Safety and Security Enhanced Wheelchair

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Group 10
Safety enhanced Wheelchair

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1 Executive Summary

This project was a Safety and Security Enhanced Wheelchair, or “SmartChair.” It augments a normal, non-motorized wheelchair to create a “smart” wheelchair at a much lower cost than full electronic chairs currently on market and with more automated capabilities. A pair of microprocessors were used to handle communication between pressure pads (to detect when the user was entering or exiting the wheelchair), wheel locks, switches, a basic battery display, and RFID receiver for user proximity detection. In addition, there was a GPS system in place that will allow for the user to go to a personal webpage and view the path and last known location of the wheelchair (for caretakers, especially of the elderly). All of these were powered by one battery which will attempt to charge from the wheels spinning. The main objective of this project was to create a “smart” wheelchair without excessive costs, making most modern technological conveniences available to wheelchair users. The GPS system website portion was powered by Google Maps. The RFID system was integrated into the microprocessor (MSP 430). The pressure pad input and locking mechanism output will also go through the MSP 430. In addition, there was optional switches available (such as by the handles) to lock or unlock the wheelchair but only when the RFID was in range. Regarding the RFID key and receiver; a button was used to lock the wheelchair, regardless of the state of the pressure pads, when leaving it unattended and the RFID key was used to unlock the wheelchair from this mode. This project, when completed, will offer benefits to current wheelchair users to improve their safety, security, and convenience given the technologies listed. In the initial prototype, ergonomics and aesthetic appeal was of no concern, and only the functionality of all the components was tested. Extra safety for the user, comfort, and aesthetics would be a focus for the final design; the prototype will primarily consider the technical aspects. The exception to this was the website interface for the GPS module, which was a simple but elegant layout. The design also attempted to be as modular as possible. If one component fails, the others should continue to function as correctly as possible given the one failed component. This will mitigate risk to the essential components of the project while also increasing the chance of success. Power efficiency was a must to reduce how often charging was needed. This project, when completed, will offer benefits to current wheelchair users to improve their safety, security, and convenience given the technologies listed. These features will have been tested in a wide variety of environments to ensure that even the more adventurous users still have a functional device no matter where they go!

2 Project Description

2.1 Motivation

According to the US Census, about 3.6 million people in the USA use a wheelchair and 11.6 million use a cane, crutches, or walker to assist with mobility

(US Census, 2010, pg 8, http://www.census.gov/prod/2012pubs/p70-131.pdf). Only a small fraction of these people use electronic wheelchairs [R1].

This project was intended to bring modern convenience to the millions of people using manual wheelchairs, presumably because of cost, without having them incur the full expense of a “luxury” electric wheelchair. The project should increase the safety and security of the wheelchair users, while also making life easier for any caregivers they might have.

In seems unacceptable in this day and age that an assistant must first circle a wheelchair and remember to manually lock each wheel separately before moving someone in or out of the chair—to avoid an accident and possible great injury to the wheelchair user.

It should also be noted from the census that the employment rate of wheelchair and walker users was very low, at 17.4% and 14.5% respectively [R2], this suggests that they may want a more advanced assistance device but may not have the income to purchase the full electronic wheelchairs. This project should allow for such lower-income users to still access the convenience and safety offered by modern technologies.

As seen in Figure A, not only has wheelchair usage been increasing (ever since it doubled from 1980 to 1990 and continued to grow in usage per capita), but it was projected to keep growing over the coming decades. The motivation was here because technology will continue to get cheaper and there was no need for these people to be lacking in technologically modern transport if they need mobile assistance in their day-to-day lives.

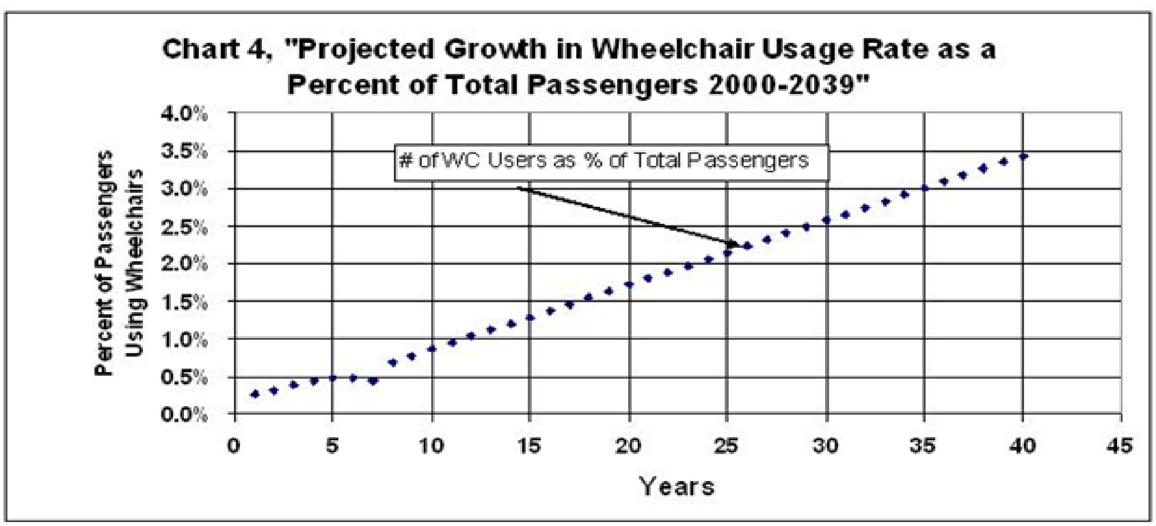


Figure 2.1: *Projected percent of passengers that were wheelchair users*
Used pending permission from access-board.gov

2.2 Goals and Objectives

The Safety and Security Enhanced Wheelchair should be able to lock and unlock its wheels based on pressure pads (for automatic detection of user entry/exit) or switches (for convenient manual override of the wheel locks). This should occur as long as the battery has enough charge to power the locking mechanism. When the pressure pads detect a user was attempting to enter or exit the chair (for example: if more weight applied on the armrests than in the seat) the wheels was locked until a few seconds pass that the weight has settled in the seat.

The project also supports secure locking of the device with a switch when the user was going to leave it unattended. The device was unlocked from this state only by an RFID key which the user was included. This was a feature to support the security of the device and deter theft of the wheelchair (a common problem in theme parks).

A key part of the project was the power supply. Although the microprocessor uses little current, the battery may require outlet charging if the locking mechanism turns out to be too much of a drain. Voltage will need to be transformed in a maximum efficiency manner for all the different components' requirements. Capacitors may be required to build and hold a larger charge for the locking mechanism. Overall the system should be as low-power as possible.

By way of a web interface, the user should be able to track the location history of the wheelchair with knowledge of the key supplied with the GPS in the unit. This web interface was simple and allows someone to find the last known location. A useful purpose of this would be to allow caretakers to locate the wheelchair user in case of them wandering off (as does happen on occasion in care facilities, especially for the elderly).

An MPS430 will efficiently centralize the combined logic for all these modules in the project, while implementing add-ons where necessary (such as for an RFID receiver). The locking mechanism does not need to be quiet, as an audible recognition of the locking/unlocking may be useful to the user. The project was easy to use, being mostly automated with only a few optional switches to change behavior. Once built, the unit was integrated with the wheelchair. The only moving part (and therefore the only part prone to failure over time) would be the mechanical locking mechanism, but hopefully the mechanics will last for several years at least.

We hope that this project will prove to be of benefit to wheelchair users; improving their safety, security, and convenience by using modern technology.

2.3 Project Requirements and Specifications

2.3.1 Software Requirements

Software requirements were built around the needs of the project as the version of a final product being discovered. These software requirements are meant to be comprehensive not extensive. These requirements describe what features must be included in the software application. These requirements also describe how the software will interact with the hardware to form a seamless bond between the two, to create a finish product.

- The sensor chip must be wireless
- The Device shall have a GPS locator
- The Device GPS locator
- The LCD should determine whether the device is unlocked or locked
- The device must have a programmable sensor chip
- The wireless remote (sensor chip) should be battery powered
- Wireless remote must have a unique key to device
- The wireless remote should flash when device brakes are being unlocked

2.3.2 Hardware Requirements

Hardware Requirements are for reference as the project is developed and designed, and for guidance toward the final goal of this project. These requirements are there to be comprehensive, but not overly extensive. Ideally, all of the requirements ahead will be achieved throughout the development process. However, as the project progresses alterations may have to be made.

- The device must be a wheelchair
- The device should be equipped with custom automatic brakes
- The brakes should be battery powered
- The device must have custom brakes on both wheels
- The device shall be equipped with a pressure sensitive pad
- Pressure sensitive pad must be able to determine if user is getting up or not
- The pressure pad must determine whether owner is out of the chair or not
- The device's brakes should be power by battery
- The battery must have a charging device
- The brakes must automatically lock when the pressure pad detects no weight
- The brakes must automatically unlock when device remote is in range
- Brakes must be able to remain locked when remote is not in range
- The device must be equipped with a hand bar to lock manually
- The brake must have a failsafe in case power goes out

2.3.3 Specification

The Specifications displayed in the Table below are for the Overall design of this project; therefore most of the measurements include not just one component but multiple components.

Wheelchair	2 Big Wheels(16” x 18” x 18”)
Battery Life	12 hours
Power Consumption	5V-12V
Weight	< 20 pounds
Pressure sensitive pads(3)	3 strips (0.5lbs each)/ 5V
LCD voltage	5V
Solenoid(2)	12V
RFID	5V
Unattended Button	5V
GPS/GSM	5V

3 Research

3.1 Existing Products

Lock Controller - While researching for this project, few similar projects were found. One project by a team at University of Alberta made a wheelchair lock controller in year 2010-2011 (Figure B). This was basically brake hardware with a switch attached to it. Just the fact our locking mechanism was automatic was an advantage, not even considering the great number of other features our wheelchair upgrades add**.**

Figure 3.1A- *Wheelchair Lock Controller - David Baron, Denis Gerow, Matthew Leggott*

GPS Tracking – There was a product already on the market for tracking wheelchairs by GPS. It was standalone, as was our design. Its stated purpose was also for tracking the elderly (although it also lists teens as a potential target). The GPS tracker was about the size (Figure C) and complexity of a standard GPS system which needs a SIM with data to work (Figure D). Our device will have the same hardware but the software side was superior. The software for our GPS unit will allow the user to be sent emails as well as have a location history (not just current location) tracked online. This was far more user-friendly than the approach used by ElectroFlip. [R3]

Figure 3.1B – *GPS Tracker by ElectroFlip – Size Comparison* [R3]

Figure 3.1C – *GPS Tracker by ElectroFlip — Insides* [R3]

RFID Proximity Lock— Although the use in wheelchairs seems to be novel, the concept of proximity locks by RFID keys was common for door entry (Figure E) [R4]. The only flaw which some models have was that if you power cycle the device (by disconnecting and reconnecting a wire) they will trigger the unlock. This flaw (which we will avoid in our design) would not matter so much with the wheelchair as someone taking the effort to break and reconnect the correct power lines would be comparable to someone stealing a chained bike, and that was if you assume the 'hacker' knows the electrical layout of our project.

Figure 3.1D — *Example RFID door lock with 10 keys* [R4]

Pressure Pad—There was a product for "fall detection" which was very similar to the pad detection for locking. A comparable item would be the *Smart 45-Day Pressure Pad for the chair.* (Figure F). [R5]

Figure 3.1E *— Sensor Mat for Chair* [R5]

This item recommends replacement after it "expires" which presumably would be every 45 days. Such a requirement will not exist in our enhanced wheelchair product. As the pads were wired, power will not be an issue. Since pads will make indirect contact, other concerns mentioned on the product page (such as bacteria) will also not be as much of a concern in our project. In addition, to make use of the product you must buy a much more expensive smart call alarm (Figure G) [R6]. This totals a much greater cost to simply have an alarm go off when the weight was removed from the pad. The alarm (Figure G) and the key (not shown) were far too complicated and expensive a solution for simply sensing a weighted pad.

Figure 3.1F— *Smart Safety Auto-Reset Fall Prevention Monitor with Adjustable Tone, Volume and Delay for Bed, Chair and Floor Mats* [R6]

3.2 Relevant Technologies

3.2.1 GPS

GPS was one of the technologies relevant to our project. To track the device's location, satellite-based location tracking was both low-cost and widely available for tracking the device across the world. Approximate location (the entrance to a building the device was currently in) was enough in most cases, so GPS's relatively low accuracy from inside a building was a negligible downside.

3.2.2 GPS Server

There were some open-source GPS servers which can be downloaded and were free to use; this helps both the cost of man-hours and the financial cost of the project. The server receives data from the GPS unit and sends the data elsewhere to be turned into a useful report. In our case, that data would be sent to be logged for the location history map. To allow the tracking to work as far as possible, both the GPS and the GPS Server must be able to receive and transmit data; therefore the GPS server will use the cell towers (GSM) to send data.

3.2.3 GSM

To go along with GPS for global coverage, GSM was used because it was a standard available worldwide by cell phone towers (as opposed to CDMA, which was only used in certain parts of the world). This way the entire tracking package can work worldwide in case the user of the wheelchair wishes to travel out of North America to anywhere in the rest of the world.

3.2.4 Pressure-Sensitive Pads

To detect the weight of the user on the seat and handles (in order to determine when to lock and unlock the wheels), pressure pads were needed to be installed in a comfortable way within the device. Such pads will allow for user movement.

3.2.5 PHP

To make use of the GPS data, we need a webserver that can dynamically change the web page it displays to the user in a way that simply HTML does not allow. This was where server-side PHP comes into play, allowing for a Turing-complete programming language for the web.

3.2.6 Database Server

To store all the data coming from the GPS server, and be able to read it out quickly for website display when necessary, we need a fast and robust database system. MySQL was the standard for the majority of database servers and it was free. There were other database servers but most were not free and the remaining have simply fallen behind MySQL's technical abilities and performance for most purposes.

3.2.7 Web Server

To actually output the web pages to users which could be accessing the display history from anywhere in the world, a robust web server was needed. A free, familiar, and very popular server was Apache. This will allow relatively painless integration with PHP5 as well as MySQL for the purpose of displaying the tracking webpage portion of the project.

3.2.8 RFID

RFID technology was used to give a "unique" key to a user, which outputs a specific frequency. A receiver was then used which will cause some action to occur when a key matching the required code was placed in proximity to it. This technology was used to securely lock the wheelchair when unattended.

3.2.9 Cable Disc Brake

This type of Brake was necessary for our project because we wanted a brake that could apply a solid lock on the wheel without requiring a great amount of force applied. This type of brake technology can be easily locked and unlocked with (relatively) low power motors.

3.3 Strategic Components

3.3.1 GPS Module

The GPS module was a strategic component because of power. When given a better connection, the module will consume more power by updating constantly. Even though (due to a requirement of a clean power source) the GPS module will have its own power source, a balance between update frequency to get the device’s location and power usage will have to be achieved in order for the GPS module to last long enough for comfortable use, without making the frequency of the location update too slow to be useful if the user was on the move.

3.3.2 GSM Module

Similar to the GPS module, the GSM module was a strategic device because it communicates will cell towers, which consumes power, while still needing to conserve power usage in order to last long enough for regular use. The GPS module gets the device’s location and the GSM module must send that data to be used by the web server.

3.3.3 GPS Server

The GPS server was used to log and trace the device’s location using the information sent from the GSM module. If the server did not exist, information would be limited to getting a text message or similar format with just the current GPS coordinates. This would not be a very useful or user-friendly solution to tracking a possibly moving device.

3.3.4 RFID Receiver

The RFID Receiver functions as a strategic component which only needs to be online when the device enters an “unattended” lock state. Once in the lock state, the device will remain locked until the correct RFID key was shown to the receiver. Due to the fact that the RFID was not needed when the device was unlocked, the receiver can stop consuming power until the device was put into secure lock “unattended” state again.

3.3.5 RFID Key

The RFID Key was a standalone key with a lifespan which should not be any concern to the user. This key was necessary (and should have a backup) to unlock the wheelchair once the device was put into a locked “unattended” state. The key only needs to be coded with the same RF used to unlock the chair when received by the RFID receiver.

3.3.6 Wheel Brake / Lock (Cable Disc Brake)

A core part of the project, the wheelchair brake/lock mechanism needs to work reliably and consistently. It will lock in response to the unattended mode after which it will unlock from the RFID key. It will also lock when there was more pressure on the armrests than on the seat (when the user was getting in or out of the wheelchair), in order to safely allow the user to maneuver without having to worry about manually locking the wheels first. It will also be able to lock and unlock using a switch by the handles, in case someone was assisting the wheelchair user. The cable disc brake was key because of its relatively low power requirement to apply braking force as well as the reliability of it for medium to long term usage, especially if we were applying braking while the wheelchair was usually at a stop.

3.3.7 LED Screen

The LED screen was a strategic component which displays basic information about lock status and (optionally) battery level. The technology was so low-power that it can be powered just by the output from the microcontroller to display basic data.

4 Design Detail

4.1 Development Strategy

Developing the final project will require that we break the system down into different components. Our method is for each person to choose different components that they are interested in implementing or learning about. Table 4.1 shows which team member is responsible for which component. Each individual must research every aspect of their component and be capable of implementing the design, schematic, and coding. Multiple meetings are held to get the whole team up to date on the projects current state, provide component data and specifications if a dependency occurs, and discuss any current or forthcoming issues. Using this strategy we have team members that are basically an expert on his components, instead of knowing a little about all the components.

Name	Component(s)
Angelo Biaggi	GSM module, GPS Module, and Microprocessor
Trent Gallagher	Locking Mechanism and pressure sensors
Ryan Pearce	RFID
Lomar St.Louis	LCD and power supply

Table 4.1: *Team member chosen components*

4.2 RFID

4.2.1 Technology Overview

RFID stands for “Radio Frequency Identification,” and was a generic term for technologies that use radio waves without touching the object as a means of identifying objects (or people). The most common method (and the method we were using in this project) was using a unique serial number attached to an antenna.

There were two types of tags; in this project we were using Passive Tags. Passive tags have a shorter range than active tags but require no power source of their own. They work by harvesting the RF energy emitted by the receiver, modulating it and then transmitting the data back to the reader. The reader receives these waves and translates them into digital data. That data can then be used by our microprocessor software to check if the key matches.

There were four common frequency ranges used by RF systems. LF (low frequency) was around 125 kHz. HF (high frequency) was around 13.56 MHz. UHF (ultra high frequency) was around 868/928 MHz. Microwaves were 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.

4.2.2 Receiver Overview

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 was about 2.5 by 3 inches while only being 0.14 inches thick (Figure 4.2.2). The serial port was connected to the microprocessor by 4 ports; these ports were VCC, /ENABLE, SOUT, and GND (Figure 4.2.3).

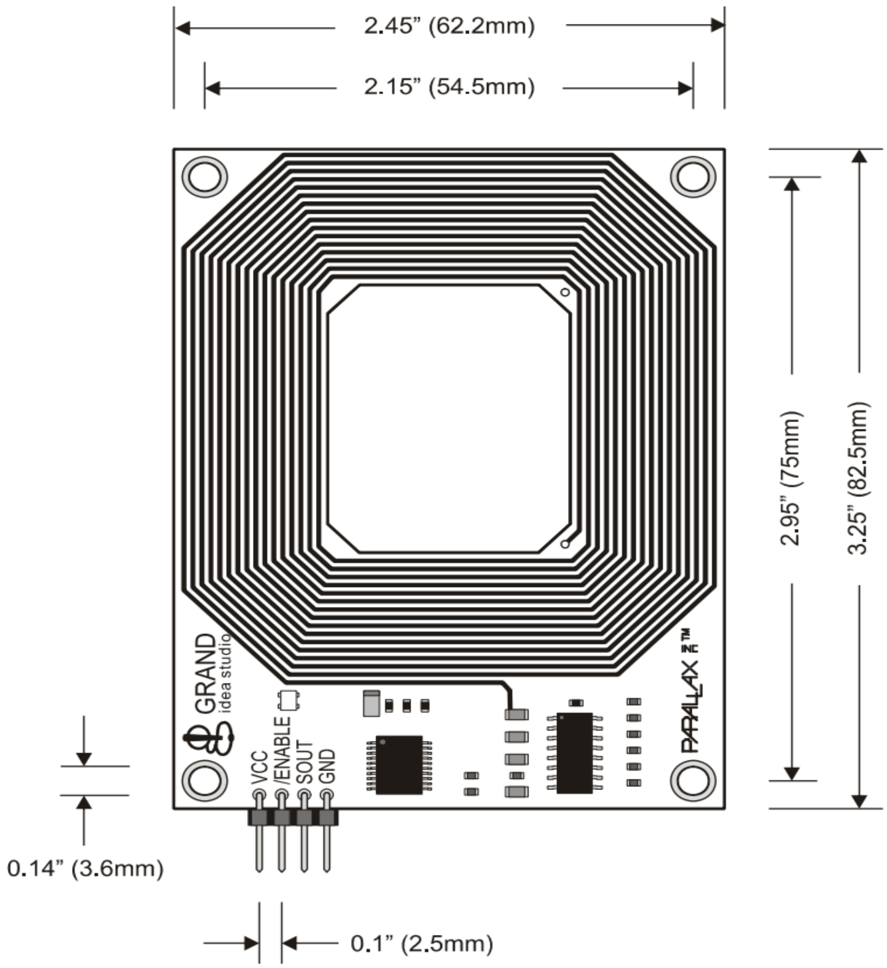


Figure 4.2.2: *RFID Card Reader, Serial*
Used with permission from Parallax

4.2.3 Serial Interface

The serial interface used by the receiver has 4 ports; VCC, /ENABLE, SOUT, and GND. This interface allows for easy connection to any microcontroller. The function of each port can be found in Figure 4.2.3.

Pin	Pin Name	Type	Function
1	VCC	P	System power. +5V DC input.
2	/ENABLE	I	Module enable pin. Active LOW digital input. Bring this pin LOW to enable the RFID reader and activate the antenna.
3	SOUT	O	Serial output to host. TTL-level interface, 2400 bps, 8 data bits, no parity, 1 stop bit.
4	GND	G	System ground. Connect to power supply's ground (GND) terminal.

Note: Type: I = Input, O = Output, P = Power, G = Ground

Figure 4.2.3: *RFID Receiver Serial Ports*[R7]

he standard circuit to interface was very easy given this layout, with only needing +5V into the VCC (and GND in GND of course), an enable line and an output line going to the microcontroller (Figure 4.2.4b).

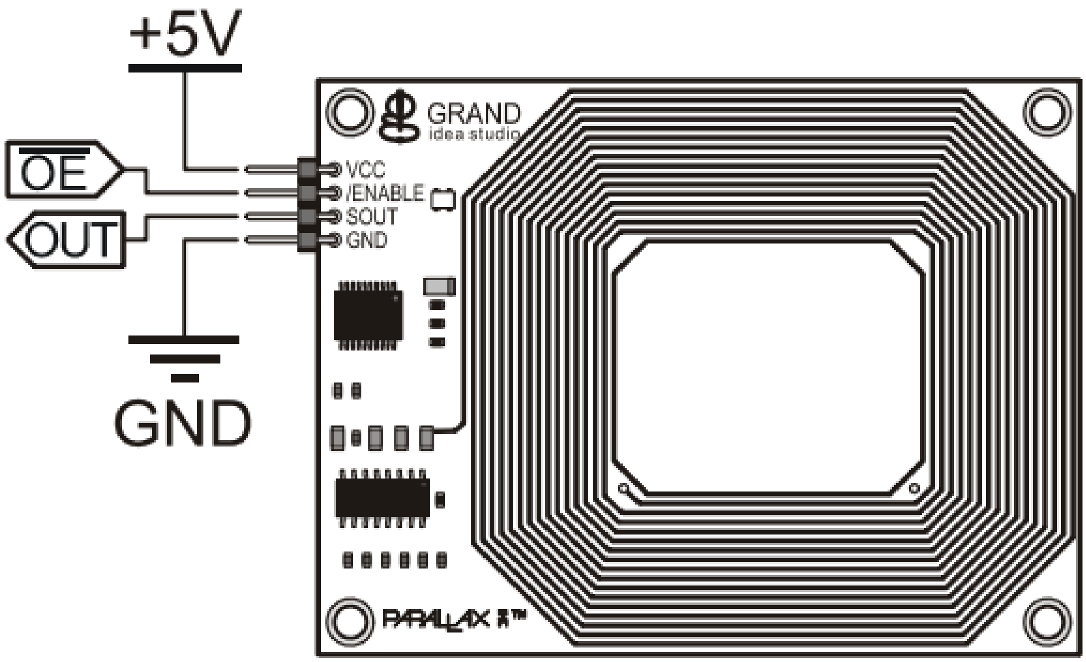


Figure 4.2.3b*: Example Circuit for connecting RFID Reader.*
Used with permission from Parallax

4.2.4 On-board LED

The LED gives basic feedback for the user. For the states of the LED, see Table 4.2.5.

LED Color	Meaning	Occurs When
GREEN	Idle state - Not searching	/ENABLE port was either HIGH or disconnected
RED	Actively searching for RFID key	/ENABLE was LOW
Blank	No power	VCC was low or disconnected

Table 4.2.4*: LED Colors on RFID Receiver*

4.2.5 Basic Usage

Once the LED was red (actively searching for a signal when /ENABLE was pulled LOW). The RFID tag's face should be parallel to the front or back face of the antenna. The card may work held sideways, but the max distance from the antenna was greatly reduced. The tags used in this project should have a read distance of approximately 4 inches ([R7,] Parallax pg.4).

4.2.6 Possible Issues

As mentioned, holding the tag perpendicular to the face of the antenna will greatly reduce the distance it works at. Interference can be caused by other RF devices working near the same frequency. This includes other RF tags, so if the user has more than 1 RFID key on the same keychain (for example), the RFID receiver could fail to read any of them correctly. Environmental conditions could reduce the distance from the approximately 4 inches to something much lower.

On the other hand of interference, RF noise could cause a tag response without an actual tag being near the unit. A suggested solution to this problem would be to read twice in a row within a short amount of time to insure that the data was a valid tag and not noise.

4.2.7 Communication Protocol (Serial)

The serial communication details were as follows. There was no parity bit. 8 data bits and 1 stop bit. The least significant bit was sent first. The rate was 2400 bits per second. Data was transmitted at 5V as an asynchronous serial signal which was not inverted (Table 4.2.7)

Communication	Serial
Data bits	8
Stop bits	1
Parity	No
Bit Order	Least significant bit first
Transfer speed	2400 bps
Signal	5V TTL-level, non-inverted asynchronous serial

Table 4.2.7*: RFID Serial connection communication details*

4.2.8 Communication Protocol (Tag)

The RFID Key will transmit the following format when it was in range of the device. 12 bytes of ASCII were sent total. The start byte was 0x0A (Line Feed). The end byte was 0x0D (Carriage Return). The middle 10 bytes were the actual unique ID digits 1-10 (Figure 4.2.8). The entire string was sent serially from the tag. The start and end byte were one way to determine that the signal was a valid tag.

Start Byte (0x0A)	Unique ID Digit 1	Unique ID Digit 2	Unique ID Digit 3	Unique ID Digit 4	Unique ID Digit 5	Unique ID Digit 6	Unique ID Digit 7	Unique ID Digit 8	Unique ID Digit 9	Unique ID Digit 10	Stop Byte (0x0D)

***Figure 4.2.8**: 12 bytes sent from Key*
Used with permission from Parallax

If, as an example, a tag had a valid ID of 7A0F0184F0, the following bytes would be modulated and returned to the receiver: 0x0A, 0x37, 0x41, 0x30, 0x46, 0x30, 0x31, 0x38, 0x34, 0x46, 0x30, 0x0D . The ASCII values surrounded by the newline and carriage return characters.

4.2.9 Specific Power Characteristics (DC)

Assuming VCC = +5V and the Temperature was 25C (77F), see Table 4.2.9 for DC power specifications.

Parameter	Symbol	Test Conditions	Specification			Unit
			Min.	Typ.	Max.	
Supply Voltage	V_{CC}	---	4.5	5.0	5.5	V
Supply Current, Idle	I_{IDLE}	---	---	10	---	mA
Supply Current, Active	I_{CC}	---	---	100	200	mA
Input LOW voltage	V_{IL}	$+4.5V <= V_{CC} <= +5.5V$	---	---	0.8	V
Input HIGH voltage	V_{IH}	$+4.5V <= V_{CC} <= +5.5V$	2.0	---	---	V
Output LOW voltage	V_{OL}	$V_{CC} = +4.5V$	---	---	0.6	V
Output HIGH voltage	V_{OH}	$V_{CC} = +4.5V$	$V_{CC} - 0.7$	---	---	V

***Table 4.2.9**: DC Characteristics of RFID Receiver*
Used with permission from Parallax

Although running outside of the specifications given in Table O could cause undesired behavior, there were tested maximum specifications for the RFID system. These stresses could cause irreversible damage to the components (Table 4.2.9b).

Condition	Value
Operating Temperature	-40ºC to +85ºC
Storage Temperature	-55ºC to +125ºC
Supply Voltage (V_{cc})	+4.5V to +5.5V
Ground Voltage (V_{ss})	0V
Voltage on any pin with respect to V_{ss}	-0.3V to +7.0V

Table 4.2.9b: Maximum ratings
Used with permission from Parallax

Exceeding any of these values can cause permanent damage to the components and Table P should be strictly adhered to during all testing and usage of the RFID Receiver.

4.2.10 Unattended Button

Although not connected to the RFID module directly, this button was logically a core part of the RFID system. The button was used to initiate an "unattended" mode in the wheelchair. This will keep the locks enabled until the correct RFID tag was put to the receiver to unlock the wheelchair again. The intention here was to allow the user to leave the device somewhere that would make it much more difficult for an unauthorized user to borrow or steal. This was very useful in theme parks and other places where the user may leave their wheelchair out in a public and often crowded area where such unauthorized use may be attempted by a user.

4.2.11 RFID Software Behavior

The basic function of the program was to read tags from the RFID reader and compare them to known tags which were stored in the EEPROM table. If a match for the tag was found, the lock was disabled. The basic elements of the software can be found in Figure 4.2.11.

