Wheelchair Warning System

University of Wisconsin – Madison
College of Engineering – Biomedical Engineering
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Team Members:
Farshad Fahimi – BWIG
Jimmy Fong – BSAC
Tyler Witt – Communications
Yik Ning Wong – Team Leader

Client:
Sandra J. Rodriguez
University of Wisconsin – Madison
Vascular Clinic – General Surgery

Advisor:
John G. Webster, Ph. D
Department of Biomedical Engineering
University of Wisconsin – Madison

Structures that are handicap accessible are a primary concern of the disabled since they make everyday life less problematic. Our point of concern deals not with inanimate objects, but rather with the maneuvering through masses of pedestrians. Several accidents can occur and further injury may be the consequence. A device needed to be designed that will cause others to be made aware of their surroundings by seizing their attention through the use of light and/or sound. Taking these requirements into consideration, we have developed a set of switches that can be activated by either the wheelchair occupant or operator, which, in turn, actuate both light and sound alarms.

§1 Problem Statement:

A major problem for wheelchair users is their inability to alert others of their presence. This problem is magnified when users are unable to vocally identify themselves. Such is the case for our client's daughter, Jessica, who suffers from cerebral palsy. This impairment not only affects her vocal capabilities, but also restricts the movements in her left hand. Her mother, Sandra Rodriguez, assists her daughter around on a daily basis. Currently there is no system that can be attached to Jessica's wheelchair to alert the public of her presence. Ms. Rodriguez has requested that we develop an audible and visual warning system to inform others of her daughter's presence.

§2 Client Requirements:

When developing a client's project, several requirements must be considered. These necessities will assist our team when developing methods for a final design.

This device is designed to grasp the attention of the public. When being guided around by her mother, Jessica needs a product that will alert the people in her close proximity that she is nearby. They can then avoid these obstacles with ease. Her mother would also like to be notified that someone is in the path of the wheelchair by Jessica, in case she is does not spot them herself. The overall layout of the device must be fitted to Jessica's wheelchair. However, our client would like the apparatus to have the ability to be modified slightly to fit any wheelchair. When implementing the final project onto the wheelchair, we must consider its daily purpose. The pieces of equipment must not interfere with the normal use of the wheelchair when operated by Jessica and her mother. Normal function of the wheelchair must not be inhibited when our device is attached.

The signal to notify others and Jessica's mother must be an audible amplification. Our client would like a noncomputerized noise from a speaker that can be easily identified by herself and others near Jessica. Due to Jessica's impairment, the design must be right-hand activated and not require a great amount of physical force to operate.

§3 Background & Competitive Products

As previously mentioned, our client's daughter, Jessica, suffers from cerebral palsy (CP). CP is not a disease or illness; rather, a physical disorder which affects movement and fine motor skills. There are three main classifications of CP: *SPASTIC,* *ATHETOID,* and *ATAXIC*. Spastic is the most common form of CP and is characterized by stiff, jerky movements. Athetoid is a form of CP in which the individual is affected by unwanted movements and loss of posture. Ataxic is associated with balance problems, shaky hand movements, and irregular speech.

Since the degree of impairment can vary greatly between patients, it is often difficult to distinguish one form of the disorder from another. In our case, Jessica has limited motor skills in her left hand, a speech impairment, and a minor walking disability. On this account, it is necessary for her to employ the use of a wheelchair when traversing crowded areas such as theme parks. This gives rise to the problem of alerting others of her presence.

Currently, Ms. Rodriguez verbally attempts to draw the attention of those seemingly unaware of Jessica's presence. However, when Jessica detects a trouble situation, she is unable to do the same because of her speech impairment. After meeting with Ms. Rodriguez and her daughter, it was decided that an ideal solution to the problem

would be a system capable of producing an audible and/or visual output that could be activated by either the wheelchair user or operator.

Students from Elizabethtown College have developed a similar device for a woman affected by cerebral palsy. Their fully automated design uses proximity sensors to produce an audible output which increases in intensity as the wheelchair nears stationary objects such as water fountains or walls. A major concern with this type of design is the over-activation of sensors in crowded areas. This constant triggering would render the warning system useless in the specific problem scenarios we intend to encounter.

