Making The World A Better Place:
Wireless Door Opener
Second Semester Report
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Abstract

The project introduced here is relevant to Electrical Engineering and to making the world a better place. Performed by four Good Samaritans Jason Hall, Garet Scranton, Chris Wagner, and Zhangjing Yi for CSU ECE401: Senior Design I, the system being developed serves to open a handicapped door without any human interaction. This would eliminate many issues which plague the current handicapped door system and render them nearly useless. The project uses wireless technologies that already exist for the specific application of opening doors when a wheelchair is in close proximity; but only when opening the door is actually desired. Utilizing a combination of Electrical Engineering skills such as designing, testing, and implementing a digital circuit system, the team has created a system to accomplish this goal.

The project is now in its third semester and is planning new goals. After reading interviews from last year's group project we were able to diagnose exactly what was wrong with the current system, develop goals for the new system, and move forward into the redesign. The main goal not accomplished last year was power management. This is the key factor to the operation of the device so redesign is paramount. As the system on Colorado State University's campus identically matches what is being used in public, the group's focus lied strictly in upgrading the system on campus in the given year, with hopes for future teams to expand it all over campus. In addition to prior year conditions, the solution being developed and designed to meet the following goals/constraints include: the system should open handicapped doors wirelessly with no user input, the system should run on a battery which can be easily recharged, the system should be weatherproof, the system should be relatively cheap (under $75), the system should work only within 15-20 feet of the desired door, and the system should only open a door when the user would want it to based on the designed input circuit. Focusing on our main goal the transmitter and receiver has been replaced with a transceiver device. In addition, new modularized circuits will be implemented. The circuits to be designed and incorporated include a voltage regulator circuit. This will be a major factor in power reduction. Another is a modified oscillator circuit. This will cut down the duty cycle and also conserve power. Finally, a shortened timer circuit and an input circuit will conclude the redesign and will meet the needs of handicapped citizens.

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Chapter 1 - Introduction:

A significant number of people are wheelchair bound for life. Some are born this way, others have unfortunate accidents. This Wireless Door Opener project was categorized under "Making the World a Better Place" due to the fact that if the end goal was reached, it would have an immediate and beneficial impact on those who use the device. We set out to improve the lives of people with limited or no movement in their arms and hands. We aim to help them with a task many take for granted, opening a door. The switches placed next to each door are a tolerable invention but they were designed with one premise, that the user would voluntarily push the button. We aim to eliminate that assumption and give those who wouldn't be able to push the button the ability to freely enter and exit a building without seeking assistance.

Figure 1 - Current Door System

The current door opening system at CSU, shown in Figure 1, is beneficial to those with arm movement but as mentioned earlier not all users have the ability to move their arms. The current system on campus uses two types of wireless technology. The older version uses a 300MHz transmitter and receiver while the new version uses an increased frequency of 433MHz. Each transmitter can control numerous receivers while each receiver can receive signals from an infinite number of different transmitters. Each receiver and transmitter is equipped with a ten bit dual-position dip switch. Only when identical combinations are chosen on the transmitter and receiver do the devices communicate. This is necessary due to the huge range of the transmitters. If a transmitter is activated, any receiver in the range will be activated. Thus, the receivers are set to different codes to prevent other doors from opening.

One of the major problems with the current door opening system is that the range of the transmitters is too large (300ft+). With the current range, if the receivers are all configured to the same code, any door within that transmitter's range will open. This could pose safety and security problems by opening unnecessary doors. If the range of the transmitters could be decreased, there would be no need for the different codes and therefore no need for different transmitters. Then, in theory, you could use just one transmitter for a whole building containing a number of different receivers. In addition, the newer models being phased onto campus currently do not work with the older, lower frequency receivers. Right now a person going into a building would need numerous transmitters to activate the receivers that are set to different codes and frequencies.

Another problem with the current CSU door opening system is that the push buttons outside of doors cause users unnecessary hassle. Anytime you see an automatic door opener, towards the bottom there is a button associated with it which houses a transmitter inside it.

When the button is pushed, the transmitter sends a signal to the receiver which tells the door to open. The problem is that every transmitter inside the button operates off of a battery. Batteries don't last forever and in time the battery's power will be exhausted. Also the batteries are subject to the weather if the button is placed outside. This can lead to premature failure of the battery. There is no backup device to keep the button operational when this happens. This means the transmitter is not operational and the door cannot be automatically opened by any other means. This can cause a huge problem for handicapped people needing to get through a door. In the case of this happening, a CSU facilities maintenance person must be contacted and a technician will have to go out to the button and manually replace the battery. Each building on campus has numerous entrances, exits, and restrooms which have these systems. Each door has two push buttons, one on the inside and one on the outside. This means there could potentially be a hundred or more transmitters on the verge of failing here on campus. This is an inconvenience and a waste of time for everyone.

The final problem with the automatic door opening system is timing. When the button is pushed, the door will open and stay open based on the delay set in the door opening mechanism. The problem is that when the door opens, if the handicapped person is not through the door by the time the delay is up, the door will close on them. If a handicapped person's wheelchair should get caught or if they stop for any reason within range of the door's swing, they will get hit. This is coupled with the fact that some doors and buttons are awkwardly placed, forcing the handicapped people to perform advanced maneuvers after pressing the button to avoid being hit by a door opening towards them, before trying to make it through in time.

Our proposed system to fix the problems stated above should meet the following requirements: the system should open handicapped doors wirelessly with no user input, the system should run on a battery which can be easily recharged, the system should be weatherproof, the system should be relatively cheap (under $75), the system should work only within 15-20 feet of the desired door (shown in Figure 2), and the system should only open a door when the user would want it to based on the designed input circuit. By successfully implementing this system, we would essentially overcome all problems with the current system. As the system would be the responsibility of the disabled people, they could charge the batteries as needed and not worry about the batteries in the wall devices. Also, as wheelchairs are mostly inside, users would not have to worry about the elements wearing down the transceiver. It would also pulse often to keep the door open long enough to pass through safely. This is all on top of the convenience provided as the device would open doors for you when needed. This system should be phased into CSU and then extended further into other public places.

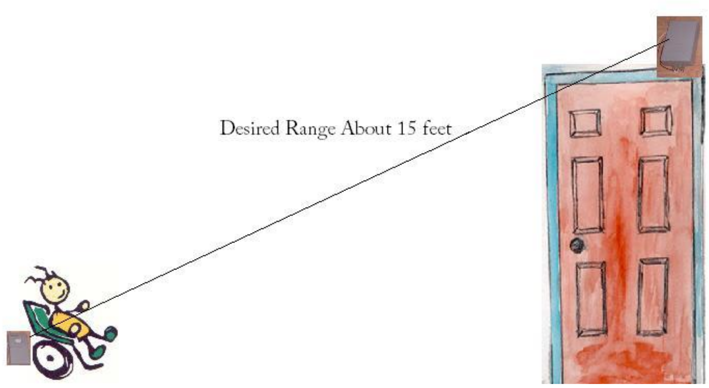

Figure 2 - Proposed System

Chapter II of this report contains a critical review of the previous work done on the wireless door opener project, titled the Justin Project. Also included is last year's contribution. Chapter III explains the donations including donations and transceivers. Chapter IV explains the hardware design and is split into various categories which pertain to the circuit systems considered and reviewed followed by problems. Chapter V contains the business aspects of the project, including marketability and integration plans among other topics. Chapter VI consists of the conclusions and future work proposed for next semester.

Chapter II - Summary of Previous Work:

The Wireless Door Opener project is a continuation and rework of a project known as the Justin Project which was done in the fall and spring semesters of 2005-2006 here at CSU. The rationale for starting the project was that a member of the CSU alumni had a driving accident in 2005 and was instantly paralyzed, becoming quadriplegic. Through the inspiration of the alumni's story, as well as help from family and friends, this project was started to help people with disabilities to overcome one of the problems they encounter in everyday life, opening doors. They wanted to allow the doors to be opened without any sort of interaction, using radio wave technology. The system would pulse concentric circles of radio waves and as someone breached the fields, the system would react accordingly and open the door.

Plenty of research was done on disabilities themselves as well as the ADA government regulations that surround them and various handicapped laws. However, the project got hung up in the research stages and too much time was put into deciding on the type of technology to be used for the project. They investigated Avalanche Transceivers, Radio Triangulation, Ultrasonic and Infrared Rangefinders, Global Position Systems (GPS), and an Array of Radio Fields. They decided in the end to use the array of radio fields but by the end of the second semester, no working prototype unit was implemented. Thus, the project did not get as far as desired and there was an extensive list of future work proposed.

The system was also fairly specific and focused. They did not plan to integrate with any current door system in use but preferred to start from scratch and spent a lot of time investigating different forms of integration using various development kits.