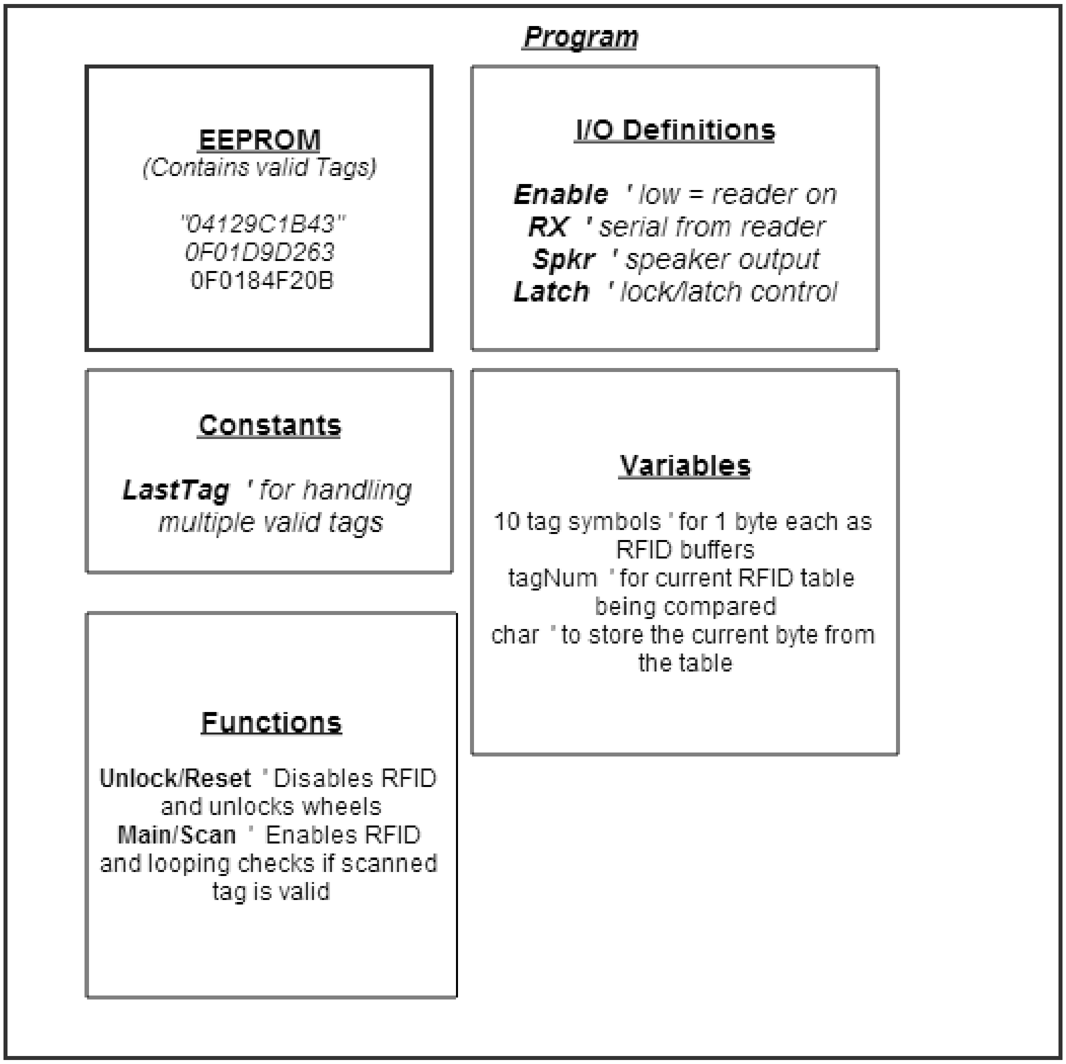


***Figure 4.2.11**: RFID software - Program space layout*

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

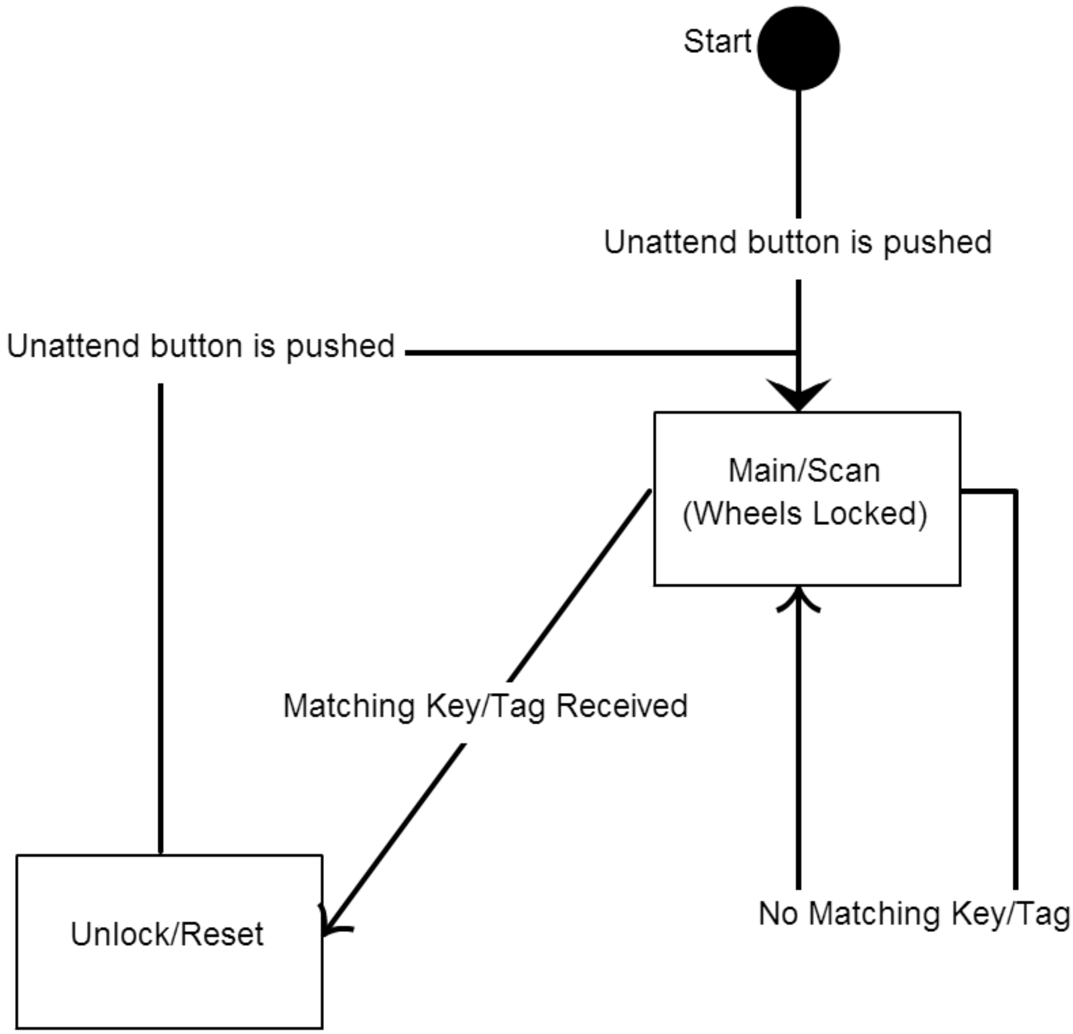


***Figure R**: The cycle of the unattended device RFID lock*

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

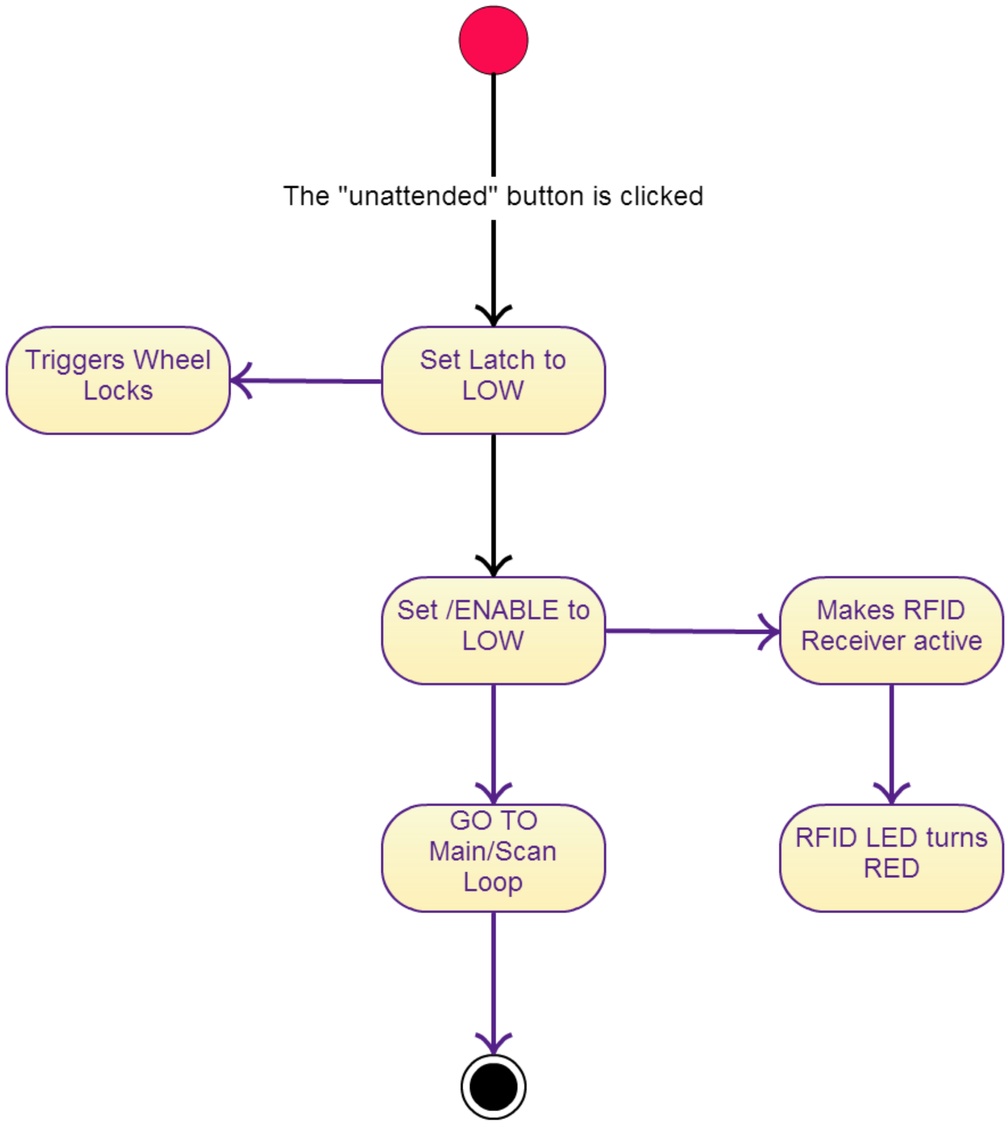


***Figure S**: Actions resulting from "unattended" trigger on microcontroller*

After all this was done and the initial unattended mode was in place, the Main/Scan loop begins and continues until an unlock occurs from a correct RFID tag/key being given (Figure T). 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.

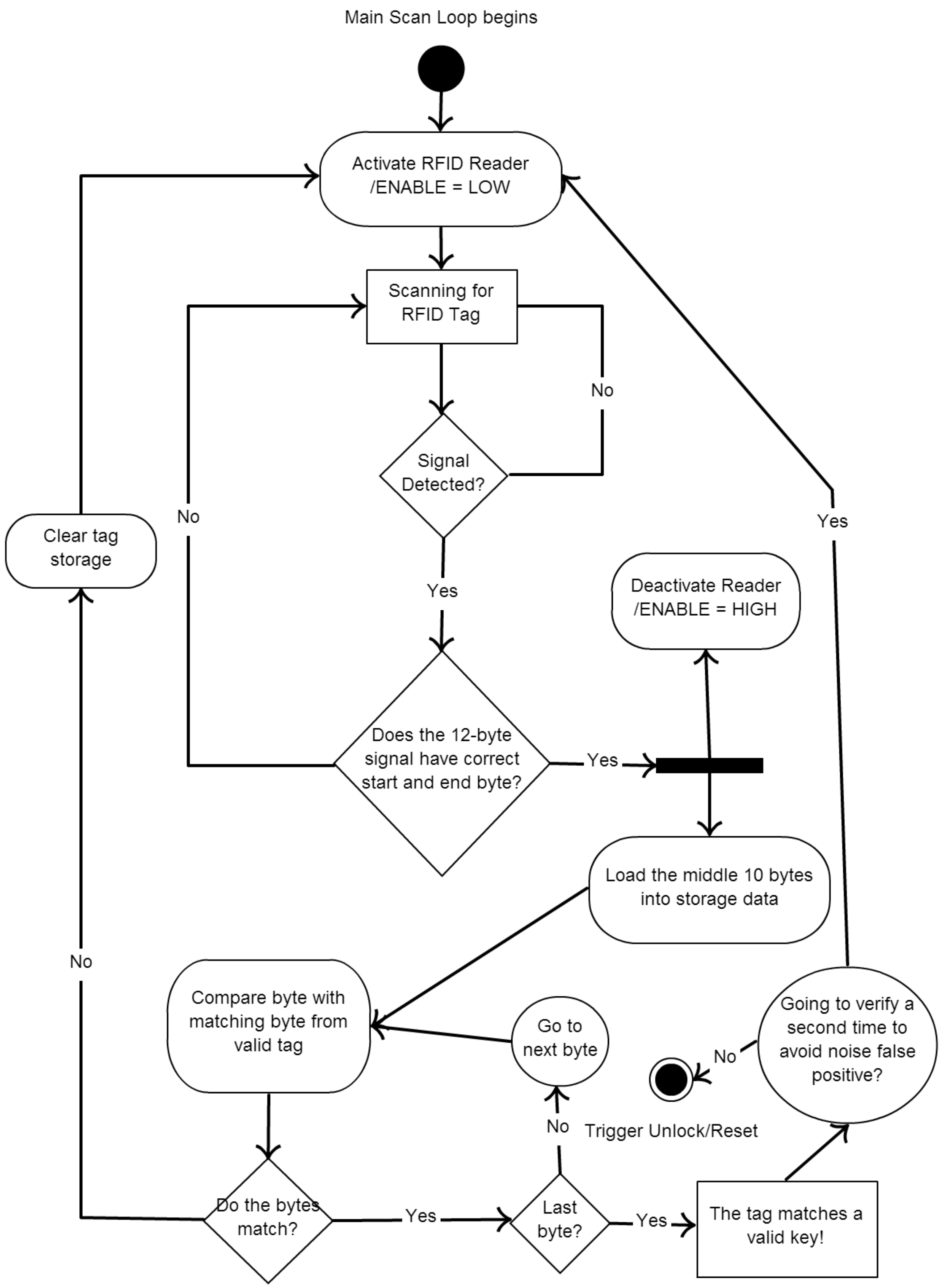


***Figure T**: The main scanning loop for RFID Software*

In the above figure, the end of the loop logic was “Trigger Unlock/Reset.” The details of this behavior can be found in Figure U. What this will do was shut off the RFID receiver until “unattended mode” was reactivated by the user switch at a later time.

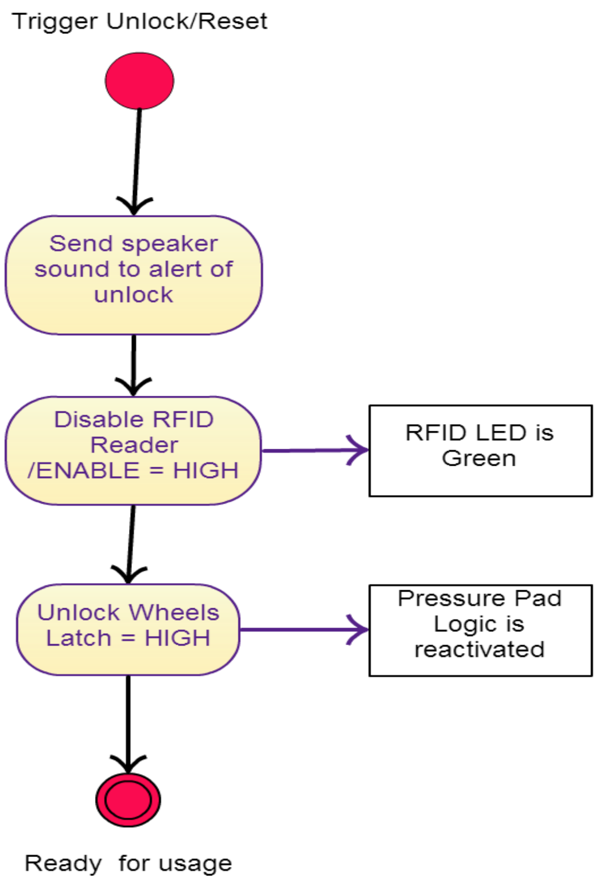


Figure U: *Unlock/Reset activities and results*

The speaker sound was an optional feature in the device design. While it was useful to have extra feedback while testing, some users may find an audible response annoying and unhelpful when there was already an LED that will turn red when the device was 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.

4.2.12 RFID Master Key

It was possible to store more than one valid key in the EEPROM. This may be used to allow for a “Master Key” that would allow any model to be unlocked. This key would be used for unlocking in cases of returns or lost keys, but the code should not become public knowledge. Each wheelchair device would have its own unique key of course. This would be a necessity for manufacturing, as allowing the chair to be locked but not unlockable if the key was lost would result in a multitude of useless wheelchairs over time and with lost keys.

It was a consideration, however, that other code (especially relating to the GPS/GSM modules) was running in the microprocessor as well. Too many alternate keys could either fill up the EEPROM or cause the looping comparison for RFID to take too long and stall out other modules' functionality. It was most likely, however, that the benefits of having alternate keys to recover the device quickly would be worth the tradeoff of increased calculation load on the microprocessor.

4.3 Locking Mechanism

4.3.1 Brakes

The locking mechanism for our project was the most essential and important component for the safety enhanced wheelchair that we were going to be creating. There were many different parts that were involved with creating the locking mechanism. The locking mechanism for the safety enhanced wheelchair needs to function correctly one hundred percent of the time. The reason why the locking mechanism needs to function correctly one hundred percent of the time was due to the fact that if a failure occurs at any time with the locking mechanism, then the failure could result in a life threatening fall by the person who was attempting to get out of the safety enhanced wheelchair. A life threatening fall was completely unacceptable not only because the fall was life threatening to the person, but because the main focus of our safety enhanced wheelchair was to help those who need to use wheelchairs and to remove and prevent the sometimes fatal incident of falling when attempting to get out of the wheelchair.

There were two main parts that the locking mechanism consisted of for the safety enhanced wheelchair. The two main parts of the locking mechanism were the actual brakes and an actuator. When first starting this project, our group initially had plans to use the existing manual locks that come standard with every wheelchair. We were going to find a way to utilize the existing standard manual locks by building a device that would be able to appropriately rotate the standard manual locks. This was going to be achieved either by having the device being connected directly to the standard manual locks or by using an extension piece that would be attached to both the standard manual locks and the device itself, which would then allow the standard manual locks rotate properly. Upon further investigating and discussion amongst our group, we decided to keep the standard manual locks as an optional backup brake. We also ended up deciding that it would be best to create our own locking mechanism since this way we would be able to fully control every aspect of it. Another positive of creating our own locking mechanism was that if anything did go wrong or if anything fails during any portion of our prototype testing, we should be able to troubleshoot the problem faster and easier than if we used a locking mechanism that had already been created by other individuals or a company.

For the braking portion of the locking mechanism of our safety enhanced wheelchair, there were three different types of braking mechanisms that were researched. The first braking mechanism that was researched was the standard manual wheelchair locks. The second braking mechanism that was researched as a potential way to stop and lock the wheelchair was automatic wheelchair brakes. The third and final braking mechanism that was researched and took under serious consideration was disc brakes. Every single standard manual wheelchair lock functions in a push-pull fashion. Some require the lever to be pushed so that the bar presses firmly on the tire to accomplish a locked wheelchair. Other standard manual wheelchair locks require the lever to be pulled so that the bar presses firmly on the tire to successfully have the wheelchair get in to a locked state. The locking of the standard manual wheelchair locks requires sufficient strength and coordination. For the industry standard of the manual wheelchair locks, they require approximately twenty-five pounds of force just to lock one of the manual wheelchair locks. This task can be daunting enough, and unfortunately it needs to be accomplished for both of the manual wheelchair locks for the two main tires of the wheelchair to successfully prevent accidental falls that could end up being fatal. This difficult task can result in the person operating the wheelchair to experience significant pain and discomfort. Ultimately our group decided not to use the standard manual wheelchair locks because we decided that we would remove them so that the person who was operating our safety enhanced wheelchair won't ever have to go through the terrible experience, even accidentally, of using these locks that were not one hundred percent safe and sometimes cause considerable pain. In the Figure 4.3.1 provided below, an example of the standard manual wheelchair locks was displayed. Since the standard manual wheelchair locks were relatively easy to install and uninstall, they can be reinstalled on the safety enhanced wheelchair per the client's request if he or she chooses to utilize them as an optional backup system. The advantages and disadvantages of standard manual wheelchair locks were listed below.

Advantages

- Simple design
- Most cost effective locking mechanism
- Durable

Disadvantages

- Requires significant force to fully lock
- Can cause pain and discomfort
- Not one hundred percent reliable

Figure 4.3.1 *– Standard Manual Wheelchair Brake Lock*
Used pending permission from www.sportaid.com

The second type of locks for wheelchairs was automatic wheelchair locks. The automatic wheelchair locks were currently commercially available by two different companies. The cost of the automatic wheelchair locks range from approximately $375 to $1,100. They require the use of spring activated lever, fixed gear blocks, and gear hubs. The concept behind the automatic wheelchair locks was that they use the spring activated levers to shift and move the fixed gear blocks so that the gear blocks collide with the gear hubs. The fixed gear blocks end up fully clenching together against the gear hubs to prevent the wheelchair from being able to move. The automatic wheelchair locks only activated when the person stands up from the wheelchair, so when the person was sitting in the wheelchair, the automatic locks should not lock. Even though these automatic wheelchair locks were very close to what we need for our safety enhanced wheelchair and have many great features, unfortunately our group cannot afford the cost of the automatic wheelchair locks and we also do not have any need for its ability to not interfere at all when folding the safety enhanced wheelchair for easy portability. The advantages and disadvantages of automatic wheelchair locks were listed below.

Advantages

- Low maintenance
- Durable
- No interference when operating and folding the wheelchair
- Override brake release for when moving the wheelchair when it was unoccupied

Disadvantages

- Least cost effective locking mechanism
- Incompatible with the MSP430

Currently disc brakes were the latest in technology for wheelchair brakes and some were even used in a patented brake system. Disc brakes allow the person using and controlling his or her wheelchair to be able to safely descend hills, ramps, and any uneven surfaces. The required force to activate the disc brakes on wheelchairs was significantly less than any other non-autonomous braking system that was currently built for wheelchairs. Since the force that was necessary to enable the disc brakes on wheelchairs was minuscule, it greatly helps to reduce the pain, strain, and discomfort that can occur on the wheelchair user's shoulders, wrists, and elbows. The insignificant force required to lock the disc brakes also help to prevent and reduce injuries that occur due to repetitive overuse. The patented disc brakes system for wheelchairs uses a two piece hub, which was a vital piece of the braking system. This patented disc braking system that was currently on the market also allows for the person within the wheelchair to brake in incremental stages. One of the many great advantages of disc brakes was that they supply fantastic stopping power even when having to deal with significant amounts of water and heat. The reason why the disc brakes handle so well under tough conditions was because they use either hard metallic or ceramic pads. These hard pads that were used should provide more reliable braking power compared to soft rubber pads that were used on other brakes. The tremendous stopping power of disc brakes was due to the fact that they use calipers that were attached to the frame of the wheelchair and rotors that were attached to the hubs of the wheelchair's wheels. The vast amount of stopping power that can be produce by disc brakes was excellent for our safety enhanced wheelchair. The reliable and powerful braking of disc brakes allowed our group to create the safety enhanced wheelchair so that it can only move when we want it to, when it was appropriate based upon when the person using the safety enhanced wheelchair was actively using the wheelchair or was planning to get out of the wheelchair, and when it was appropriate based upon the set of conditions that were programmed within our code. The advantages and disadvantages of disc brakes were listed below.

Advantages

- Durable
- Light weight
- Cost effective
- Low maintenance
- Simple installation
- Tremendous braking power
- Reliable in all weather conditions

Disadvantages

- Difficult to repair and clean
- Can fail due to debris buildup
- Adjustments needed due to cable stretch
- Requires breaking in to achieve maximum braking power

There were currently two different types of disc brakes for wheelchairs. One type of disc brakes was cable disc brakes and the other type was hydraulic disc brakes. There were several advantages and disadvantages between both types of disc brakes. Cable disc brakes and hydraulic disc brakes have about the same performance when it comes to braking power, but the hydraulic disc brakes do have slightly greater braking power. The cables used for cable disc brakes need to be changed out when they reach the point of being too stretched out because cables that have too much wear resulted in braking power that was less than the maximum that braking power that was possible to be achieved by the cable disc brakes. The hydraulic disc brakes were better sealed and do not require the changing of any cables since cables were not used within the hydraulic disc brakes system. Also, the hydraulic disc brakes were lighter than the cable disc brakes, but the cable disc brakes were easier to adjust when necessary. A serious negative to the hydraulic disc brakes was that serious issues can arise due to the hydraulic fluid getting on the rotors and brake pads. If this were to happen, the brake pads would become completely useless because they would cease to function properly, so our group would be forced to throw them out and buy new ones. Due to this possible negative scenario along with the cable that was required for cable disc brakes being more compatible with the stepper motor for the locking mechanism, our group had decided to choose the cable disc brakes as the brakes that would be used for the locking mechanism for the safety enhanced wheelchair. In the Figure 4.3.2 provided below, an example of the cable disc brakes that our group used as the brakes for the locking mechanism for the safety enhanced wheelchair was displayed. For the safety enhanced wheelchair, our group was going to be using the Avid BB7 cable disc brakes. The cost of the Avid BB7 cable disc brakes was approximately $69 and come with a six bolt rotor, a caliper, adapters, and mounting hardware. The brakes were able to fit post mounts that were seventy-four millimeters and also come with adapters for WAS disc brake mounts that were fifty-one millimeters. The product specifications of cable disc brakes were listed below.

Product Specifications

- Mechanical two piece forged aluminum calipers
- Tri-align caliper positioning
- Sintered pads
- Dual knob pad adjustment
- Cable disc brakes
- G2 CleanSweep rotors
- Weighs only 329 grams

Figure 4.3.2 *– Cable Disc Brake*
Used pending permission from www.mtbreview.com

4.3.2 Actuators

For the actuator that was necessary of the locking mechanism of our safety enhanced wheelchair, there were different types of actuators that were researched. The first type of actuator that was researched as a potential device that could be used to engage the cable disc brakes was a servo motor. The second type of actuator that was researched and took under serious consideration was a stepper motor. The third and final type of actuator that was discussed and researched was actuators that were piston driven. Initially our group was considering using the piston driven actuators, but in the end, our group decided not to choose the piston driven actuators to be used for the safety enhanced wheelchair. There were several reasons for this but there were a few keys reasons for this decision. If the piston driven actuators would be used for our safety enhanced wheelchair, we would need to have two piston driven actuators. This can lead to severe complications. Being able to correctly control, troubleshoot, and program two piston driven actuators simultaneously posed a great challenge. Our group's biggest concern was for the person who would be using our safety enhanced wheelchair. If for some reason one or both of the two piston driven actuators malfunctioned, stopped working, or fired the piston incorrectly, it could result in serious harm to the person using the safety enhanced wheelchair due to the wheelchair potentially not being locked, which was our group's goal to prevent. If for any reason at least one of the piston driven actuators did not fire correctly and on time, it would result in the safety enhanced wheelchair moving backwards or rotating around while the person using the safety enhanced wheelchair was trying to get out of it. This scenario was completely unacceptable, which was why our group ended up decided to research other actuators to be used to safely lock the safety enhanced wheelchair. In the Figure 4.3.3 provided below, an example of a piston driven actuator was displayed.

Figure 4.3.3 *– Piston Driven Actuator*
Used pending permission from www.sportaid.com

The next actuators that were researched for potentially being used as a way to engage the disc brakes were servo motors and stepper motors. While both servo and stepper motors were similar, there were major differences between. The way our group went about choosing either a servo motor or a stepper motor was to consider a few key design factors. We took under consideration cost, speed, acceleration, torque, and drivers. There were two major key differences between servo motors and stepper motors. Servo motors typically have a minimal about of poles. There were approximately four to twelve poles on average in servo motors. On the other hand, stepper motors have a vast amount of poles. There were usually anywhere from fifty to one hundred poles within stepper motors. The great quantity of poles was generated by either an electric current or a permanent magnet. The poles within the stepper motors were north and south poles that were magnetic pairs. At every single pole within both servo motors and stepper motors, the motor shaft should be able to be stopped without any problems arising. Being able to stop the motor shaft at a precise angle or at a specific pole was far more challenging with servo motors compared to stepper motors. The use of a position encoder was typically required for servo motors. When precise movements were necessary of servo motors, the position encoder was an absolute necessity since it keeps track of the motor shaft’s position. Unlike servo motors, stepper motors use their vast quantity of poles to move with tremendous precision and accuracy between every single pole. This allows stepper motors to be controlled without the need of any type of position feedback. The advantages and disadvantages of stepper motors were listed below.

Advantages

- Highly reliable
- Open-loop control
- Easier drive control
- High torque at low RPMs
- Most cost effective motor
- Tremendous amounts of poles
- Quick starting, stopping, and reversing
- Constant holding torque when unpowered
- Noncumulative accuracy error of 3% - 5% per step

Disadvantages

- Low efficiency
- Vibration issues
- No reserve power
- Not great for accelerating a load
- Skips steps if there isn’t sufficient torque
- Resonances occur if not controlled correctly
- Loses substantial amount of torque towards maximum RPM

The driving of a servo motor to an exact position was a lot more difficult compared to driving a stepper motor to a specific position. The way servo motors were driven to an exact position was by gathering the data of the current position provided by the position encoder and the position of where the servo motors was instructed to move to. Then take the difference between those two positions and finally correctly adjust the current to the required amount to be able to successfully move to the intended position. In the Figure 4.3.3 provided below, an example of a servo motor was displayed. To be able to drive a stepper motor to an exact intended position was far easier than what it takes a servo motor to be driven to the same position. The way a stepper motors was driven to a specific position was by the use of drive pulses. To achieve one step of the motor shaft of the stepper motor, only a single drive pulse was required. Due to the fact that the size of a single step of stepper motors was constrained to a permanent amount of rotations, driving to the desire exact position becomes a matter of providing the correct amount of pulses to the stepper motor. Based upon these two different ways of driving the motors of servo and stepper motors, stepper motors were definitely a better decision to be used for the safety enhanced wheelchair. The advantages and disadvantages of servo motors were listed below.

Advantages

- High speed
- High torque
- Can handle AC and DC
- No issues with vibration
- Produce relatively low noise
- Efficiency was between 80% - 90%
- Quickly reaches peak RPM speeds
- Can double the torque for brief periods
- Maintains 90% of torque at high speeds

Disadvantages

- Complex drive circuitry
- Least cost effective motor
- Requires feedback for accuracy
- Greater amounts of maintenance required
- Requires gear boxes when used for low speeds

Figure 4.3.3 *– Servo Motor*
Used with permission from www.RobotShop.com

It was determined that after conducting necessary research about servo motors and stepper motors that the actuator for the locking mechanism of the safety enhanced wheelchair would most likely be stepper motors. When considering acquiring the most appropriate stepper motor that was completely suitable for being the actuator of the locking mechanism for the safety enhanced wheelchair, our group followed several significant criteria when selecting the best stepper motor. The vital criterion that was followed was speed requirement, winding configuration, load, preferred mechanical motion, and stepper mode. Based upon this criterion, our group selected a geared bipolar stepper motor from robotshop.com that costs forty-five dollars. In the Figure 4.3.4 provided below, an example of the geared bipolar stepper motor that our group used as the actuator for the locking mechanism for the safety enhanced wheelchair was displayed.

Figure 4.3.4 *– Geared Bipolar Stepper Motor*
Used with permission from www.RobotShop.com

This particular bipolar stepper motor that was most likely going to be used for the safety enhanced wheelchair had a planetary gearbox. The bipolar stepper motor that had been chosen was efficient and relatively small due to it coming equipped with a planetary gearbox. The planet gearbox was comprised of three main components. The three main components were the ring gear, planet gear, and sun gear. This planetary gearbox makes the bipolar stepper motor have a higher torque to weight ratio, greater resistance to shock, lower backlash, and better efficiency. There were three different stepper motor modes that can be utilized by the geared bipolar stepper motor. The three types of stepper motor modes were full-step, half-step, and microstepping. The first type, full-step, had the stepper motor step the entire regular step angle. The full-step mode had two different excitation modes. One of the excitation modes was single phase full-step excitation, and the other excitation mode was dual phase full-step excitation. The geared bipolar stepper motor would only function with one phase being energized at any given time when using the single phase full-step excitation mode. This particular mode should not be used for our stepper motor because it would make the motor function at a static speed. If the motor were to function at a static speed, the necessary speed and torque that was required to engage the cable disc brakes would not be able to be generated. The only benefit to the single phase full-step excitation mode was that it requires the least amount of power amongst all of the excitation modes. The other excitation mode, dual phase full-step, had the stepper motor use two phases that were energized for a period of time. Barely any resonance problems occur with this excitation mode, and it also produces exceptional speed and torque but at a cost. The exceptional speed and torque that was thirty to forty percent greater than that of single excitation only occurs because it necessitates double the amount of power. The stepper motor used the dual phase full-step excitation mode because it produced exceptional speed and torque, which was absolutely necessary to lock the cable disc brakes fast enough on the safety enhanced wheelchair so the wheelchair did not roll away from the person using it and subsequently cause a fall to occur. If for some reason our group was not able to provide sufficient power for the increased demands of the dual phase full-step excitation mode due to the limitations of our power supply, then the half-step excitation mode would be utilized instead.

The second type of stepper motor modes that can be used was half-step excitation mode. This mode utilizes dual phase and single phase functions by switching back and forth between them. This essentially results in producing regular full steps that become fifty percent less than the average full step. The half-step excitation mode had double the resolution and an alternating torque that changes on alternate steps, which was counteracted by the actual step that occurs only being half of the original step distance. One of the greatest benefits of using this stepper mode was that it essentially had solved the problem about resonance because it was nearly one hundred percent free of resonance problems. Also, there was a wide variety of stepper motors that were compatible with the half-step stepper motor mode. This particular mode would be utilized to enable the cable disc brakes on the safety enhanced wheelchair if resonance problems start occurring and remain a constant issue. The half-step stepper motor mode would also prove to be beneficial if the full-step mode was unable to handle the load with the torque it could manage to generate. If the half-step mode enabled the cable disc brakes in an inconsistent and rough manner, then the microstepping mode would end up being utilized in its place.

The third type of stepper motor modes that can be used was the microstepping mode. This particular mode was the most recently developed stepper motor mode. It also was the best solution when better resolution and smooth motion was a necessity. These two features were able to be produced because the original step angle gets divided into lesser angles. Microstepping occurs by using cosine and sine functions to properly segment the current within the two motor windings. Some rather expensive microstepping drivers allowed the divisor to be selected. However, other microstepping drivers that were less expensive do not have the option of having a divisor that can be changed when desired. The most common ranges for divisors of the microstepping stepper mode were the division by two hundred fifty-six and the division by ten. The cost associated with the microstepping stepper mode increases significantly with higher divisor ranges. This particular mode would be utilized to enable the cable disc brakes on the safety enhanced wheelchair if the cable only needed to be wound an incredibly short distance. Also, if the cables for the mechanical disc brakes needed to be pulled smoothly and in an evenly consistent fashion, then the microstepping mode would be the best option available that would be employed. Another reason for potentially using this particular mode would be because the cables for the mechanical disc brakes needs to be wound a precise amount that cannot be achieved by the use of the full-step and half-step modes.

Two phase stepper motors have two different winding conventions. The first winding convention was unipolar, and the second winding convention was bipolar. Stepper motors that use the unipolar winding function by having a center tap per phase for each winding. The magnetic field used to rotate the motor shaft was directed by turning on every segment of the windings. The unipolar winding convention allows for the reversal of magnetic poles without the requirement of changing the current's direction. This allows for each winding to have a rather simple commutation circuit. Within this unipolar winding convention, there were typically were three leads for each phase, which results in having a total of six leads within common two phase stepper motors for the center tap. However, both of the two phases were usually combined together internally, which ends up resulting in there only being five leads for the unipolar stepper motor. If our group were to use the unipolar winding convention, we would be able to use the MSP430 to engage the drive transistors in the correct order. Being able to control a unipolar stepper motor by using the relatively cheap MSP430 from TI makes this winding convention one of the most popular ways to accomplish accurate angular movements. The advantages and disadvantages of stepper motors that use the unipolar winding convention were listed below.

Advantages

- Easy to operate
- More torque at higher speeds
- Most cost effective winding convention
- Does not generate a great deal of heat

Disadvantages

- Requires more wires
- Poor torque at low speeds
- Low to moderate performance
- Utilizes only 50% of the winding
- Cannot change driver's output current direction
- Energizing a set of coils was achieved one at a time

The other type of winding convention used by two phase stepper motors was bipolar. The stepper motors that have the bipolar winding convention only use a single winding for each phase. This feature did cause a side effect. It makes the reversing the current within the winding more complicated. To achieve reversing the current within the windings, the magnetic poles need to be reversed as well, which can only be achieved by an even more complex driving circuit. The greater complexity of the driving circuit was due to requirement of needing to use H-bridge drivers. Stepper motors that use the bipolar winding convention only have two leads for each phase. If static friction starts presenting problems for the H-bridge drivers, increasing the frequency of the signal for the stepper motor should help to significantly reduce the problem. Due to the bipolar winding convention producing a greater amount of initial torque than the unipolar winding convention, our group had decided to use a stepper motor that utilizes the bipolar winding convention. The geared bipolar stepper motor had the following specifications that were displayed below in Table 4.3.1. The stepper motor that was used to enable the cable disc brakes did not need to sustain a tremendous amount of torque at high speeds. Since the cables for the disc brakes only need to be wound a very short amount, the most amount of torque that can be generated in an incredibly short period of time was what was needed to successfully enabled the cable disc brakes and keep the safety enhanced wheelchair in a locked state to prevent any possible injury to the user of the wheelchair due to unexpected movement from the wheelchair. Bipolar stepper motors produce approximately forty percent more holding torque compared to unipolar stepper motors. This was an important and necessary feature for our group's safety enhanced wheelchair. Not only did the stepper motor that was being used for the safety enhanced wheelchair's locking mechanism need to be able to produce enough initial torque to wind the cable sufficiently for the disc brakes to become enabled, but the stepper motor also needs to be able to sustain the holding torque so that the disc brakes remain enabled to keep the wheelchair in a locked state. The advantages and disadvantages of stepper motors that use the bipolar winding convention were listed below.