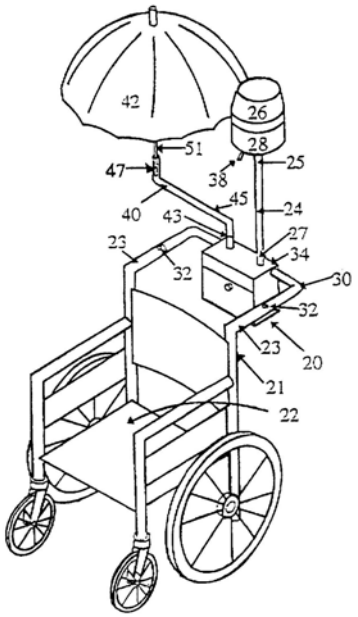

Fig. 1 Patent #5,791,761

Further investigation, involving a patent search, yielded various types of wheelchair warning systems which are summarized in the following table:

Table 1: Patent Search Results

Patent No.	Device Description
5,477,211	A device utilizing gravity sensitive switches to activate auditory/visual/sensory alarms when tilted beyond specified angle.
5,791,761	Removable wheelchair accessories: lamp/umbrella/storage apparatus (Fig.1)
6,163,249	Device producing an audible warning in order to draw attention to an individual in distress.

It is important to note that all of these warning systems are automatically activated audible outputs with the sole intent of identifying wheelchair users in distress,

such as a toppled chair. Our design differs in that we aim to utilize both audible and visual outputs that can be manually activated to alert others of the user's presence.

§4 Alternative Solutions

The three proposed design alternatives that will be further discussed are the dual control panels, the infrared sensor, and the two-way switches. Each design contributes its own advantages and disadvantages, which also will be analyzed. As part of the client specification, the warning systems should activate an audio warning, but it was later determined that each design should activate a visual warning as well. The use of a design matrix will compare the three designs considering the factors of ease, cost, safety, and effectiveness.

§4.1 Dual Control Panels

Just as a television remote can incorporate distinct functions into a single device, the control panel in this design offers the user options on how to operate the warning system. This dual control panel system offers a versatile way for both the person occupying and the person guiding the wheelchair to warn others of their presence.

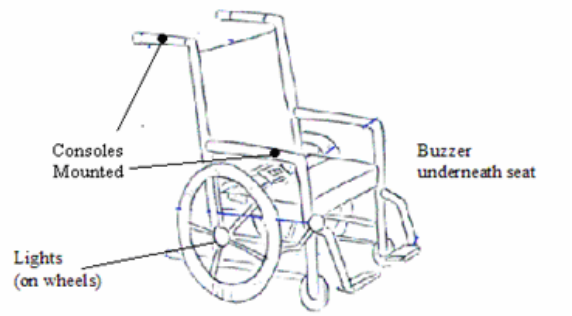

Fig. 2 Dual Control Panels

As the name suggests, this design is composed mainly of two control consoles that are mounted on both the back handle and the right armrest of the wheelchair (Fig. 2). Each of these rectangular consoles house three push-button switches (Fig. 3). One switch activates the sound buzzer mounted

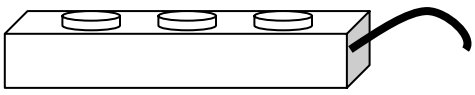

Fig. 3 Three push button switches

underneath the seat to give a monotone warning. A second switch sets off the red, white and blue warning lights on wheels of the wheelchair. The third switch of the circuit would activate both the visual and audio warnings simultaneously. These switches in conjunction give the option of activating the alarm to the person who detects the obstacle first – may it be the occupant or the person guiding the wheelchair.

For each control panel, the circuit is composed of two diodes, three push-button switches, a light, an audio buzzer, and a 9 V battery (Fig. 4). The diodes in the circuit allow for the various functions of the switches, but along with the increased flexibility of the system, there is an associated voltage drop of approximately 0.7 V per diode. This voltage drop, in turn, results in reduced intensity of light and sound.

