Safety and Security Enhanced Wheelchair

Ryan Pearce, Trent Gallagher, Angelo Biaggi, and Lomar St.Louis

Dept. of Electrical Engineering and Computer Science, University of Central Florida, Orlando, Florida, 32816-2450

***Abstract* — This paper presents the designs utilized to take a standard wheelchair and upgrade it with modern conveniences to improve the safety and usability for the operator(s). This is achieved by the use of a locking system triggered by both pressure pads or a unique Radio Frequency Identification (RFID) tag detected by the project. In addition, the chair will have a tracking and message alert system on it using GSM and GPS technologies to be able to use it in most locations around the world. This project was chosen because the current high-end wheelchairs do not seem to make good use of technology and are very cost-inefficient in their implementations. This project strives to achieve these features at a much lower price point compared to existing similar projects.**

***Index Terms* — Radiofrequency identification, RFID tags, GSM, Global Positioning System, DC Motors, Servomotors**

I. INTRODUCTION

Wheelchair usage is rapidly increasing in today's society, yet these devices are making little use of modern technology. Used by an ever-aging populous, this project is intended to improve the safety and security of the users. A GPS and GSM system can be used to locate the chair, see if it is currently locked or in motion, via text message and Google maps. A locking mechanism on the wheels will allow the chair to be left unattended or automatically lock for entry/exit from the chair without needing to manually lock the wheels first. The unattended system uses an RFID reader and a unique tag supplied to the user to allow them to lock and unlock the chair. This will reduce the chances of theft of the chair, a common problem in locations such as theme parks. The automatic locking when the user is attempting to enter or exit the chair is achieved by using pressure pads to detect extra armrest pressure, which will be the trigger for locking the wheels. An LCD screen will also be on the device to give basic feedback and status information to the user.

II. RFID

The security module uses an RFID reader and unique RFID tag. Together, this will let the device be left in an unattended mode so the user can leave it. This feature is often requested by theme parks to reduce the instances of hijacked wheelchairs while the user is on a ride.

The requirements of the RFID system were as follows:

- Must be functional in the presence of normal interference in populated areas.
- Must function if damp (rained on).
- Must function in a range of temperatures and humidity levels typical of habitable areas.
- Must consume a small amount of power.
- Must be able to penetrate at least a couple inches of wheelchair armrest material.

A. RFID Receiver

The RFID section of the project involves an RFID receiver connected to the microprocessor as well as an RFID key (with backups). To directly connect to a microprocessor, we use a serial port (rather than a USB port which we would use if we had an operating system running). The total profile will be about 2.5 by 3 inches while only being 0.14 inches thick (Figure 1). The serial port will be connected to the microprocessor by 4 ports; these ports are VCC, /ENABLE, SOUT, and GND.

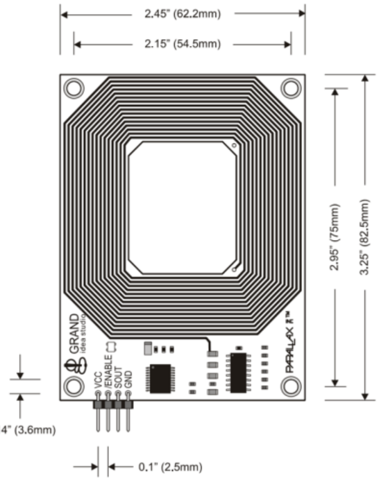

Fig. 1. Layout and dimensions of RFID Receiver device.

This receiver meets all the requirements listed above. The data is received over a standard serial protocol, with 8 data bits, 1 stop bit, no parity, and a transfer speed of 2400 bps. This low transfer speed is acceptable for the application of reading key on occasion. Noise is filtered out in software.

B. RFID Tag

There are four common frequency ranges used by RF systems. LF (low frequency) is around 125 kHz. HF (high frequency) is around 13.56 MHz UHF (ultra high frequency) is around 868/928 MHz Microwaves are the highest at around 2.45 GHz or 5.8 GHz. In the case of our project we do not need a high frequency for such limited data (and higher frequencies would require more expensive equipment at possibly greater power draw, as well). 125 kHz (low frequency) tags suffice for this project.