Advantages

- Tremendous holding torque
- Utilizes 100% of the winding
- Excellent torque at low speeds
- Can change driver's output current direction
- Both set of coils can be connected in series or parallel

Disadvantages

- Difficult to drive correctly
- Can generate a great deal of heat
- Loses torque quickly at high speeds

Specifications	
Motor Type	Bipolar Stepper
Step Angle	0.018°
Step Accuracy	5%
Holding Torque	48 kg*cm
Rated Torque	48 kg*cm
Maximum Torque	250 kg*cm
Recommended Voltage	12 V DC
Rated Current	1.7 A
Coil Resistance	1.7 O
Shaft Diameter	8 mm
Weight	568 g
Number of Leads	4
Gearbox Type	Planetary
Gear Ratio	99.5:1
Maximum Strength of Gears	48 kg*cm
Shaft Maximum Axial Load	49.1 N
Shaft Maximum Radial Load	98.1 N

***Table 4.3.1** – Specifications of Stepper Motor*
Used with permission from www.RobotShop.com

Now that the stepper motor had been chosen, it needs a way to be controlled. Unfortunately, stepper motors cannot be controlled by microcontrollers when the microcontroller was directly connected to the stepper motor. To control a stepper motor by using a microcontroller, a stepper motor driver controller board or a half-h driver needs to be used as a go between. By placing the stepper motor driver controller board or the half-h driver between the microcontroller and the stepper motor, it allows for the proper communication and powering to occur. Our group considered originally considered using a stepper motor driver controller board, but after conducting further researched, we decided on using a half-h driver. The reason why our group decided to choose to use a half-h driver was because it allows the polarity of the supplied power to be independently controlled. Half-h drivers were configured transistors that allowed the control of stepper motors bi-directionally.

Since we were definitely going to be using a half-h driver, it was very important that we select a half-h driver that can fully support the voltage and current that was going to be supplied and subsequently produced. The decision of choosing a half-h driver compared to a regular transistor was that the half-h drivers allowed for bi-directional driving, while a simple transistor only allows for driving in one direction. Initially our group was going to use the L298 H-Bridge motor driver. The L298 H-Bridge motor driver was a more complex half-f driver. It was relatively cheap since it only costs $2.95, which was a great help to our budget. The L298 H-Bridge motor driver was configured to permit drive inductive loads and regular TTL logic levels. It achieves this by being dual full-bridge motor driver that handles high current and voltages extremely well. It can have function up to forty-six volts of supply voltage and was rated for up to four amperes of DC current. Since the L298 H-Bridge motor driver was capable of handling two motors, our group had decided that even though this device had better specifications than what was required to sufficiently operate the geared bipolar stepper motor, there shouldn’t be a need to use this device because of the increased complexity.

With the decision to not use the L298 H-Bridge motor, it was decided that we would conduct research for a half-h driver that had a simpler design. The simpler designed half-h driver also needed to still be able to handle the current and voltage demands of the geared bipolar stepper motor. While conducting the research, our group discovered a L293 H-Bridge motor driver. The L293 H-Bridge motor driver was a relatively simple half-h driver. For this device to control the geared bipolar stepper motor, it requires the use of four controller pins, four ground pins, four output pins, three five volt pins, and one pin for the power supply of the geared bipolar stepper motor. While the L293 H-Bridge motor driver was similar to the L298 H-Bridge motor driver in how they function, the L293 H-Bridge motor driver was easier to prototype with. Since it had standards pins, it should also be easier to place onto a prototyping board or breadboard while during the prototype phase of constructing the safety enhanced wheelchair. There was one drawback of the L293 H-Bridge motor driver. Due to sudden stops of the geared bipolar stepper motor, current could potentially flow backwards from the stepper motor and end up frying the L293 H-Bridge motor driver. This damaging flow of current should be able to be prevented or at least stopped before it can damage the L293 H-Bridge motor driver by installing diodes between the geared bipolar stepper motor and the L293 H-Bridge motor driver. Since diodes only allowed current to flow in only one direction, they proved to be a sufficient method to provide protection to the L293 H-Bridge motor driver and the rest of the circuit. The L293 H-Bridge motor driver had the following specifications that were displayed below in Table 4.3.2.

Specifications	
Wide Supply-Voltage Range	4.5 V to 36 V
Maximum Output Voltage	36 V
Maximum Switching Voltage	36 V
Peak Output Current	2 A
Drivers Per Package	4
Input Compatibility	TTL
Delay Time	800 ns
Pin Package	16PDIP
Price	$2.20
Drive Currents	Bidirectional
Output Current Per Channel	1 A
Peak Output Current Per Channel	2 A
Maximum Junction Temperature	150°C
Storage Temperature Range	-65° – 150°C

***Table 4.3.2** – Specifications of L293 H-Bridge motor driver*
Used with permission from Texas Instruments

To get an even better understanding of exactly what the L293 H-Bridge motor driver can handle and achieve, it was put through a series of tests by the company, Texas Instruments. The tests were given specific parameters and test conditions that would reveal the capabilities and shortcomings of the L293 H-Bridge motor driver. While conducting the tests, VCC1 was set to five volts, VCC2 was set to twenty-four volts, and the temperature was set to twenty-five degrees Celsius, which happens to be seventy-seven degrees Fahrenheit. The results of the DC power tests for the L293 H-Bridge motor driver that were conducted by Texas Instruments were displayed below in Table 4.3.3. While it would be best to stay within the DC power specifications that were within Table 4.3.3, there were maximum operating specifications for the L293 H-Bridge motor driver that have been found by Texas Instruments through conducting tests. Our group paid close attention to these maximum specifications that were displayed below in Table 4.3.4, so that we construct and operate the locking mechanism for the safety enhanced wheelchair within the L293 H-Bridge motor driver's maximum and minimum parameters.

PARAMETER			TEST CONDITIONS		MIN	TYP	MAX	UNIT
V_{OH}	High-level output voltage		L293: $I_{OH} = -1$ A L293D: $I_{OH} = -0.6$ A		$V_{CC2} - 1.8$	$V_{CC2} - 1.4$		V
V_{OL}	Low-level output voltage		L293: $I_{OL} = 1$ A L293D: $I_{OL} = 0.6$ A			1.2	1.8	V
V_{OKH}	High-level output clamp voltage		L293D: $I_{OK} = -0.6$ A			$V_{CC2} + 1.3$		V
V_{OKL}	Low-level output clamp voltage		L293D: $I_{OK} = 0.6$ A			1.3		V
I_{IH}	High-level input current	A	$V_I = 7$ V			0.2	100	μA
		EN				0.2	10	
I_{IL}	Low-level input current	A	$V_I = 0$			−3	−10	μA
		EN				−2	−100	
I_{CC1}	Logic supply current		$I_O = 0$	All outputs at high level		13	22	mA
				All outputs at low level		35	60	
				All outputs at high impedance		8	24	
I_{CC2}	Output supply current		$I_O = 0$	All outputs at high level		14	24	mA
				All outputs at low level		2	6	
				All outputs at high impedance		2	4	

Table 4.3.3 *– DC Characteristics of L293 H-Bridge motor driver*
Used with permission from Texas Instruments

			MIN	MAX	UNIT
	Supply voltage	V_{CC1}	4.5	7	V
		V_{CC2}	V_{CC1}	36	
V_{IH}	High-level input voltage	$V_{CC1} \leq 7$ V	2.3	V_{CC1}	V
		$V_{CC1} \geq 7$ V	2.3	7	V
V_{IL}	Low-level output voltage		−0.3†	1.5	V
T_A	Operating free-air temperature		0	70	°C

Table 4.3.4 *– Maximum Operating Specifications of L293 H-Bridge motor driver*
Used with permission from Texas Instruments

A simplified block diagram of the driving circuit for the locking mechanism of the safety enhanced wheelchair provides an easy to understand visual representation on how the MSP430, L293 H-Bridge motor driver, and geared bipolar stepper motor were connected and communicated together. In the Figure 4.3.5 provided below, a block diagram of the driving circuit that our group utilized for the locking mechanism for the safety enhanced wheelchair was displayed. The simplified block diagram of the driving circuit displays the parts numbers, the ports that were necessary to use, and the wired connections between leads.

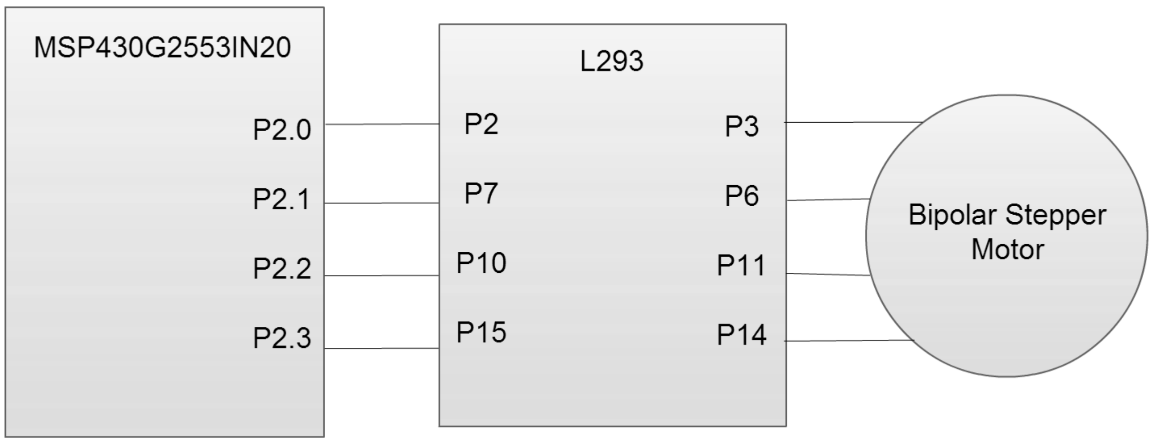


Figure 4.3.5 *– Block Diagram of Locking Mechanism's Driving Circuit*

To gain even better insight into how the driving circuit was constructed and how the L293 H-Bridge motor driver was built, a block diagram with far greater detail was required. In the Figure 4.3.6 provided below, a more elaborate block diagram of the driving circuit that our group utilized for the locking mechanism of the safety enhanced wheelchair was displayed. The more complex block diagram provides the best understanding of why particular pins were used instead of different pins, what specific pins would be utilized by the geared bipolar stepper motor and the MSP430, and even how to properly setup diodes within the drive circuit to have protection against harmful current coming from the stepper motor when it was stopped suddenly.

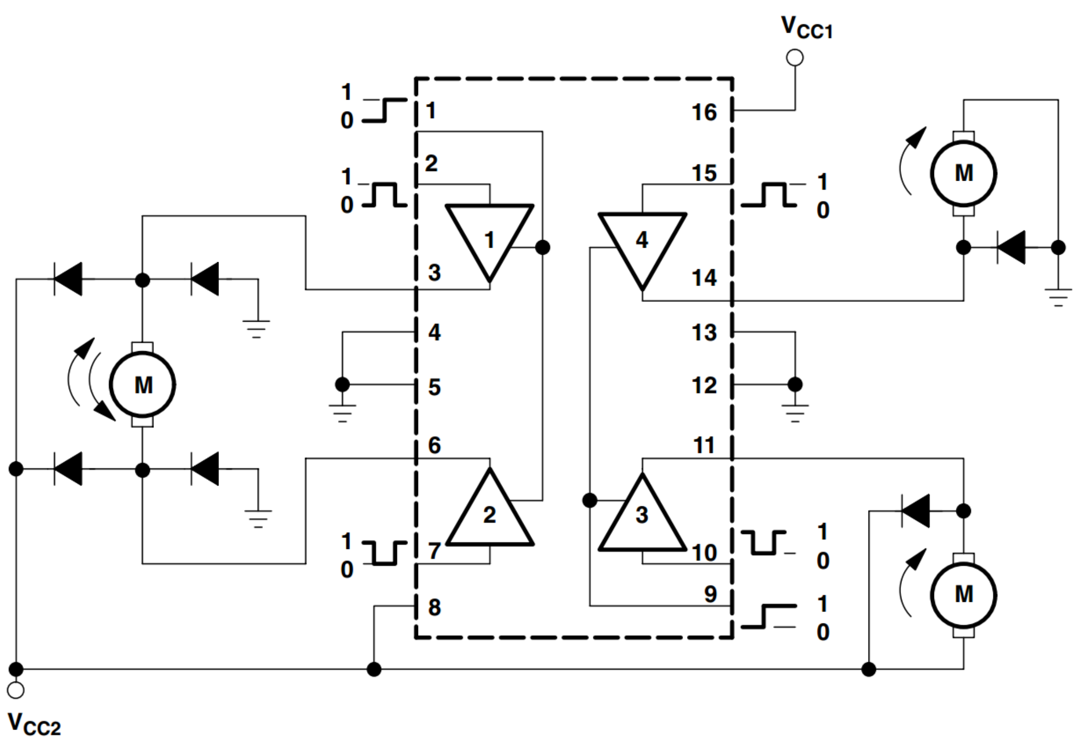


Figure 4.3.6 *– Block Diagram of L293 H-Bridge Motor Driver*
Used with permission from Spark Electronics

After conducting thorough testing on the geared bipolar stepper motor within the senior design lab, the group determined that it was not the absolute best option to be used for the locking mechanism. While this revelation was rather unfortunate, the best possible solution came forth shortly afterwards. Through even more research, the group confidently decided to use solenoids as the actuators for the locking mechanism. The type of solenoids that were used was box frame solenoids. The stroke range of the solenoids was one eighth of an inch to one full inch. The pull force range was from twenty to one hundred thirty ounces. The solenoids were 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. They had a coil resistance of 4.68 ohms, eight mounting holes, class one hundred five coil insulation, and were made of steel. To properly operate the solenoids, they required 12 volts, 2.6 amperes, and a total of 32.3 watts. The purpose of the solenoids was to pull the cables of the two disc brakes. This caused the disc brakes to become fully engaged, which prevented the wheelchair from rolling forwards and backwards. The maximum pull force of one hundred thirty ounces was more than sufficient to fully engage the disc brakes because the amount of ounces that it took to completely activate the disc brakes was forty-eight ounces. In the Figure 4.3.7 provided below, an example of the mechanical box frame pull solenoids that our group used as the actuator for the locking mechanism for the safety enhanced wheelchair was displayed. Also, the mechanical box frame pull solenoids had the following specifications that were displayed below in Table 4.3.5.

Figure 4.3.7 *– Solenoid*
Used pending permission from Grainger

Specifications	
Type	Box Frame
Stroke Range	1/8 in to 1 in
Pull Force Range	20 oz to 130 oz
Width	1.5625 in
Depth	1.625 in
Length	2.1875 in

Coil Volts	12 DC
Seated Amps	2.6 A
Seated Watts	32.3 W
Coil Resistance	4.68 Ω
Price	$54.70
Coil Insulation	Class 105
Terminals	Solder Lug
Duty Cycle	Intermittent
Materials of Construction	Steel
Standards	UL, RoHS
Mounting Holes	8-32 UNC-2B
Pull Force at 1 in. Stroke	20 oz
Pull Force at 3/4 in. Stroke	22 oz
Pull Force at 5/8 in. Stroke	30 oz
Pull Force at 1/2 in. Stroke	40 oz
Pull Force at 3/8 in. Stroke	60 oz
Pull Force at 1/4 in. Stroke	85 oz
Pull Force at 1/4 in. Stroke	130 oz

Table 4.3.5 *– Specifications of Solenoid*
Used pending permission from Grainger

The proper utilization of the solenoids to get the disc brakes fully engaged when appropriate occurred through the use of two mosfets and two diodes, which were an essential requirement. The mosfets that were used were the N-channel FQP30N06L mosfets. They can handle up to 60 V, 32 A, and 175°C. Also, they were 9.9 mm wide, 29 mm long, and 4.5 mm thick. These N-channel mosfets have exceptional maximum switching characteristics. Their turn-on delay time was 40 ns, turn-on rise time was 430 ns, turn-off delay time was 130 ns, and turn-off fall time was 230 ns. The main reason for choosing these mosfets was because they have 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 was required to be able to use the 5 V from the Arduino microcontroller to reliably switch on and off the current flowing through the mosfets. The diodes that were chosen to be used were the 1N4001 rectifier diode. They were frequently used for reverse voltage protection and they also had a high surge current capability and low forward voltage drop. The key reasons for choosing these rectifier diodes were because they can withstand up to a 30 A peak surge current and 50 V of peak repetitive reverse voltage. They can also operate in temperatures that range from -55°C to 175°C. The purpose of these diodes was to protect the mosfets and other electronic components from any potentially harmful current that was forced back from the solenoid when switching occurs within the mosfets. In the Figure 4.3.8 provided below, an example of the N-channel FQP30N06L mosfets that our group used as the actuator for the locking mechanism for the safety enhanced wheelchair was displayed. Also, the N-channel FQP30N06L mosfets had the following specifications that were displayed below in Table 4.3.6.

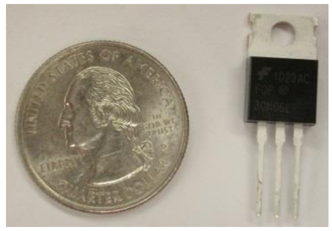


Figure 4.3.8 *– N-channel FQP30N06L Mosfet*

Specifications	
Model	FQP30N06L
Drain-Source Voltage	60 V
Drain-Source Current	32 A
Gate-Source Voltage	± 20 V
Power Dissipation	79 W
Gate Threshold Voltage	1 V – 2.5 V
Operating Temperature Range	-55°C – 175° C
Switching Turn-On Delay Time	15 – 40 ns
Switching Turn-Off Delay Time	60 – 130 ns

Table 4.3.6 *– Specifications of Mosfet*
Used pending permission from Grainger

The solenoid only drew power when the mosfets received a high output signal from the Arduino microcontroller. The high output signal was produced from a digital I/O port that was on the Arduino microcontroller. When the brakes did not need to be engaged, the solenoids were powered off by sending a low output signal to the mosfets from one of the digital I/O ports that was on the Arduino microcontroller. Since the digital I/O port that was being used had PWM capability, the speed and distance of pulling the pistons of the solenoids was able to be controlled by sending the appropriate PWM signal to the gate pin of the mosfets. To be able to control the solenoids on command, they had been setup to directly receive 12 V into their positive terminal, the negative terminal was connected to the source pin of the mosfets, the diodes were connected between the positive and negative terminals, the digital I/O port of the Arduino microcontroller was connected to the gate pin of the mosfets, and the drain pin of the mosfets were connected to ground. The schematic that was used to control the solenoids using the Arduino microcontroller was displayed below in Figure 4.3.9.

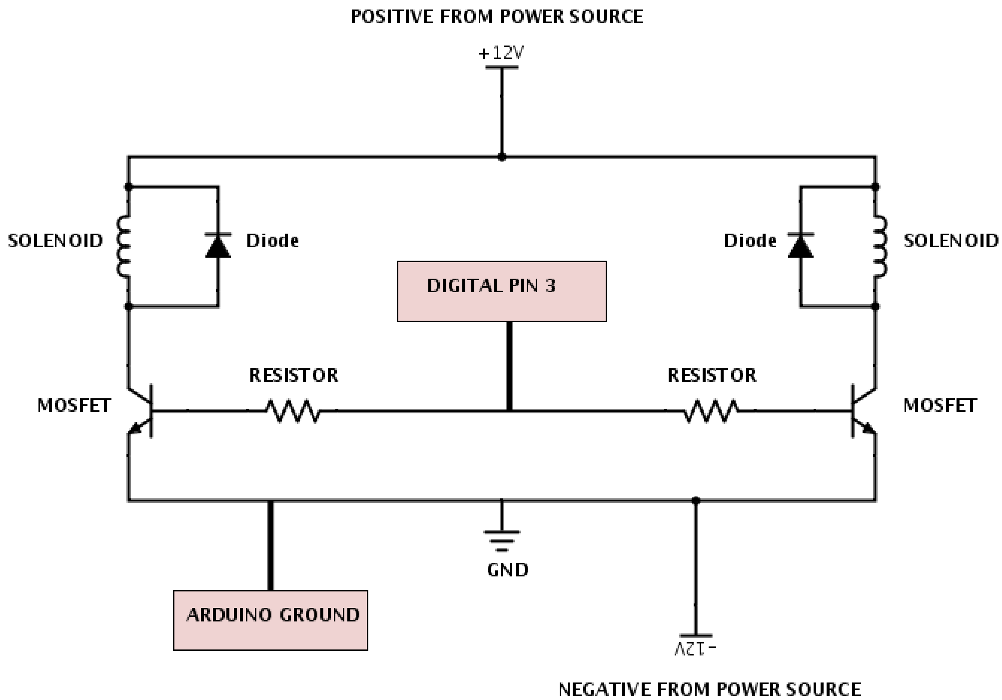


Figure 4.3.9 *– Schematic for Solenoids*

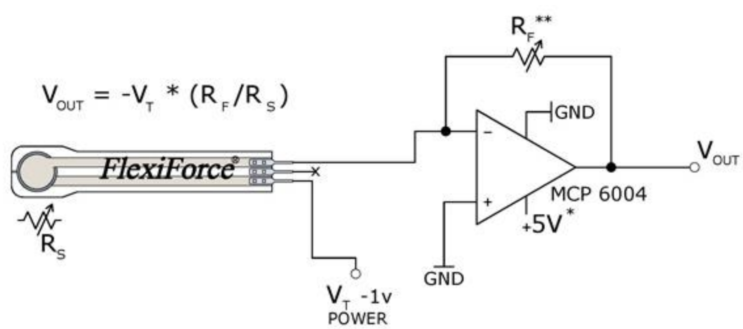
4.4 Pressure Sensors

The use of pressure sensors was absolutely essential for this project. Since our focus was to make the wheelchair as safe as possible, it was vital to know when the person gets out of the wheelchair. To be able to tell when the person using the wheelchair was attempting to get out of it, pressure sensors were going to be placed on the arm rests as well as on the actual seat itself. Upon conducting research, our group found that the sensors produced by the company Tekscan were the most compatible to the requirements of our project. Tekscan produces a wide variety of sensors, but there FlexiForce force sensors were the type of sensors that were best suited for this project. There were several different models of FlexiForce force sensors, which were A201, HT201, A301, and A401. After analyzing all of the different FlexiForce force sensor models, the A201 and A401 models were determined to be the best force sensors to use on the safety enhanced wheelchair.

With the use of the FlexiForce pressure sensors, determining when the person was getting out of the wheelchair should be possible. To accomplish this, FlexiForce pressures sensors, A201 Sensors, were strategically placed on the arm rests of the wheelchair. The decision to use the A201 FlexiForce sensors on the arm rests was made based upon the size of the sensor. Due to the A201 FlexiForce sensors having a smaller width and greater length than the A401 FlexiForce model, the A201 FlexiForce sensors were more appropriate to fit the arm rests of the safety enhanced wheelchair. In the Figure 4.4.1 provided below, an example of the A201 FlexiForce sensor that was used within this project was displayed.

Figure 4.4.1 *– FlexiForce A201 Sensor*
Used with permission from Tekscan

The reason for choosing the A201 FlexiForce pressure sensors was because the A201 sensors fit the requirements of this project perfectly. The sensors were 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 A201 FlexiForce pressure sensors come in different versions that were for detecting different levels of pressure ranges. Since a person was applying pressure on the sensors in the arm rests of the wheelchair, the A201 FlexiForce pressure sensors that were built to measure up to approximately twenty-five pounds were used. The amount of pressure that these sensors can measure can be adjusted by modifying the drive voltage and the resistance of the resistor, which allowed for pressure that was up to one thousand pounds to be measured accurately. For this project, the drive voltage needs to be lowered to approximately 0.5 V and the resistance of the resistors needs to be approximately 1 kΩ. In the Figure 4.4.2 provided below, an example of the type of circuit required to modify the drive voltage and the resistance of the resistor for the A201 FlexiForce sensor that were used within this project was displayed.



- * Supply Voltages should be constant
- ** Reference Resistance R_F is 1kΩ to 100kΩ
- Sensor Resistance R_S at no load is >5MΩ
- Max recommended current is 2.5mA

Figure 4.4.2 *– A201 FlexiForce Circuit*
Used with permission from Tekscan

To be able to completely understand and fully utilize the A201 FlexiForce pressure sensor to its highest potential, a list of specifications was absolutely necessary. The A201 FlexiForce pressure sensor had the following specifications that were displayed below in Table 4.4.1.

Specifications	
Thickness	0.208 mm
Length	197 mm
Width	14 mm
Sensing Area	9.53 mm diameter
Connector	3-pin Male Square Pin
Substrate	Polyester
Pin Spacing	2.54 mm
Linearity Error	< ±3%
Repeatability	< ±2.5% of full scale
Hysteresis	< ±4.5% of full scale
Drift	< 5% per logarithmic time scale
Response Time	< 5 microseconds
Operating Temperatures	-40°C – 60°C
Force Ranges	4.4 N, 110 N, 440 N
Temperature Sensitivity	Output variance of 0.2% per degree

Table 4.4.1 *– Specifications of A201 FlexiForce Pressure Sensor*
Used with permission from Tekscan

By using the FlexiForce pressure sensors, determining when the person was attempting to get out of the wheelchair becomes feasible. To be able to accomplish this task, FlexiForce pressures sensors, model A401, were tactically placed on the seat of the wheelchair. The decision to use the A401 FlexiForce sensors on the seat came about due to the size of the sensor. Since the A401 FlexiForce sensors have a greater width than the A201 FlexiForce model, the A401 FlexiForce sensors were vastly more appropriate to be used on the seat of the safety enhanced wheelchair. In the Figure 4.4.3 provided below, an example of the A401 FlexiForce sensor that were used within this project was displayed.

Figure 4.4.3 *– FlexiForce A401 Sensor*
Used with permission from Tekscan

The A401 FlexiForce pressure sensors were chosen because they fit the specific needs of this project rather well. With these sensors, adjusting the amount of pressure that can be detected was relatively simple. This feature was a necessity since a lot of fine tuning was most likely going to have to occur to set these sensors to detect the most appropriate range of pressure. Even though they were extremely thin, they were able to measure and detect changes in applied load. Also, there were different versions of the A401 FlexiForce pressure sensors that were rated for different ranges of pressure. Since a person would be sitting on the sensors in the wheelchair, the A401 FlexiForce pressure sensors that were built to measure up to approximately one hundred fifty pounds were used. Modifying the resistance of the resistor or modifying the drive voltage adjusts the pressure ranges that the A401 FlexiForce pressure sensors can measure. This type of modifying produces the ability to accurately measure pressure up to one thousand pounds. For the A401 FlexiForce pressure sensors to be set to be able to measure the correct range of pressure that was going to be experienced during this project, the resistance of the resistors needs to be approximately 1 kΩ and the drive voltage needs to be lowered to approximately 0.5 V. In the Figure 4.4.4 provided below, an example of the type of circuit required to modify the drive voltage and the resistance of the resistor for the A401 FlexiForce sensor that were used within this project was displayed.

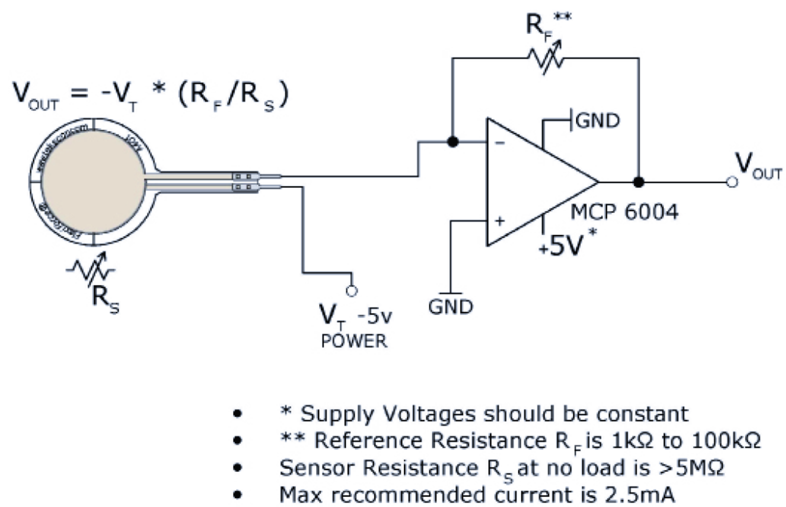


***Figure 4.4.4** – A401 FlexiForce Circuit*
Used with permission from Tekscan

To be able to completely understand and fully utilize the A401 FlexiForce pressure sensor to its highest potential, a list of specifications was absolutely necessary. The A401 FlexiForce pressure sensor had the following specifications that were displayed below in Table 4.4.2.

Specifications	
Thickness	0.208 mm
Length	56.8 mm
Width	31.8 mm
Sensing Area	25.4 mm diameter
Connector	2-pin male square pin
Substrate	Polyester
Pin Spacing	2.54 mm
Linearity Error	< ±3%
Repeatability	< ±2.5% of full scale
Hysteresis	< ±4.5% of full scale
Drift	< 5% per logarithmic time scale
Response Time	< 5 microseconds
Operating Temperatures	-40°F – 140°F
Force Ranges	0 – 1 lb, 0 – 25 lb, 0 – 100 lb
Temperature Sensitivity	Output variance of 0.2% per degree

***Table 4.4.2** – Specifications of A401 FlexiForce Pressure Sensor*
Used with permission from Tekscan

4.5 Liquid Crystal Display Module (LCD)

The Liquid Crystal Display (LCD) that we are designing to be implemented for our will wheelchair assembly will be at least 3 to 4 inches in length in order to preserve the space of the chair. LCD screens can be custom made to suit most needs. For our project we will custom design the screen will be used to track the battery life of the overall power supply to determine whether it's at one hundred percent or reaching zero percent, which at that time will then notify the user if the power supply needs to be charged or not. The device will also determine whether the chair the braking mechanism is in the unlocked position or in the locked position, which is crucial for the user to insure that when the user leaves the chair the chair is properly locked.

4.5.1 Liquid Crystal Display Panel

When choosing the LCD for our project, we've chosen to use a character-like display by SparkFun Electronics instead of graphic or color display mainly because of the Low-cost, power usage, and the size of the module. Since our project only requires displaying 3 lines of information, we then only need to a module that will be 16 characters per line with a maximum of 2 lines with a 2 row connector. Any more than that will be just a waste of space and since the user just only needs to observe it for data display, we don't to need to really make any major graphic changes to it. The character display has an electro-luminescent backlight to provide for better power efficient and has a cold Cathode fluorescent light which will is known for consuming less power than light emitting diode displays. Figure 4-5.1a shows the outline diagram of the LCD screen for this project which contains the dimensions, which was one of the factors that made us choose this particular screen. We didn't want to have a LCD screen which was too big for the arm rest or would cover too much room preventing the user from comfortably resting their arm on the armrest. Also the Arm rest will be on top of one of the pressure pads that will measure whether the user is getting up or not.

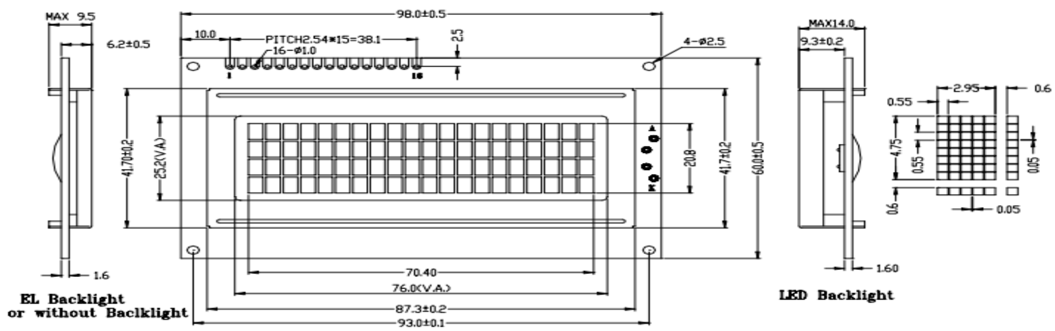


***Figure 4-5.1a**: Outline Dimension of the LCD Screen*
(use with permission from sparkfun.com)

The LCD that we've chosen to use comes with a Hitachi HD44780 Crystal Display Controller/Driver built onto the back LCD screen. The 44780-display controller requires 12 pins of a microcontroller to work properly. The controller can be configure to drive a dot-matrix LCD under the control of a 4 or 8 bit microprocessor, which is very useful since all the functions such as Display RAM, liquid crystal driver, and Character generator(which produces static or animated text) will require it. A minimal system can be interfaced with this controller. The Device has a 9,920 bit character generator ROM (240 character fonts) and an 80 by 8-bit display RAM which we used to store the data we needed to be displayed on the LCD display. Figure 4-5.1b is shows the LCD controller and driver with the labeled pins and how it's connected to the LCD screen.

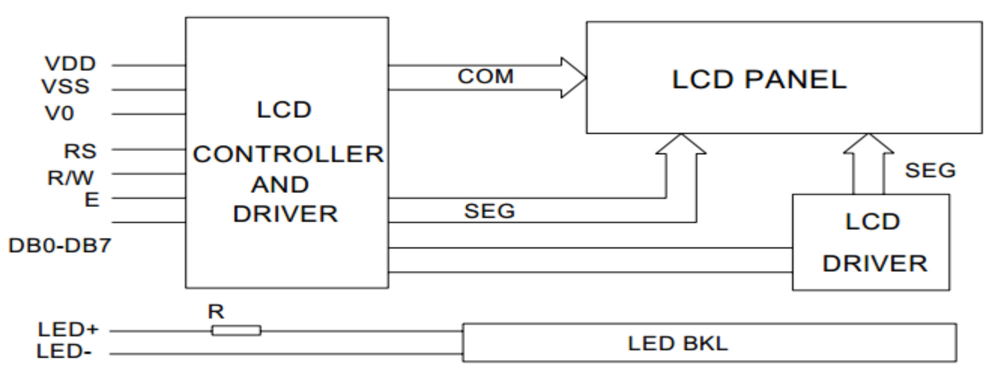


***Figure 4-5.1b**. Block diagram of the LCD controller and driver connected to the LCD screen.*
(use with permission from sparkfun.com)

Since the device comes with a display controller we have a microcontroller connected to certain pins in order to send the information that we need to be displayed on the LCD screen. Pins 1-3 are reserved for the power supply, Pins 4-6 are for the read/ write operations Pins 7-14 are used for the data buses in order to be able to send the Data to the LCD. Figure 4-5.1c is a list of interface pin description on the display controller that will be used by either the microcontroller or the battery source. It has the pin number, the symbol, the external function (shows which pin is only for the power supply or microprocessor) and the function of each symbol.

Pin no.	Symbol	External connection	Function
1	V_{SS}	Power supply	Signal ground for LCM (GND)
2	V_{DD}		Power supply for logic (+5V) for LCM
3	V_0		Contrast adjust
4	RS	MPU	Register select signal
5	R/W	MPU	Read/write select signal
6	E	MPU	Operation (data read/write) enable signal
7~10	DB0~DB3	MPU	Four low order bi-directional three-state data bus lines. Used for data transfer between the MPU and the LCM. These four are not used during 4-bit operation.
11~14	DB4~DB7	MPU	Four high order bi-directional three-state data bus lines. Used for data transfer between the MPU
15	LED+	LED BKL power Supply	Power supply for BKL (Anode)
16	LED-		Power supply for BKL (GND)

Figure 4-5.1c: *Pin Interface Description List*

We have an idea of which pins will be used in order to send the information from the microprocessor. We will also be using a data pin in order to send information about the battery power level. The LED backlight (LED+ & LED-) will be set to turn off when the battery power level goes under 40 percent or by user input. This microcontroller will act as the power management system and therefore, it is able to calculate the remaining power on the battery at all times. Once battery power information is obtained by the microcontroller, it will run some code to be able to send the given information to the *HD4470* LCD drive controller. Once the *HD4470* LCD drive controller receives the selected bits of data, then the battery information can be refreshed on the LCD in order to display the most current status of the battery. Figure 4-5.1d shows the LCD write mode timing diagram since we will be only writing to the LCD and The user will be reading the information from the LCD screen. The Diagram shows the Frequency and the time in which data will be written to the LCD and displayed on the LCD screen.