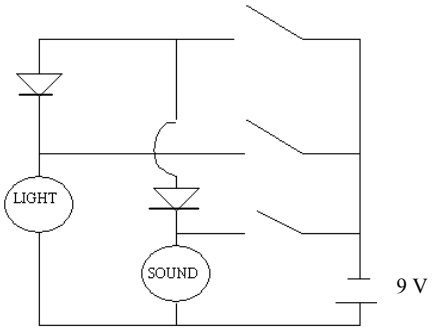

Fig. 4 Dual Control Panel schematic

Overall, this design offers a cost-effective and versatile solution to the problem, but diodes in the circuit lessen the effectiveness of the warning. Also, the control panels are not as ergonomically friendly, which is a problem for a person with limited use of his or her hands. The panels would be awkward and cumbersome when mounted, and detract from the usability of the system.

§4.2 Infrared Sensor

The infrared sensor design utilizes a sensor to detect obstacles that are too close to the wheelchair and activates the audio and visual warning. This system allows the presence of the wheelchair to be known, in addition to also alerting the users to the obstacle.

The inspiration for this design was the parking proximity sensor sold by Parkingsensors.co.uk. These sensors are used in many vehicles to assist the driver in parallel parking by sounding an audio warning when the vehicle bumper is near another bumper. This design would include a modified sensor in which both lights and sound would activate once an obstacle is detected. The range and coverage of the sensor would also be modified so that the sensor is suitable for detecting objects at knee-level on a wheelchair. The sensors, the light and the audio speaker would be mounted together on the front-right vertical bar of the armrest (Fig. 5), which would be also connected to a 12 V battery source underneath the seat.

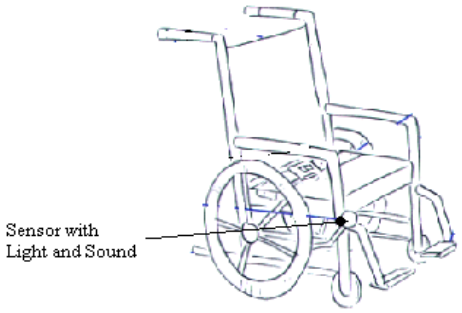

Fig. 5 Infrared Sensor

Once the sensor was triggered, one of three different audio warnings would be emitted from the speaker depending on the proximity. The nearer the object is to the wheelchair, the shorter the time interval would be between the beeps emitted. The red, white and blue lights would start flashing immediately when the speaker is first activated and would last for the duration of the audio warning.

Fig. 6 Infrared Proximity Sensor

This system offers an automated way for the wheelchair's presence to be known in case the users of the wheelchair fail to detect an obstacle. Infrared proximity sensors (Fig. 6), however, are at times prone to misdetections and could prove to be unreliable. If the sensor fails to detect an obvious obstacle in his or her path, the user would have to

resort to manually announcing her presence. The sensor is convenient for the user, but the system is not as effective.

§4.3 Two-Way Switches Design

The third design alternative is similar to the dual control panels design in that there are two control panels located at the back handle and right armrest of the wheelchair (see Fig. 2). Identical red, white, and blue warning lights, along with a monotone buzzer are also used in the two-way switches design. The warning lights are attached to the wheel and the buzzer is mounted underneath the seat. For each control panel, one switch is designated for operating the warning lights and the other is for operating the buzzer. Either the occupant or the guider of the wheelchair is able to activate both the lights and the buzzer. The control panels are attached to the handles of the wheelchair by circular clamps. The panels are designed with an ergonomic palm contour to allow the occupants more comfort while operating the alarm system (Fig. 7).