C. Software Behavior

See below for the logic behavior of the two functions, Unlock/Reset (Figure U) and Main/Scan (Figure T). Unlock/Reset is triggered when the receiver is given the correct tag or key, the receiver is shut off and the wheels are unlocked. Main/Scan is triggered when the "unattended" button is pushed, the wheels are locked and the RFID receiver begins to actively scan for keys until it finds a matching one, at which time the Unlock/Reset function is triggered again until the unattended button is hit (Figure 2).

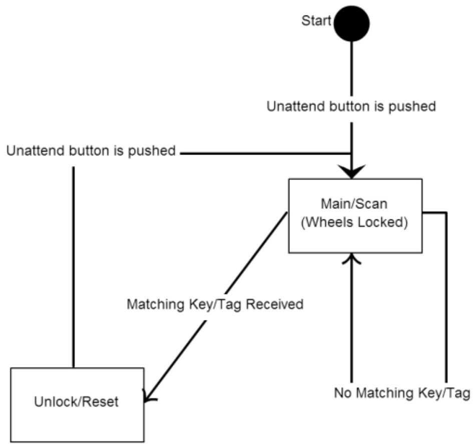

Fig. 2. The cycle of the unattended device RFID lock

Before the Main/Scan loop occurs, several actions are taken by the microcontroller right when the "unattended mode" button is pushed (Figure 3). The motor is sent a signal to lock the wheels, the RFID receiver is set to active (by setting /ENABLE to LOW), which causes the LED to turn red. There is also an optional speaker that could make a noise, but it is not mentioned in the figure because it could cause more annoyance to the user than helpful feedback. The LED being red will be a clear indicator that the wheelchair is locked, and should serve as a helpful reminder to the user without bothering surrounding people as the speaker output would.

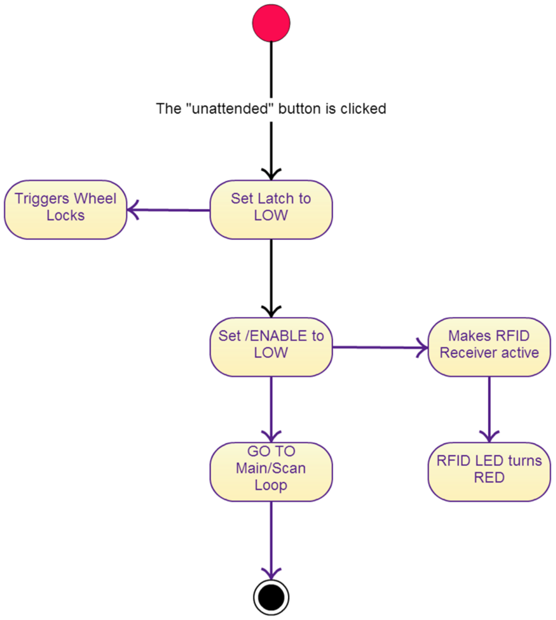

Fig. 3 Actions resulting from "unattended" trigger on microcontroller

After all this is done and the initial unattended mode is in place, the Main/Scan loop begins and continues until an unlock occurs from a correct RFID tag/key being given (Figure 4). Until this occurs the wheels will remain locked, the RFID LED will remain red, and the RFID receiver will continue to query. As an extra safety precaution to assure the key actually was supplied to and not just detected in noise, the loop will check for a match to occur twice in a short period of time (few seconds) before unlocking.