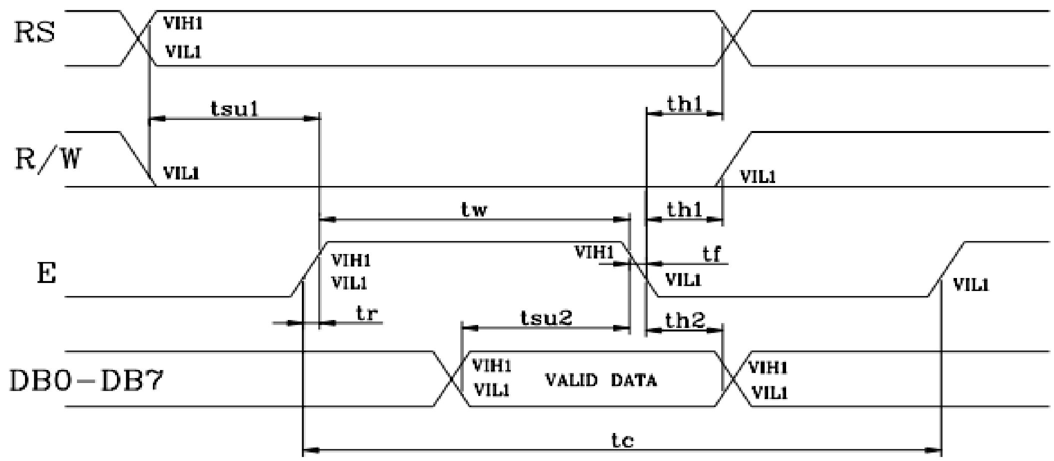


Figure 4-5.1d: *LCD Write mode timing Diagram*
(use with permission from sparkfun.com)

Basically the Chart above is showing that the data Figure 4-5.1e shows an activity diagram of what the LCD will display when the solenoids is in the locked and unlocked position. It also shows when the RFID card is detected or not.

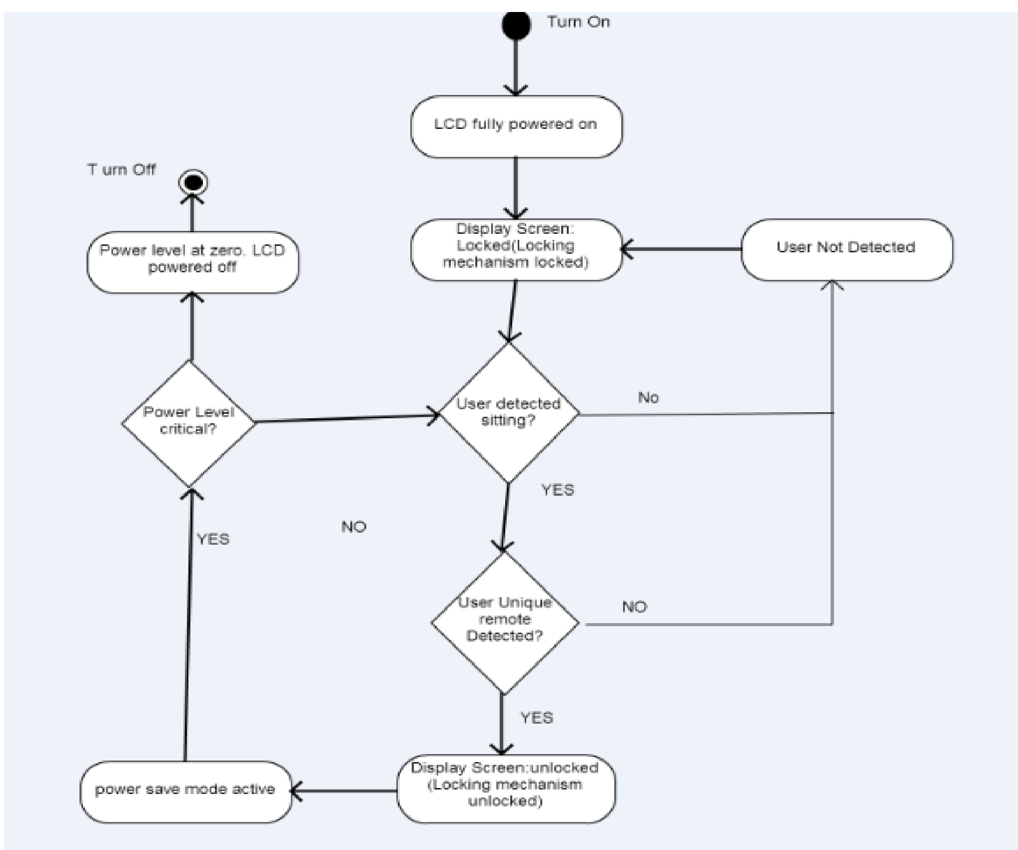


Figure 4-5.1e*: Activity diagram of The LCD screen unlock/lock display*
(Use with permission from sparkfun.com)

4.5.2 Character Generator

Once we figured out that, all the pins are connected and we will then successfully be able to send a signal from the microcontroller to the LCD panel. We then need to figure out how we're going to display characters. Based on the device were using, we will need to access the character generator library, which contains all the symbols, letters and numbers for us to display anything we want. Figure 4-5.2b shows a graph character chart and what pins need to be active to display that particular character.

***Figure 4-5.2b**. display's the pins for the character generator (use with permission from sparkfun.com)*

Figure 4-5.2b shows an activity diagram of a user running through the controller to be able to program a single character to be displayed on the LCD screen.

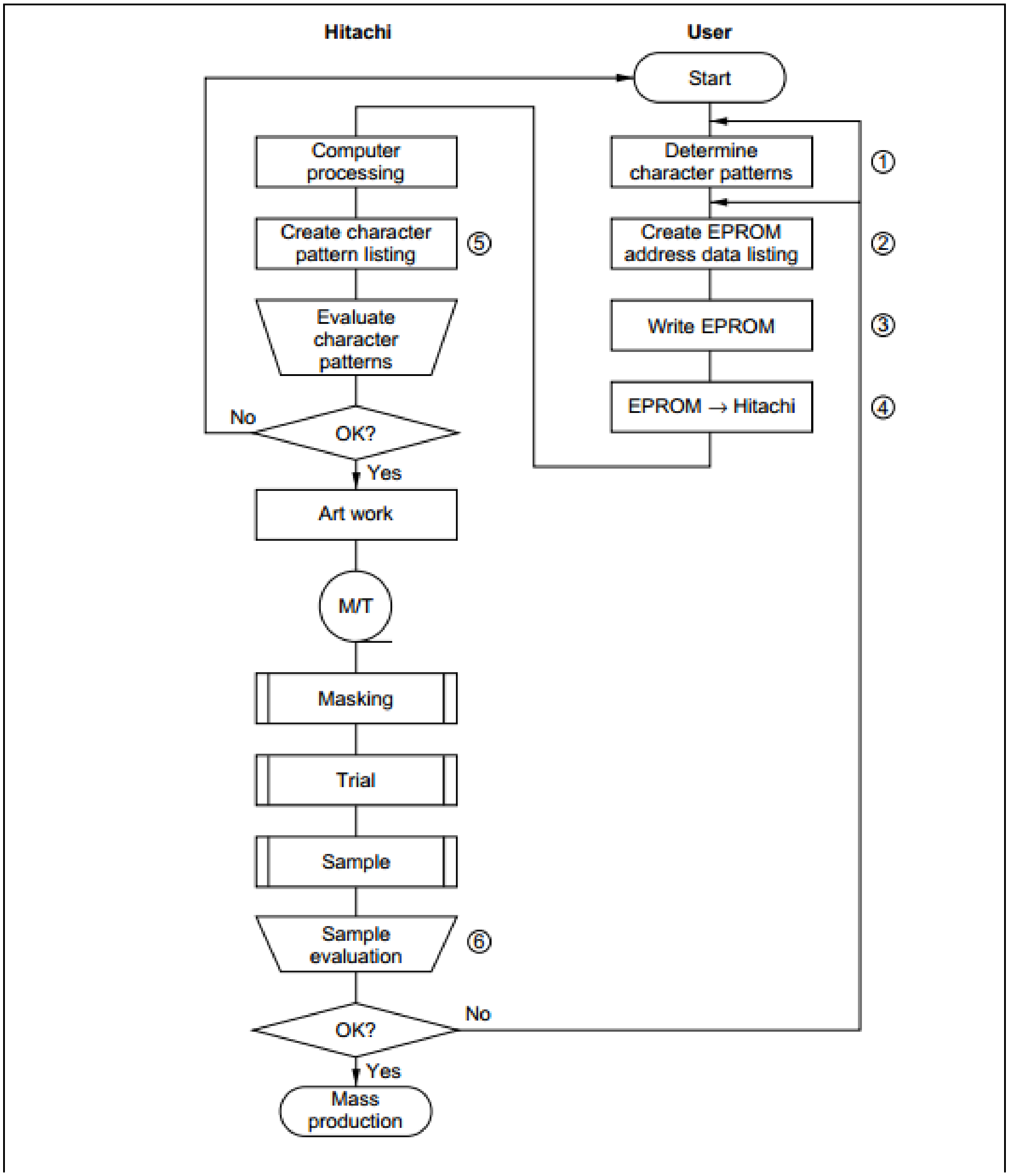


Figure 4-5.2b : *shows an activity diagram of the user producing to the LCD driver*

(reprinted with permission from sparkfun.com)

When every character that is required has been programmed through the Character generator, then we have been able to display the characters on the LCD screen in which we can the test to see if the word comes up or not.

4.6 Power supply

4.6.1 Power supply source

Choosing the power supply for this project is very critical for this project since all of the devices will be power by this single power source. There are many essential parts to the design of our power system that will provide the power requirements to all of the components of our system. We have research and discuss many potential solutions to each area of our design and then make decisions based on cost, availability, feasibility, efficiency, and precision. We created the most cost efficient, as well as electrically efficient system as possible, which would then translate into an overall high performance solution to our design requirements. For our senior design project we got a power supply that is powerful enough to handle several factors which will be first being able to power the locking mechanism to ensure that it locks the wheels when the user is not either in the area or if use requested it to be locked or unlocked. Second, the power supply will need to power the pressure sensitive pads which will be need to detect to see if the user is sitting completely down in the chair in order to unlock the locking mechanism. Third, the power supply will need to power the liquid crystal display, which will be used to display how much of the remaining battery will be left and to display whether if the locking mechanism on the wheelchair is in the unlocked or locked position. The fourth thing is that the power supply powers the rfid sensor which is used for unlocking the chair. The fifth is that the power supply is rechargeable for everyday use.

Some advantages of using rechargeable batteries are many which include performance, reliablability and weight. Since rechargeable batteries as their name states can be recharged many times over, the total service life exceeds that of disposable batteries by a lot. Also because they are rechargeable it will save the consumer money allowing the patient to recharge the batteries for an infinite number of times. It is very important to be environmentally conscious and since the lifetime of these batteries is so much longer than the disposable ones they reduce the amount of hazardous waste due to batteries. The rechargeable batteries with no hazardous can be disposed of in regular landfills and those with hazardous waste can be recycled. After mentioning all those factors for our project, we got a power source which is not only rechargeable it handles the entire circuit. Table 4.6.1a handles shows a chart of all the voltages of every feature we will need in this project.

Component	Power Requirement
Microcontroller	5V DC
Solenoid(2)	12V DC
LCD screen	5V DC
LED Backlight on LCD screen	5V DC
RFID Sensor	5V DC
Pressure Pads(3)	5V DC per sensor
GPS	5V DC
GSM	5V DC
Power Supply 1 & 2	12V/ 7AH

Table 4.6.1a *- Components and their power usage*

The are several components that have to have that have separate power sources such as the GSM module that will have its own independent power source. The RFID card will not be connected to the power source because it will use remotely but the sensor will have a power supply. Besides these two components everything else will be powered by one power source. Two voltage regulators were required to provide a constant voltage level, which we will need to prevent overloading the circuit since so many components are attached to it. Since our power source will need to be 5 and/or 12 volts, we have two voltage regulators that will be able to handle that. Figure 4.6.1b describes a schematic of the voltage regulator and how if functions through a set of diodes and resistors to present an output.

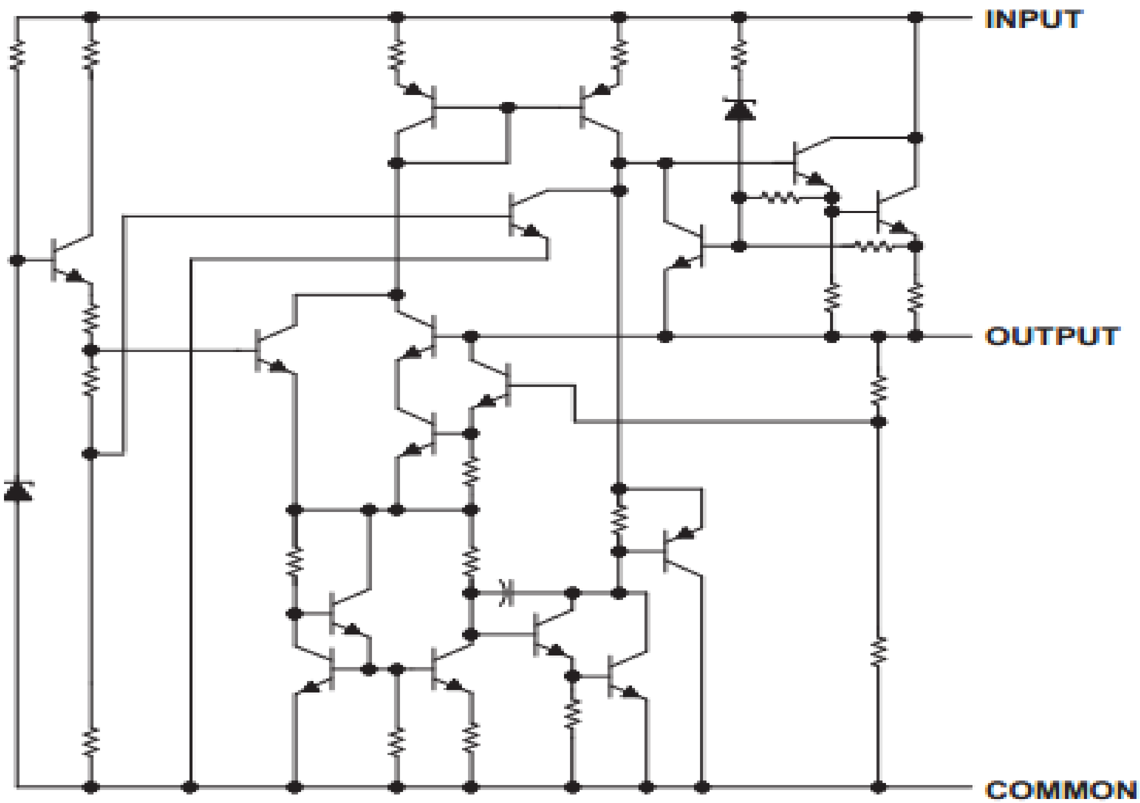


Figure 4.6.1b schematic of the voltage

The voltage that we believe will fit best with for our main power source in our design will be LT1676 switching voltage Regulator made by linear technologies. The LT1676 has a minimum input voltage of 7.6 volts, a maximum of 60 volts, and with a peak current of 700ma. Figure 4.6.1c shows the comparison of the different voltage regulators for the U7800C series. The diagram shows why we will choose the LT1676 over our previous options.

			MIN	MAX	UNIT
V_I	Input voltage	μA7805	7	25	V
		μA7808	10.5	25	
		μA7810	12.5	28	
		μA7812	14.5	30	
		μA7815	17.5	30	
		μA7824	27	38	
I_O	Output current			1.5	A
T_J	Operating virtual junction temperature		0	125	°C

***Figure 4.6.1c :** different voltage regulators of the UA7800 series*

Since we have a power supply with around 12 volts, we have considered have one Lead acid rechargeable battery by Jameco that supplies 12 volts with 7500 mA. The weight of on is 6.8 pounds, which is perfect for this project. The battery supplies the locking mechanism to provide the 12 volts needs in order to power it effectively and supply power to the sensor pads, the LCD screen, and RFID sensor with the exception of the GSM module/GPS which is powered by its own individual source. Figure 4.6.1d shows our overview circuit of our power supply connected to a 5 voltage regulator. we came to this conclusion simply because having a non-commercial power supply will be too costly and too heavy for the wheelchair to be moved without having a lot of resistance against. While doing our research we looked at the comparison of every rechargeable type of battery and choose the lithium Ion commercial battery based on the weight, temperature, and nominal voltage. Lead Acid tend to have one of the lowest cost per-watt ratios, much lower than lithium-ion chemistries in operation, the lithium-ion electrochemistry is susceptible to damage from overcharging or other faults in the battery charge control. Therefore, it requires a more sophisticated charging technique with mandatory protection against overcharging. In addition, it is essential to build protection circuitry into the battery pack so that thermal dissipation does not cause the battery to light on fire and/or explode. Lithium is also highly reactive with water so care must always be taken to not overexpose these batteries to water.

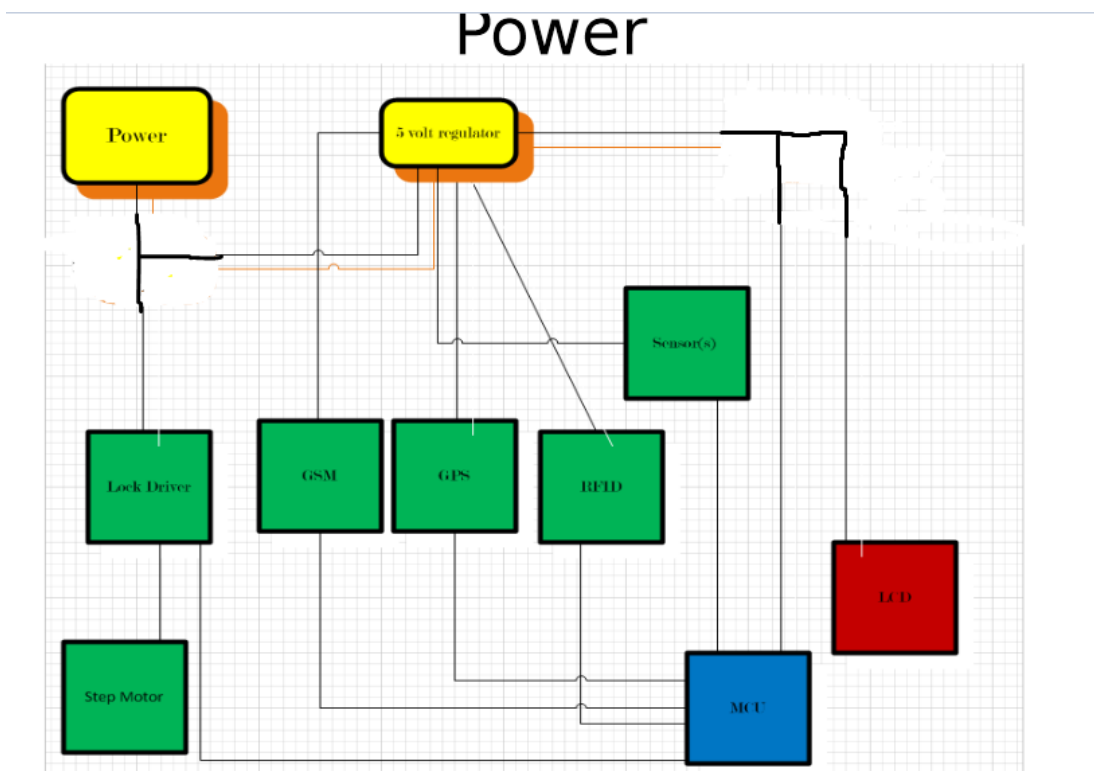


Figure 4.6.1d*: shows the diagram of how eachthe voltage regulator with an input of 12V*

The advantages of using rechargeable batteries are many which include performance. Since rechargeable batteries as their name states can be recharged many times over, the total service life exceeds that of disposable batteries by a lot. It is very important to be environmentally conscious and since the lifetime of these batteries is so much longer than the disposable ones they reduce the amount of hazardous waste due to batteries. The rechargeable batteries with no hazardous can be disposed of in regular landfills and those with hazardous waste can be recycled.

Figure 4.6.1d shows the comparison chart we used to come up with the decision of selecting our battery type.

Battery Characteristics	Lead Acid	Nickel Cadmium	Nickel Metal Hydride	Lithium Ion
Energy/Weight (Wh/kg)	30-40	40-60	30-80	100-160
Energy/Size (Wh/L)	60-75	50-150	140-300	250-360
Power/Weight (W/kg)	180	150	250-1000	250-340
Charge/Discharge Efficiency	50-92%	70-90%	66%	80-90%
Energy/Price (Wh/USD)	7(sld) - 18(fld)	—	2.75	2.8 - 5
Self-discharge Rate (per mo.)	3-20%	10%	30%	8% (21°C)
Time Durability	—	—	—	24-36 mo.
Cycle Durability	500-800	2,000	500-1,000	1,200
Nominal Cell Voltage	2.105V	1.24V	1.2V	3.6V
Nominal Capacity	7200 mAh	900 mAh	700 mAh	4800 mAh
Size	151x98x98mm	73x29x52mm	51x48x22mm	127x80x43mm
Weight	3940g	210g	135g	678g

Figure 4.6.1d*: Battery type comparison chart*

Since there is one battery which one provides the locking mechanism and the other supplies the sensor pads, in this project these two components are not able to function without the other. In this case, the system will be designed so that if the batteries runs low or is out of power, it will act as if the entire system is running low battery are low or out of power until the power supply is charged to a state in which they can work in unison. Figure 4.6.1e shows the discharging of the battery's to provide us with an insight on how long that battery will be charged before it dies in nominal capacity.

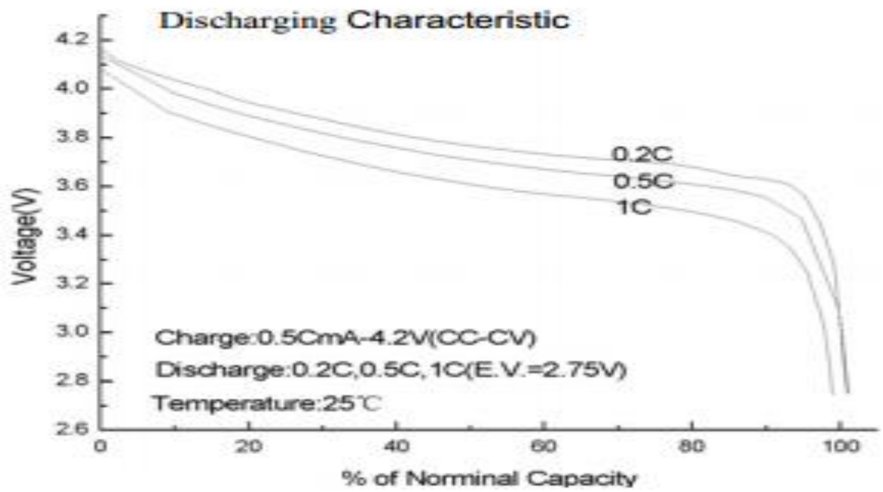


***Figure 4.6.1e**: discharging characteristic graph of the voltage while being used*

The battery came with its own DC portable charging adapter, which makes it very easily for the battery to be charging in case that the user is nowhere near home. Figure 4.6.1f shows the charging characteristic based on how much voltage, current and capacity is being used over time. This graph gives an idea of how long it takes the battery to charge, which is crucial because we don't want it to take a very long time to charge the battery to the point where it will inconvenience the user.

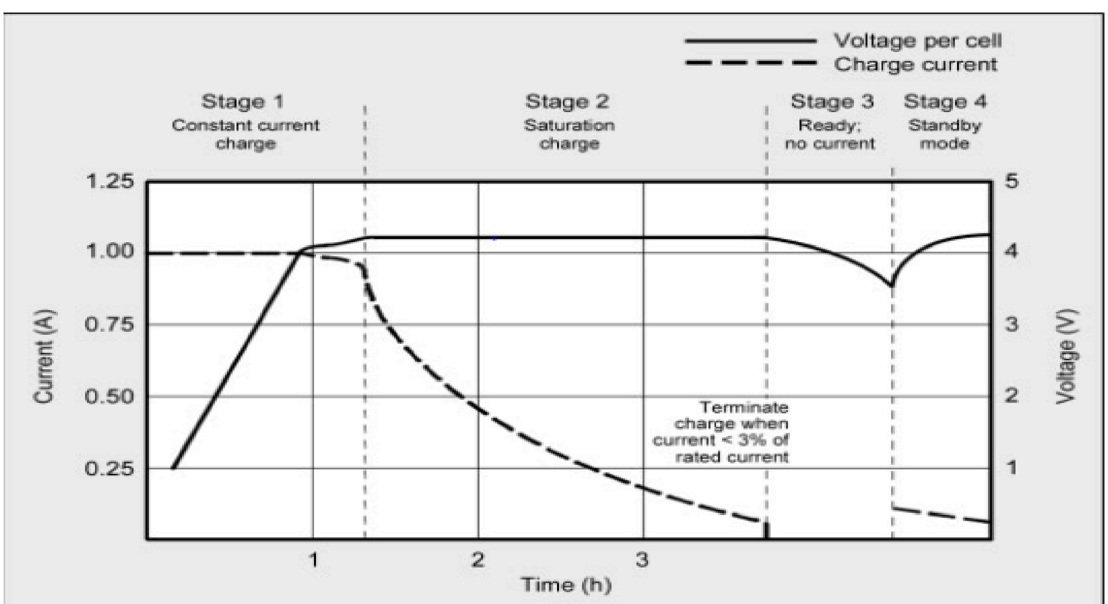


***Figure 4.6.1f** Charging Characteristic graph for the voltage, current and capacity levels*

When it comes time to connect the batteries to our circuit, we have using 2 female power jack PCB mount socket connectors, since our battery comes with two male connectors and female connector which will all give the same 12 volt output. The connector that will require the connection for our male connector will need to be a socket with a 2.1mm barrel-type in diameter, which has a comes with a life cycle of 5000 cycles, an insertion force of 5lbs maximum and withdrawal force of 0.5 lbs. minimum . Figure 4.6.1g shows a diagram of the actual power jack mount socket we will need to be to have in order to supply power from the battery to the circuit.

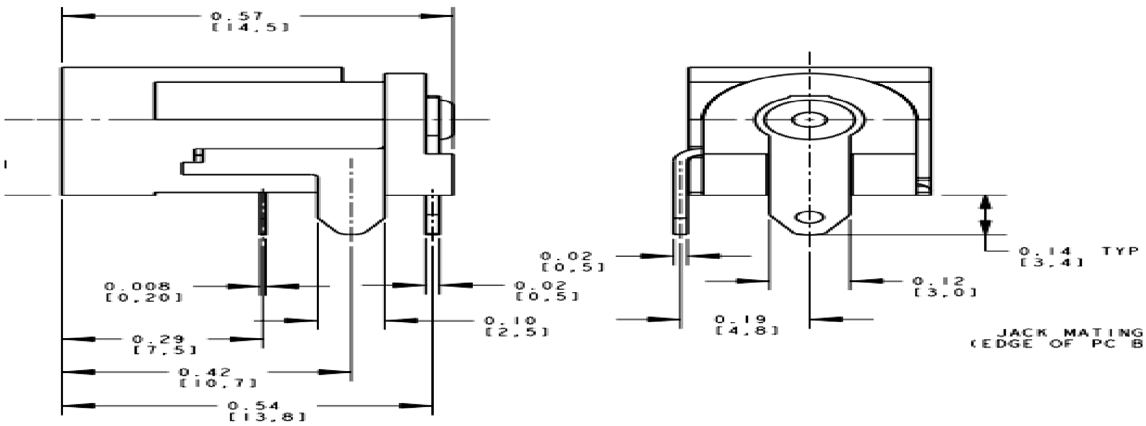


Figure 4.6.1g *Diagram of Power jack mount socket*

Once the power is connected to the rest of the circuit, we can then manipulate the voltage through a series of voltage regulators. Figure 4.6.1f Describes an example of a circuit in which a switching voltage regulator is used similar to the one we require for our design because we will have voltage that will be entering one source but be used in several different ways.

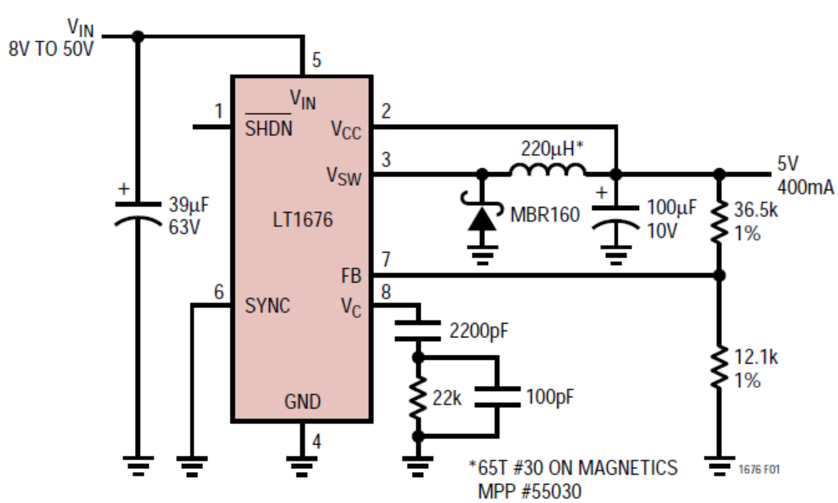


Figure 4.6.1j: *switching output regulator*

For our project, we built our two voltage regulators based on the diagram from above. Due to some parts being unavailable we had to change some of the values of some of the capacitors and resistors. Figure 4.6.1j-1 shows the diagram that we made in LTsplice for our project to be sure that I circuit will still put out an output of 15 volts when we have an input of 12 volts.

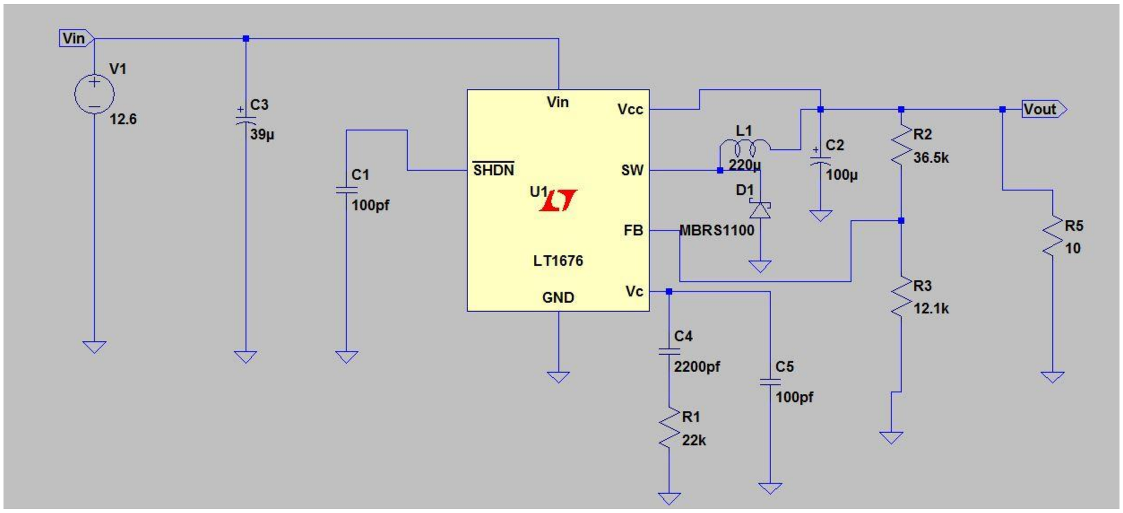


Figure 4.6.1j-1: *Diagram of the switching regulator*

Once we change the values to the ones we order we were able to get an output current of 500ma with 5 volts shown in Figure 4.6.1j-2. The red line shows the output current of 500mA against at 10ohm resistor, the yellow line shows an input voltage of 12V, and the blue line shows and output voltage of 5 volts, with the circuit on the bottom of the simulation.

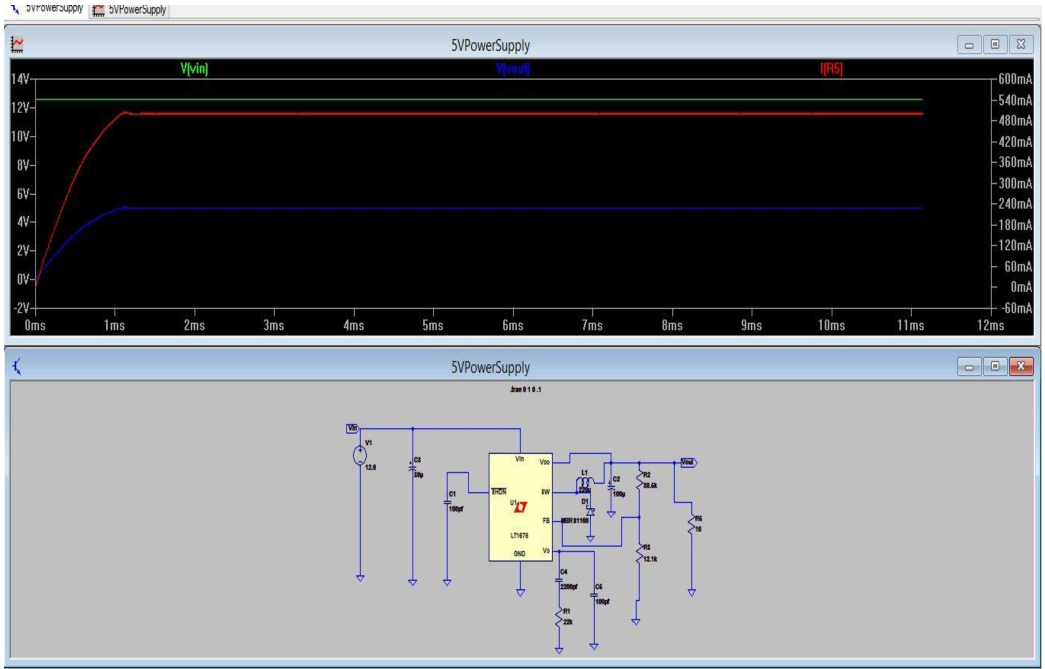


Figure 4.6.1j-2: Simulation of the output and input voltage

4.7 GPS Module

Being that our system will be on a wheelchair it must be portable, easy to improve, power efficient, and of course affordable. The FGPMMOPA6H GPS Standalone Module, designed by GlobalTop Technologies Inc., will be the GPS module of choice for our design. Its power consumption, reliability, and physical characteristics meet and surpasses all of our requirements making it a perfect module for our design. Buildings are our biggest enemy when it comes to signal strength. Since the signal has to travel through many obstacles which can weaken the signal. With the addition of an antenna we can help boost the signal and help prevent signal loss.