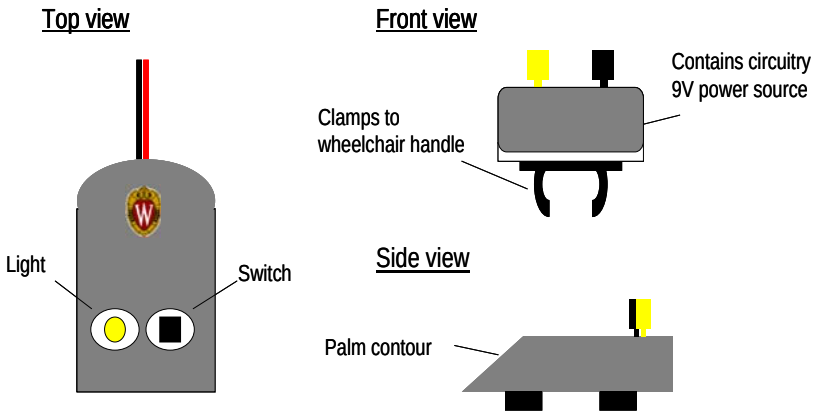

Fig. 7 Control panels located at back handle and armrest of wheelchair

The major characteristic of the third design is the use of single throw double pole (STDP) two-way switches. By using a two-way switch, either the occupant or the wheelchair operator is able to activate the lights or buzzer individually. As seen in the circuit schematic (Fig. 8), the light and buzzer are connected in parallel with a 9 V

battery. Each circuit element is connected in series with a two-way switch which allows the operation of each element from the two control panels. The user is able to switch on each element individually or both simultaneously.

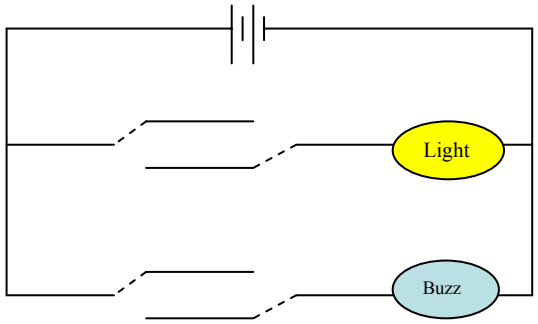

Fig. 8 Circuit Schematic of Two-way Switch Design

The two-way switch design has a multitude advantages that lead us to consider it as our final design. The two way switches design is cost effective because only a light and a buzzer are involved. In addition, the system is easily operable by a person who has limited use of his or her hands. Furthermore, circuit malfunctions can be easily found because the alarm elements are in parallel. In the event of a malfunction, the functional elements of the circuit need not be disturbed while repairing the defective component.

A disadvantage of the circuit is that the circuit's connecting wires are somewhat lengthy. This is a result of the switches being located at the back handle and the wheelchair armrest, while the buzzer is mounted underneath the seat. Details describing the type and specifications of these components are discussed in the subsequent sections of this report.

After considering the factors of ease, cost, safety, reliability and effectiveness in the design matrix, the dual control panel design had problems mainly with ease, reliability and safety. The multiple options for the user could make for a longer decision when it is best for the user to activate the system immediately. The less intense lights and sound of the system reduce the effectiveness of the system. The dual control panel

design is cost-effective, but the decision was made that the overall effectiveness of the warning was more important. The infrared sensor design's automatic activation provides the user with an easy way to alert others, but the $140.87 cost of the sensor coupled with the unreliability of the sensor prevents the design from proceeding. The switches system of the third design scored highest in the areas of reliability, safety and effectiveness – the areas most important for a successful product. The efficiency of the circuit, and the manner by which the lights and sound function together, makes this design the preferred method by which to complete the project. Table 2 organizes the factors taken into consideration when comparing each design alternative.

Table 2 – Design Matrix

	Dual Control Panels	Infrared	Two-Way Switches
Ease	6	10	8
Cost	6	2	7
Safety	5	8	8
Reliability	4	3	9
Effectiveness	8	3	8
Total	**29**	**26**	**40**

§5 Final Design

The two-way switches design is a user-friendly, inexpensive, safe, and effective solution for a wheelchair alarm system. The circuit schematic consists of two sets of two-way switches, four LED lights, and a buzzer. Each set of switches are contained in one of two control panels, located at the right arm rest and right push handle. The other components (lights, buzzer, and circuit board) are sealed in plastic housings and attached to the frame of the wheelchair.

§5.1 Internal (Circuit) Design

The main characteristic of the final design is the use of single-pole double-throw, (SPDT) two-way switches (Fig. 9). SPDT two-way switches with on-on positions were used to control the alarm system components. With the on-on positions of the SPDT switches, we avoid the situation of an open circuit when one user has one switch at the on position while the other user has the switch at the off position. The two on positions allow for immediate activation of the system by using a single switch.

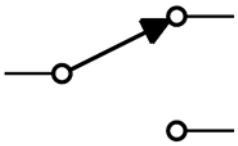

Fig. 9 Simple schematic of the on-on single-pole double-throw (SPDT) switches used.

