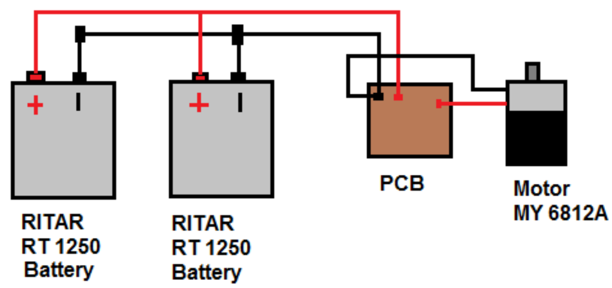

Figure 8 – Power Supply

E. Voltage Regulation

It is important to provide clean power to the ATMega328P. This includes feeding it with a regulated 5V power and a steady voltage for its ADC reference. The 5V power line on the chip is not completely susceptible to small variations in the line but the ADC reference voltage is detrimental to the conversion of our analog signals; any perturbation on the line could potentially throw off the sensor readings. In order to provide the clean power needed for the ATMega328P careful consideration was made in selecting its accompanying hardware. The hardware selected accomplished filtering out the unwanted noise stemming from the voltage regulators. The voltage regulator that we will use is the LM7805, which satisfies our entire requirement for powering our electronics.

V. Data Control

The last control unit is called Data Control. This unit consists of three parts. The first device that will be in this unit is the GPS EM-406A, which will give an approximation of altitude, longitude, latitude, and speed. The GPS information will be displayed on the second device, which is the LCD screen, which is a 4X20 display. All of these components will be connected to the ATmega 328p which will control all these process. The microcontroller will be programmed using Arduino software similar to C.

A. GPS

We decided to add localization to our E-Skate in case of theft or lost. Having a GPS implemented on the E-Skate will solve this problem and will also give us an accurate speed of the E-Skate as well. After doing all the research about different types of GPS modules, we have come in with a conclusion of choosing the EM-406A, the reason for this is mainly because it is less expensive and it is great to work with according to the research made. It has 20 channel receivers, and it outputs NMEA 0183 protocols. With are very easy to program and implemented. It does have a little high volt operation, but it supports Wide Area Augmentation System (WAAS) in default mode. The WAAS capable receiver can give a position accuracy of better than 3 meters 95% of the time. Table X shows the specifications of the EM-406A and Figure Y shows the actual GPS module while being tested on the display on Figure 9.

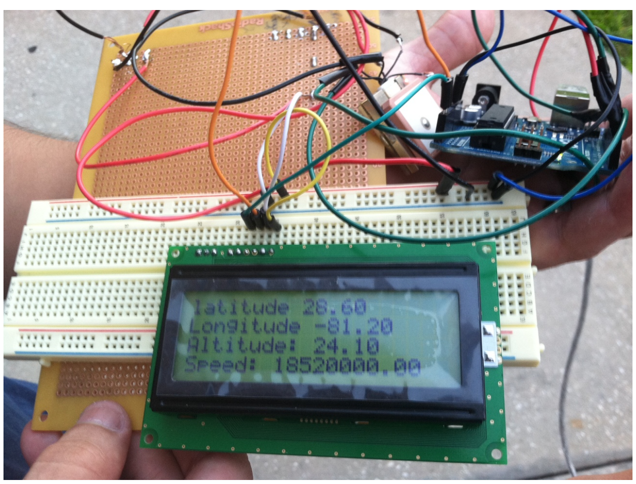

Figure 9 – EM-406A GPS Module

B. Display

The LCD display used is a 4 row 20 column Newhaven NHD-0420D3Z-FL-GBW display. This display was chosen for the ample room to be able to display as much information as possible. This display can be configured to work with 3 different communication methods. They are all serial communication and are RS232, I^2C and SPI. The communication method chosen is the I^2C for its simplicity. To power this LCD it requires 5 Volts which allows us to connect into the power supplied by the power regulator and doesn't need us to design a separate circuit. The backlighting of the LCD is Yellow/Green. Figure 9 shows the LCD screen.

VI. Software Design

The software design of the E-Skate consists of three separate components. They are data control, motor control and wireless control. Data control controls the information being printed to the LCD. Wireless control controls the information on where engine speed should be based on throttle position. Motor control controls the motor velocity by controlling an H-Bridge.