4.7.1 GPS Risk Factors

The GPS module has very strict electrical requirements. Bypass capacitors, ferrite beads, and maintaining critical path resistances leaves little room, if any, for error. It requires a clean and well regulated power source and noise must be less than 20 millivolts. Noise can significantly affect the receiver's sensitivity and leads to unreliable or corrupted data. Despite being that the GPS coordinate position is vital for the GSM module we have confidence that electrical interference will be the biggest risk factor.

4.7.2 Module

The module’s compact and lightweight design makes it easy to use for a small housing as well as portable. Taking advantage of the 15 mm by 15 mm dimensions we can place the module in a strategic location to reduce noise interference and also have smaller PCB, saving in costs. The module has a pin position layout very similar to a vast majority of GPS modules as seen in figure 4.7.2A and figure 4.7.2B shows the pin descriptions. This helps us switch out the older model and place in the newer one without having to change very little code and wiring if necessary. Lastly it also uses two different protocols; NMEA-1803 and SIRF Binary. Power consumption is a very closely looked at aspect.

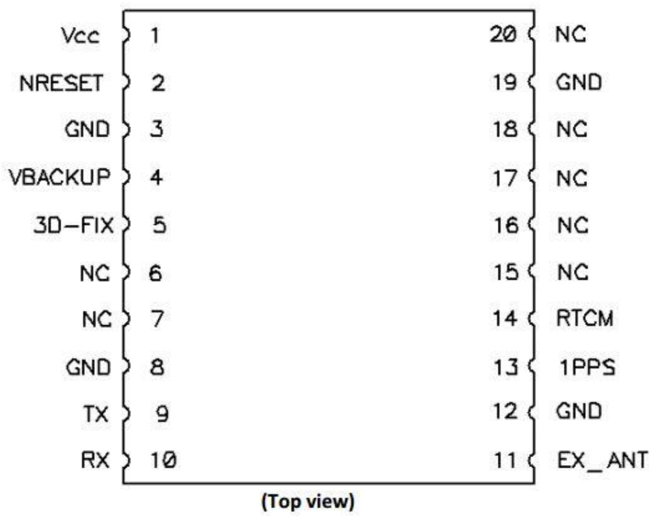


Figure 4.7.2A: *The FGPMMOPA6H GPS Standalone Module*
Used with permission by GlobalTop Technologies Inc.

Pin	Name	I/O	Description & Note
1	VCC	PI	Main DC Power Input
2	NRESET	I	Reset Input, Low Active
3	GND	P	Ground
4	VBACKUP	PI	Backup Power Input for RTC & Navigation Data Retention
5	3D-FIX	O	3D-Fix Indicator
6	NC	--	Not Connect
7	NC	--	Not Connect
8	GND	P	Ground
9	TX	O	Serial Data Output for NMEA Output (UART TTL)
10	RX	I	Serial Data Input for Firmware Update (UART TTL)
11	EX_ANT	I PO	External active antenna RF input. DC power from VCC and provide for external active antenna.
12	GND	P	Ground
13	1PPS	O	1PPS Time Mark Output 2.8V CMOS Level
14	RTCM	I	Serial Data Input for DGPS RTCM Data Streaming
15	NC	--	Not Connect
16	NC	--	Not Connect
17	NC	--	Not Connect
18	NC	--	Not Connect
19	GND	P	Ground
20	NC	--	Not Connect

Figure 4.7.2B: *GPS module Pin Descriptions*
Used with permission by GlobalTop Technologies Inc.

4.7.3 SMA Interface

The antenna does not connect directly he GPS module. A SMA interface, seen in figure 4.7.4 is the 89761-6771 SMA interface. The 50 ohms critical resistance between the module and and the antenna is handled by using this internal impedance within the SMA female interface and connects directly to the GPS module with a MCX connector.

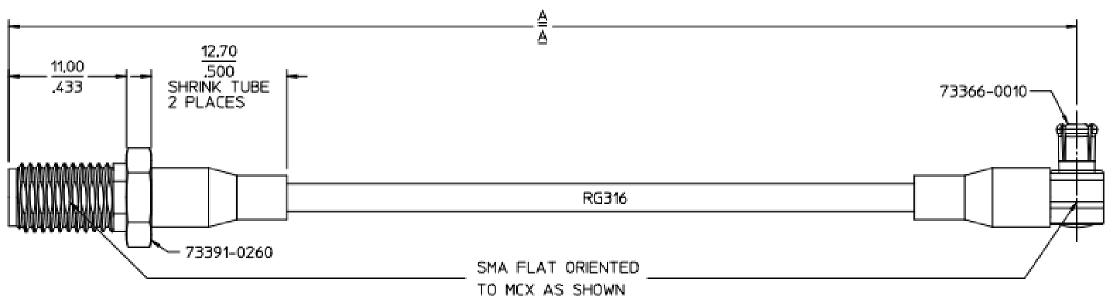


Figure 4.7.4: *SMA interface dimensions*
Used with permission by Molex

4.7.4 Power Specifications

Our main goal is to use as little energy as possible to save power for other vital functions such as the actual locking mechanism. The R4 module does exactly that. Figure 4.7.5 shows all the electrical specifications of the module. It requires a supply voltage of 3.3 volts, without an antenna, and a supply current of 56 milliampere. In addition the ability to add a backup battery is available and is required if we want to use CGEE start. Providing a clean well regulated power source to the module is a top priority because its is highly susceptible to noise. Noise affects the receivers sensitivity and should be kept below 20 millivolts and bypass capacitors should be placed as close as possible to the module. To help with power consumption there are two different power modes; Full power and Hibernate. Full power is the biggest current consumption state but is also when the measurements are of the highest quality. Hibernate is the lowest current consumption state but tracking and processor blocks are powered down, although the RTC is still running. It continuously switches between both statuses. The combination of all these different power reducing elements lets our wheelchair last longer on a single charge and saves energy for more vital components.

	Symbol	Min.	Typ.	Max.	Unit
Power Supply Voltage	VCC	3.0	3.3	4.3	V
Backup battery Voltage	VBACKUP	2.0	3.0	4.3	V

	Condition	Min.	Typ.	Max.	Unit
Operation supply Ripple Voltage	—	—	—	50	**mVpp**
RX0 TTL H Level	VCC=3.0~4.3V	2.0	—	VCC	**V**
RX0 TTL L Level	VCC=3.0~4.3V	0	—	0.8	**V**
TX0 TTL H Level	VCC=3.0~4.3V	2.4	—	2.8	**V**
TX0 TTL L Level	VCC=3.0~4.3V	0	—	0.4	**V**
Current Consumption @ 3.3V, 1Hz Update Rate	Acquisition	—	25	—	**mA**
	Tracking	—	20	—	**mA**
Backup Power Consumption@ 3V	25°C	—	7	—	**uA**

Figure 4.7.5: *Electrical specifications*
Used with permission by GlobalTop Technologies Inc

4.7.5 Positioning

GPS modules are subject to interference due to different environments and conditions. Low signal strength leads to long startup times as well as inaccurate or late coordinates. Even at low signals the GPS module’s TTFF is 34 seconds from a cold start. It’s horizontal accuracy is within 1.8m, or 5.9 feet and also can store upto 3 days of ephemeris data that results in faster TTFF. Three satellites are needed to triangulate the signal and generate a position. The GPS module can track up 22 satellites at the same time ensuring a precise position. No prior programming is required since the module handles all the require initialization and calculations on its own.

4.7.6 NMEA Messages

NMEA Messages are the data specification format for the GPS module.I uses is the ASCII characters for input and output. Each message starts with a $ and ends with <CR><LF> and within each message each segment is separated by commas, making parking very easy. The structure is a straightforward way of communicating the data in a useful manner and the amount of documentation available makes for easy understanding. This protocol also have error checking in the form of a checksum. The checksum is the exclusive-or of the entire message. It provides for a simple and effective way to check for proper transmission and prevents us from processing corrupted data. Below in table 4.7.7, is an example of a type of NMEA message broken down.

Incoming GPS Data:
$GPGGA,053740.000,2503.6319,N,12136.0099,E,1,08,1.1,63.8,M,15.2,,0000*6
4

Name	Example	Units	Description
Message ID	$GPGGA		GGA Protocol header
UTC Time	053740.000		hhmmss.sss
Latitude	2503.6319		ddmm.mmmm
N/S indicator	N		N=North S=South
Longitude	12136.0099		dddmm.mmmm
E/W Indicator	E		E=East W=West
Position Fix Indicator	1		
Satellites Used	08		Range 0 to 12
HDOP	1.1		Horizontal Dilution of precision
MSL Altitude	63.8	meters	
Units	M	meters	
Geoid Separation	15.2	meters	
Units	M	meters	
Age of Diff. Corr.		seconds	Null fields when DGPS is not used
Diff. Ref. Station	0000		
Checksum	*64		
<CR><LF>			End of message

Table 4.7.7: *Example of NMEA Message*

4.7.8 GPS Software behaviors

An integral part of the wheelchair is to be able to track its location. Having the ability to know where exactly the wheelchair is adds a great deal of security and peace of mind. To achieve this attribute we will be using a GPS module connected to our microprocessor to handle the incoming data.

This technology has become an everyday commodity that has gained enough popularity and its familiarity makes GPS modules a very affordable and readily available piece of equipment. Along with these improvements, the NMEA Messages makes it easy and simple for engineers, with even no prior experience with this protocol, to understand and work with this straightforward standard of data specification. With more and more new developers and applications using this GPS modules that manufactures of different modules have similar pin positions making integrating new and more sophisticated GPS technology seem like a seamless transition.

The GPS module automatically turns on and enters full power mode when the wheelchair is powered on. The module then attempts to acquire a coordinate location. Signal strength, weather, or external noise can all prevent the module from working correctly so we must check must check if a coordinate location is received. Two possibilities are possible at this stage; No data is received or Corrupt data is received.

In the case off no data being received we continue to attempt to acquire the coordinate location. If the coordinate location is never received, an infinite loop is created so we must have a timer to breakout of the loop. Since the TTF for the GPS module is 35 seconds from a cold start we will use a one minute timer. When the timer expires we will enable low power mode to conserve battery life. In the case of corrupt data, data from the module is sent to the microprocessor but through the parsing of the data we compare the checksum and the exclusive or of the message to see if they are equal; if not then this data is discarded.

If a valid GPS coordinate location is received, the data is sent to the GSM module. The module then engages low power mode to conserve battery life. To engage full power mode either our five minute timer expires or a certain event is triggered. The reasoning for the timer is to have an-up-to-date coordinate position in case of a valid GPS coordinate location is not received and to breakout of an infinite loop if an event is never triggered. Certain events trigger the module to “wake up” and engages pull power mode and we begin the process again. Below in figure 4.7.8 we have the activity diagram demonstrating the logical methods discussed.

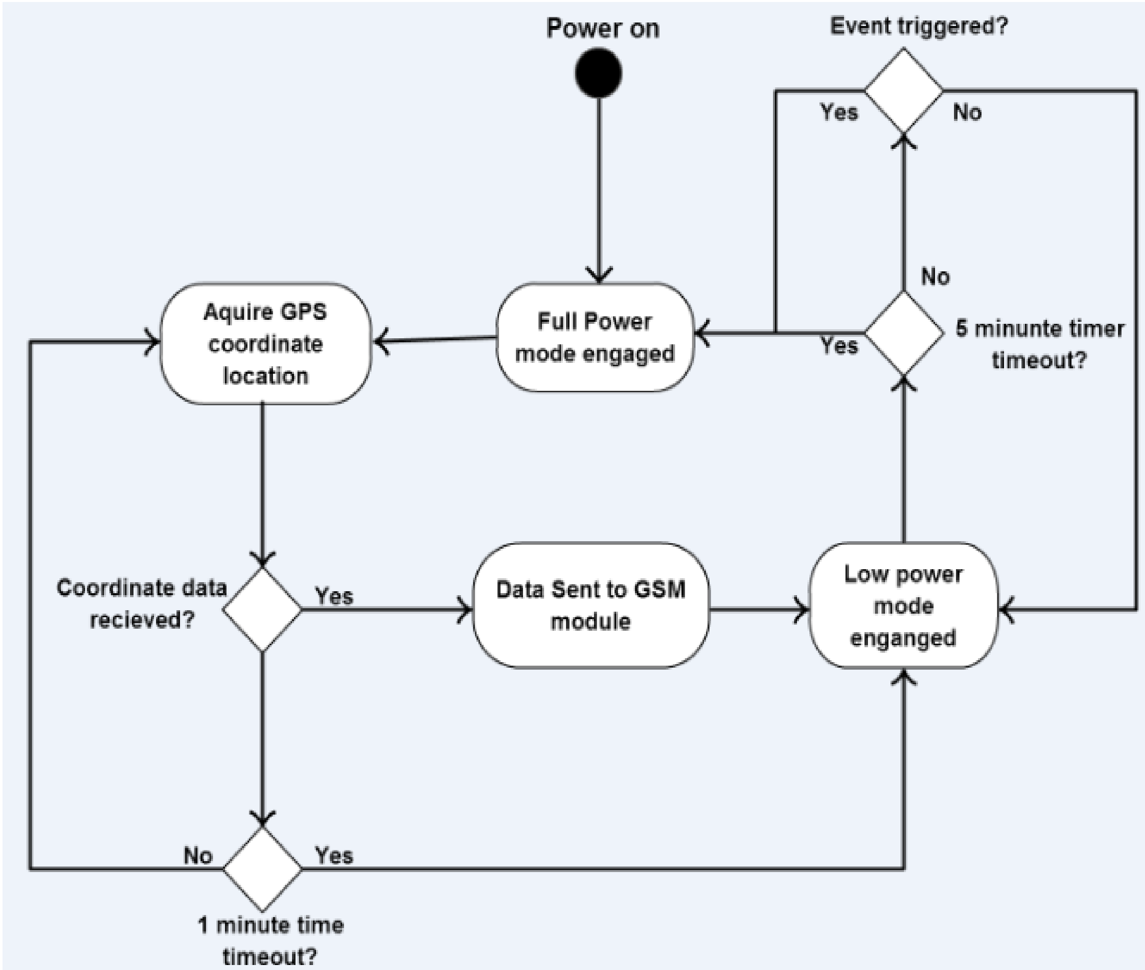


Figure 4.7.8: *GPS Module Activity Diagram*

4.8 GSM

The use of a GSM module on our wheelchair will add a variety of different features. This module will essential accomplish most tasks that a cell phone can, such as sending and receiving SMS messages and emails. Applying this technology to our chair allows for on-the-go and on-demand access to information. A SMS message can be sent to the chair and a response can be given ranging from it's location to it's battery life. Events can also trigger the chair to send out a message with the corresponding message with the corresponding trigger. Communication is the big aspect of using a GSM module. The constraint of locality is taken away and gives freedom to the user to independently go about their way wherever they please. Taking into consideration all the requirements wanted for our wheelchair, the M10 GSM module, developed by Quectel Wireless Solutions, is what we felt suited our application requirements and fit within our budget.

4.8.1 GSM Risk Factor

The GSM module presents a unique risk factor. The GSM module is responsible for sending SMS message and e-mails with the GPS coordinate location of the wheelchair when certain events occur. If this module fails then are putting the user at risk of not being able to locate their position. Being that the user is at risk makes for this to be a high risk module. Its is crucial that extensive testing is done to ensure that no logic errors exist and that the hardware is not easily susceptible to failure.

4.8.2 Module

Similar to the GPS module requirements the dimensions of our module is 29 mm by 29 mm by 3.6mm (figure 4.8.2) and weighing 6 grams making it a relatively small and lightweight module. Further improvements in GSM technology means we may have to update the hardware in the future. Like most modules, the SIM300 has a parallel 60 pin board-to-board connector allowing for integration of better and sophisticated hardware without having to change the design. A network indication led is can be added which will blink a certain pattern indicating the modules network status. It can also support a LCD display interface that can be used to display the time, help with debugging, and display data output.

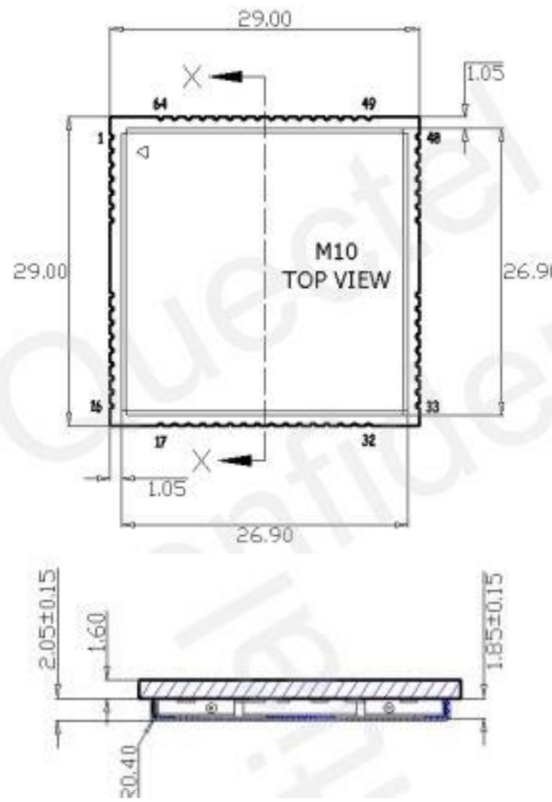


Figure 4.8.2: *M10 GSM Module Dimensions*
Used with permission from Quectel Wireless Solutions

4.8.3 SIM Card Holder

A 1.8 volt or 3 volt SIM cards are supported and the SIM card holder will depend on whether a 6 or 8 pin card will be used. An ESD is recommended component to add between the actual module and the SIM card holder even though the module has built in ESD. An have chosen to use an 8 pin SIM card holder and the recommended holder is the 91128 SIM Card Holder (figure 4.8.3), developed by MOLEX.

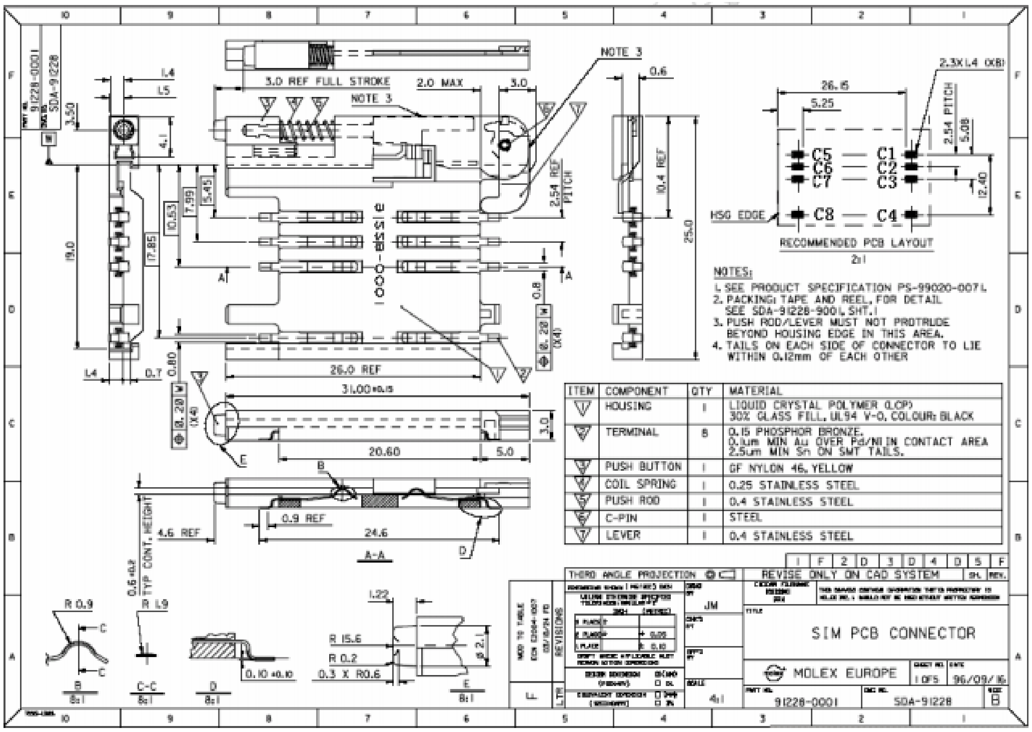


Figure 4.8.3: *Molex 91128 SIM Card Holder Schematic*
Used with permission from Molex

4.8.4 Power Specifications

Power consumption must be kept to an absolute minimum to save and extend our battery life. Our SIM300 needs a power supply between 3.4 volts and 4.5 volts and has a current consumption as low as 2.5 milliampere. The power supply must be sufficient enough to handle a current burst of up to 2 ampere. The module will be connected to the microprocessor via the pin positions. Figure 4.8.5 shows all the voltage supply pin description as well as the power on and off. In addition the module comes with the ability to have a backup battery to have an accurate and continuing RTC. A simple coin-cell battery will be connected to PIN15. Having the backup battery allows the module to be turned on from alarm mode instead of from a full power down. Similar to the GPS receiver, bypass capacitors are wanted to reduce the interference of noise. Having that the voltage never drop below 3.4 volts even when there is a transmit burst is a crucial factor to take into account. This can cause the module to not receive a supply voltage and will turn off. In addition to the module itself we will need a SIM card holder. The SIM interface will be powered have a voltage supply of 2.8 volts.

Power supply				
PIN NAME	I/O	DESCRIPTION	DC CHARACTERISTICS	COMMENT
VBAT	I	Module main power supply. The power supply of module has to be a single voltage source of VBAT=3.4V~4.5V. It must be able to provide sufficient current in a transmitting burst which typically rises to 2A.	Vmax= 4.5V Vmin=3.4V Vnorm=4.0V	
VCHG	I	Voltage input for the charging circuit	Vmax=6.5V Vmin=1.1 * VBAT Vnorm=5.0V	If unused, keep this pin open. Charging function is not supported in default.
VRTC	I/O	Power supply for RTC when VBAT is not supplied for the system. Charging for backup battery or golden capacitor when the VBAT is supplied.	VImax=VBAT VImin=2.6V VInorm=2.75V VOmax=2.85V VOmin=2.6V VOnorm=2.75V Iout(max)= 730uA Iin=2.6~5 uA	Recommend to connect to a backup battery or a golden capacitor.
VDD_EXT	O	Supply 2.8V voltage for external circuit.	Vmax=2.9V Vmin=2.7V Vnorm=2.8V Imax=20mA	1. If unused, keep this pin open. 2. Recommend to add a 2.2~4.7uF bypass capacitor, when using this pin for power supply.
GND		Digital ground		
Power on or power off				
PIN NAME	I/O	DESCRIPTION	DC CHARACTERISTICS	COMMENT
PWRKEY	I	Power on/off key. PWRKEY should be pulled down for a moment to turn on or turn off the system.	VILmax=0.3*VBAT VIHmin=0.7*VBAT VImax=VBAT	Pull up to VBAT Internally.

Figure 4.8.5: *Power supply and power on/off pin descriptions*
Used with permission from Quectel Wireless Solutions

4.8.5 M2M Data plan

In order to connect to the GPS server we will need connect to a GSM network. To connect to a GSM network we will need a M2M data plan, which can be provided through cellphone companies or even companies that only do M2M; A normal data plan on a GSM plan works just as well. The SIM card small integrated circuit is responsible for authenticating the device's permission to connect itself to a GSM network as well as giving the device its own unique identity. AT&T will be our data provider since it is affordable and have a reliable and large coverage area. The SIM card will also be provided by AT&T and will make give our module access to the network.

4.8.6 AT Commands

AT Commands are a command language that consists of short strings. When combined they can perform operation command. The ETSI GSM 07.07 specifies AT style commands that are used within GSM modules. The commands syntax starts with "AT", followed by string of characters, and ends with <CR><LF> to terminate the command line. In the case of the SIM300 in our design we can used AT commands to control the wake up functions of the module when in low power mode. Using AT commands will let us control specific operations such as receiving and sending SMS messages and emails.

4.8.7 GSM Software Behavior

A vital component was that the module must have is GPRS capabilities in order to be able to connect to a network. GPRS is the reason we can surf the web, check emails, and view videos on our mobile devices. This requires data usage which implies that we need a GSM network provider. Luckily many companies offer machine to machine data plans which helps cut the cost of the plan and the cost is based on the amount of data needed. Being that we are using a GSM module we must choose a GSM network provider. AT commands will be used to control the different task such as sending a SMS message or e-mails as well as turning on the module from it's alarm state. Extensive documentation on the syntax is available and makes for easy integration into the project.

Upon the wheelchair turning on the GSM module will automatically enable the full power mode. Next the modules will attempt to connect to the network. If connection to the network is not made it will keep trying until a timer times out. Establishing a connection is a rather speedy process so there is no need to wait longer than one minute. When the timer expires the module will be sent into sleep mode. Gaps in data coverage, low signal strength or noise interference can all be causes of why we can not connect to the network.

Once a connection to the GSM network is established the module will receive the data. On the initial startup the microprocessor will send the GPS coordinate position or a default message incase the GPS position can not be found in the form of a SMS message by default. After the message is sent the low power mode is activated. When the module is in low power mode it will only wake up when data is received. If no data is ever received then there is no reason for the module to be powered on and it will essentially be at a standstill. The only way to wake the module up is for it receive data. Once data is received the module enters full power mode and the process begins again. Figure 4.8.8 illustrates the logical methods just discussed.

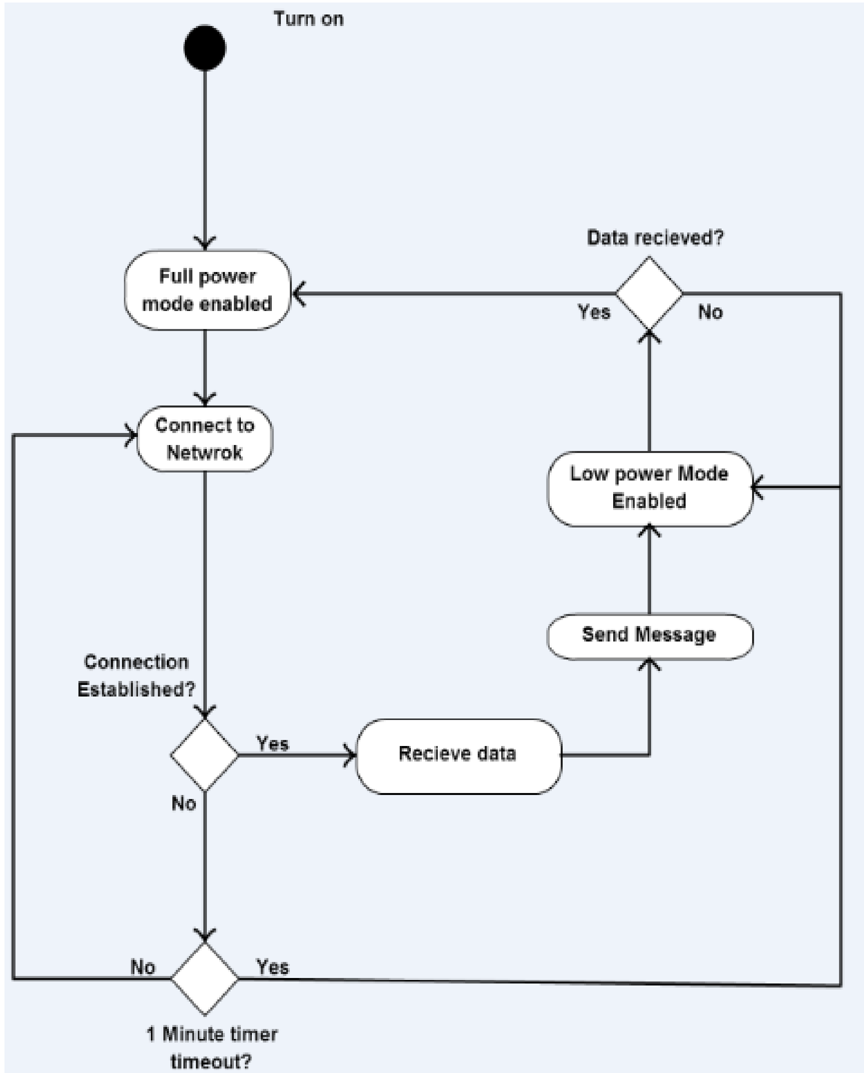


Figure 4.8.8: *GSM Activity Diagram*

4.8.8.1 Microprocessor and External Source Data

Data is received by the GSM module will come from either the microprocessor or from an external source such as a text message or email. If the data is coming from the microprocessor means a trigger event was set off. The RFID, pressure pads, and the GPS module are all the components that have events that can trigger the microprocessor to cause the module to send data from the microprocessor. If data is coming from an external source a message was sent to the GSM module itself. The only two ways that external data we will be received are SMS message and emails. Weather sending data using a text message or email there is a strict format of how the message must be sent. Even the send message activity method handles both data sources differently. Data from the microprocessor will be basically be an output and always send data to something or someone else. Data from an external source will basically act as a input and will always be sent to the microprocessors where it will be processed.

4.9 Microprocessor

The microprocessor will contain all the code and essentially be the brains of all the electrical components. Important requirements must be the amount of I/O ports to handle the GPS, GSM, LCD, pressure pad and the RFID. As like the other components its must be low power consumer to extend the battery life.

4.9.1 Code Integration Risk Factor

The microcontroller controls all the components and events that happen. The biggest risk factor that will most likely be integrating all the different coding section together into one cohesive working program. If any logical error in our code can have severely negative consequences. We are going under the assumption that all coding sections work as intended. The possibility of having components not function properly make integration the highest risk aspect of the whole design. The user, mechanics, and modules are all at risk and dependent on having the microprocessor work properly.

4.9.2 Processor Chip

A number of components in our design will transmit and receive data to and from the Atmega328 designed by Atmel Corporation. 16 touch enabled I/O pins doesnt give us the amount of pins we need so we will be using two Atmega328. One will control the GPS and the GSM while the other controls the rest of the components (figure 4.9.2). The processor supports the use of a 16MHz watch crystal oscillator but also has the option to use a digitally controlled oscillator that is triggered by resets. All the data the is incoming and outgoing will be handled by the digital I/O lines. The Atmega328 will be connected using two 10 pin IC sockets, one on each side, mounted on a PCB.

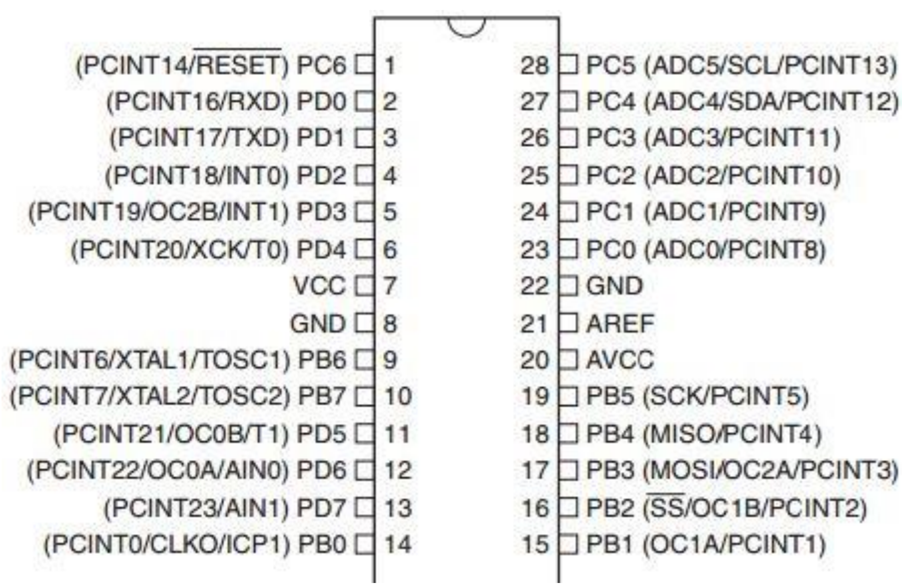


Figure 4.9.2: *Atmega328 Pin Position*
Used with permission by Atmel Corporation

4.9.3 IC Socket

In order to connect the microprocessor to the board we must find the correct socket. Since our Atmega328 has 20 pin we will a 20-pin DIP socket. The 390261 20-pin DIP socket, developed by AMP/TYCO Electronics(figure 4.9.3). This will be mounted on to the the PCB board.

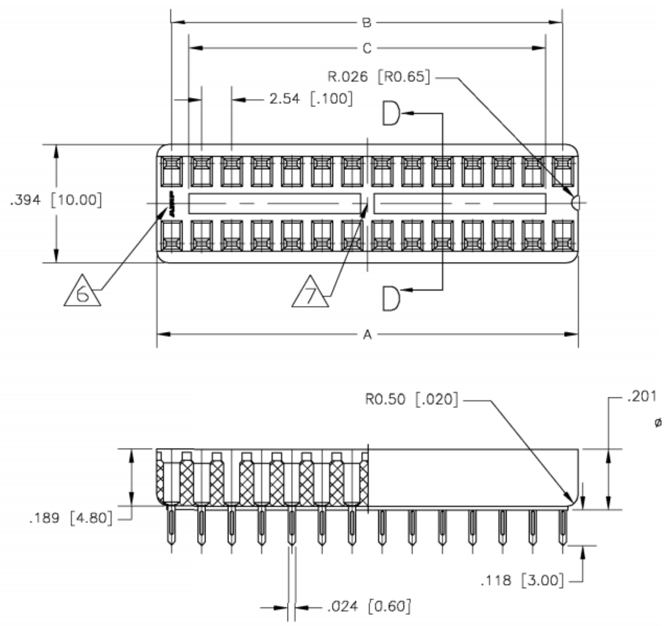


Figure 4.9.3: *390261 20-pin DIP socket dimensions*
Used with permission by by TE Connectivity

4.9.4 Power specifications

Needing a power supply of 5 volts , as shown in figure 4.9.3, it reduces the power consumption which helps with the overall battery life. In addition to i using very little power it has five software selectable low power modes. When the processor in in low power mode an interrupt can be triggered to wake up the processor. Table 4.9.4 displays all five power modes along with the corresponding active/disabled clocks. The task is executed and then enters the previous low power state. Low power modes are used when no actions are being processed and different low power states are available to meet our exact needs. Waking up the Atmega328 takes less than one microsecond, reducing delay times that may occur.