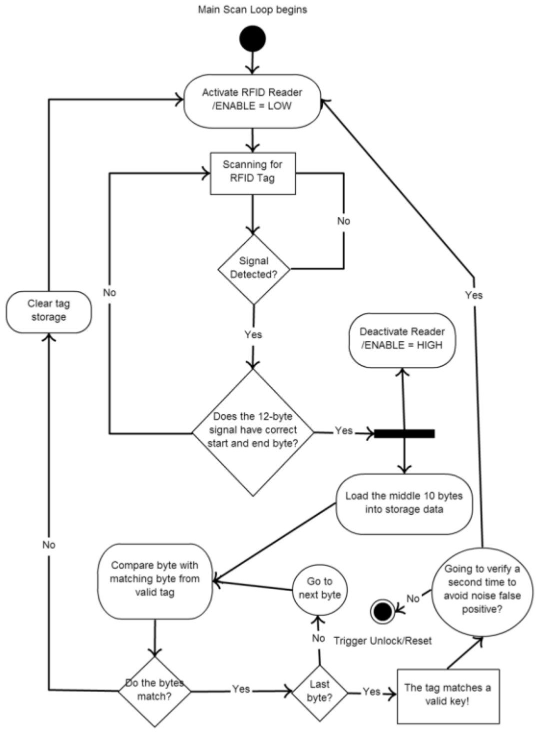

Fig. 4 The main scanning loop for RFID Software

The speaker sound will be an optional feature in the device design. While it is useful to have extra feedback while testing, some users may find an audible response annoying and unhelpful when there is already an LED that will turn red when the device is locked. The green as a confirmation of unlock, accompanied by the locking mechanism actually releasing the wheels, should be enough in this Unlock/Rest phase

III. MICROPROCESSOR

The microprocessor contains all the code that will control all of the electrical components. The ATmega328, designed by Atmel Corporation, is the Arduino compatible microprocessor that is in our system. Needing only 7 to 12 volts to power on but having a voltage range of 6 to 20 volts and drawing only 40mA per I/O pin makes this a very low power consuming microcontroller. In addition is contains 35kb of flash memory and has 14 digital I/O pins, which 6 provide PWM outputs that will be used for our locking mechanism. Being that we will need to connect a GSM, GPS, RFID, LCD, pressure pads, and a locking mechanism to our microcontroller we are using two ATmega328s to be able to have enough digital input and output pins.

The ATmega328 will be handing all data through the digital I/O pins. Being that the microprocessor is Arduino compatible existing open source libraries for various components that add extra reliability that the system will communicate with the modules effortlessly. Using the Arduino development environment, each pin can be calibrated to be either input or output. Since the GSM and the GPS modules do not depend on the other components, then these two will be on their own ATmega328 while the rest will share the other.

IV. GPS MODULE

Using a GPS module will give us the ability to be able to track the exact location of the wheelchair. The GTPA013 module, designed by GlobalTop Technology, is our choice for our Safety Enhanced Wheelchair. Needing only 5 volts to power on and drawing a maximum of 25mA, while tracking, fits our standard of having a low power module. The GPS has very strict electrical requirements. A bypass capacitor and maintaining a critical path resists leaves little room for error. It requires a clean well regulated power source and noise must be less than 20 millivolts. Noise can significantly affect the receiver. No prior programming is required since the module handles all the required initiation and calculations on its own. Also a ceramic antenna is directly attached to the module. The GTPA013 can also can track up to 22 different satellites at one time but only needs three to start sending valid data, has a “Time to First Fix” that takes as little as 45 seconds, and has a position accuracy of 1.8 meters. Taking advantage of the 15mm by 15mm dimensions we will place the module in a strategic location to reduce noise interference and also makes for having a smaller PCB, reducing the overall cost. Needing only an Rx and TX pin for data transmission saves the amount I/O pins for other future components. Overall to completely have a functioning GPS module take a total of just 4 pins, two for data and the other the for power supply. Its power consumption, reliability, and physical characteristics meet and surpass all of our requirements making it a perfect module for our design.

The module outputs data using the NMEA 0183 protocol. There are a variety of different ID headers that give different information but the data id header that we will be more concerned with will be the $GPRMC (Global Positioning Recommended Minimum Coordinates. It gives us the time, a status code with an indication if it’s a valid data stream, the actual latitude and longitude coordinates, speed, the date, and a checksum for reliability of a correct data transmission, as shown in table 5. The GPS module continuously outputs data to microprocessor which is then parsed within our code. Only data with a valid status code will be considered. It will continue to update as long as it is powered up and has a reliable connection to the satellites.