The project was renewed as part of a "Make the World a Better Place" series of projects hosted by Olivera Notaros, head of Senior Design 2007-2008. Learning heavily from the Justin Project, our project team made sure to follow a strict project development process. As we decided not to continue where they left off, and made very different design and implementation plans, we started over while keeping very similar end goals as the Justin Project.

During the second year of work the project gained new members with fresh ideas. This team was made up of Jon Kay, Jason Hall, and Garet Scranton. All three students were ECE majors. Led by Jon Kay the group kept to a strict timeline and numerous set goals. We started by taking knowledge of the Justin Project, interviews, and technology to elaborate a plan to make the most efficient system possible. It led to the design plans for a transmitter-receiver pair. The pair system would meet all criteria as described earlier. The system took a significant focus on range as we felt this was a considerable downfall of the existing system. Early second semester a prototype was conceived and was implemented for testing. This stage led to the arrival of problems with the system. The calamitous problem that wreaked havoc was excessive power use. Simple put the transmitter draw far more power than planned. However, that year led to the foundation of a functioning yet practical system that could be improved and expanded to meet original designs.

By the end of the year, the project team successfully designed a prototype system which met most of the original project goals. The solution was well received by the primary tester and plenty of feedback was gathered to improve upon it. Future work proposed on the project includes working out the problems with the solution and moving from the prototype phase into the manufacturing and marketing phase.

Chapter III - Hardware Design:

A. Transceivers

i.) Comparisons

Since the transceivers are the core component of our design, it is critical for us to find an appropriate transceiver in order to achieve our goals. For the reason that our last year design could only last for two or three days with batteries, it is critical that we need to improve our design with a lower power consumption components. Also, we will need to build a prototype for testing before we put the design into a PCB layout. Therefore, our ideal transceiver will be the one that has low-power consumption, short range, and an accessible pin layout.

a.) Panasonic (Zigbee Module PAN4555)

Firstly, we found Zigbee module transceiver from Panasonic. It meets our expectations on short range transmission. It has fairly low power consumption, which is 120mW. However, it uses high level communication protocols. This technology, which is widely used in Wireless Personal Area Networks (WPANs), is capable of transmitting the signals that we need to use, but it is overkill for our usages. Furthermore, the biggest disadvantage of this unit is that it has a very small size of 12.2mm x 16.4mm x 2.2mm with 20 I/O pins, which is good for minimizing the size of final products, but it is really difficult for hand soldering. After analyzing the accessibility of Zigbee module transceiver from Panasonic, we decided it is not the right choice for our purpose.

b.) Vishay (RFW3M)

Secondly, we looked at transceivers from Vishay. The RFW3M was the first transceiver that appealed to us and compared to PAN4555 the Zigbee Module from Panasonic, it has the same power consumption and the advantage of accessible pin sizes for hand soldering. The Vishay RFW3M has three operating channels for frequency agility, which is a great functionality for the usage of frequency varying. Nevertheless, the signal that we need to transmit between the door end and the wheelchair end is a 100ms pulse every 2 seconds and for the reason the average user’s walking speed is 4mph. Therefore, it will take one pulse when approaching the door from a distance of 15-20 feet. Therefore, our purpose of transmitting only requires one frequency. Also, in order to select the correct frequency, the processor on the RFW3M has to be programmed before usage; and each time the processor loses its power supply, the chip requires recompilation. This would be impractical, as the transceiver would need to be reprogrammed on a daily basis. Considering the reasons above, we object the Vishay RFW3M as the core of our design.

c.) Vishay (RFW122)

Lastly, as we proceeded to investigate the Vishay product line we encountered the RFW122. According to the RFW122 datasheet, in transmitting mode the RFW122 consumes typically 72.6mW (22mA $\times$ 3.3V), which is about half the power consumption of the previous two models. With this power consumption, it could last for up to a week with 4 AA batteries. However, we are redesigning our transmitting circuit with a switch that controls the transceiver to be set to sleep-mode. Operating in this mode it consumes about 0W of power. Whenever the input sees a pulse, which appears 5% (100ms / 2s) of the operating time it switches to the transmitting mode. The RFW122 would last twice as long as the previous two choices. Also it uses a three line serial digital data I/O line interface. This means the duty cycle doesn't require an inter-chip frequency selection. It is driven by an outer-chip clock so that it doesn't affect data when it loses power supply. Moreover, the RFW122 has a size of 16.1mm $\times$ 11mm with only 12 pins, which are hand solder accessible.

d.) Vishay

Recalling last year's transmitter and receiver kit and the synonymous issues we decided to implement the Vishay RFW122 transceiver which operates at 2.4 GHz. Vishay is one of the leading producers of discrete semiconductors and passive components. They incorporate a transmitter and receiver into one device. The Vishay RFW122-M RF transceiver is a short-range wireless radio transceiver. The transceiver can send data up to 3Mb per second which is far more required for our project. Implementing one Vishay in the door and another on the wheelchair they would use handshake communication. The transceiver would constantly send out a signal and when the other transceiver came into range it would "wake up" from a sleep mode and send a signal back to inform the first transceiver. Once out of range the wheelchair transceiver would re-enter sleep mode and the door transceiver would close the door. Like last years design, Vishay is small and will be easy to incorporate into a small enclosure. The primary reason for this technology choice is the fact that Vishay transceivers draw very small amounts of current in sleep mode. In the lab, early tests show the transceivers communicating with a square wave input and a pulse output as seen in the figure.

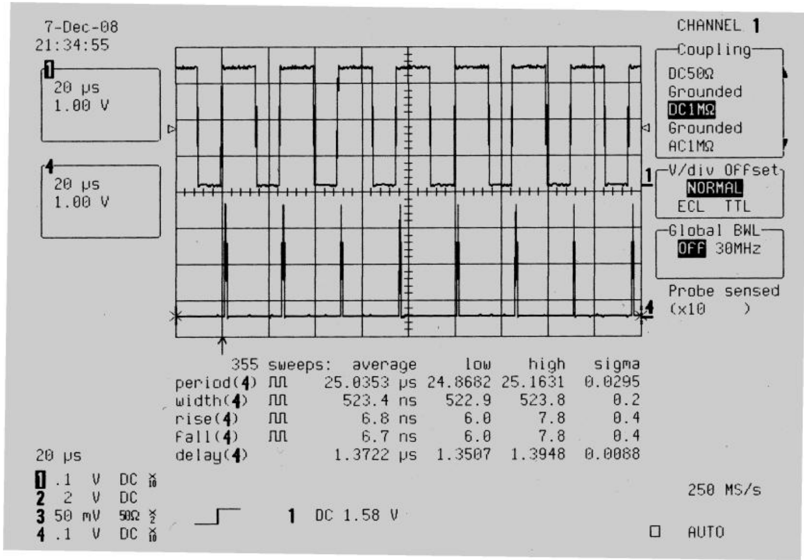

Figure 4 – Input (top) and Output (bottom)

The following figures show a 500ns pulse on the top of the plot while spectral density is on the bottom. The rising edge of the square wave initiates a pulse based on different frequencies. The measured frequencies include 5 kHz, 25 kHz, 40 kHz, and 50 kHz. The last figure is when the transmitter is off and the receiver is on.