Parameter	Condition	Min.	Typ.[2]	Max.	Units
Power Supply Current[1]	Active 1 MHz, V_{CC} = 2V		0.3	0.5	mA
	Active 4 MHz, V_{CC} = 3V		1.7	2.5	mA
	Active 8 MHz, V_{CC} = 5V		5.2	9	mA
	Idle 1 MHz, V_{CC} = 2V		0.04	0.15	mA
	Idle 4 MHz, V_{CC} = 3V		0.3	0.7	mA
	Idle 8 MHz, V_{CC} = 5V		1.2	2.7	mA

Figure 4.9.4: *Voltage Specifications*
Used With permission by Atmel Corporation

Power-save mode[3][4]	32 kHz TOSC enabled, V_{CC} = 1.8V		0.8	1.6	µA
	32 kHz TOSC enabled, V_{CC} = 3V		0.9	2.6	µA
Power-down mode[3]	WDT enabled, V_{CC} = 3V		4.2	8	µA
	WDT disabled, V_{CC} = 3V		0.1	2	µA

Table 4.9.4: *Atmega328 Power Modes*

4.9.5 Microprocessor Software Behavior

Again, when the wheelchair is powered on the microcontroller powers on as well into full power mode. Next, each component is individually initialized a is ready to work. The microprocessor is now ready to handle the triggered events. There are two types of triggered events; The events that are happen and the low level and events that involve a user or a physical action. The low level events are internally triggered by other components in the system. An example are when timers expire and case a change in the state of the module. Physical action events are triggered when a user or physical action results in an a change of activity state in the components. For example when a button is pressed, or the RFID chip gets out of range.

5 Design Summary

5.1 Overall summary

The overall design of this project was created to meeting the objectives mentioned in the requirements. The purpose of this project is to create a design that will be not only user power efficient, but also comfortable for the user as well in which, the chair shouldn't have too much weight on it because it will cost more resistance for the user to move it. Since our mainly goal was to be able to have the chair lock in place when the user RFID sensor was not available, this is the motivation of our project. We will be using a microcontroller in order to control the output on the LCD screen and the RFID sensor. Figure 5.1a is the main design of the wheelchair and all the required features mention above.

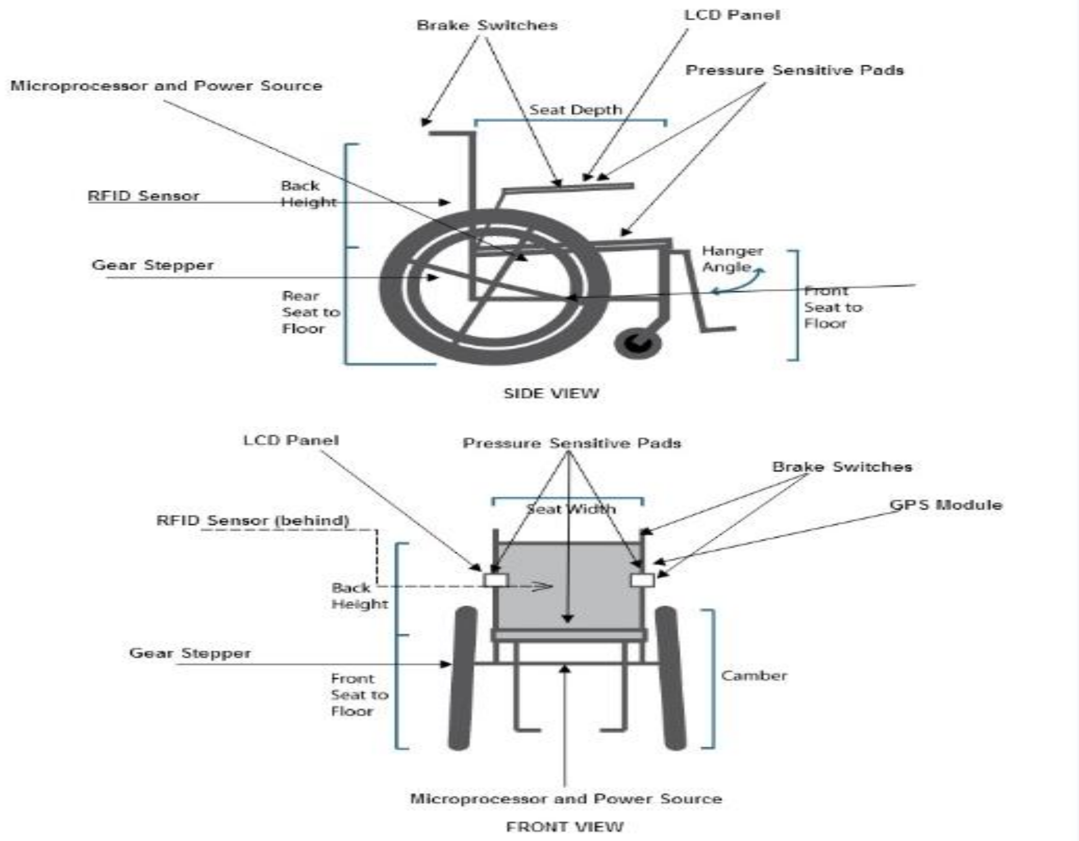


Figure 5-1.1a: diagram of the overall prototype wheelchair design

Each and every one of our features has a unique design to the circuitry of the board. We have several components that require the microcontroller and the microcontroller requires it in order to send signals to each other. For example, The LCD requires data from the stepper motor in order to display whether the chair is in the unlocked/locked. Another example is the microcontroller required a signal from the solenoids in order to detect whether the user is sitting in the chair and the RFID key is in range before unlocking. Figure 5.1.1b shows a block diagram of all the features and how they will potentially be connected together.

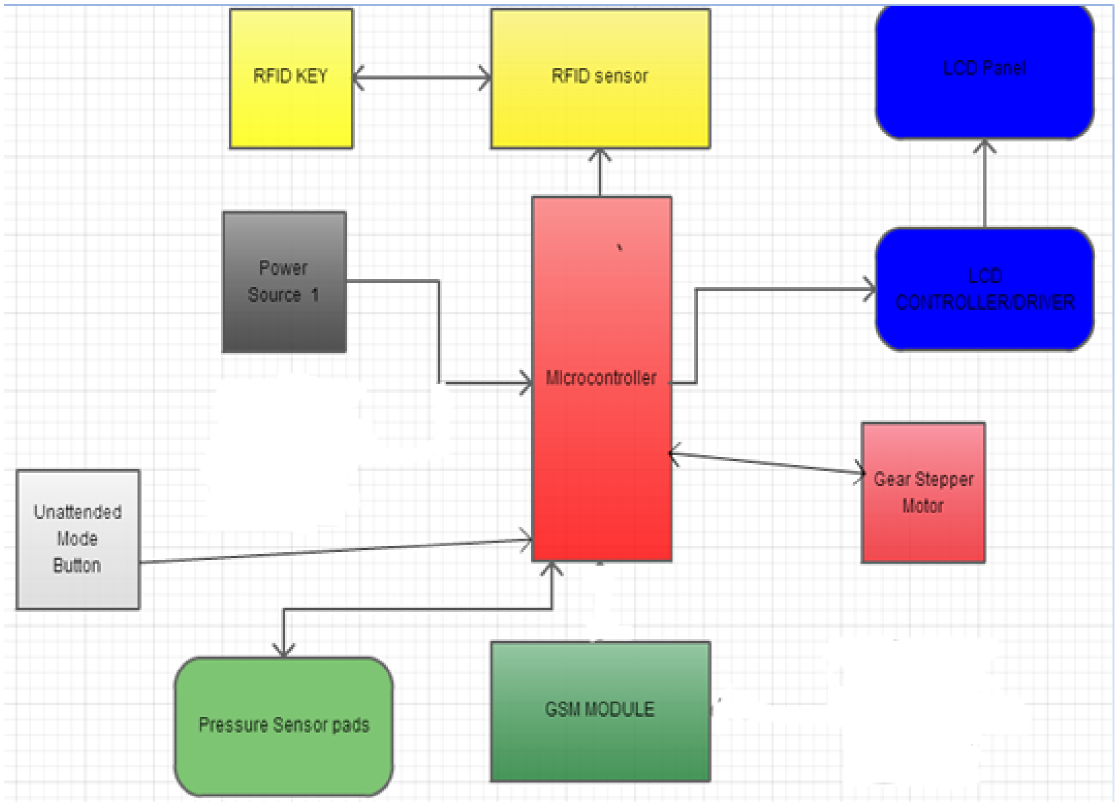


Figure 5.1.1b: all the features being used

5.2 LCD Controller/ Driver

Since the LCD driver is one of the major parts of the LCD screen, knowing where all the pins connect to is a major part in order to provide efficient functionality to the LCD screen. Figure 5.2.1a shows a block diagram of the LCD driver and its functionality from the input to the actually output display.

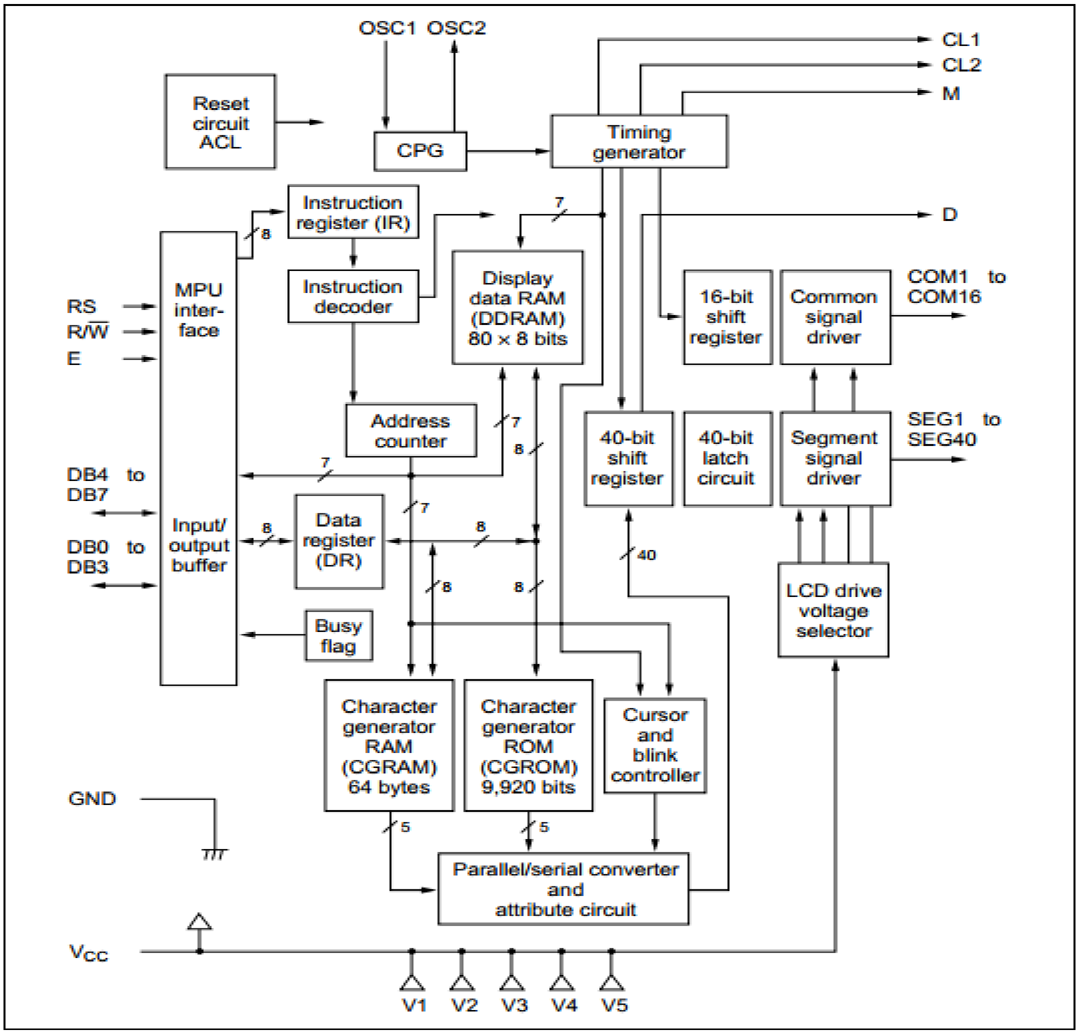


figure 5.2.1b: *Block diagram for The LCD driver*

5.3 LCD Power

Since our project has a LCD panel with an LED Backlight. The device requires two inputs of power. One power input is used as the power source to power up the LCD display so that the information can be available in real-time for the user which will be 5V with the supply current being 1.5 with a maximum of 3mA. The second power input is for the LED light so that the user can be able to have a backlight when the user might not be in a well-lit area which will is the maximum of 5V and a minimum supply current of 150mA. To be able to supply the entire LCD driver we will need to fetch the power from the microcontroller instead of putting a battery source directly on the LCD. Figure 5.4.2 shows a block diagram of how the process works of retrieving power to power up the LCD panel and the LED back light.

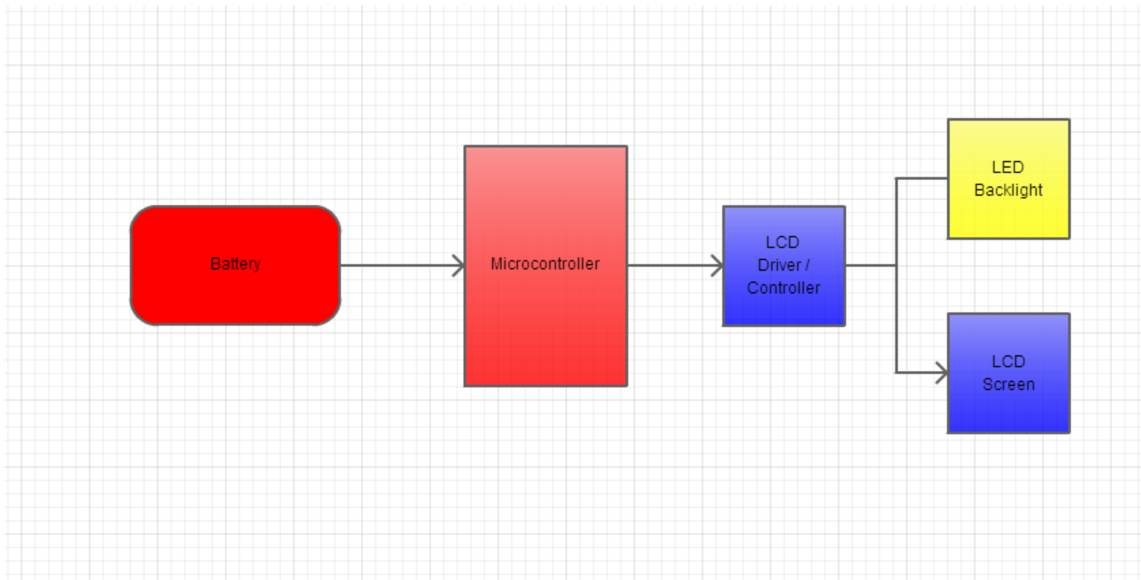


Figure 5.4.1 shows the block diagram the LCD circuit

5.3.1 LCD Risk Factor

As far as the Risk factor for the LCD, It has a very low risk factor considering the fact that there's no output there's only an input. The only risk that would be taken into account is that the LCD might get overload and either fry the LCD controller or send a feedback surge, which will be minimal consider the fact the voltage can hold a maximum of 5 volts.

5.4 GSM Shield

The GSM module will be connected to the same Atmega328 as the GPS module since there lays dependence between both components. Due to difficultly of mounting a complete working GSM module with the SIM card and antenna we will be using the actual Arduino GSM shield on our final prototype. For our design the data transmission only relies on two pin positions coming from the GSM shield. Those Pins are GSM TX and GSM RX which connect to pin PD2 and PD3, respectfully. In Figure 5.5.1 shows the shield and its size compared to a U.S. quarter.

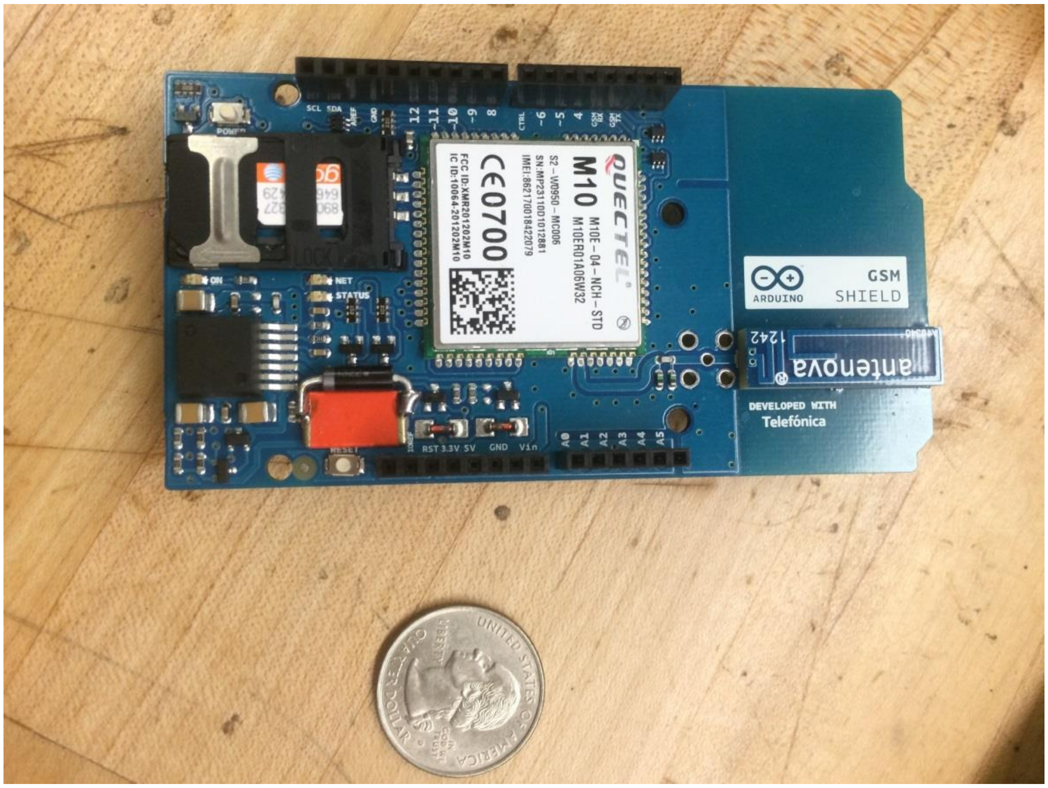


Figure 5.4.1: *Arduino GSM shield*

5.4.1 GSM Shield Power

In order to power the hold shield we will need a 5 volts power supply. The power supply will need to have a steady 700mA to 1000mA current to handle transmission burst.

5.5 GPS Module

The design for the GPS module is fairly simple. The RX and TX connect to the Arduino’s pin position 9 and 8, respectfully. The GPS takes some time to find a first fix so a red LED light is equipped to that will flash once every second when attempting to get a fix. Once a fix is acquired the LED will flash once every fifteen seconds. The GPS is simply outputting data that the Atmega328 deals with parsing the data. In Figure 5.6.1 is a picture of the GPS comparing size to a U.S. quarter.

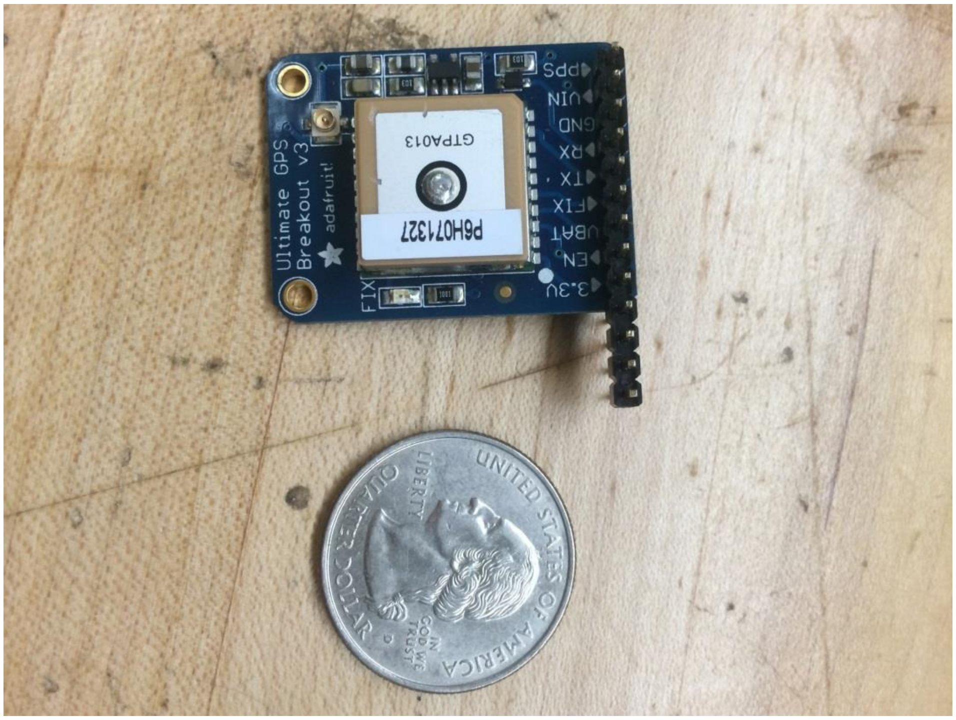


Figure 5.6.1: *GSM Module*

5.6.1 GPS Module power

The module itself needs only 3.3 -4.2 volts to operate but since we are using the breakout board it will need 5 volts to operate. Once powered on the GSM will start outputting random incorrect data until a fix is acquired.

6 Project Prototype and Coding

6.1 Printed Circuit Board

A printed circuit board is necessary to facilitate effective communication between the microcontroller and every other device which includes the GCM module, the LCD Controller, The Pressure Pads, the Gear stepper and The Power supply. The microcontroller will either be mounted on the device or will be connected to the PCB board through 20 pin connector, which will connect it to the other components via conductive pathways. The conductive pathways that connect each of the electrical components are built into the board based on a schematic diagram that is provide to the printed circuit board manufacturer at the time of purchase. The software contains extensive libraries with many parts from numerous manufacturers, making it a solid choice for the layout environment. The schematic of our self-designed microcontroller board was created using EagleCAD, and it is a somewhat familiar environment. In the board layout developer, each component of the schematic is displayed as its corresponding physical dimensions. Each part is placed on the board, and traces are drawn to meet the necessary connections. Each layer of the board is shown in a different color. There are options to attempt auto trace placement, but most often the board will be designed by manually placing the traces and then editing the layout to fix errors in trace rules.

As part of our project we will design a PCB that will house all our circuitry components. We need to design one of sufficient size that can contain are

- LCD driver/controller
- Microcontroller
- GSM module
- Gear stepper
- 18-24 Volt power supply
- RFID sensor/RFID key
- Pressure Sensor Pads

The method to selecting how to get the necessary PCB for the design is by choosing to go with a manufactured PCB. The PCB manufacturers we looked at for the project are ExpressPCB, PCBFaBexpress , and Sunstone .ExpressPCB and Sunstone both have student pricing which will be utilized if the PCB is chosen to be purchased from a manufacturer. The main options from these two providers are that there is a two-layer variety and a four-layer version available for purchase. The benefit of the 4 layer version is that the power and ground layers can be whole planes inside the PCB. This allows the PCB to be smaller and have a reduced number of traces on the top and bottom of the PCB. Having the PCB with 4 layers is almost double the price of a standard two-layer board. For the purposes of this design, a four-layer PCB is an unnecessary expense and will not be considered.

6.1.1 ExpressPCB

This company offers quite a few features that would be useful for us in designing our board. For instance, their website features a section containing resources on getting started with PCB design. In addition, ExpressPCB offers their own line of software tools for designing circuit schematics, as well as software for actually laying out the PCB itself. Additionally, these software tools are completely free of charge, and the ExpressPCB software even has a built-in ordering functionality so that users can actually use the software to order their board after laying it out. Figure 6.1.2 demonstrates some of the functionalities of the ExpressPCB software. There are built-in functions that allow the user to choose components and place them on the board. Here, the user can also add traces, and specify how wide they need to be, among other things. This software also offers countless component libraries in order to facilitate the board layout process

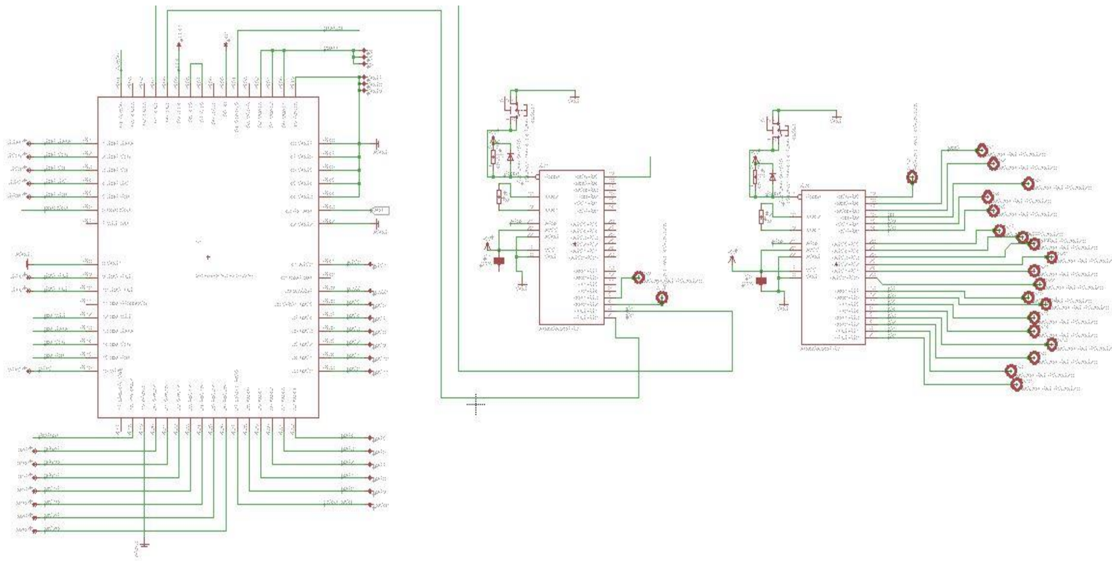


Figure 6.1.2: *PCB Complete circuit board of our circuit*

6.1.2 PCBFabExpress

Another PCB manufacturer we investigated was PCBFabExpress. Based on the experiences of students, who told us, have utilized this manufacturer before, we have decided that that this could possibly be a viable option for us. In addition to the word of mouth referrals that we have received for this manufacturer, we have also discovered that there is a discount available for students. Being the thrifty Senior Design group that we are, we decided that this was worth a further investigation, and found that we could actually receive up to $150 off the total cost of our board just by purchasing with them. This alone is an incredible reason for us to go with PCBFabExpress. While they do not offer their own free PCB CAD software like the other manufacturers we have looked into, they do offer assembly service, either via customer- supplied components, or as a turnkey service, meaning that they would supply the parts. While this would be convenient for us, we feel that this would not be necessary for a few reasons. First, this would likely drive up the costs for us drastically. Additionally, having someone else assemble the printed circuit board for us would almost entirely defeat the purpose of the Senior Design process, as assembling a circuit board is a skill that we as electrical engineering students should acquire throughout the course of this process.

6.1.3 Sunstone Circuits

Another PCB manufacturer that we investigated is Sunstone Circuits. Similar to ExpressPCB, they also offer a design tool called PCB123 that enables users to lay out their own PCB and then order using the designs they have created. It even includes a built-in tool that allows customers to calculate the total cost of the board before they order. The remarkable thing about this software is that is completely free to use, and includes much more functionality than many of the other leading PCB CAD software suites available on the market such as CadSoft's EAGLE software. This would definitely prove useful in laying out our board, as we are looking to reduce costs wherever we possibly can, and having free CAD software would be helpful for doing this. The software is very robust, featuring a Design Rule Check tool that checks to ensure that the board being created meets many essential design criteria that are crucial to PCB design.

When choosing to go with a manufactured board, one thing to consider is pricing deals of the two available PCB manufacturers. ExpressPCB has a $51 deal were there are three identical 3.8” x 2.5” Printed Circuit Boards that can be purchased to use in the design. The price of all three of these identical boards is very economical but the design made by the group has no need other than for backup purposes for a secondary board. Sunstone also has economical prices for manufactured boards. Sunstone offers up to 60 square inches of PCB area for $33. This is an approximately 8” x 7” piece of PCB material. Sunstone also allows student buyers to purchase only a single board at a time to aid in cost effectiveness, but one disadvantage of using a punchboard instead of a PCB is that the size will be bigger because we will use regular electrical components. On the other hand, by using a company that builds our PCB is a more expensive. Also, it is difficult because we need to learn how to use a program to design the schematic and the connection layers of the circuit so that the company can build the PCB. We will need to take some time to learn how to use this software and design our PCB correctly because if we made a mistake, we cannot solve the problem and we will need to redesign the circuit and order a new PCB again.

One advantage of using a company to build our PCB is that the final product will look very professional. In addition, getting a PCB from a company is what it is currently being use in the industry, so we will beneficiate by learning all the process that takes in order to design and construct a PCB. Finally, once we receive the PCB, we need to mount and solder the surface mount components manually. In the present day, there are different companies that build custom PCB. Next, we will compare some companies and present the some advantages and disadvantages from each company.

The convenience of buying a manufactured PCB versus the group making one is that the schematic designs from the free software from that manufacturer or the Eagle Light software can be submitted in an email to the manufacturer and the PCB can be made directly from that schematic. This maximizes the exactness of the PCB design with almost no possibilities of manufacturing defects. Also there are benefits of having a manufactured PCB that aid in the assembly of the circuit. Purchasing a PCB will definitely be mandatory when assembling the design.

Once the PCB is delivered, which we have chosen PCBExpress, there are two accessible techniques to populating the PCB. The first is to populate it by hand soldering each component to the board, and the second is to solder the components using a stencil technique. Using a stencil with solder paste is a very fast and efficient technique to solder many boards of the same time, however since only one or two boards will need soldering, using this technique will not be efficient.

Since our project required so many changes, we used a perf board at the end of the day, so that we can make sure that if we made any changes, we were easily able change it without having to order another printed circuit board. We construct to prototype boards, one board containing both voltage regulators shown in figure 6.2.1-A, and the other board containing both microcontrollers connected to two mosfets, with an resistor for the solenoid, Three 512k ohm resistors for the pressure pads, and one 10k resistor for the unattended button, and the two crystals for the microcontroller, in order to enable the clock shown in figure 6.2.1-B.

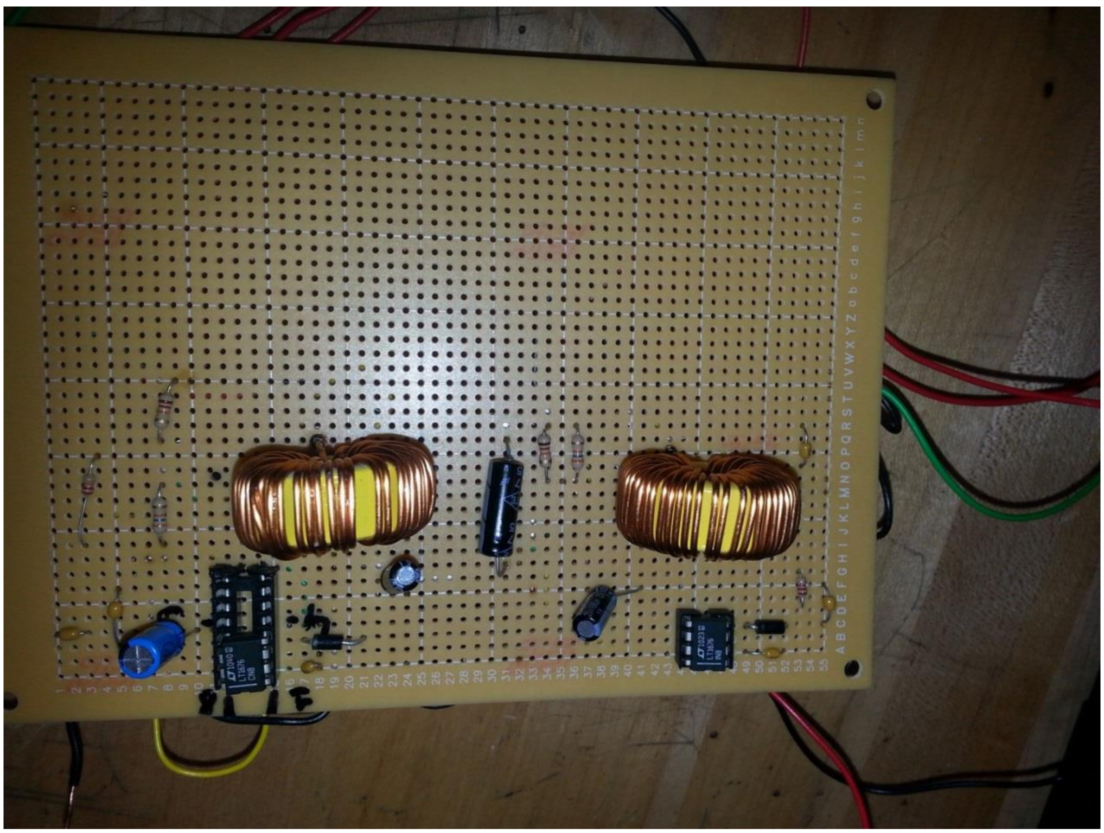


Figure 6.2.1-A: Two switching voltage regulators

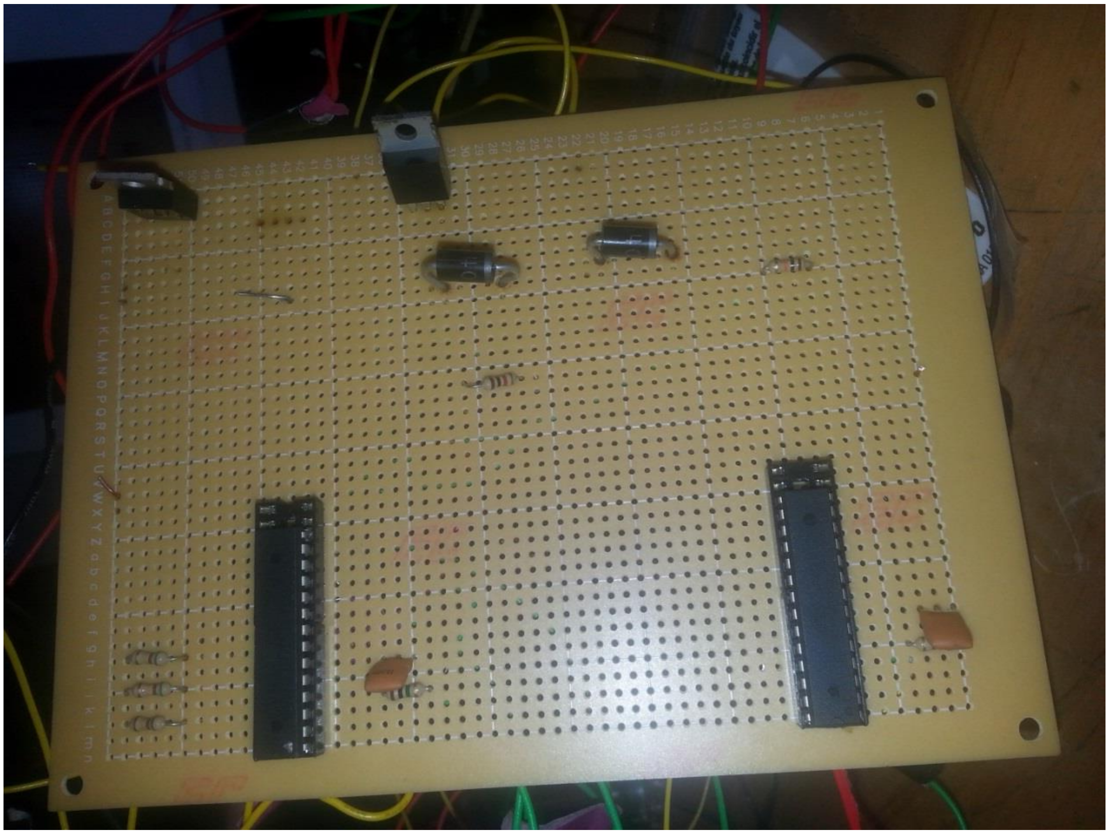


Figure 6.2.1-B shows the two microcontrollers in connection with everything else

6.1.4 PCB LCD

The LCD display is so crucial in this experiment because it the only way to display the information for the user. Figure 6.1.6a is a PCB schematic of the LCD driver from the LCD screen we will be using for this project. Which shows the pins and the actually voltages of the circuit which is 5 voltages. The pins we used to connect the microcontroller are digital pin 12,11,9,8,7,6 to the LCD for the data lines, enable and write.