Message ID	$GPRMC	$GPRMC
Time(in GMT)	194509.000	07:45:09pm
Status Code	A	Active
Latitude	4042.6142,N	+40° 42.6142’
Longitude	07400.4168,W	-74° 00.4168’
Speed (in knots)	2.03	2.03
Tracking Angle	221.11	221.11°
Date	160412	16th of April, 2010
Checksum	A*77	77

Table 5: Example of incoming GPS data and representation of data

V. GSM MODULE

The use of a GSM module on our Safety Enhanced Wheelchair adds a variety of different features. The module essentially accomplishes most tasks that a cell phone can perform. Applying this technology to our chair allows for on-the-go and on-demand access to information. The M10 module, designed by Quectel Wireless Solutions, is the choice module for our system. To have a completely functioning GSM module we only need the data transmission pins to the ATmega328 and two other pins for a power supply. In addition to the module itself we must have a SIM card holder for the SIM card in order to connect to out GSM network as well as an antenna port. The SIM card holder needs 5 pins to operate and the antenna need three pins, two of which are ground, to operate and are all connected to the GSM module itself. Similar to all the other components it must be small, consumes low power, and reliable. It needs 5 volts to power on but we must use a bypass capacitor of 100uF to help with current bursts whenever there is a transmission and must be able to supply sufficient current up to 2A. Its 29mm by 26.9mm makes it a relatively small module which fits nicely on the PCB.

In order to connect to the GSM network we will need a GSM data plan. For our data plan we are using an AT&T pre-paid plan with a standard size SIM card that will authenticate our device’s permission to connect to the network. The antenna connecter will be a standard antenna pad that can connect a 50 ohm impedance antenna. Having the pad gives us the ability to switch out antennas in case of a failure or better technology is available. Taking in to consideration of these factors we have a great deal of reliability for data transmission.

Even though the GSM module is capable of different tasks, we will only be focused on sending and receiving SMS messages. Specifically a user will send a SMS message to our GSM module and will receive GPS coordinates along with date, time; if no data is available due to some error then an error message will be sent. The GSM module presents a unique risk factor. The GSM module is responsible for sending SMS messages with the GPS coordinate location of the wheelchair. If the module fails then we are putting the user at risk of not being able to locate their position. Extensive testing has been done to ensure that no logic errors exist and that the hardware is not easily susceptible to failure.

In order to communicate with our GSM module and other phones we will need to use AT commands as stated in the ETSI GSM 07.07. Our GSM is an AT command based module so the AT protocol will be used. The AT commands are sent from cell phones as well, so the GSM can take the data sent, parse it, and then send it the ATmega328. There, depending on the data received, will be an event triggered and the required data is then sent to the GSM module to be sent of back to the original phone number that initiated the event. In addition there will be a “bank” of valid phone numbers that will trigger events to prevent any unauthorized personal to gather any data about the Safety Enhanced Wheelchair. Figure 6 is a state diagram that demonstrates how the GSM module will work in the system.