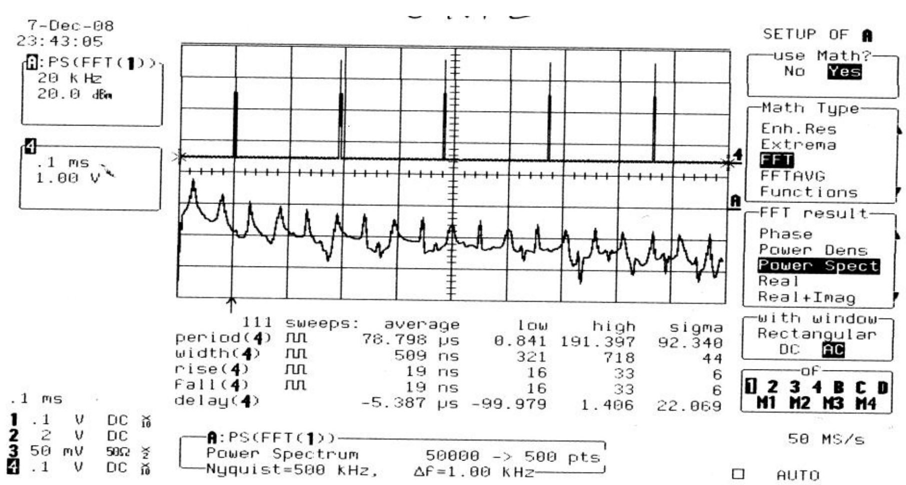

Figure 5 – 5 kHz

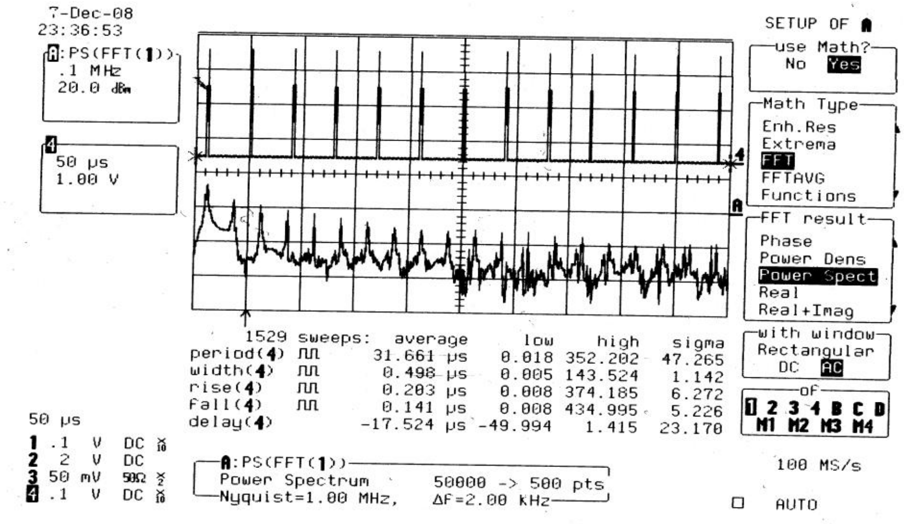

Figure 6 – 25 kHz

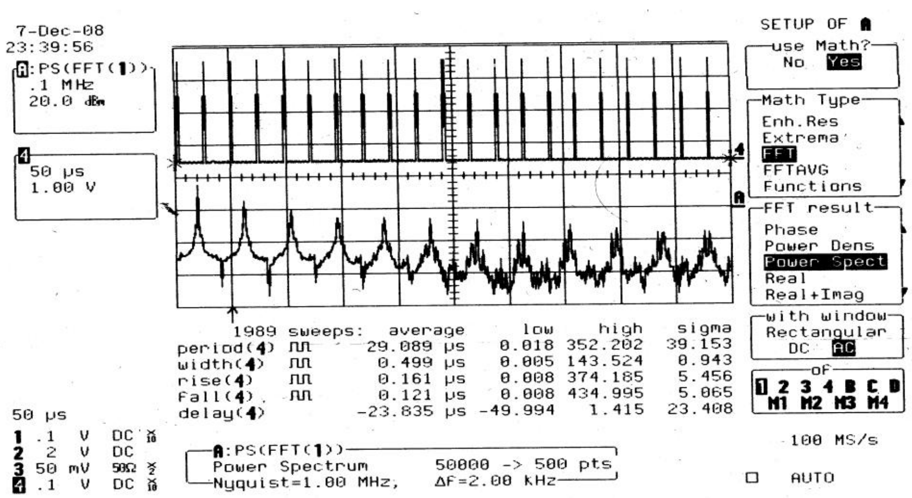

Figure 7 – 40 kHz

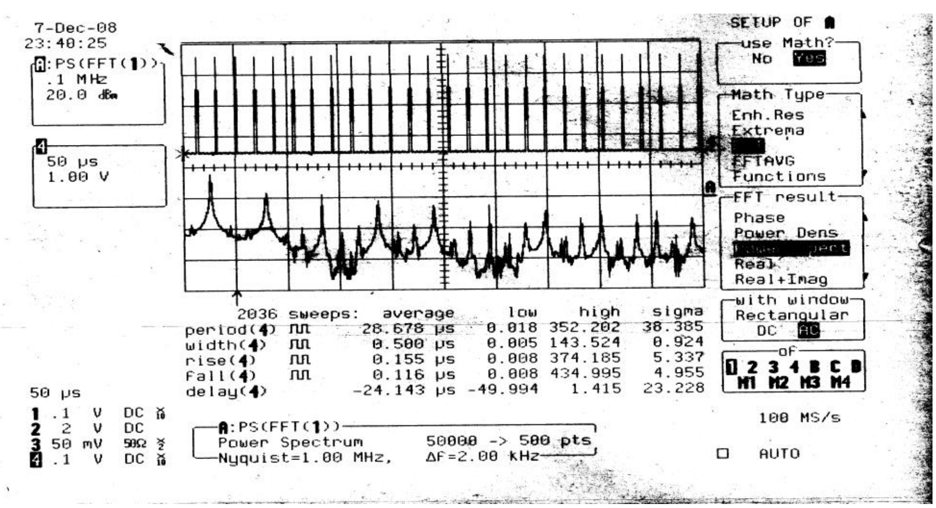

Figure 8 – 50 kHz

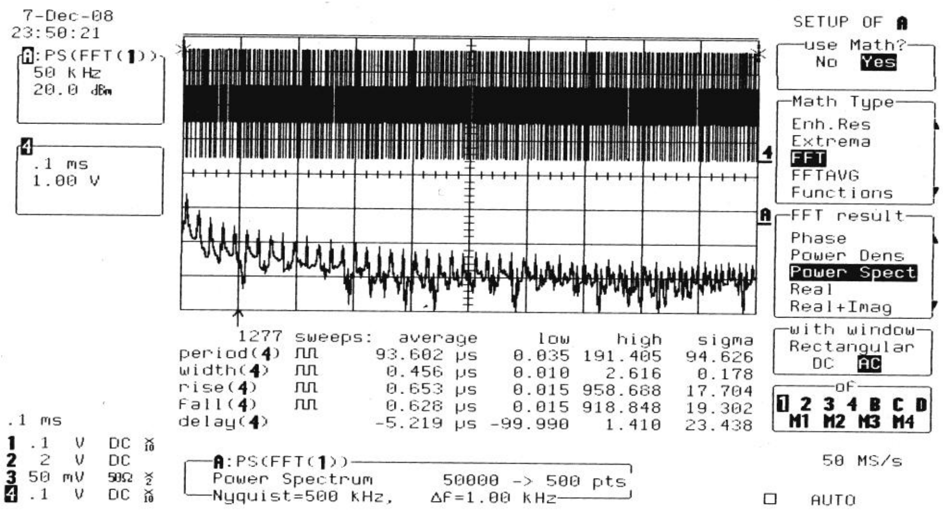

Figure 9 – Wheelchair (trans.) Off, Door (trans.) On

e.) TR 1000

RF Monolithics, Inc. offers a transceiver for short range applications. It has a size of 10.2 by 7.06 mm, requires a voltage between 2.2 and 3.7 V which means that it can take a lithium ion battery to power it. It has a current consumption of 3.1mA in receive mode 12mA in transmit mode and 0.7uA in Sleep mode so for your typical Lithium ion battery that has a rating of around 1000mA-h it will be able to last for around 322 hours in receive mode, 83 hours in transmit mode, and about 167 years in just sleep mode with the powering the transceiver only. The transceiver has a power output range between -40 dBm and 10 dBm wich according to the website gives it a range of between 3 and 200 meters in open space which will give us more than enough range for our application. This type of application will also allow us to be able to put some sort of range constrictions on the signal that we will put out. It also has a maximum data rate of about 115.2 kbits per second so it will be able to meet any kind of data transfer needs we may have in the future. A single transceiver unit costs around $10 and RFM also stated that no license is required to use the TR1000.

ii.) Timer Circuit and Microprocessor Timing

a.) Timer Circuit

Once we knew what sort of system we were going to be integrating with, our next area of focus was making the system automated as stated in our primary goals. One of the circuits designed to implement this function was known as an oscillator circuit, which was implemented in our circuit design in the first semester of 2009. Using an oscillator hooked up to a relay, we could replicate closing and opening the switch on the transceiver. We fine tuned it to allow the transceiver to pulse a signal for 100ms every 2 seconds. This gives our transceiver a 5% duty cycle. At our goal range of 15-20 feet away from the door, this 2 second time seemed acceptable as both individuals we talked to. They traveled about 4mph on average but then slowdown to a crawl when approaching a door. The timing plot for the circuit is shown in Figure 10:

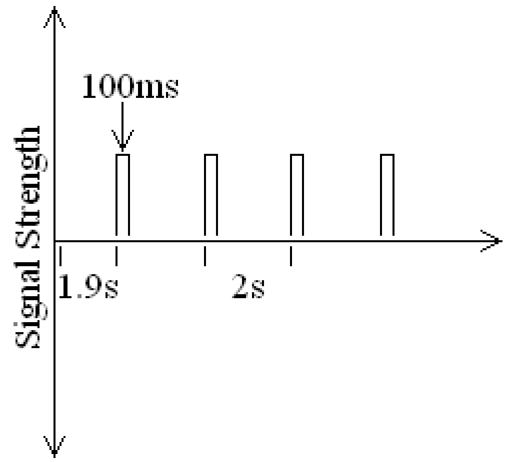

Figure 10 - Oscillator Circuit Timing Plot

In this way, it would be analogous to pressing the button outside the door once every 2 seconds. It was mentioned earlier that if the person is not through the door by the time delay ends that the door will shut on the individual. This can be a nuisance and potentially damage the wheelchair and the door. By pulsing every 2 seconds, the system would definitely prevent the door from closing on the user while inside the doorway.

b.)Microprocessor Timing

Due to the reason of inaccuracy and power consumption of timing using hardware, in the second semester of 2009, the circuit dealt with timing problem from the software perspective.