A. Data Microcontroller

With data control we have the GPS input data to the microcontroller and the output it to the LCD. The data microcontroller does this by creating instances of the serial connection as well as the GPS as well as the LCD. The serial connection needs an instance as this allows us to use any pins for the GPS which would in turn allow us to connect the dedicated serial connection to a computer for troubleshooting. The instance of GPS has the software to encode the data taken from the serial connection and stores the data to be accessed later (few milliseconds). Once the string is encoded into what location the GPS is in, the microcontroller looks at previous locations and from the difference can determine a velocity. The instance of LCD is used to print out to a LCD the data from the GPS. The data it prints out is the latitude, longitude, altitude and velocity (speed). The LCD instance can be called anywhere in the software flow, and can allow us to print the data we want whenever. The following flow chart shows how this works together.

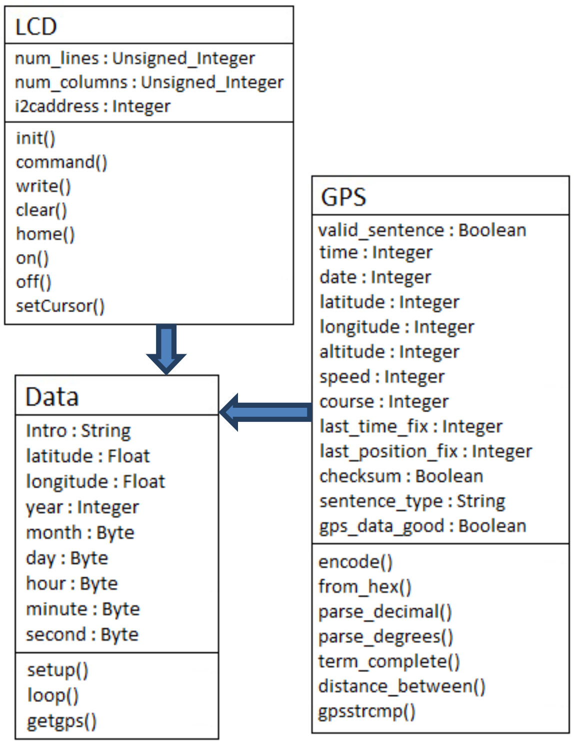

Figure10 – UML of Data Microcontroller

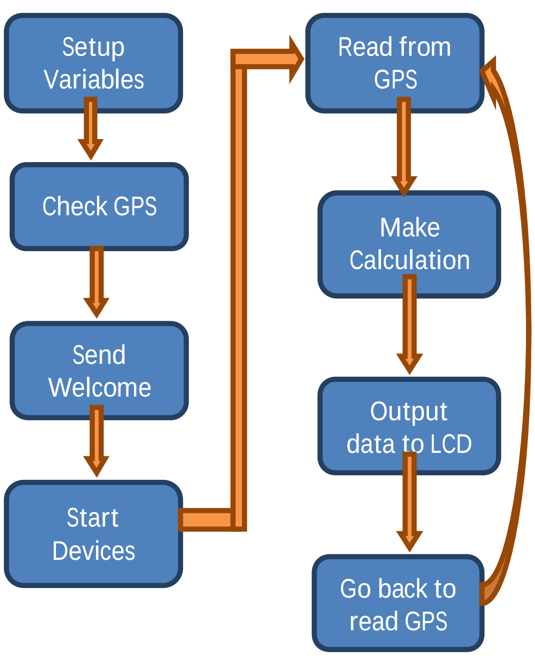

Figure11 – Flowchart of Data Microcontroller

A. *Wireless Microcontroller*

The wireless microcontroller sends data to the motor controller wirelessly depending on the throttle position. The microcontroller reads an analog signal from a potentiometer. The microcontroller will read a value from 0 to 1023 which 2^{10} -1 because it is a 10 bit analog to digital converter. This value is then mapped to a value between 0 and 255 as this is the duty cycle range for the motor. The microcontroller makes an instance of the Xbee module which allows for a dedicated serial connection to a computer for troubleshooting. The value is then sent through the instance of the Xbee wireless module. This process is repeated at 200 times a second, and keeps going until power is turned off. Below is the software UML for the wireless microcontroller.