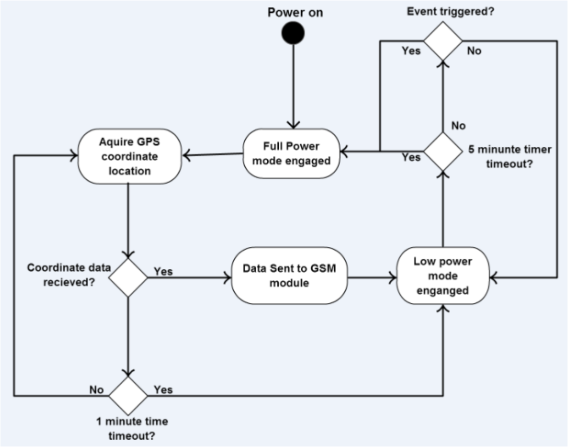

Figure 6: State diagram for the GSM module

VI. PRESSURE SENSORS

The use of pressures sensors is absolutely essential since our focus is to make the wheelchair as safe as possible and it is vital to know when the person gets in and out of the wheelchair. The pressure sensors have been placed at the optimal locations on the wheelchair, which is the arm rests as well as on the seat itself. This provides the ability to tell when the person who is using the wheelchair is attempting to get in and out of it. The pressure sensors that are being used are the A401 FlexiForce force sensors that are produced by Tekscan. These Tekscan force sensors are the most compatible to the requirements of our project. The sensors are incredibly thin, flexible, detect changes in applied load, measure the rate at which the applied load changes, and the range of pressure that can be measured can be easily adjusted. The amount of pressure that these sensors can measure without any modifications to increase or decrease this value is twenty-five pounds. The A401 FlexiForce force sensors are 0.208 mm thick, 58.8 mm long, 31.8 mm wide, have a 25.4 mm diameter sensing area, a response time of less than five microseconds, can be safely operated between the temperatures of -40°F to 140°F, and can accurately sense forces from zero to one thousand pounds.

There is one pressure sensor on each arm rests and one pressure sensor on the seat of the wheelchair. The pressure sensors that are on the arm rests have been strategically placed towards the end of the arm rests where the person who is using the wheelchair will most often place his or her hands when getting in and out of the wheelchair. The pressure sensor that is on the seat of the wheelchair has been placed near the center of the seat to provide the most accurate reading possible every time someone gets in and out of the wheelchair.

To be able to use the A401 FlexiForce force sensors, these sensors are being supplied five volts and are also being connected to the analog input pins of the Arduino microcontroller. A total of three analog input pins are being used. This grants the ability to detect when a force is being applied to each individual force sensor. When a force is applied to the force sensors the resistance of the force sensors decreases, which increases the voltage that gets received by the analog input pins. This increase of voltage is easily detected by the Arduino microcontroller and is what is being used to determine if a person is getting in, out, or currently sitting in the safety and security enhanced wheelchair.

VII. LOCKING MECHANISM

One of the main goals is to stop the standard wheelchair locks from ever being used by the person who is using the wheelchair. The standard wheelchair locks are unreliable and are commonly forgotten about when attempting to either get in or out of the wheelchair. Due to this serious safety issue, the locking mechanism that has been implemented completely removes the necessity for the standard wheelchair locks. The locking mechanism actually allows the person who is using the safety and security enhanced wheelchair to no longer worry about remembering to use the standard wheelchair locks before getting in and out of the wheelchair.

To create a locking mechanism that is the safest and most convenient for the person using the wheelchair, the locking mechanism does not require any activation by the user of the wheelchair. The entire locking mechanism is comprised of two main components. The two main components of the locking mechanism are disc brakes and a solenoid.

VIII. DISC BRAKES

The required force to activate disc brakes on wheelchairs is significantly less than any other non-autonomous braking system that is currently built for wheelchairs. One of the many great advantages of disc brakes is that they supply tremendous stopping power even when having to deal with significant amounts of heat and water. The stopping power is significant in tough conditions due to the fact that they use hard pads, which provide more reliable braking power compared to pads that are soft and rubber. The tremendous stopping power of disc brakes is due to the fact that they use calipers and rotors, which also makes then incredibly reliable. Each disc brake has mechanical two piece forged aluminum calipers, tri-align caliper positioning, sintered pads, dual knob pad adjustment, G2 CleanSweep rotors, and weigh only three hundred twenty-nine grams.

One disc brake has been assembled and mounted for each wheel of the wheelchair. The rotors are attached to the wheels because they need to spin with the wheels. The calipers are attached to the frame of the wheelchair because they need to stay stationary. Even though the rotors and calipers are attached to different parts of the wheelchair, the calipers are still mounted properly on the rotors. Since the disc brakes utilize bicycle cables to function properly, the bicycle cables have been properly connected from the calipers to the solenoid.