For the door end of the system, it utilizes the timing of 50% of the time transmitting a 2kHz signal and the other half of the duty cycle attempting to receive the 2kHz signal from the approaching chair. The duty cycle of the door end is 20Hz. The timing plot of the door end is shown in Figure 11.

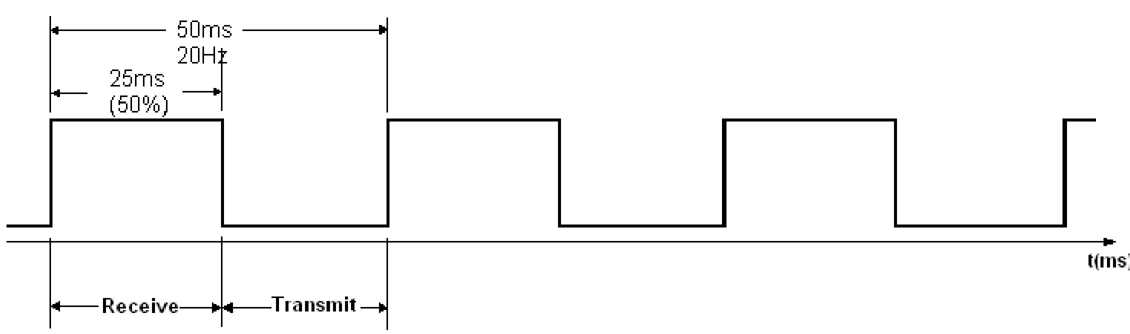

Figure 11 – Timing plot of the door end of the system

As for the chair end of the system, a timing plot is shown as Figure 12. The transceiver on the chair end is operating in 40Hz duty cycle. The microprocessor sets the transceiver on the chair end with two modes. In mode 1, the chair has 5% of the time receiving and the other 95% of the time sleeping. Once the chair receives a 2kHz signal from the door end in that 5% of the duty cycle time, the microprocessor will switch the transceiver into mode 2. In mode 2, instead of having the 95% of time in sleep mode the transceiver has 95% of the duty cycle time transmitting a 2kHz signal intend to inform the transceiver at the door end that the chair is within the door's detecting range.

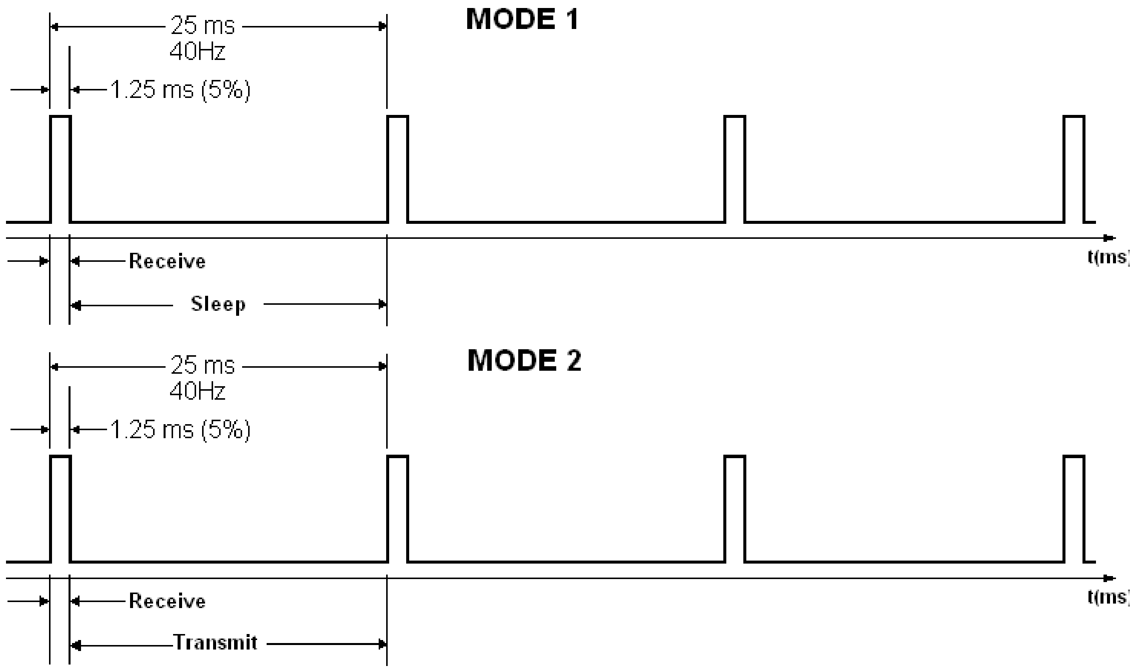

Figure 12 – Timing plot of the chair end of the system

The reason that the door end duty cycle has twice the frequency as it is in the chair end is because that the 5% of the receiving time on the chair end could catch at least one transmitting signal from the door end. Therefore, whenever the chair gets into the signal range of the door, it only takes 23.75 ms for the chair circuit to react to switch to mode 2 and starts communicating with the door.

Power management is an important part of electronic projects. Due to the fact that our device is so small and we cannot incorporate big batteries, we need an input circuit to allow the transmitter to only be active when needed. In the microprocessor timing way, the chair circuit is kept in power consumption saving mode when it is outside of the desired signal range, in which the microprocessor on the door end starts the door opening sequence detection. Since the transceiver consumes approximately 0 when in sleep mode, the power consumption of the entire chair circuit is from the microprocessor. The microprocessor, PIC16F685, consumes 0.2mA with 3V voltage supply, which means it consumes 0.6mW when operating. With 95% of the duty cycle time in sleep mode, the chair circuit consumes less than 1W in majority of the operating time. A 1000mAhrs Lithium ion battery, which is widely used in cell phones, will last the chair circuit about 2564 hours, which means three and half months.

Part of our goal was to make the times very adjustable especially when in the design and prototype phase. The main reason being, we knew once we passed off the prototype to our tester that we would need to keep changing the times to his liking until it worked as needed. The timings on these circuits are modified by the microprocessor which is nicely programmed in assembly language for easy access.

iii.) Emergency Shut-off

There are times were the user may want the ability to shut the transmitter off for personal or emergency reasons. Currently the oscillating circuit has an on/off switch that can be toggled at a moment's notice. A possible feature that could be added in the future is a security switch. The transmitter could be fitted with a key-activated turn on/off switch. This would be a single pole, single throw device that would operate similar to a relay. When the key is switched on, the device will "turn on" and the circuit will operate as intended. Without the key, the transmitter would be useless. This feature would be similar to a key used when starting a car. This component is inexpensive and would be a simple add-on. This feature would benefit the overall product and make it more marketable. We also intend to add an override button to operate the system. In case of failure, this button would bypass the rest of the bonus circuitry and just open the door.

iv.) Dipole Antenna:

For the exterior antenna we wanted to go with a fairly simple design. We decided to try out a Dipole or Half wave antenna. This is a very simple antenna design that is created by placing 2 wires directly opposite of each other so that the ends are separated by one half the wavelength of the transmission frequency. This allows the ends of the antenna to have the maximum voltage difference across them which will set up an EM field that will radiate in all directions around the wires. As you can see from the figure the field radiates in almost a doughnut pattern around the 2 wires of the antenna.