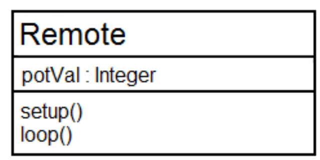

Figure12 – UML of Wireless Microcontroller

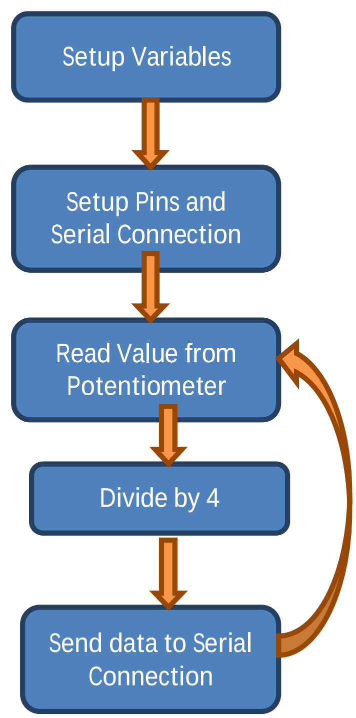

Figure13 – Flowchart of Wireless Microcontroller

A. *Motor Microcontroller*

The motor microcontroller controls how fast the motor turns. This is done with a Pulse-Width Modulated (PWM) signal from the microcontroller. The microcontroller range for the duty cycle of the PWM signal is from 0 to 255. This value is sent from the wireless microcontroller and is received and outputted to the motor pin. The H-Bridge requires 2 pins for control, one for Inhibit which sets either the H-Bridge to sleep when set to LOW and to work when set to HIGH. The other pin is the PWM signal. The signal from the wireless microcontroller is read at 200 times a second, and keeps going until power is set to off. During testing of communication between the wireless and motor microcontrollers, signal analysis was done, and was found that the communication between the microcontrollers received a fair amount of noise. This noise would affect the components so much that it would heat them to the point of failure. This also created an audible noise, which was annoying to the group and would be annoying to a future user. The software was designed to reduce this noise with noise reduction code. The signal stores the previous value read by the microcontroller, then it compares the present value to a preset noise value which was determined in the noise analysis.

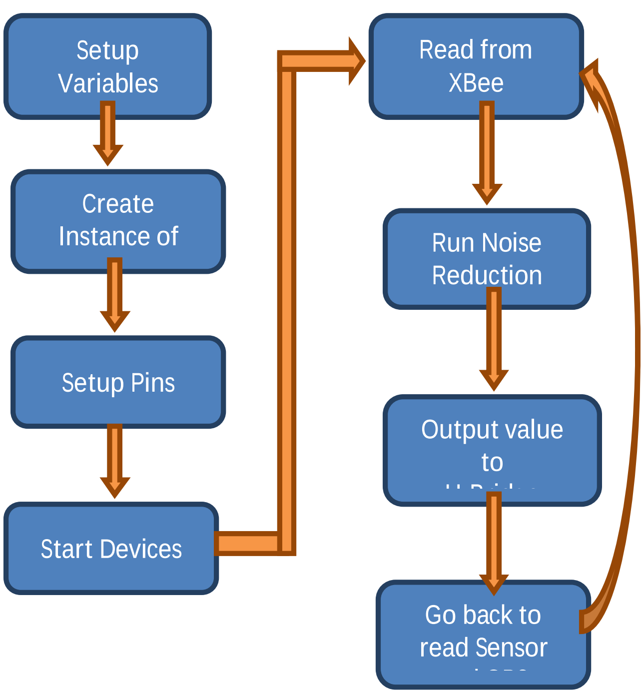

Figure14 – Flowchart of Motor Microcontroller

If the value is that predetermined value, it is replaced with the previous value and outputted to the H-Bridge. This noise reduction code was found to reduce noise by 99%. Any leftover noise was found not to affect the motor microcontroller by any significant amount. This also had the effect of reducing heat produced by the H-Bridge.