IV. SOLENOID

The type of solenoid that is being used is a box frame solenoid. The stroke range of the solenoid is one eighth of an inch to one full inch. The pull force range is from twenty to one hundred thirty ounces. The solenoid is one inch and nine sixteenths of an inch wide, one inch and five eighths of an inch thick, and two inches and three sixteenths of an inch long. It has a coil resistance of 4.68 ohms, eight mounting holes, class one hundred five coil insulation, and is made of steel. To properly operate the solenoid, it requires 12 volts, 2.6 amperes, and a total of 32.3 watts. The purpose of the solenoid is to pull the cables of the two disc brakes. This causes the disc brakes to fully engage, which prevents the wheelchair from rolling forwards and backwards. The maximum pull force of one hundred thirty ounces is more than sufficient to fully engage the disc brakes because the amount of ounces that it takes to completely activate the disc brakes is forty-eight ounces.

To be able to properly utilize the solenoid to engage the disc brakes when appropriate, the use of a mosfet and diode are an essential requirement. The mosfet that is being used is the N-channel FQP30N06L mosfet. It can handle up to 60 V, 32 A, and 175°C. Also, it is 9.9 mm wide, 29 mm long, and 4.5 mm thick. This N-channel mosfet has exceptional maximum switching characteristics. Its turn-on delay time is 40 ns, turn-on rise time is 430 ns, turn-off delay time is 130 ns, and turn-off fall time is 230 ns. The main reason for choosing this mosfet is because it has an incredibly low gate threshold voltage, which ranges from 1 V to 2.5 V. The gate threshold voltage of less than 2.5 V is required to be able to use the 5 V from the Arduino microcontroller to reliably switch on and off the current flowing through the mosfet. The diode that has been chosen to be used is the 1N4001 rectifier diode. It is frequently used for reverse voltage protection and has a high surge current capability and low forward voltage drop. The key reasons for choosing this rectifier diode is because it can withstand up to a 30 A peak surge current and 50 V of peak repetitive reverse voltage. It can also operate in temperatures that range from -55°C to 175°C. The purpose of this diode is to protect the mosfet and other electronic components from any potentially harmful current that is forced back from the solenoid when switching occurs within the mosfet.

The solenoid will only draw power when the mosfet receives a high output signal from the Arduino microcontroller. The high output signal is produced from a digital I/O port that is on the Arduino microcontroller. When the brakes do not need to be engaged, the solenoid will be powered off by sending a low output signal to the mosfet from one of the digital I/O ports that is on the Arduino microcontroller. Since the digital I/O port that is being used has PWM capability, the speed and distance of pulling the piston of the solenoid is able to be controlled by sending the appropriate PWM signal to the gate pin of the mosfet. To be able to control the solenoid on command, it has been setup to directly receive 12 V into its positive terminal, the negative terminal is connected to the source pin of the mosfet, the diode is connected between the positive and negative terminals, the digital I/O port of the Arduino microcontroller is connected to the gate pin of the mosfet, and the drain pin of the mosfet is connected to ground. The schematic that has been used to control the solenoid using the Arduino microcontroller is displayed below in Figure 7.

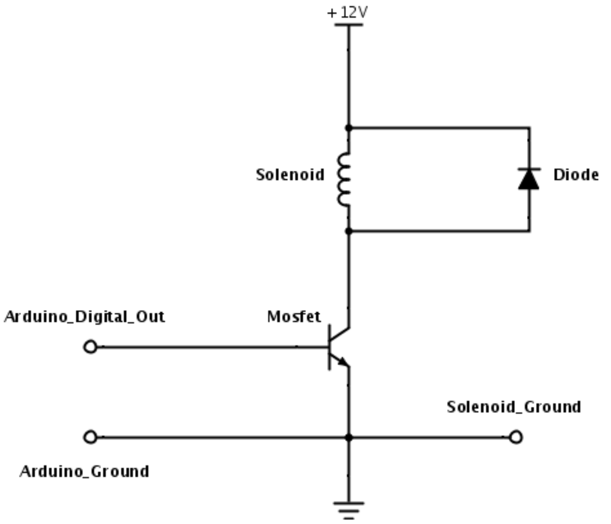

Figure 7: Schematic for controlling the solenoid

X. LCD SCREEN

The LCD chosen for this project is a HD44780U character-like display which of consists of 4 rows with 20 characters on each row. The primary purposes for the LCD is to display whether the locking mechanism is in the Unlocked/Locked Position, The Power level of the Power supply, and whether the RFID is being has been detected or not detected. All of these feature just to display info for the user. Figure 8 shows exactly how the display screen will look.