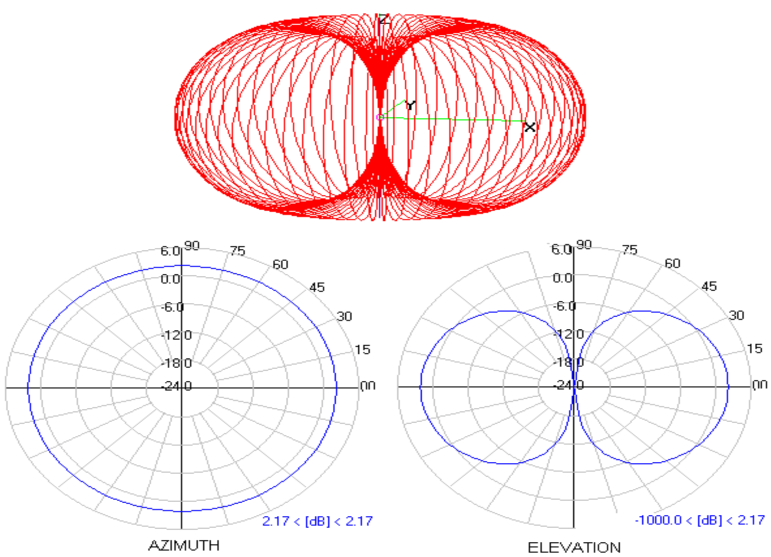

Figure 13 – Antenna Field Radiation

As you can see when you are looking down the wires of the antenna (the Azimuth direction) the electromagnetic field will radiate out equally in all directions. When you look at the antenna from the top (the Elevation direction) with the wires along the 90 and 270 degree direction you can see that the field is strongest in front and in back of the antenna. We predict that this type of radiation pattern will give us enough directional radiation so that we can prevent from opening the door when it is not in front or in back of the transmitter.

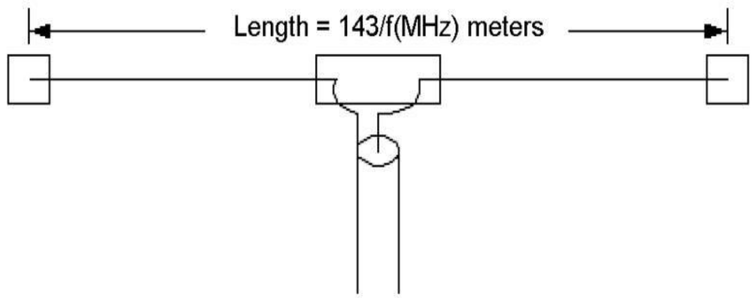

Figure 14 – Elevation Direction

v.) Transmission Range

The current system here on campus uses transmitters and receivers that were originally designed for a garage door opening system. These include both the 300 MHz and 433 MHz transmitters and receivers previously mentioned. As our system is proposed to be automatic, and in theory would constantly be pulsing the door open signal, all doors within range would be constantly opening. As most new buildings are designed with bathrooms in the same location on multiple floors, the signal would pass through the floor and doors could be mysteriously opening in other parts of the building with nobody being there. Since we do not want this, our goal as stated before was to tone the range down to approximately 10-15 feet only. We measured a standard ceiling is about eight or more feet tall. This would make the transceiver on the floor directly above or below out of range if you account for a few feet between floors which are also filled with various pipes, cables, and metals which would reduce the signal strength too.

B. Circuits and PCB design

i.) Door Circuit and PCB design

The door circuit is composed with a voltage supply, a voltage regulator, a microprocessor, a transceiver and an antenna. The overview of the circuit is shown in Figure 15. One thing that we encountered during our prototype phase was that the various different types of door openers on campus not only work on different wireless technologies, but also have different power sources. Thus, added to the door side of our system is a full wave rectifier into a voltage regulator which allows the device to be powered by 12V DC as well as 26V AC. These were the two most common voltages which we ran into on CSU’s campus. The voltage regulator, a buck, takes the voltage from the door system and regulates it into a constant 3V, which is the voltage that the microprocessor and the transceiver are operating at. A buck converter is a step down DC to DC converter. The simplest way to reduce a DC voltage is to use a voltage divider circuit. This is what was used last year to drop the voltage supply, but voltage dividers waste energy, since they operate by bleeding off excess voltage as heat. Also, output voltage isn't regulated (varies with input voltage). A buck converter, on the other hand, can be remarkably efficient easily reaching up to 95% for integrated circuits. The transceiver and the microprocessor are connected in the way that forms a control system with commands and feedbacks. Among all four output pins of the microprocessor, three of which are controlling the strength of the signal the transceiver is sending out to form a group of concentric circles, while the only other input pin to the microprocessor has the application of takes the signal detected by the transceiver and uses interrupts from software perspective. The antenna is utilized to receive or transmit signals controlled by the transceiver. The schematic and the PCB layout of the chair end circuit are shown in Figure 16 and Figure 17 in such order.