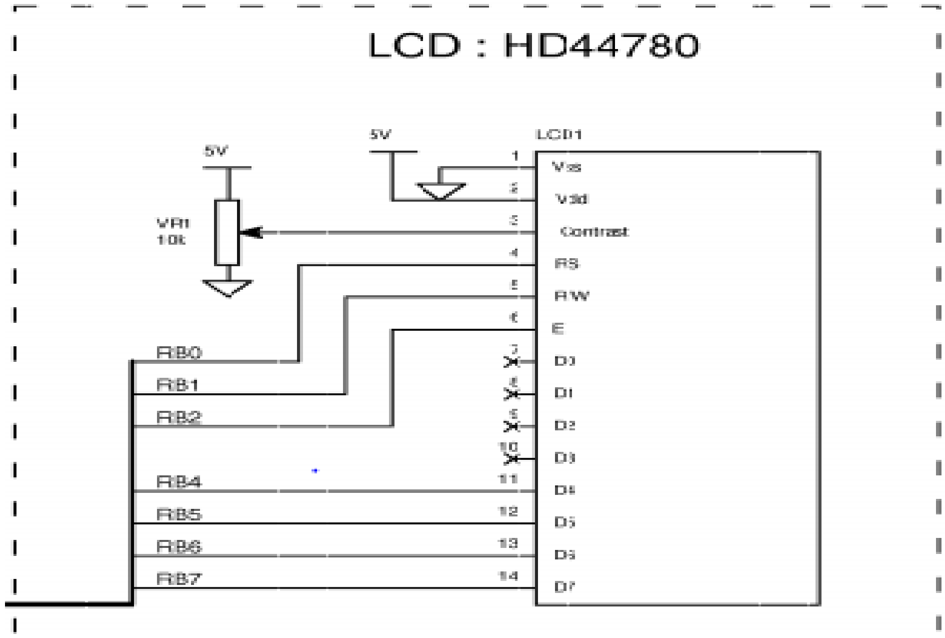


Figure 6.1.6a *- PCB schematic for the LCD screen*
Used with permission from sparkfun.com

6.2 Microcontroller Coding Plan

6.2.1 Coding Interface

Arduino has developed a free IDE that works with a variety of Arduino products including the Atmega328 microprocessor. The Arduino development environment supports C++, Microsoft Windows and LINUX operating system. Debugging can all be done within the IDE itself. Using it's libraries help easy the coding being done. Arduino makes for a straightforward development environment that handles both coding and debugging.

6.2.2 Arduino Uno Development Board

Programming the actual microprocessor will be done with the Arduino Uno Development Board. It comes with one Atmega328 microprocessor. As expected Arduino works perfectly with the development board connected via a USB cable which also powers the board as well. It is essential a plug and use piece of equipment since there is no need for driver installation. Data will all be transmitted using the serial communication with a baud rate as high a 9600 Baud and 11520 baud rate depending on the piece of hardware. Also equipped on the development board are two LEDs as well as a reset button. The LEDs help with giving visual feedback to show that the program is indeed on the microprocessor and the push buttons give the user feedback or can be used as a reset. The Atmega328 is placed in the middle with a 10-pin DIP sockets on each side that correspond to it's pin position. The DIP sockets help with easy plug in and removal of lines and allow us to connect additional components for implementing and testing code

6.2.3 Microprocessor

All code that will be on the microprocessor will be developed using the C++ programming language. As stated earlier the microprocessor and the Arduino Uno development board will be used extensively together as well as be used to test if individual components work properly with microprocessor. When the microcontroller receives data it may have to parse the input

6.3 GPS Coding Plan

6.3.1 Module

Data is transmitted from the module to the microprocessor by two pin positions. Pin 8 (TX) is the serial output while pin 9 (RX) is the input pins. Both use NMEA-0183 protocol by default. Any incoming data that will also be sent to the module using the NMEA-0183 protocol. No coding is done to the actual module we are simply sending and receiving data.

6.3.1.1 Parsing NMEA-0183 Messages

When the microcontroller receives a NMEA message the protocol header is parsed. In our case we are only interesting in GPS coordinate positions , any NMEA Messages that have does not start with "$GPGGA" will be ignored. When we do receive the data that we are looking for we will parse the whole message by separate all the elements when a comma is encountered. Then the the checksum parcel is used to compare the exclusive-or of the rest of the message ; Excluding the "$" and "<CR><LF> which appear at the beginning and end. The checksum prevents us from ever sending corrupt data. Now we have parsed data that can be used for other components such as our GSM modules

The GPS module is also capable of receiving NMEA message as well. When sending data to the module the NMEA input message all fields are required, if not then the data shall be ignored. Using the query/rate control example in figure 6.3.1.1 can choose the type of protocol header that we want our module to output by changing the "MSG" field to the desired input. .

Query / Rate Control Example[1]			
Name	Example	Units	Description
Message ID	$PSRF103		PSRF103 protocol header
Msg	00		See Figure 24
Mode	01		0=SetRate, 1=Query
Rate	00	seconds	Output: off=0, max=255
CksumEnable	01		0=Disable, 1=Enable Checksum
Checksum	*25		
<CR> <LF>			End of message termination

1. Default setting is GGA, GLL, GSA, GSV, RMC and VTG NMEA messages are enabled with checksum at a rate of 1 second.

MSGValues	
Value	Description
0	GGA
1	GLL
2	GSA
3	GSV
4	RMC
5	VTG
6	MSS (not supported)
7	Not defined
8	ZDA
9	Not defined

Figure 6.3.1.1: *query/rate control example*

6.4 GSM Coding Plan

6.4.1 GSM Development Board

Testing of the GSM module will all happen on the Arduino GSM Shiels. We simply using it to be able to power all the vital components and control the module. All necessary components, such as the SIM card holder and the antenna are built into the development board. This takes away the need to have to physically implement each element to get the module in a running state. An LED is used to verify that the module is running and the frequency at which the light blinks gives a visual indication of the network status; Weather the network was found or not and is there is GPRS communication. Pins TX and RX are used for the data transmission.

6.4.2 GSM Module

All data between the microcontroller and the GSM module happens in the RX and TX pins. AT commands are a widely used and straightforward data specification used by our GMS module. The module will be responsible for sending the actual data and be able to receive data. Other pins positions are used of powering and operating the SIM card and the antenna.

7 Project Prototype Testing

7.1. RFID Testing

The RFID system was tested both on a functional level (does it work? Does the receiver respond to the key?) as well as at a technical level (does it really work in the specified temperature ranges? How far can it really detect the device from?). These questions were order.

The range of tests were answered by a battery of tests on both the tag(s) and the receiver itself. Using RFID transmissions at the low frequency range, 125 kHz, and an antenna. The tests in this section was carried out until the device was determined to be in fully working important because we wanted to be sure that the device will work in conditions which we may not find here. Rain, snow, and high levels of interference from other devices could have all contributed to unexpected failures of the technology on the field if not thoroughly tested in lab and live environments first.

7.1.1 Tag Testing Introduction

In our project we use passive RFID tag technology. Passive technology harvests energy from the receiver, modulates it and returns its 12 byte signal containing the key. An “interrogator” works much the same way a receiver does, causing the key to transmit its signal.[R8] One technique of testing was to use a vector signal analyzer to record signals from both the tag and the interrogator as they communicate (Figure V-1)

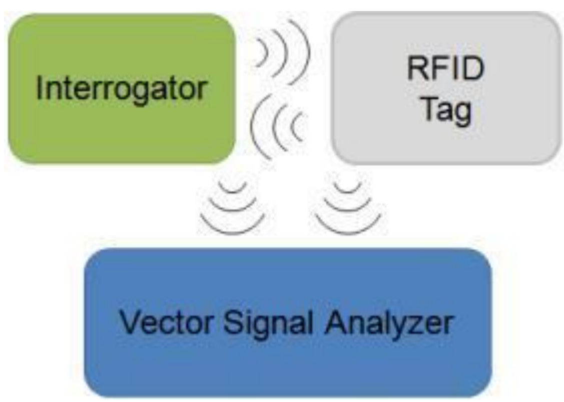


***Figure V-1**: RFID Testing “Sniffer” Architecture*
Used pending permission from National Instruments

This system, while good for basic testing of the tag, was not much better than just holding it up to the receiver and making sure it works. A true test should be robust enough that it checks for unexpected circumstances which could cause bugs, just like a thorough test of a software product. While this test was only useful if there was some issue with the way the default behavior works, a Stimulus-Response architecture (Figure V-2) was vastly more useful.

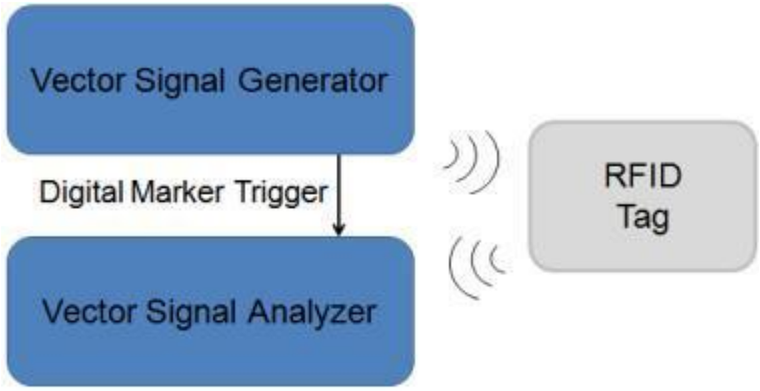


Figure V-2*: RFID Testing Stimulus-Response Architecture*
Used pending permission from National Instruments

This architecture was very useful and commonly used because measurements were easily automated and results were predictably reproducible.[R9]

There was an even more detailed method of testing which was not necessary for our project. This was called Real-Time Interrogator Emulation (Figure V-3) and would be used to test new RFID implementations for full protocol support. This testing would increase the budget and time requirements of the project beyond allotted amounts.

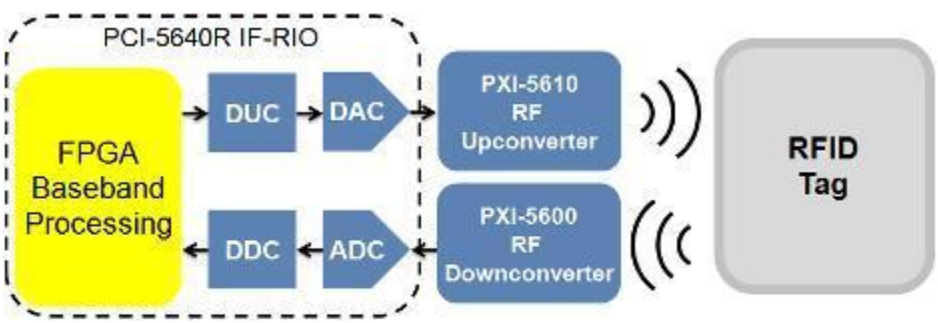


Figure V-3*: Real-Time Baseband Processing*
Used pending permission from National Instruments

7.1.2 Tag Testing Basic Results

First, the tag was tested for basic functionality. This was that given an interrogation signal, it sends back the correct key. This behavior should be consistent and the correct 10-byte key should be received in less than 1 second, surrounded by the correct start and end bytes for a total of 12 expected correct bytes. This should be tested at various distances in a lab environment with little interference as well as an outside environment with urban RF interference.

Tag Position	Tag Distance (inches)	Result (Pass / Fail)
Parallel	1	*Pass*
Perpendicular	1	*Pass*
Parallel	2	*Pass*
Perpendicular	2	*Pass*
Parallel	3	*Pass*
Perpendicular	3	*Fail**
Parallel	4	*Pass*
Perpendicular	4	*Fail*
Parallel	5	*Fail*
Perpendicular	5	*Fail*

***Table V-4**: Results of Tag Testing with low environmental interference*

Tag Position - The antenna position refers to if the antenna of the tag was parallel to the interrogator (optimal) or perpendicular (not optimal or recommended). It was useful to see how close a perpendicular antenna must be to get a positive response.

Environmental Interference - The "Low" and "High" interference levels refer to if the test was done in a lab with low interference or outside in an urban environment where RF noise was higher.

Tag Distance - Approximate distance from the center of the tag to the interrogator antenna. A distance of 0 while parallel describes a situation where the tag was touching flat against the interrogator.

Distances tested were 0, 1, 2, 3, 4, 5, 6, and 12 inches away. This particular passive tag was rated for about 4 inches, but the technology of passive tags was said work up to a foot away. In total there were 2*7*2 = 28 situations tested in this phase of basic tag testing.

The test was carried out very simply. The tag was oriented as instructed, then moved the number of inches away instructed. If the tag responded with the correct data within one second, it passes for the current interference level environment. If it does not respond with correct data, the tag fails the test (Figure V-5).

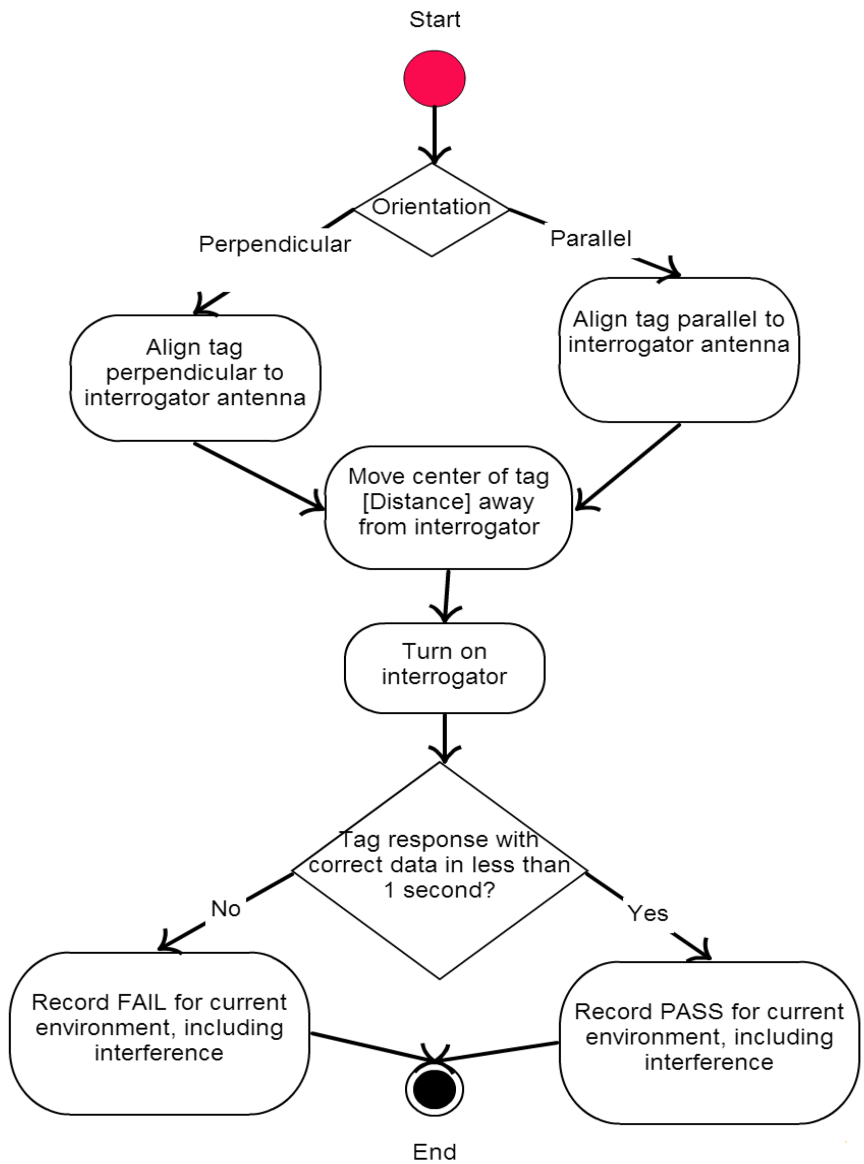


***Figure V-5**: Flow chart for running the Basic Tag tests.*

7.1.3 Receiver Testing Basic

For the test scenarios in which the basic tag testing passed, it can be assumed the tag works correctly in those scenarios. So to do basic tests on the receiver, all the passed tag scenarios should be carried out using the receiver module. The receiver should be given the subset of tests that were found to have a result of PASS in the basic tag testing in Table V-4. if the receiver was working correctly, all these tests should pass (unless the interrogator had a stronger signal than the actual receiver module).

These tests will require connecting a reader to the data out port of the receiver and recording the bytes sent out. When the receiver queries, the key should modulate and respond with the correct key. This behavior should be consistent and the correct 10-byte key should be received in less than 1 second, surrounded by the correct start and end bytes for a total of 12 expected correct bytes. This should be tested at various distances in a lab environment with little interference as well as an outside environment with urban RF interference.

The tester was a PC running ComTestSerial[R10], and used to control the /ENABLE and record the SOUT ports. This free program will allow accurate and high-performance hardware to be used to test our serial ports without any extra expense.

The tester will connect to the Input and Output ports of the RFID receiver (Figure V-6). The receiver was powered by another 5V source across the VCC and GND.

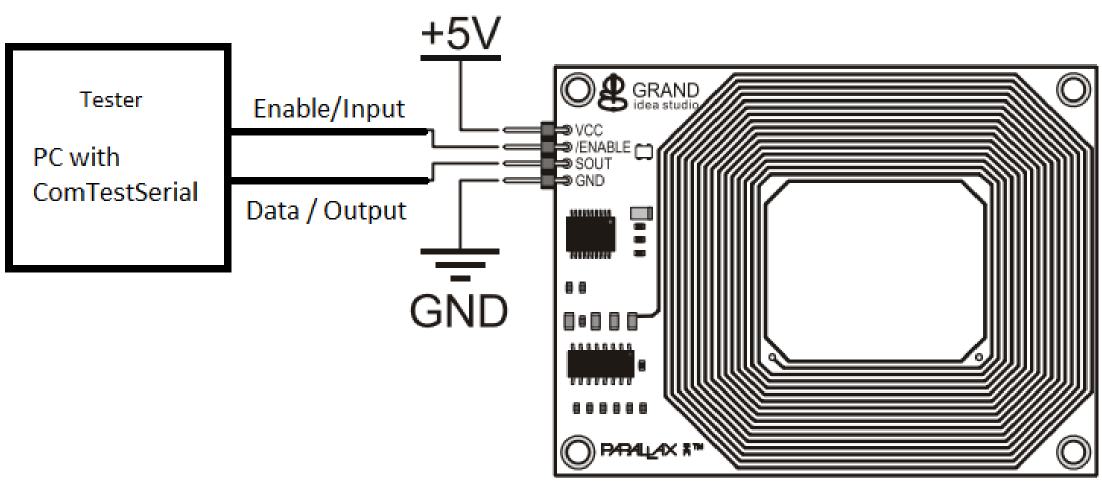


***Figure V-6**: ComTestSerial PC connection to Receiver for Testing*

The tag was placed at the correct location in the correct environment for the current test case. The tester will work as follows: the /ENABLE flag was set to LOW at the start. All data coming from SOUT was recorded for the following second. This data was compared with the expected 12-byte code. If the code matches the RFID key, the test was a PASS. Otherwise, it should be recorded as a FAIL (Figure V-7).

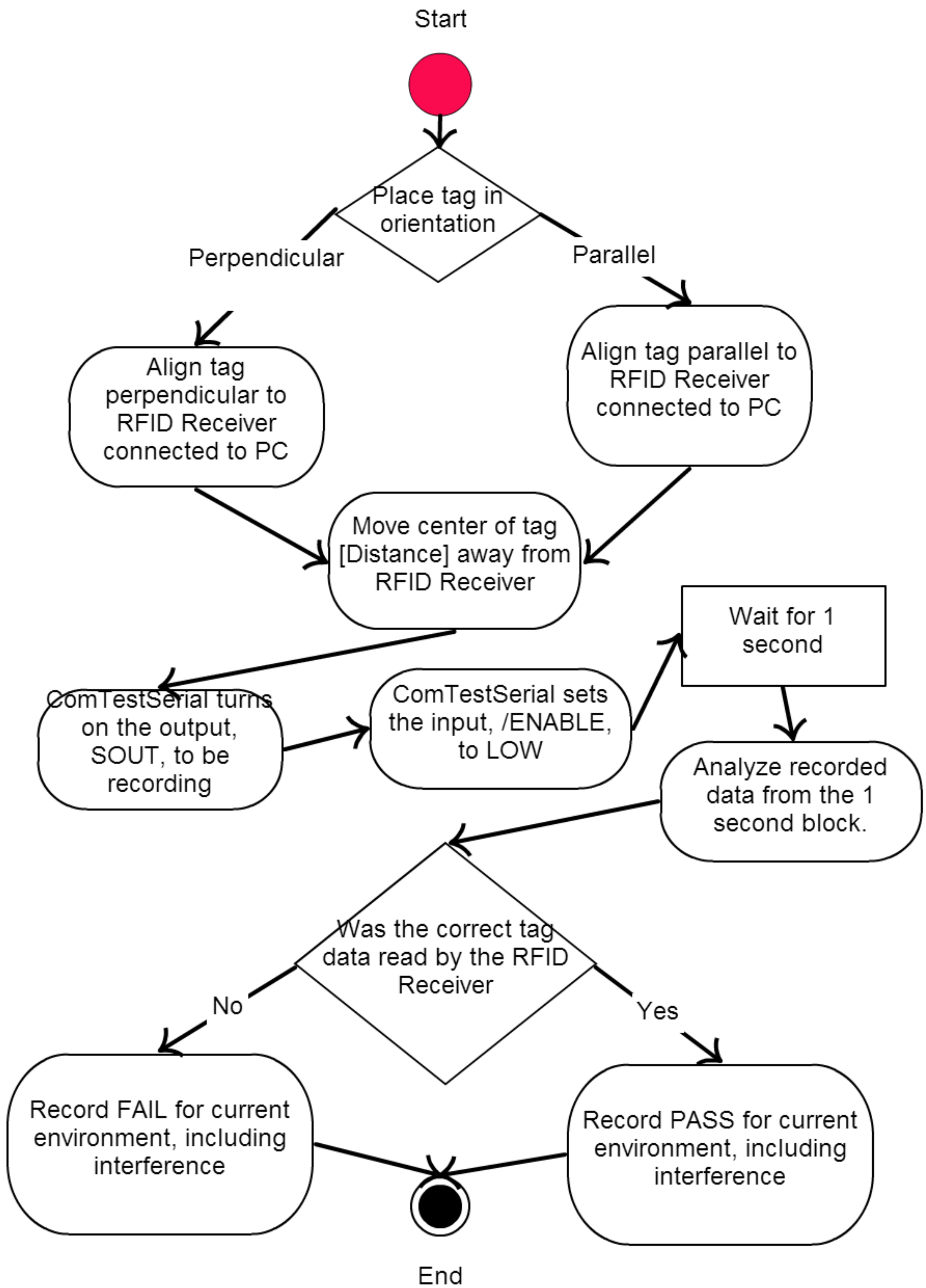


***Figure V-7**: Basic Receiver Testing with ComTestSerial on PC*

These tests were a subset of the tests run on the tag, including only those which passed for the tag. All were expected to pass with rare exceptions for noise interference differences or signal strength differences between the interrogator and the actual receiver module which was being tested now.

7.1.4 Receiver Testing Advanced

Advanced testing of the receiver allows us to test circumstances which we may not come across in the basic testing environments. This can include getting wet (from rain or otherwise), being exposed to heat or cold near its maximum rated threshold for the components (Table P), and being required to detect the RFID while experiencing volatile motion or vibration (like being located on a moving train).

Moving away from the environmental to a more technical side of the advanced testing, we need to test for noise. The software will have a double-check in it to verify that a valid key that was read was not the result of random noise, however it was still important to figure out if random noise will cause a valid signal from the receiver eventually. The other technical test should be an “extreme” level of RF interference, giving us a test if the device can still be unlocked when near a strong signal source.

These tests were carried out based on passing the basic testing for the RFID Receiver (Figure V-5). Each test will run as a subset of passing the basic testing, and will not rely on other advanced tests passing or failing in any way to determine their own validity for testing environments and settings (tag position, distance, etc.).

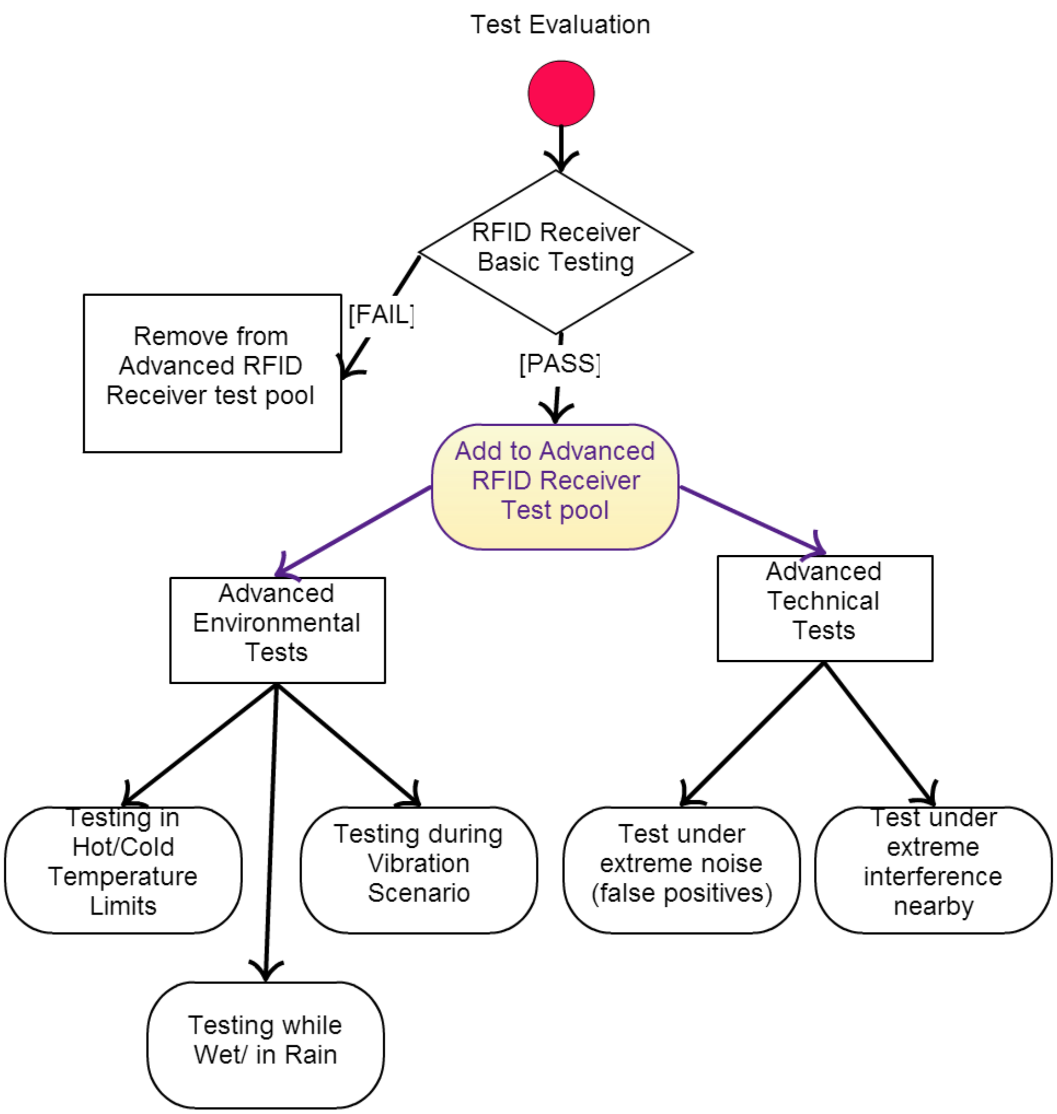


***Figure V-5**: Breakdown of Advanced Testing for the RFID Receiver*

7.1.5 Receiver Testing Advanced - Environmental

The same testing procedure was followed for each of these environmental variables as was followed for the basic RFID Receiver testing. If the environment cannot be tested in a lab, the ComTestSerial software connections to the RFID Receiver module were made with a laptop.

The liquid test was done simply. The RFID Receiver was made wet equivalent to a standard rain storm with several inches of rain. Following that, the tests were carried out just as they were in Table V-4 but with water. It was expected that the RFID Receiver should work the same under this condition. All advanced testing should be a subset containing only tests that were passed in the RFID Receiver basic testing.

For the testing of the temperature ranges, a temperature-controlled environment was used and the device was tested in the same way it was tested for the basic RFID Receiver tests (Table V-4).

Passive Modulator Distance (inches)	Temperature	Result (Pass / Fail)
0	-18C	*Pass*
0	43C	*Pass*
1	-18C	*Pass*
1	43C	*Pass*
2	-18	*Pass*
2	43C	*Pass*
3	-18C	*Pass*
3	43C	*Pass*

***Table 7.1.3.5**: Test Results for Advanced Environmental - Temperature with Low Interference*

The final environmental test was a test during vibration. The device was placed on a vibration test bed. While signal reception was not expected to be a problem, connections (internal or external) could be faulty and extreme vibration could cause issues. This was tested as the other advanced tests were: as a subset containing the RFID Receiver tests that passed the basic testing phase.

These environmental tests will ensure the product was robust in a wide variety of environments it may be exposed to by an end user. We hope that these tests decrease the number of failures and disappointments experienced by the adventurous or traveling users of the wheelchair.

7.1.6 Receiver Testing Advanced - Technical

For the technical side of testing, most issues beyond current tests would be caused by extreme noise and interference in the radio frequency range we were using (125 kHz). To test for this, an RF emulator was used (see Figure V-2). The emulator was used to test for false positives as well as the blocking potential of random RF noise.

To test for the possibility of false positives, the emulator was placed close to the device (at a range in which the passive key always works, probably 3 inches or less) and begin generating random bytes on the frequency of the device (Figure

V-7). This test will take some time. In the Software Design section, it was pointed out that the software side can query the correct key twice in a short period of time. While this will practically eliminate the possibility of false unlocks, we still want to see how prone the receiver was to such a malfunction.

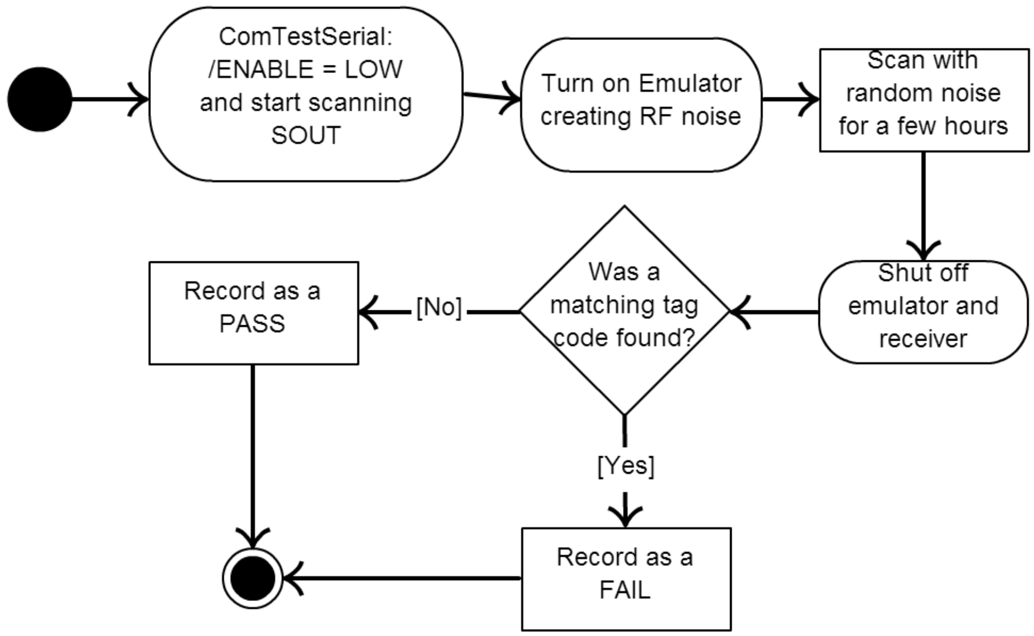


***Figure V-7**: Test Procedure for Receiver Advanced Testing - False Positive*

The other test was if the actual passive key can work with interference and if so, how strong. The emulator was turned on making random noise at 125 kHz but this time placed different distances away (10 ft, 5 ft, 3 ft, 2 ft, 1 ft). The key was tested in all ways as a subset of the passed basic tests but with the interference at these 5 different distances (Table V-8).

Passive Modulator Position	Passive Modulator Distance (inches)	Noise Distance (ft)	Result (Pass / Fail)
Parallel	0	1	*Pass*
Parallel	1	2	*Pass*
Parallel	2	3	*Pass*
Parallel	3	5	*Pass*
Parallel	3	10	*Pass*

***Figure V-8**: Tests done for the Emulated Extreme Interference Test*

It was expected that the further distances will not have any effect due to the low frequency having a very limited range of detection. We hope that these advanced technical tests on noise would expose possible issues in extreme areas such as RF testing facilities or extremely crowded city areas, or anywhere that has extensive use of RFID technology at that frequency range.

7.2 GPS

7.2.1 GPS Testing

The GPS module will be primarily tested for its accuracy, quality, and reliability of its transmitted data. Dependencies exist within the system that use the GPS coordinate positions and having corrupt or old data may have a negative effect on the overall system. Since no transmission is ever one hundred percent accurate threshold values will be used to determine if the module passes or values any test

7.2.1.1 Transmission Reliability Test

For this method we will be taking the module to different locations and exposed to different conditions that may have an affect on the signal strength. Such locations can be inside a building or outdoors while conditions will be weather related. The amount of time it took from the trigger event to the actual receiving of the data will be the metric for reliability. The smaller the difference between the time the more reliable the signal strength is.