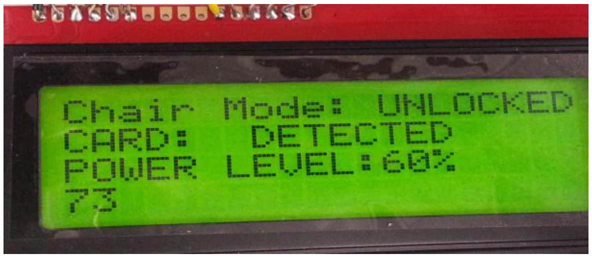

Figure 8: 20X4 LCD displaying the data required

The device has an input voltage of 5V, which will be draw the power will be draw from the microcontroller.

The LCD will receive data from the RFID Sensor, Motor driver, and power supply in order to update the information needed, which will all be connected to the same microcontroller. The LCD will be connected to the microcontroller using a 4 digital I/O ports for data lines, Digital I/O port for the enable, and one more pin for the r/s port. The Dimensions for the LCD is 116.0 * 36.0 * 26.0 mm

XI. POWER SUPPLY

The Power supply that we are using is a Lead Acid 12V battery with a capacity of 7.5Ah. It has been primarily chosen this battery because cost, availability, feasibility, efficiency, precision, size and weight. For this project, the power supply will handle both microcontrollers, GSM, GPS, liquid crystal display, the solenoid, RFID, and Pressure pads. Our dimensions for the battery are 4.65' x 2.25' x 3.12'. The battery used in this project is shown in Figure 9.

Figure 9: 12 volt battery with 7.5Ah

Because the power supply requires so much, it will only be able to be on for about 7 hours. Since the solenoid is the only component that has a voltage of 12, we are using a voltage regulator to step down the voltage for the other components.

XII. VOLTAGE REGULATOR

The primary purpose for the voltage regulator is to drop the voltage from 12 volts to 5 volts, which for this project the RFID, GSM, LCD, microcontroller, GPS, and Pressure pads cannot handle more than 5 volts otherwise it will burn out the components. Figure 10 below shows our circuit with our voltage regulator attached, which is the LT1676 regulator, which puts an has a peak switch current rating of 700mA. It will the circuit used for the microcontroller.

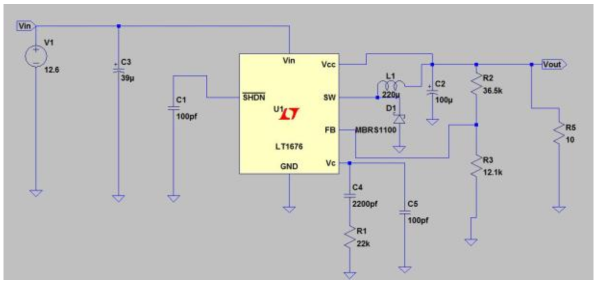

Figure 10: Circuit showing the voltage regulated

We built this circuit in LT splice since the regulator used is made by the same company. We used 2 special capacitors with weight of 39uF and 100uF, and a MBRS1100 diode along with the rest of the circuit. When we simulated it are able to output the result of 5 volts for the voltage output (Vout) and 500mA for the current when we measured the R5 resistor showing 10 ohms. The Figure 11 below shows the simulated results of the voltage regulator circuit. Which the green line is the voltage input(12V), The voltage output is the blue line, and the current output is the red line.