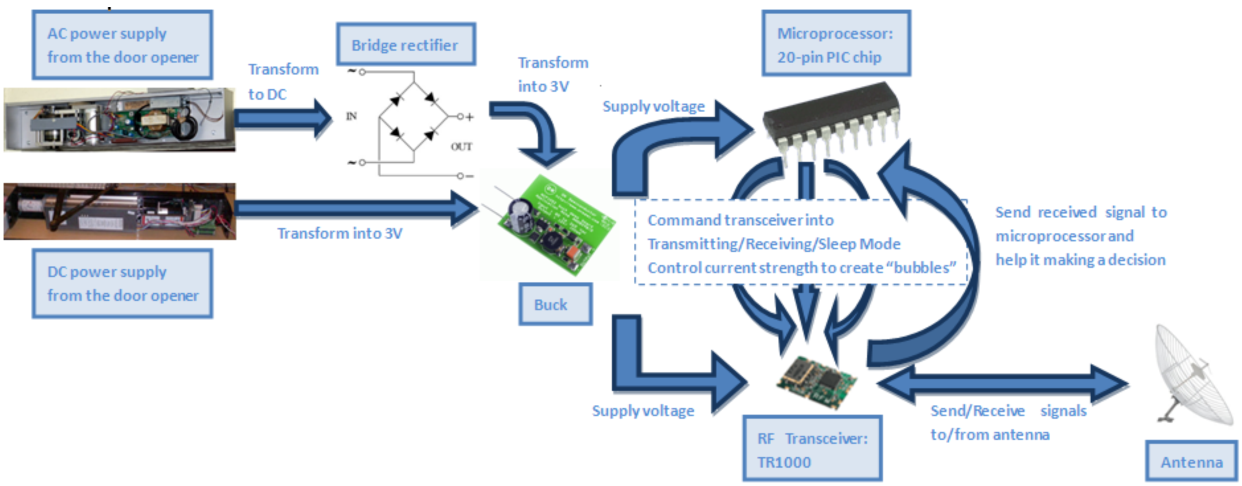

Figure 15 – Circuit overview of the door end circuit

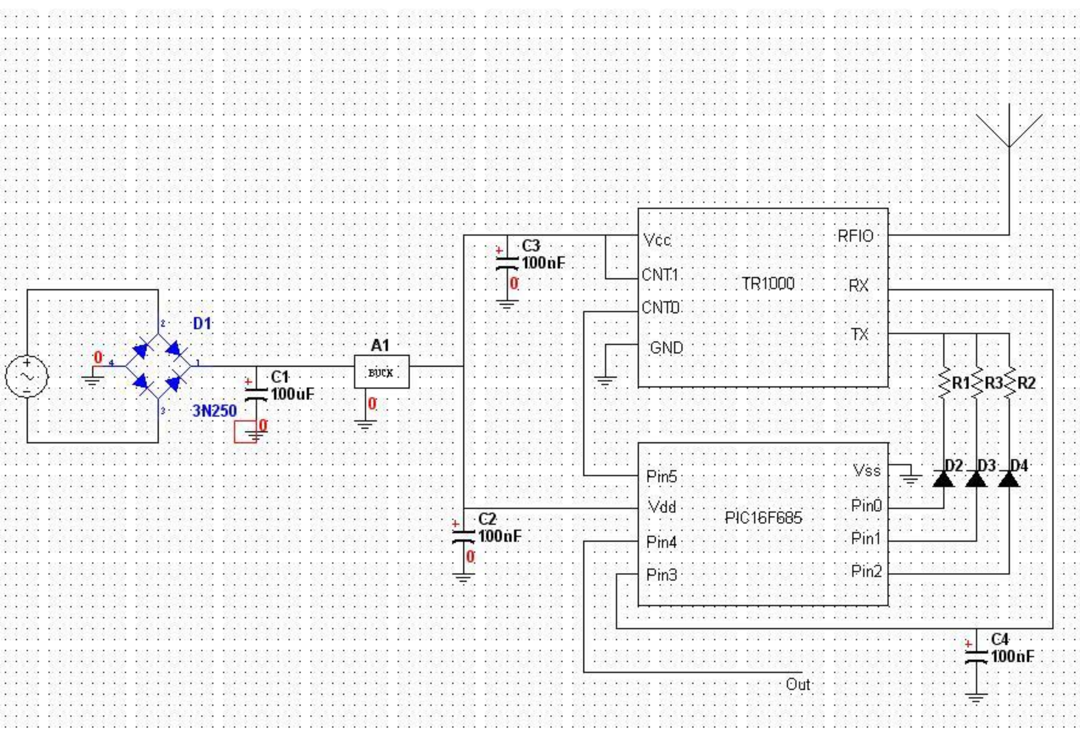

Figure 16 – Schematic of the door circuit

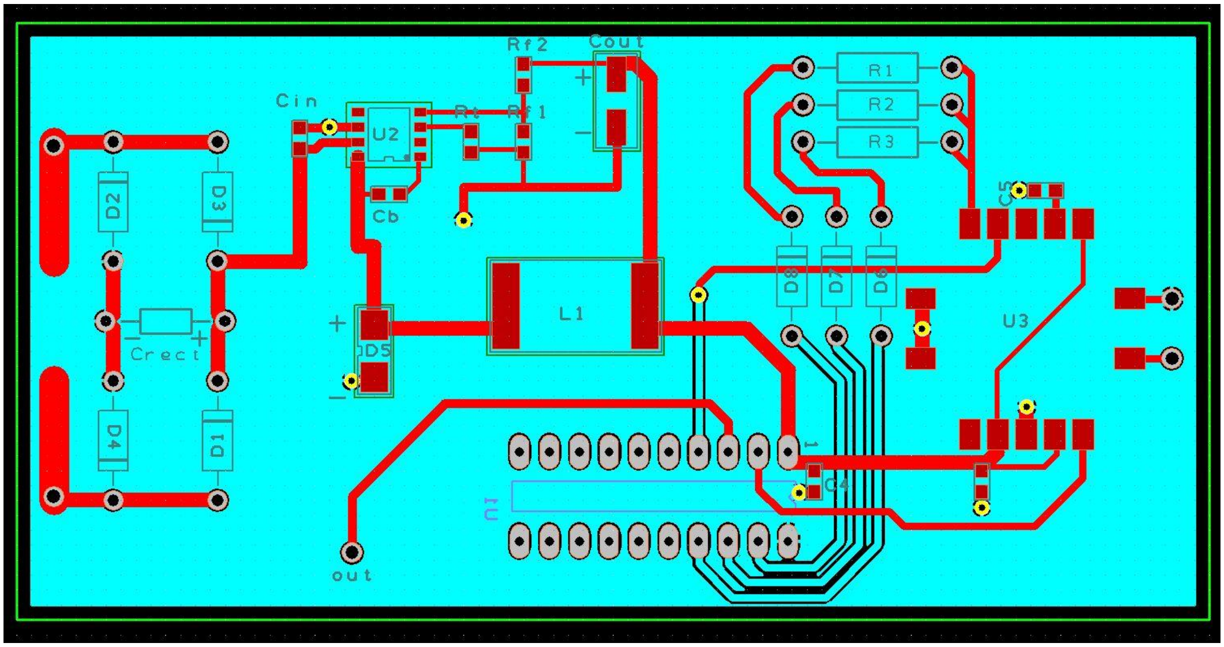

Figure 17 – PCB layout of the door end circuit

ii.) Chair Circuit and PCB design

The chair circuit is composed with a voltage supply, a voltage regulator, a microprocessor, a transceiver and an antenna. The overview of the circuit is shown in Figure 18. A Lithium ion battery gives out a 3.7V as the voltage supply to the entire circuit. The voltage regulator, the buck, takes in the 3.7V from the battery and regulates it into a constant 3V, which is the voltage that the microprocessor and the transceiver are operating at. The transceiver and the microprocessor are connected in the way that forms a control system with commands and feedbacks. The antenna is utilized to receive or transmit signals controlled by the transceiver. The schematic and the PCB layout of the chair end circuit are shown in Figure 19 and Figure 20 in such order.