7.2.1.2 Transmission Quality Test

Our method for testing will consist using the checksum error detecting for the quality of the module. The module will be taken to different locations and it will constantly output the GPS coordinates. The microprocessor will compare the checksum and the exclusive-or of the message. If they are both equal then we have a valid transmission. If they are not equal the we have received corrupted data and a invalid data counter is incremented. A checksum ratio will be used as the metric for the quality of the transmission where the number of invalid data transmission is divided by the overall number received transmissions. Zero is the best case where none of the transmissions received were corrupted and a value of one is the worst case since every transmission failed.

7.2.1.3 Transmission Accuracy Test

In this method the module will be taken to multiple pre-determined locations, with known coordinate positions. The modules is then triggered to transmit the coordinate position. We compare the received position from the module to our actual known coordinate and observe how accurate the data is. Threshold values will be chosen +/- intervals and will from the known position. The lower the threshold value the more accurate the transmission is.

7.3 Power Supply

7.3.1 Power supply testing

The conditions for testing will be performed using the following constants: The measuring equipment, test leads, Input DC voltage, reference test voltage, and the test voltage. These conditions must be a constant or the process of testing and calculating will get very unpredictable, which we do not want. The measuring equipment for the power measurements were fabricated by a calibrated voltmeter and ammeter, but can also be effectively be measure using a power analyzer and oscilloscope. As we can find specified in IEC 62301, the measurements of active power of about 0.5 watts or greater needs to be calculated using an uncertainty factor of greater than 2%, while active power measurements with less than 0.5 watts has an uncertainty factor greater than 0.01 watts. For our project we have a voltage greater than 0.5 watts so we will use a 3% correction factor.

The Test Leads that were used for the measurement equipment are just as important if not more important than the equipment itself. The leads should be constructed of a large enough gauge and short length that it does not affect the readings and to avoid the introduction of induced voltage errors in the testing process. In IEEE 1515-2000 table B.2, "Commonly used values for wire gauges and related voltage drops" can be used to verify the correct wire gauge is used.

The test voltage for the power source will be 17V, that way we can successfully test the power supply on the circuit to verify that current is reaching through all the resistors, transistor and diodes is needs to reach without overloading the system. Even though our reference The Input AC Reference Source Voltage should be capable of producing and delivering at least 10 times the nameplate input power to the UUT that can be specified in IEEE 1515-2000.

7.3.1.1 Power Supply Risk Factor

When dealing with the power supply for the entire circuitry, there are a lot of risk factors to be considered. Since we are using two power sources for the microcontroller and its connections, we have to take very slow precautions because any current in the circuit that might not be supply right might cause an overload in one of several of the components possibly destroying them or frying the circuit. Another risk factor we had to consider is having solenoids draw too much power from the circuit, because one of the two powers sources to rapidly lose power over the other one.

7.3.2 PCB Testing

Once the PCB comes back from fabrication, there would be several steps taken to ensure it's made for our correct qualifications. The followings steps would occur in this order:

- Visual inspection of PCB runs.
- Using an ohm meter to ring out power and ground lines to ensure no inadvertent grounding of power runs.

After the part is installed we need to:

- Conduct visual inspection of solder joints
- Conduct ohm checks to ensure proper power and ground

After all ohm and visual tests are conducted we will test the individual circuits as indicated in the following sections. The individual circuits can be checked by using the isolation switches placed on the PCB. Theses switches will enhance the troubleshooting and testing process. For example, between the voltage regulators, which creates 12 volts from the wall power, and the microcontroller we will place a switch that can isolate the 12 volts. There will be a test point on the output of the voltage regulator to allow us to verify the regulator output voltage.

After the voltage and current test, the PCB must be programmed. The PCB has to be programmed to operate every component on the wheelchair assemble. Then one by one each component must be connected to the PCB to make sure that all programs installed on it perform the desired task to the appropriate component. The only problem with a custom made PCB is that it does not come preloaded with code, so it must be determined whether a problem that arises is occurring inside the PCB or somewhere within the attached component or its corresponding circuit. We will test this Problem by using the Ardunio development board just see if it has no errors in the any of the circuit which will save us a lot of time on debugging if we fall into trouble.

Since we used a perf board we have tested the connection of each wire using a digit multimeter to make sure each component has been solder correctly and is been linked to what is has been supposed to be linked to.

7.4 LCD

7.4.1 LCD Screen Testing

The LCD will display data that will be sent from the RFID and the Solenoid . Since it requires two sources and the microcontroller, to show when the right RFID card is detected or not. Figure 7.2.2a shows the RFID(Labeled as key) and the locking mechanism (labeled as brakes) to show the user what happens when the each function is being used. We use the Rfid tags and test the right ones and the wrong ones to show whether or not it will be displaying correctly on the screen.

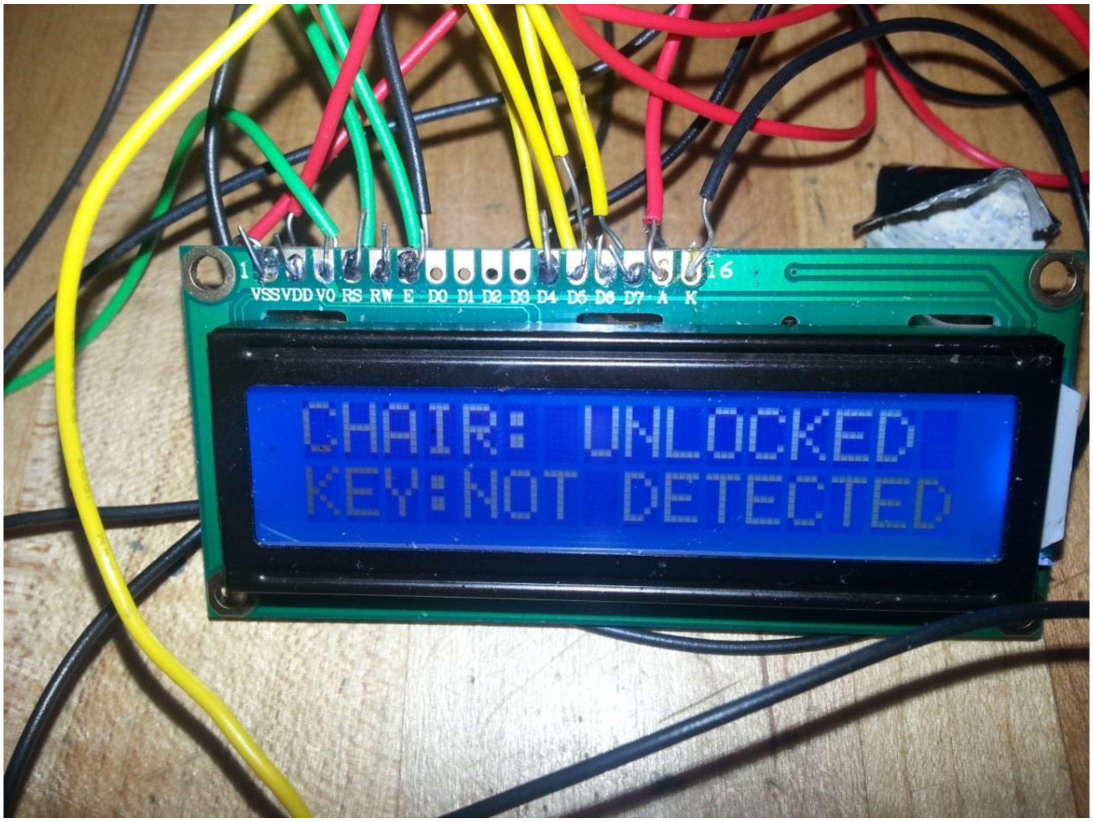


Figure 7.4.2a *– LCD Panel when is displays RFID and Locking mechanism*

The second part of data that will be displayed LCD screen will read whether if the solenoid is in the locked or unlocked position. Since there will be pins that won't be used. We will first need to check to see that characters "unlock" and "locked" display correctly on the screen with the correct size font. Second, we check to see if the character generator displaying the two words will be programmable to the pin(s) when that particular one's are selected to be active.

To check if the display works with that particular pin(s) without having it connect to the entire circuit, we will use a switch to simulate whether the inputs presents the correct output. If the switch is turned on the it will need to present the word "unlocked" on the LCD screen and when that Switch is turned off it will need to present the word "locked" on the LCD screen to show that it successful works using user input.

Once The LCD panel demonstrates that the display gives the correct output based on the inputs and Voltage, We will then connect it the PCB Circuit board in order to have a signal be sent to the pins(s) that determines whether it will display unlocked/locked. If the display's locked when the trigger to the pins is set then we have verified that is works when it is locked. When we set the pin to be non-active, no signal coming through the circuit and the display screen reads unlocked. We will then have verified that the driver is programed correctly when set to the locked position.

7.4.2 LED Backlight Driver Testing

To test the LED controller/driver, we first connected the components which require the LED driver, such as the power supply. Then we connect the driver to the power supply and ground using taking all the necessary safety precautions. When then need to figure out how then need to determine how we will send a signal to the transistor to indicate that the circuit has been turned on (only if we don't have the LED panel yet, otherwise the panel will give the indication that it is working. We can turn on the circuit by sending a small current, similar to the current a microcontroller will output to a transistor to turn on a. LED Backlight. Figure 7.2.5a shows a diagram of how much current the diode (LED) is drawing. We can see from the diagram that the current flowing through the circuit is less than 500 mA.

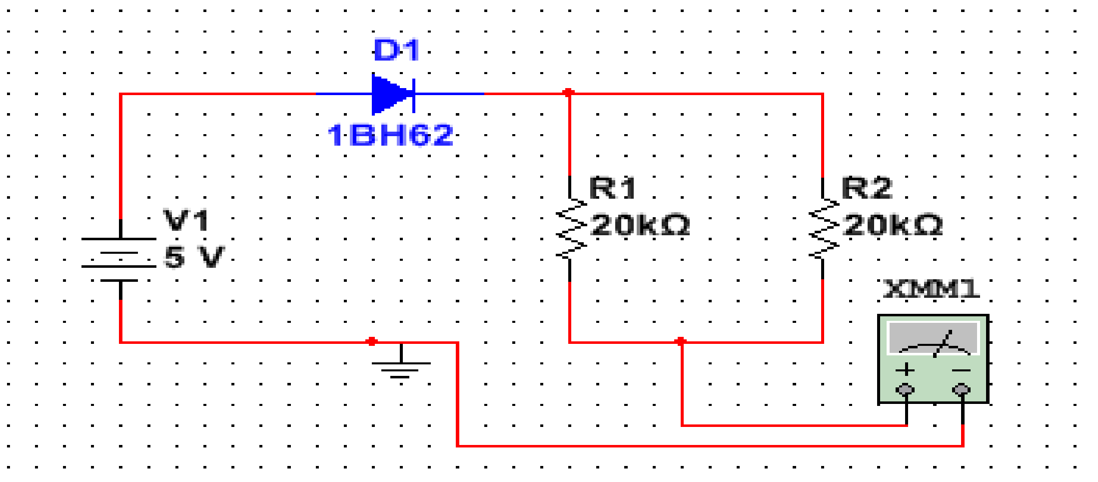


Figure 7.4.5a: *LED driver test for current diagram*

7.5 Pressure Pads

7.5.1 Locking Mechanism Testing

The locking mechanism had to work one hundred percent of the time. It was absolutely vital it never fails so that serious injury did not befall the person using the safety enhanced wheelchair. To prevent any type of injury to anyone that used the wheelchair, the testing of the locking mechanism had to be extremely thorough and rigorous. Several different parts made up the locking mechanism that was used for the safety enhanced wheelchair. Since each part needed to function properly to have a reliable locking mechanism that can be used for safety purposes, scenarios that end up testing the functionality of every part needed to be created. Listed below were the possible scenarios that were most likely to occur on a frequent basis when there was interaction between the safety enhanced wheelchair and a person. Every single one of the scenarios needed to be thoroughly tested to make sure the locking mechanism was functioning properly so that everyone who used the safety enhanced wheelchair experienced the highest possible standard of safety. The procedure of how our group produced each scenario was also provided below along with the outcomes and conditions of success.

Test Scenario #1: While the wheelchair was in motion, the locking mechanism was triggered.

Procedure:

- Sit in the wheelchair, turn the wheels to move the wheelchair, and then abruptly exit the wheelchair while it was still moving
- While no one was sitting in the wheelchair, push or pull it to gain momentum and then hit the unattended button

Outcome: In both cases, the wheelchair rapidly lost momentum and came to a complete stop.

Conditions of Success:

- The wheelchair does indeed come to a quick stop

Test Scenario #2: When on an incline, the locking mechanism gets activated.

Procedure:

- Get in the wheelchair, start going down a ramp and then activate the locking mechanism
- While trying to go up a steep hill in the wheelchair, activate the locking mechanism.

Outcome: A morbidly obese person was in the wheelchair at the time the locking mechanism was activated while going both up and down a steep incline, which resulted in the locking mechanism greatly reducing the rate of descent of the wheelchair on the inclines. This situation was repeated with a petite person, which resulted in the locking mechanism fully stopping the wheelchair from sliding down the steep incline.

Conditions of Success:

- The locking mechanism was able greatly reduce the rate of descent of the wheelchair even when it was on a steep incline and a morbidly obese person was in it.
- The wheelchair gets fully stopped while on a steep incline when a petite person was sitting in it.

Test Scenario #3: While the locking mechanism had the wheelchair in a locked state, the battery either gets disconnected or runs out of power.

Procedure:

- Keep the wheelchair in a locked state and wait for the battery to die.
- Make the locking mechanism lock the wheelchair and then disconnect the battery from it

Outcome: Even though the geared bipolar stepper motor had excellent holding torque, the coils need to stay energized to maintain the holding torque. Unfortunately due to this reason, the locking mechanism was not be able to keep the wheelchair in a locked state when it lost power no matter if the power loss was due to a dead battery or a disconnected wire.

Conditions of Success:

- The geared bipolar stepper motor was able to maintain its motor shaft position.
- The locking mechanism was able to keep the wheelchair in a locked state.

Test Scenario #4: While the wheelchair was rolling on a wet surface, the locking mechanism was initiated.

Procedure:

- Roll the wheelchair outside after it rains and initiate the locking mechanism
- Use a hose to create a wet surface and then have the locking mechanism lock the wheelchair when it was rolling on it

Outcome: Due to the fact that the safety enhanced wheelchair was designed to enhance safety, the people who use the wheelchair shouldn't be rolling it at incredibly fast speeds. With this in mind, the locking mechanism did not experience any difficulty in stopping the wheelchair on a wet surface because of the low speeds that the wheelchair was operated within.

Conditions of Success:

- The locking mechanism was able to safely and quickly bring the wheelchair to a complete halt
- The wheelchair does not slide or skid on the wet surface while being stopped
- None of the electronic components get short circuited due to the presence of water

In case any problems occurred during the scenarios above that test the locking mechanism as a whole, the two main parts of the locking mechanism can be tested individually. The geared bipolar stepper motor and the cable disc brakes can be tested independently from each other. Since there were two cable disc brakes, they needed to first be tested separately and then finally together. One possible way to test each disc brake was to one at a time, pull the cable firm to remove any slack in the cable so that the disc brakes fully engaged. Once this was accomplished, maintain the tension on the cable and push or pull the other side of the wheelchair. If the wheelchair starts to rotate in a circular manner around the location of the cable disc brake that was engaged, then the cable disc brake that was currently being tested functioning correctly and able to perform to its fullest extent of its abilities. Repeat this testing procedure for the second cable disc brake to ensure that both brakes were functioning flawlessly. To ensure a higher standard of safety, it would be best to test the brakes again, but this time they should be tested together simultaneously. To accomplish this, obtain the cable of its respective disc brake, and then once again pull the cables firm to remove all of the slack that was within the cables to be able to engage both disc brakes. Once this was achieved, have someone else attempt to move the wheelchair while you keep the tight cable tension. The person who was helping you should attempt to push and pull the wheelchair in any direction as well as attempt to rotate the wheels while sitting in the wheelchair and also while not sitting in the wheelchair.

The geared bipolar stepper motor can be tested without needing to enable the mechanical disc brakes. A slower RPM speed for the first test of the stepper motor would most likely be best since no one in our group had ever dealt with a stepper motor before this project. Also, the dual phase full-step excitation mode should be first step type that was tested because it was the easiest to achieve and also provides the most amount of torque. Although it doesn’t provide the accuracy and smooth rotating that was provided by half-step and microstepping, the absolute necessity was the most amount of torque and steps in the short bursts. Even though the dual phase full-step excitation mode appears to be the best for the locking mechanism of the safety enhanced wheelchair, the half-step and microstepping should still be tested. They may end up being sufficient enough while at the same time requiring less power, which would be tremendous positive. The stepper motor’s first test run should be of just turning its motor shaft bi-directionally. Each subsequent test should increase the level of difficulty or resistance that the motor shaft needs to spin. Eventually there should be at least one test run that requires the stepper motor to reach its maximum torque. Once these tests were completed, the next set of tests needs to be about winding certain lengths of cable. Once the average amount of cable that gets wound to provide sufficient tension to enable the disc brakes was found, the next step of testing was to fine tune the stepping of the stepper motor so that it winds that particular average of cable in the shortest amount of time possible.

7.5.2 Pressure Sensor Testing

The pressure sensors that were strategically positioned on the safety enhanced wheelchair played a crucial role in the protection of the person using the wheelchair. The pressure sensors were used to determine whether a person was in the wheelchair or not in the wheelchair. They were also used for determining whether or not a person was trying to get out of the wheelchair or was actually attempting to sit in the wheelchair. The following were scenarios that could occur on a daily basis for people that interact with the safety enhanced wheelchair. Each scenario was thoroughly tested and the outcome and conditions of success were stated for each one.

Test Scenario #1: A person was using the arm rests of the wheelchair to either get out of the wheelchair or sit in the wheelchair.

Outcome: The pressure sensors located on the arm rests of the wheelchair detected a significant amount of pressure. Based upon the pressure sensors detecting a far greater amount of pressure than what would normally be detected when arms were being rested on the arms rests, the wheelchair's locking mechanism activated and locked the wheelchair.

Conditions of Success:

- The pressure sensors on the arm rests detect the substantial increase of pressure
- The locking mechanism gets activated and locks the wheelchair
- The brakes prevent the wheelchair from having any movement

Test Scenario #2: A person was sitting in the wheelchair.

Outcome: The pressure sensor located on the seat of the wheelchair sensed the massive amount of pressure. The wheelchair remained unlocked and kept its mobility.

Conditions of Success:

- The pressure sensor on the seat continually senses a relatively constant amount of body weight
- The locking mechanism does not get activated
- The wheelchair's ability to move does not get restricted

Test Scenario #3: A person quickly gets out of the wheelchair without the aid of the arm rests.

Outcome: The pressure sensor that was on the seat of the wheelchair detected the drastic change of pressure from a great quantity to a miniscule quantity, which resulted in the locking mechanism being triggered.

Conditions of Success:

- The pressure sensor that was strategically placed on the seat of the wheelchair instantly detects the extreme change in the amount of pressure.
- The locking mechanism gets triggered
- The wheelchair's motion gets completed stopped

Test Scenario #4: A person was sitting in the wheelchair and accidentally hits the unattended button.

Outcome: The safety enhanced wheelchair did not become locked.

Conditions of Success:
- Pressure sensors function correctly by detecting the pressure of body weight
- The locking mechanism does not get triggered
- The wheelchair does not come to an immediate, undesired stop

Test Scenario #5: A person hops into the wheelchair without utilizing the arm rests.

Outcome: The wheelchair abruptly locked.

Conditions of Success:
- The pressure sensor on the seat immediately detects the significant amount of body weight
- The locking mechanism gets triggered
- The wheelchair does not role backwards
- The person sustains no injuries

8 Administrative Content

8.1 Milestone

It was evident from the very beginning of the first semester that this project was going to be a massive undertaking. During the beginning of the first semester, the initial concept of the project was conceived. Shortly after the concept of the project, the group produced a five page initial document that contained the majority of the research that had been conducted thus far. The initial document really helped to put the group in the proper mindset and also kept them actively working on this project.

The next major hurdle was being able to plan group meetings. This ended up being more challenging than previously intended due to the group members having completely different schedules and commitments. The group held regular meetings at least once a week and communicated frequently. When a group member was unable to make a meeting, it was essential the next meeting would not be missed. Through effective utilization of the time spent during the group meetings, it was realized that not a single member of the group was an electrical engineer and that every group member was a computer engineer. The group felt this put us at a severe disadvantage. Since none of the group members were incredibly knowledgeable about hardware and electric components, the focus of the first half of the semester was everything for the project that dealt with any type of electrical component or piece of hardware that the group was unfamiliar with.

One of the major decisions that were made during this first semester was to use the MSP430. This decision occurred rather early on within the research phase. It took place approximately one to two weeks after the creation of the initial document for this project. Unfortunately after further research was conducted, the group decided to switch from the MSP430 to the Atmega328. This was the most significant decision that was made by the group, which occurred half way through the second semester. While this decision essentially made all of the research that was previously conducted absolutely useless and made the group unable to keep up with the set milestone timeline, this decision actually proved to be for the best and helped the group expedite its tasks and goals once the necessary research of the Atmega328 was accomplished.

The group experienced several major setbacks throughout this entire project. Some major setbacks occurred due to severe shipping issues of critical parts that were required and other setbacks occurred due to mistakes that were made while in the senior design lab. These setbacks ranged from not receiving shipped parts for several weeks to components being destroyed during the integration and powering of all components. Fortunately, the lost shipments of critical parts eventually arrived and the destroyed components were reordered.

	Start Date	**Due Date**	**Work Duration (Weeks)**
Project Proposal	May 14, 2013	May 21, 2013	1
Research	May 30, 2013	July 11, 2013	6
Research	July 11, 2013	June 6, 2013	1
Research	June 6, 2013	June 13, 2013	1
Research	June 13, 2013	June 20, 2013	1
Research	June 20, 2013	June 27, 2013	1
Research	June 27, 2013	July 4, 2013	1
Research	July 4, 2013	July 11, 2013	1
Research	July 11, 2013	July 18, 2013	1
Research	July 18, 2013	July 25, 2013	1
Order Parts	July 18, 2013	August 1, 2013	2
Build Prototype	August 22, 2013	October 24, 2013	9
Testing & Debugging	October 24, 2013	November 21, 2013	4

Table 8.1.1 *– Project Milestones*

8.2 Budget and Finance Discussion

During the early stages of this project, it quickly became a realization that this project could end up costing near a thousand dollars to fully complete. The decision to use the highest quality parts that were the least expensive was instantly agreed upon. There was no need to use parts by the most well-known companies if the parts were priced significantly higher than the prices offered by competitors for the same parts.

In the beginning stages of this project before any type of noteworthy research started to be accomplished, the group had a desire to figure out approximately how much money this project would end up costing. The Table 8.2.2 that was shown below displays the group's initial knowledge and thoughts of what parts would be required for this project, how much each part would cost, how many of each part would be necessary, and what the total cost of this project would approximately end up being.

Item	Cost per Unit	Amount	Total Cost
Battery	$100	1	$100
Charger	$50	1	$50
Wheelchair	$200	1	$200
Microcontroller	$50	1	$50
Pressure Sensitive Pads	$75	3	$225
RFID Chip Sensor Mechanism	$50	1	$50
Total			$675

Table 8.2.2 *– Initial Project Budget*

The initial estimate of this project that the group came up with was incredibly eye opening. The group did not expect this project to end up costing approximately six hundred seventy-five dollars. Even a few hundred dollars was not initially anticipated to be able to gather all of the necessary parts to build and complete this project. The initial total cost that the group estimated caused a great deal of concern due to the fact that the group had originally decided to fund this project themselves without any sponsors. This approximate total cost made the group start actively looking and asking for sponsors. Unfortunately, not a single sponsor was remotely interested in this project, so the group did not end up getting sponsored by a company or person.

Later on in the first semester after a tremendous amount of significant research had been conducted, the group decided to reevaluate its initial total cost estimate of this project. The group was not surprised that there were now more parts needed for this project, but it was a shock to discover almost four times as many parts would be needed now compared to the original amount of parts. It was the group's great displeasure to ascertain that the reevaluated estimate of the total cost ended up being $761.07, which was even greater than the initial total cost estimate for this project. Thankfully after the switch from the MSP430 to the

Atmega328, the group reduced the amount of necessary parts and even found parts that were cheaper. The Table 8.2.3 that is presented below displays the group's final total cost of this project and quantity of each part that was needed to completely build the safety enhanced wheelchair.

Item	Unit Price	Quantity	Total Cost
Solenoid	$54.70	2	$109.4
Perfboard	$4.00	2	$8.00
Atmega328	$2.88	2	$5.76
LCD Screen	$17.99	1	$17.99
12v Lead Battery	$39.99	1	$39.99
M10 GSM Shield	$109	1	$109
20-PIN DIP Socket	$0.75	1	$0.75
DC Power Connectors	$1.26	2	$2.52
GTPA013 GPS Module	$39.95	1	$39.95
A401 FlexiForce Sensor	$19.50	3	$58.50
RFID Blue Eye Key Fob Tag	$1.99	1	$1.99
LT1676 Switching Regulator	$5.88	2	$11.76
Avid BB7 Mechanical Disc Brake	$51	2	$102
Parallax RFID Card Reader Module	$42.99	1	$42.99
RFID 54mm x 85mm Rectangle Tag	$2.50	1	$2.50
Invacare Veranda Manual Wheelchair	$99	1	$99
Total			$652.01

Table 8.2.3 *– Finalized Project Budget*

Appendices

Appendix A - Copyright Permissions

Linx Technologies

Permission to Use Figures for Senior Design Project   Inbox x

Angelo Biaggi <biagaany@gmail.com>   Jul 17 (5 days ago)
to info

Hello, My name is Angelo Biaggi. I am a Computer Engineering student at the University of Central Florida currently working on a senior design project that will be using a R4 series GPS receiver module. I would like to ask permission to use Fig 1, Fig 3, Fig 4, Fig 5, Fig 6, Fig 9, Fig 10, Fig 18, and Fig 31 from the data guide. These figures may end up in our Senior Design Documentation with full credit going to the company. This is purely educational and will not be used for commercial purposes.

Kind Regards,

Angelo Biaggi

Kris Lafko <KrisLa@linxtechnologies.com>   Jul 19 (3 days ago)
to me

Angelo,

We at Linx thank you for your interest in our information. We approve the use of the requested items with the provision that Linx Technologies is properly reference.

Good luck.

Regards,
Kris

Kris Lafko
VP of Marketing and Sales
Linx Technologies
Wireless Made Simple®

SIMCom

Permission to Use Figures for Senior Design Project   Inbox x

Angelo Biaggi <biagaany@gmail.com>   Jul 27 (1 day ago)
to simcom

Hello, My name is Angelo Biaggi. I am a Computer Engineering student at the University of Central Florida currently working on a senior design project that will be using the SIM300 GSM module . I would like to ask permission to use Fig 1, Fig 3, Fig 4, fig 6, Fig 9, Fig 10, Fig 11, Fig 12, fig 13, Fig 19, Fig 20, Fig 25, Fig 26,   table 3, table 5, table 7, table 8, table 9 and table 31 from the data guide. These figures may end up in our Senior Design Documentation with full credit going to the company. This is purely educational and will not be used for commercial purposes.

Kind Regards,

Angelo Biaggi

yonggang.dai(戴永刚) <yonggang.dai@sim.com>   9:25 PM (46 minutes ago)
to me

Hi Angelo Biaggi,

First of all, thanks for your interesting in our company and product.
Definitely, It is not problem that you use it in your documentation not for commercial problem.

Best Regards
Gunter Dai（戴永刚）
TEL:+86 21 32523406
****

Parallax Copyright Permission

From: Lauren Davis <ldavis@parallax.com> Sent: Mon 7/22/2013 3:07
To: rpearce@knights.ucf.edu
Cc:
Subject: Copyright Permission Request

Hi Ryan,

This is no problem at all. Good luck with your project.

Sincerely,
Lauren

Lauren Davis
Marketing Director
Parallax Inc.
ldavis@parallax.com
www.parallax.com

Hello,

My name is Ryan Pearce and I'm a senior Computer Engineer at the University of Central Florida. At this time, my group and I are working on our Senior Design Project and one of the aspects of this project involves the use of RFID. We would like to ask permission to use some of the figures that appear on the specification documents for item code 28140 found here http://www.parallax.com/tabid/768/ProductID/114/Default.aspx . As well as documents included with the reader tag part of the kit, found here http://www.parallax.com/Store/Accessories/Hardware/tabid/162/ProductID/115/List/1/Default.aspx?SortField=ProductName,ProductName

These images will be used in the Senior Design project documentation, and you will be credited and cited appropriately. This is purely for academic use and will not be used for any commercial purposes. Please advise if this is permissible.

Thank you,
Ryan Pearce

rpearce@knights.ucf.edu

Formal Permission Request for Senior Design Report

Trent Gallagher

Follow up. Start by Tuesday, July 30, 2013. Due by Tuesday, July 30, 2013.

Sent: Mon 7/29/2013 1:18 PM

To: 'admin2@mtbreview.com'

Good Afternoon!

I am with a Senior Design group at the University of Central Florida. We plan to utilize your Avid BB7 disc brakes with our project, and we'd like formal permission to use figures and pictures of them that are shown on your website within our report. Note that this is a strictly academic and non-commercial use of the information.

Best Regards,
Trent Gallagher
trentgallagher@knights.ucf.edu

[#MBK-597-72614]: Formal Permission Request for Senior Design Report

RobotShop Inc. <supportcenter@robotshop.com>

Follow up. Start by Monday, July 29, 2013. Due by Monday, July 29, 2013.

Sent: Mon 7/29/2013 3:22 PM

To: trentgallagher@knights.ucf.edu

Hi Trent,

Thank you for contacting RobotShop. Since the images are being used for non-commercial means, you can certainly use the images (schematics etc) found on our website. Be sure to include / list the source for each (ex. Source: www.RobotShop.com).

Sincerely,

Coleman
Technical Team - Équipe Technique
RobotShop Inc.
Putting Robotics at Your Service!®
La Robotique à votre Service!®
Web: www.robotshop.com

Sign in at robotshop.helpserve.com to see your full support history.
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Visitez http://robotshop.helpserve.com pour voir votre historique de support complet.

Ticket Details

Ticket ID: MBK-597-72614
Department: Education / Teachers
Type: Issue
Status: Answered
Priority: Support

Formal Permission Request for Senior Design Report

Trent Gallagher

Follow up. Start by Tuesday, July 30, 2013. Due by Tuesday, July 30, 2013.

Sent: Tue 7/30/2013 6:11 AM

To: 'stuff@sportaid.com'

Good Morning!

I am with a Senior Design group at the University of Central Florida. We plan to utilize your D's Locks and Invacare/Top End Push Wheelchair Brakes with our project, and we'd like formal permission to use figures and pictures of them that are shown on your website within our report. Note that this is a strictly academic and non-commercial use of the information.

Best Regards,
Trent Gallagher
trentgallagher@knights.ucf.edu

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REPLY REPLY ALL FORWARD •••

SparkFun Customer Service <cservice@sparkfun.com> mark as unread

Wed 7/31/2013 12:41 PM

Inbox

To: Lomar St.Louis <stlouis2010@knights.ucf.edu>;

Hello Lomar,

You can absolutely use the data sheets for the products we produce. You will need to provide the credit to us in accordance with the creative common rules but you are welcome to use the data sheet for your project. Please let me know if you have any other questions or if there is anything else I can do for you.

Here is information on the creative common guidelines for you as well: http://creativecommons.org/licenses/by-sa/3.0/

Best Regards,
Jennifer Miller

Customer Service Representative
SparkFun Electronics
www.sparkfun.com
303.945.2984

Hello Lomar,

Thank you for contacting Texas Instruments America's Customer Support Center.

http://www.ti.com/corp/docs/legal/copyright.shtml

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Anna Pettit

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Tekscan®

Dear Trent Gallagher

Thank you for your interest in our *FlexiForce®* products. In response to your inquiry:

"I am with a Senior Design group at the University of Central Florida. We plan to utilize your A201 and A401 sensors with our project, and we'd like formal permission to use figures, pictures, and circuit schematics of them that are shown on your website within our report. May we also receive the circuit schematic for the A401 sensors? Note that this is a strictly academic and non-commercial use of the information. "

We do allow referencing and use of the manual's figures and numbers for educational purposes. Please try to reference back to source. The circuit used for the A401 is our recommended circuit, attached is a document containing the schematic.

Please feel free to contact me if you have any questions or need additional information.

Best Regards,

Steve Tran
FlexiForce ® Inside Sales and Technical Support
(617) 464-4500 x337

Re: Formal Permission Request for Senior Design Report

Level 1 <level1@sparkfun.com>

Follow up. Start by Monday, July 29, 2013. Due by Monday, July 29, 2013.
This message is part of a tracked conversation. Click here to find all related messages or to open the original flagged message.

Sent: Mon 7/29/2013 2:24 PM
To: TrentGallagher@knights.ucf.edu

Go for it and good luck on your project (let me know if this isn't formal enough).

Michelle

Technical Support
SparkFun Electronics
6175 Longbow Drive
Boulder, CO 80301

techsupport@sparkfun.com
1-303-284-0979

---------- Forwarded message ----------
From: **Trent Gallagher** <TrentGallagher@knights.ucf.edu>
Date: Mon, Jul 29, 2013 at 11:11 AM
Subject: Formal Permission Request for Senior Design Report
To: "customerservice@sparkfun.com" <customerservice@sparkfun.com>, "ar@sparkfun.com" <ar@sparkfun.com>

Good Afternoon!

I am with a Senior Design group at the University of Central Florida. We plan to utilize your stepper and servo motors along with the drivers for them in our project, and we'd like formal permission to use figures, pictures, and circuit schematics of them that are shown on your website within our report. Note that this is a strictly academic and non-commercial use of the information.

Best Regards,

Trent Gallagher

trentgallagher@knights.ucf.edu

Thank you for contacting Grainger. Email received. (Reference - 6001070386)

DoNotReply@grainger.com

If there are problems with how this message is displayed, click here to view it in a web browser.

Sent: Fri 12/6/2013 7:15 AM

To: trentgallagher@knights.ucf.edu

Thank you for contacting Grainger.

Your request has been received and will be processed as soon as possible.

Your Grainger Service Ticket number is 6001070386 .

Thank you,

Grainger Customer Care Team

Original Request:
Other Inquiries - New Platform

Contact Information: Name: Trent Gallagher Email: trentgallagher@knights.ucf.edu Company: Formal Permission Request Account Number: Fax: Phone: Comments/Questions: Good Morning! I am with a Senior Design group at the University of Central Florida. We plan to utilize your solenoids with our project, and we'd like formal permission to use figures and pictures of them that are shown on your website within our report. Note that this is a strictly academic and non-commercial use of the information. Best Regards, Trent Gallagher trentgallagher@knights.ucf.edu

Appendix B - Work Cited

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