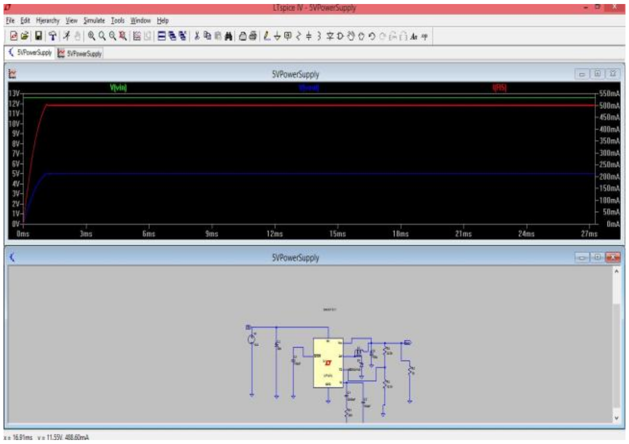

Figure 11: Results of the voltage regulator with the green

XIII. PRINTED CIRCUIT BOARD

We have design a printed circuit board using the software called eagle to implement all the components together. The printed circuit board has board microcontrollers followed by the GSM with a sim card holder mounted to the board, along with the switching regulator. The board has a series of holes in which we will connect the LCD, GPS, RFID, Pressure sensors and solenoid to it via wire. Attached is our printed circuit board which has all the components that are attached to the board. For out solenoid we are using a mosfet, so that will be implementing to power the solenoid. Figure 12 shows out printed circuit board

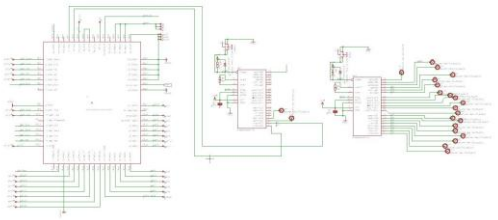

Figure 12: printed circuit board

XIV. ACKNOWLEDGMENT

For this project, The entire group would be gratefully appreciate all the teaching assistants especially Mike Tullbance for taking time aside for helping point in the right direction with good valuable information, and we also would like to thank Peter Obeng and the amateur radio club for assisting with the soldering components of our project. We sincerely thank Dr. Samuel Richie, Dr.Arthur Weeks and other all the other faculty who pushed us all the way and motivated us to stay on task to the end. We would also like to thank Linear Technology for giving us sample multiple of their components.

XV. CONCLUSION

All of these modules combined allow us to take a standard wheelchair and upgrade it with modern technology to allow a user a safer, more secure personal transportation device. These parts comprise a lower cost than other "smart chairs" and give us a more modular system which can still function if one part is damaged or lost.

XVI. REFERENCES

[1] *"M10 Hardware Design"*, 2010-07-30, Quectel Wireless Solutions
[2] *"ATmega48PA/88PA/168A/328P datasheet"*, Atmel Corporation
[3] *"FGPMMOPA6H GPS Standalone Module Data Sheet"*, 2012-1-31, GlobalTop Technology

Ryan William Pearce is a student graduating Fall 2013 from the University of Central Florida with a Bachelor of Science in Computer Engineering. He is currently working with a team on the graphics driver development of upcoming Windows based smartphones and tablets at QUALCOMM, and plans to continue pursuits in the area of mobile device development after graduation

Trent Gallagher is a senior at the University of Central Florida. He is graduating with a Bachelor of Science in Computer Engineering in December 2013. His area of interest is in low level software design and intends on working in the field of embedded systems engineering.

Lomar F. St.Louis is a Computer Engineering student graduating December 2013 from the University of Central Florida. His Interests include running, swimming, reading, volunteering, and computer architecture and quality assurance. His goal is to seek a career in Aviation software development. Upon receiving his degree, he is trying to pursue a career in quality assurance/software development for a major corporation, eventually pursing his masters in Computer Engineering.

Angelo Augusto Biaggi, a senior student of the computer engineering department at the University of Central Florida. Will pursue a working career in the computer engineering profession and will continue his studies in the Masters of Business Administration.