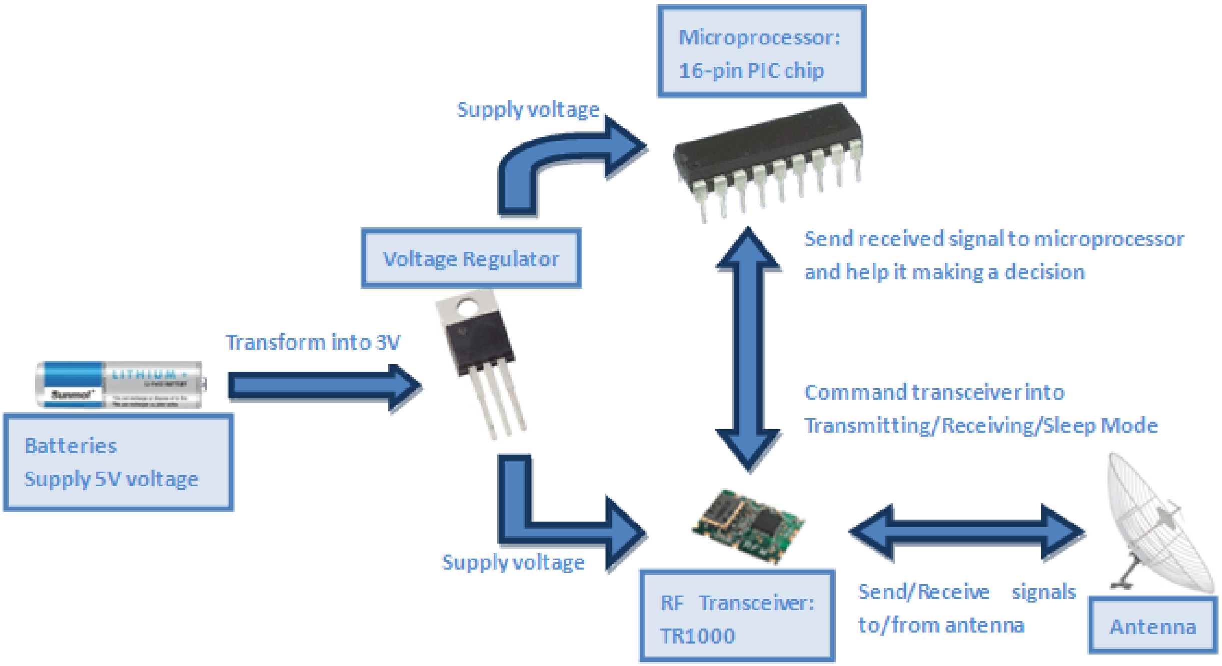

Figure 18 – Circuit overview of the chair end

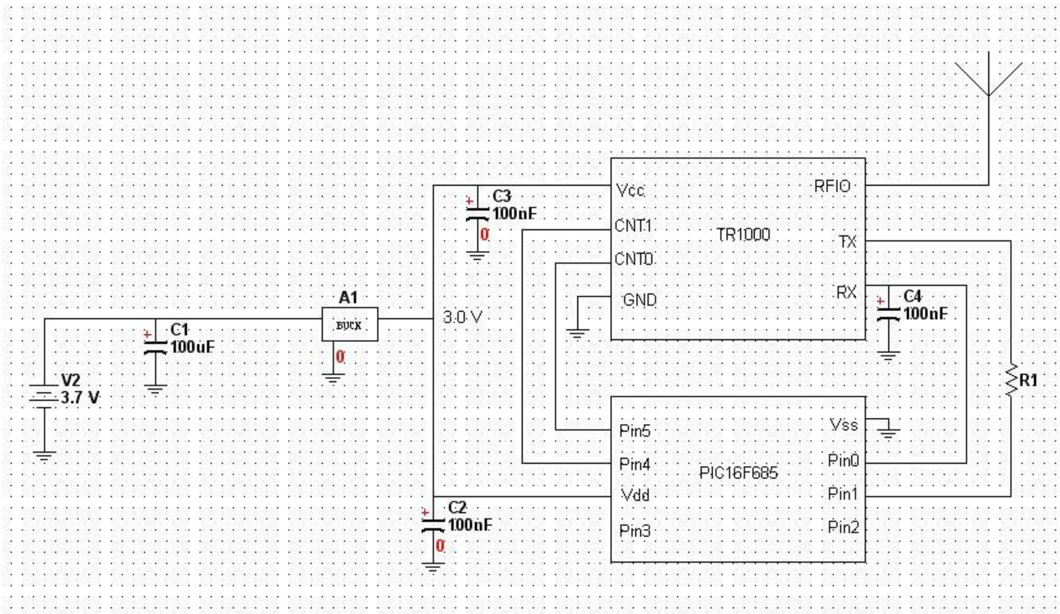

Figure 19 – Schematic of the chair end circuit

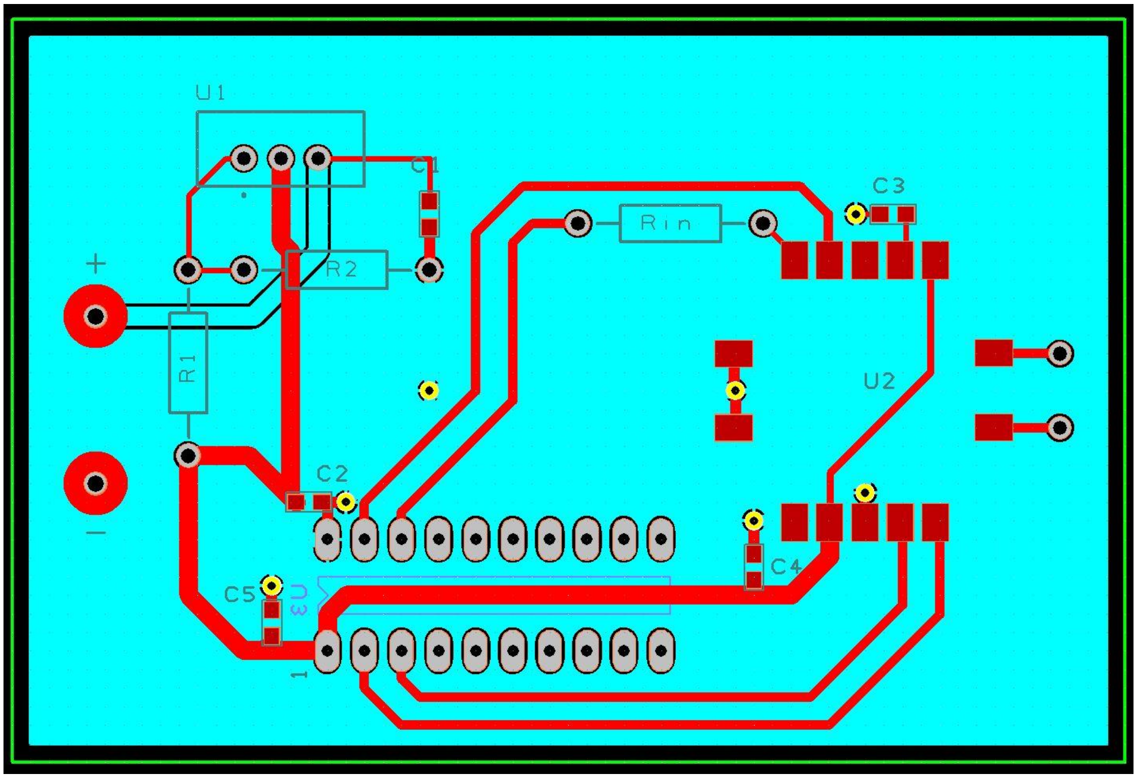

Figure 20 – PCB layout of the chair end circuit

Chapter IV– Software Design

A. Benefits and Overview of Software Utilization

Before now we have been trying to do everything with no programmable piece of hardware in our design. With the decision to use the new transceiver and to go with the different method of using different ranges of transmitted signal to tell when the chair is truly approaching the door or whether it is just passing by it will make our design much more complicated. Because of this increase in complexity of what each circuit will need to do we have decided that we can solve the problem by using microprocessors to take care of our timing and triggering. This will make it so that our design can be much more dynamic in the future if we need to be able to add certain handshake functions or data communication allowing us to put more security in who will be able to trigger the door and when we are just receiving noise from some other source. The use of microprocessors will also allow us to make a very simple hardware design and do most of our trouble shooting in software. This will allow us to change many of our parameters without make hardware changes that we would have needed to make previously.

This will also remove many of the difficulties of how we were going to be able to filter out any noise that we might see from our transmitter. Since we are using a much more standard transmitter than previously we can expect to see some noise and false triggering that we might not have seen before in our designs. This is one more reason for our decision to move to a microprocessor on each of the circuits so that we can perform Digital signal processing on the signal instead of using analog-hardware components which just would not work as well and cost more money. Also the signal that we are receiving off of the transmitter is a digital signal which will not work well with analog hardware components but is perfect for the microprocessor.

Many of the components that we would need to use in our circuit that the microprocessor can replace will cost much more that the microprocessor itself, which makes it a very logical solution for use our circuits. For all of these reasons we have decided that using a microprocessor is what we will need to do to make our design more flexible and reduce the cost of our product.

B. Software On the Door End

Our door program needs to be able to do multiple things at once and thus interrupts might be needed to perform this. In our door program we will need to send out a transmitted signal at certain desired power ranges which will allow us to tell which direction the chair is traveling and where the door is located. We will also need to be able to receive a signal from the chair when it is activated from being in range of the door transmitted signal. Once we have received a signal from the chair it will need to switch its operating mode to send a lower power signal and repeat the process described above. We have decided to use 3 Modes and once it has completed the three modes it will trigger the door to open for a given period of time. To be able to check for the right signal we need to apply some signal processing techniques that will allow us to not have any false triggering. We have decide to us a 2kHz signal as our transmitted signal and we test to make sure that that is the signal that we are receiving before it will be triggered to the next mode of operation. We are using a 50% transmit-receive cycle that is twice the period of the chair circuit so that we will always be able to detect when we are getting a signal form the chair. Below is the flow diagram of our door program.

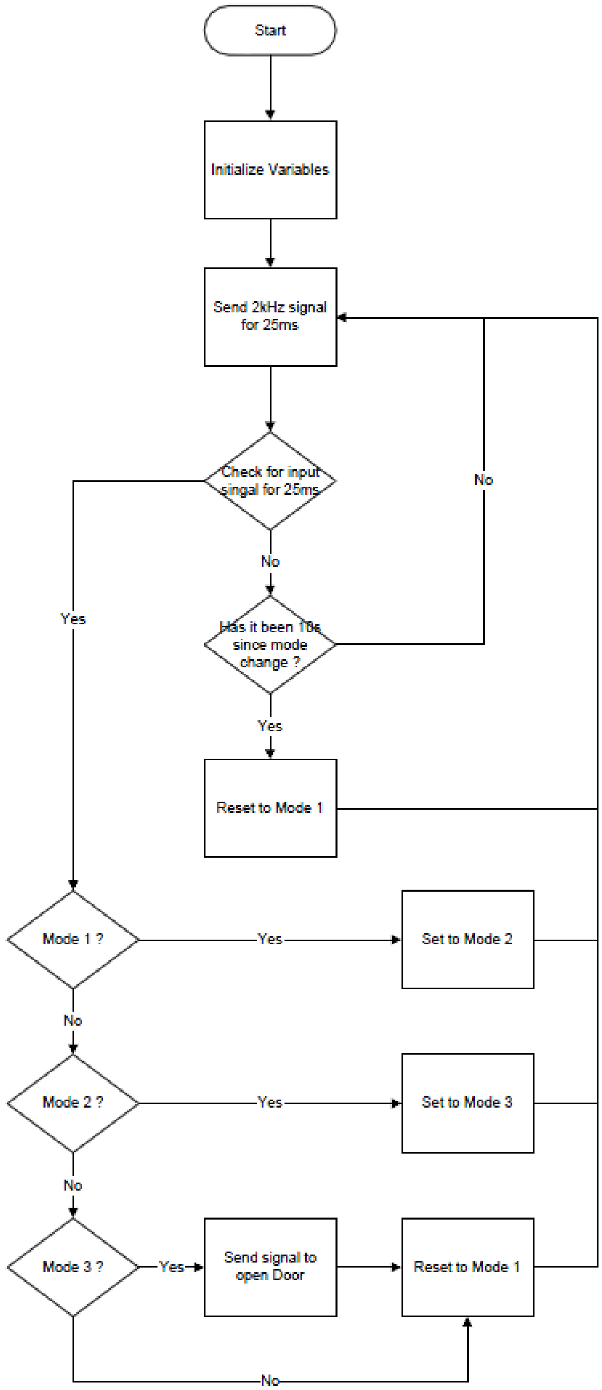

Figure 21 – Flowchart of the Door End program

C. Software On the Chair End

Our chair program will have two modes of operation and will need to be able to keep two different sets of timing. The first timing that we will do is to have a 5% duty cycle of a receive mode and 95% of the sleep mode so that we can conserve energy. This is done by looping through a certain amount of times to add up to the amount of time that we need, this is the first mode of operation for the chair circuit. Once we have received a signal from the door circuit we will switch to the second mode of operation which will have a 5% receive cycle and a 95% transmit cycle and will last for a given amount of time and go back to the first mode. Our transmit signal is a 2kHz signal which is created by doing timed loops again. Below is the flow diagram for our chair program.