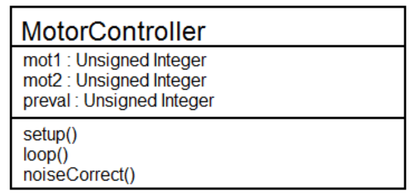

Figure15 – UML of Motor Microcontroller

VII. Printed Circuit Board

In order to maintain professionalism we decided to create printed circuit boards for our E-Skate. The design was made using a free student version of Eagle Cad. We joined the data control and wireless control into one PCB. The final schematic is shown in figure 16.

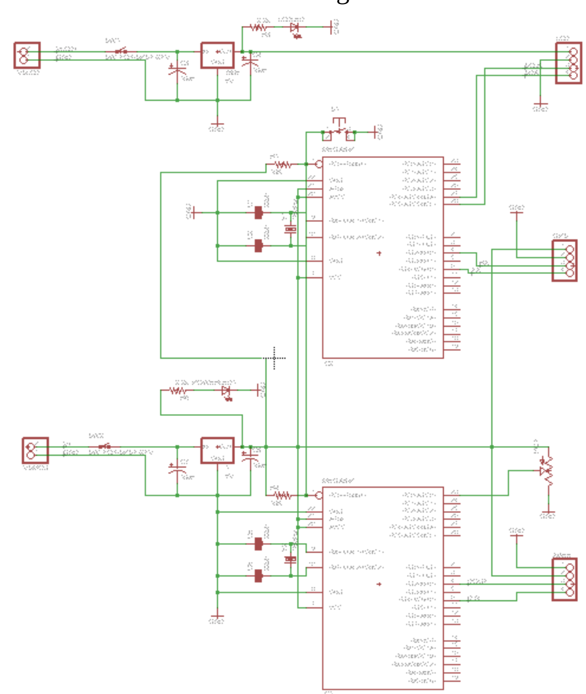

Figure16 – Data Control and Wireless Control Schematic

The second PCB design will consist of the motor control unit. This PCB will be localized at the bottom of the board and it will be connected to the battery and the DC motor. Figure 17 shows the PCB

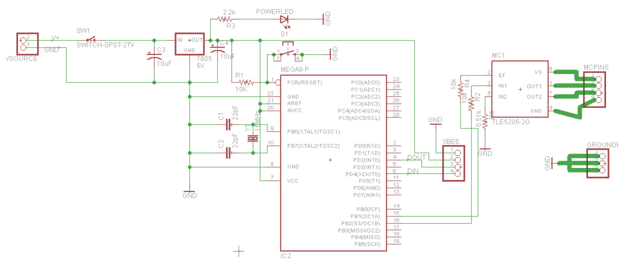

Figure17 – Motor Control Schematic

We used 4PCB to create our PCBs because they offered a great student discount, 33 dollars each PCB and they only take 1 week to create it and 1 week to ship it.

VIII. Conclusion

The scope of our senior design project bestowed upon our group a greater understanding of how all our engineering classes contribute to the design and build process. We not only learned a lot about the design build process but the importance of communication, patience and understanding with respect to working as a group. We are confident that our designs will aid our team into mastering the upcoming challenges in the future.

Acknowledgement

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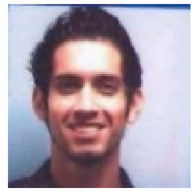
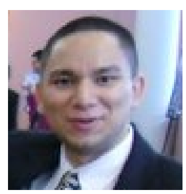
BIOGRAPHY



Cesar Romero will graduate and receive his Bachelors of Science in Electrical Engineering in December 2012. He has worked in Kimberly Clark and General Motors as an intern during the summer. Cesar plans on beginning his Masters in Science of Electrical Engineering Controls Concentration this spring of 2013.

Oscar Cedeño is planning to graduate with bachelor's degree on Electrical Engineering Science in December 15 of 2011. Currently, he is working at Publix supermarket. He also is applying at power energies industries like Progress Energy, Mitsubishi, and General Motors. Moreover, he is constantly looking to up grated his knowledge in different field of electrical engineering as filter design, controls, and telecommunication.



Camilo Romero will graduate in May 2012. He will receive his degrees as a Bachelors of Science in Electrical Engineering and a Bachelors of Science in Computer Engineering. Camilo plans to pursue his Master of Science in Electrical Engineering in the Fall of 2012.

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