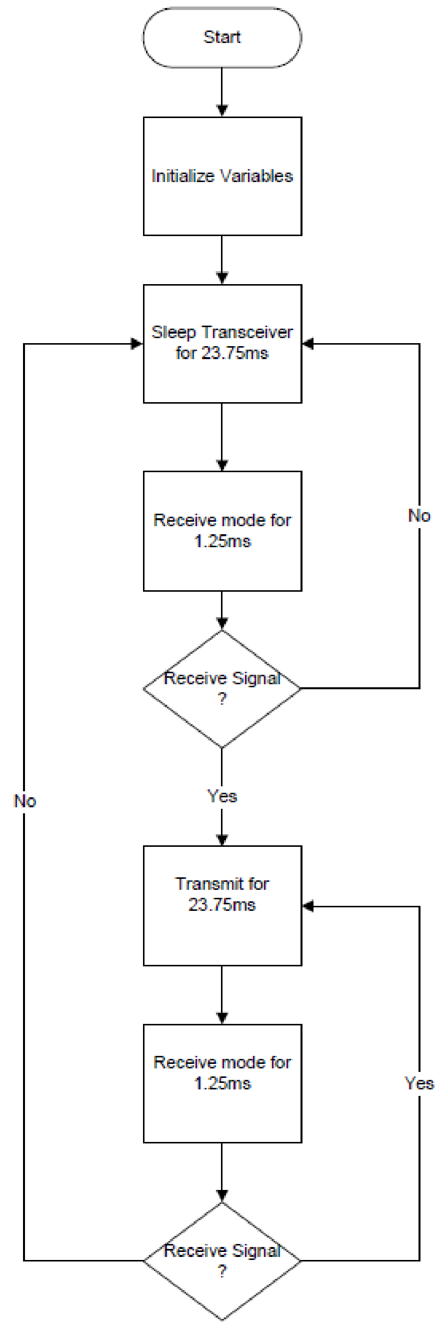

Figure 22 – Flowchart of the Chair end program

Chapter V – Business Aspects:

A. Integration Plans:

Once we have these features and potentially others engineered, the system should be compatible with any type of wheelchair. This would be available to any student, faculty, or staff member of CSU. Eventually this system is going to be deployed further on campus. Once it is campus wide, every person who needed one would have a transceiver that would control select transceivers on campus. The push buttons would still function as they do now, and as law requires. Thus, those visiting or people that haven't received a transmitter do not suffer.

We believe that our device, once fully tested and working will have very beneficial and widespread application. It could quickly be adapted to public places. Even people with arm movement who use wheelchairs would benefit from this as they wouldn't have to worry about the buttons on the wall and the awkward placement. However, it could also have widespread use for non-handicapped people who wish to have such a device to open doors for them when their hands are full.

As far as the device itself, it will be enclosed in a waterproof enclosure to prevent weather from affecting the device. This also prevents any moisture from getting inside and damaging components of the transceiver. Once a rechargeable battery is incorporated and the unit can be easily recharged, it would work very well.

B. Marketability

As described in the need section of the paper, there is currently a desire from handicapped people for a more automated and fail-proof system to allow them to open doors, especially here on campus. As our first user would be Colorado State University, the main selling point would be cost saved on maintenance. Each transmitter (which is inside of the box with the button on the wall in front of every handicapped door) is run by a 9 volt battery. These batteries are replaced on CSU's time and money by maintenance workers after being called by an irritated handicapped person who cannot open a door. Other sources of door failure mentioned before also must be fixed by a maintenance person. As our system's transmitter would be in a weatherproof box, and would be taken inside when the wheelchair was taken inside, it would not be exposed to the elements. At the same time, since it would be powered by rechargeable batteries these would be under the control and care of the individual user. In addition, with the redesign and increased efficiency of the battery system the transceiver would need less attention. Last year's transmitter worked on average 1-2 days depending on how much our tester moved around. The re-design will fix this problem and the longevity of the transceiver will be increased to seven days or more. The need for fixing and repairing the actual buttons on the doors would be much less.

Another main selling point would be the appeal to handicapped people. This could be a point stressed by the University to draw in more handicapped students and professors. This would make our campus more diverse and more handicapped accessible. As some buildings on other universities aren't handicapped accessible and don't comprise the necessary technology to open doors automatically, this would be an inexpensive and simple upgrade.

As stated earlier, there is also going to be widespread appeal for people who are not in wheelchairs. For starters this includes people with strollers, heavy machinery like forklifts at hardware stores, mail carriers on CSU campus, and more. Anyone who has had their hands full and needed to open a door at the same time knows how useful this can be. If additional security features are adapted into the device as stated in our future plans section, the system could be deployed and adapted for home use.

The entire system costs $40 per door and chair per pair As we built the layout of the circuits and got them printed on printed circuit boards, not only would this automate the building of the circuit, but would also be faster and cheaper. Once these would be produced in larger amounts, the cost per system would go down significantly to approximately $20-$30. Another advantage of putting them on printed circuit boards would be that the circuit would then use less power, as the components would be much smaller.

Chapter VI – Conclusions and Future Work:

As shown in the report, a large quantity of time went into donation request and research in the first semester 2009. In the second semester, with the previous circuitry system we realized minor revision would not solve the existing problems; therefore, redesigned the entire system with a completely different idea, which solved all the problems the previous design encountered. We successfully designed and implemented a completely revised door-opening system with a door and a chair microprocessor controlled transceiver pair. Using a group of concentric circles sent by the door end to determine both the intruding and the direction of the wheelchair, the current system solved the previous system problems with opening the door when a wheelchair is in close proximity, as well as when opening the door is not desired. Using a full wave rectifier into a voltage regulator allows the device to be powered by either AC or DC power supply with minimum power consumption. Utilizing a buck as the voltage regulator on the chair end circuit solved the power waste problem appeared in the previous work. Redesigned the entire transmitting and receiving system with software prospective solved the inaccuracy problem with the timer circuit and the problem with revising inconvenience. The current transceivers used in our system solved the problems with noisy signal sending and receiving; also the controllable switch between the sleep and operating modes greatly decreased the power consumption.

Due to the limited time for a completely re-designed system, we managed to prototype, implement into PCB, program, and trouble-shoot the final product, however we were not able to install the door-opener mechanism on the door of CSU campus for a real-life testing. The final product works appropriately in the laboratory, but not yet been implemented into real life.

Furthermore, we have started to analyze the risk of our project. We have determined there are probably many possible pitfalls with the project after we install it in the General Services building. For one, if it compromised the current system it would have to be removed. We anticipate minimal problems from the door transceiver end of the system as it is relatively basic and merely needs to close a circuit.

Other future plans would be to make additional transceiver units and do more testing when doors are very close to each other to see if any problems occur. This would include fine tuning the transceiver which will communicate with numerous other transceivers and activate each respective door at an appropriate distance for the user to maintain a constant speed.

Next, more security would be added into the device so that it could be adapted for home use. One method of adding this security would be adding a digital lock which could only be unlocked by the owner's key. It's a simple device which is inexpensive that allows only people with the key to operate the device. In turn, this would make the world a better, more accessible place for those in need.

Investigation (End of Dec.’08-Mid Jan.’09)
Understand how Vishay transceiver works in different modes
Understand how Vishay transceiver transmits information

Finalize Re-design (End of Jan.’09)
Finish circuit design of transceiver for wheelchair
Finish circuit design of transceiver for door

Development-Build-Troubleshoot (Feb.’09-Mar.’09)
Assemble all circuits
Test to ensure design meets goals

Pilot-Testing (Mar.’09-Apr.’09)
Deliver prototype and verify against initial requirements and goals
Pilot test (gain feedback from Handicapped testers)
Set up 1-2 doors in General Services Building

Implementation (Apr.’09-End of semester)
Fully deploy project in General Services Building
Get more feedback, update design
Expand to entire campus

Appendices:

Abbreviations:
CSU - Colorado State University
mAh - milli amp hours
MHz – Mega hertz
kHz - kilo hertz
PCB - Printed Circuit Board
VDC - Volts Direct Current
VAC - Volts Alternating Current
CMOS - Complementary Metal Oxide Semiconductor

Budget:
Spent so far: approximately $12
Semester 1:
 Prototype Boards
 Miscellaneous electronics

Donations:
Pat Johnson (CSU Facilities):
1 Mechanical Working Door Opener (12VDC)
1 Mechanical Working Door Opener (26VAC)
Patty Meeke of Panasonic (5 transceivers)
Leanne Berstein of Vishay (10 transceivers)
Christopher Gobak of Linear Technologies
IEEE Signal Processing Society Denver Chapter ($400)

Olivera Notaros:
Storage Place
Misc. Parts

Terry Schlicting and Colin Heffern – Gave us invaluable insight into the direction to take our project. Helped us understand the need for such a project and also have both agreed to test once prototype is working.

Guy Wagner – Has given support and encouragement to the team.

Pat Johnson – Has met with us again and agreed to work with us to best integrate into CSU's current door system.

Ashley Waddell and Olivera Notaros – Has helped with donations. This includes a list of probable charitable foundations and editing applications.

Acknowledgements:
Thank you to everyone who has donated physical items, as well as those who donated their time to give suggestions and help with the project. Thank you to our advisor, Olivera Notaros, for all of her time and effort spent furthering the project.