The two main components for the alarm system are the buzzer and the LED lights. The two components are connected in parallel to the 9 V battery and each circuit element is connected in series with a set of SPDT two-way switches. This allows the user to switch on each element individually or both simultaneously. The circuit board, containing circuit connections and the buzzer, is located in the power center underneath the seat (Fig 10).

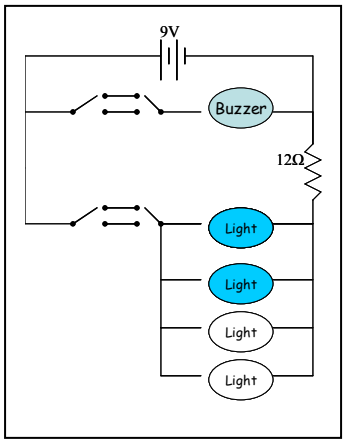

Fig. 10 Schematic of entire circuit including power source, SPDT switches, buzzer, and lights. A 12 Ω resistor is used to limit the voltage supplied to the LEDs in order to allow for optimal operating voltage.

The buzzer selected for use was a 102 dB piezo siren (RadioShack) with a 6-14 V operating range. For the visual warning, two blue ultra-bright LEDs (Tireflys®) and two red high intensity LEDs (RadioShack) were connected in. This parallel arrangement allows for the maximum voltage to reach LED, where a series type connection would have voltage loss across each LED. Another advantage of a parallel circuit is that if a light were to malfunction, the other

lights would not be affected. The optimal voltage range for the blue LED is 2.4-5 V, while the red LED optimal voltage is 4 V. The correlating resistor needed in the LED element of the circuit is 12 Ω to attain maximum efficiency. All equations used and calculations performed are provided in Appendix A immediately following this report.

§5.2 External Design

The warning system is composed of four main components: the lights, the audio siren, the switches, and the control box. The frame of the Kuschall Competitor Series wheelchair has few solid faces to mount the elements of the system; therefore, most of the elements had to be attached to wheelchair frame, which consists of circular metal bars welded together. The placement of each component could not interfere with the wheels of the wheelchair while remaining accessible to the user and effective as a warning.

In the circuit, SPDT switches were sealed within plastic housings to protect the switch terminals and the wires that were attached to them. This plastic housing, along with two rocker switches, comprises a single switch console. One console was mounted on the right guiding handlebar, and the other was mounted on the right armrest of the wheelchair. Steel clamps with slotted tightening screws were used to securely mount the consoles on each bar. To form a circuit, stranded wire was attached from each switch to the circuit board in the main control box underneath the wheelchair.

The main control box, or power center, was mounted on the transverse support bar underneath the seat of the wheelchair, again using circular steel clamps. The bottom support bar of the wheelchair provides a built-in shelter for the control box from precipitation and is elevated enough to avoid damage from the terrain. As the wires were lead to the control box, plastic wire ties were used to fasten the wires along the

Fig. 11 Internal view of the light consoles. Positive and negative leads from each LED were drawn to control box and connected to the light activating switches via a circuit board.

frame of the wheelchair in order to prevent interference during daily use. Along with the coiled excess wire, the rectangular control box housed the main circuit board and a 102 dB piezo siren. Wires also were lead out of the circuit board to two lights on each side of the wheelchair that comprised the visual warning (Fig. 11).

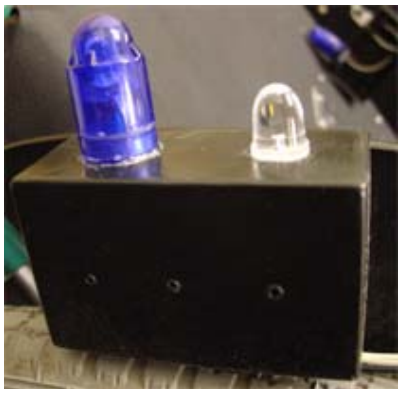

Fig. 12 Side view of the light console attached to the wheel guards of the wheelchair.

The visual aspect of the warning system is made up of a total of four ultra-bright light emitting diodes (LEDs) that were encased in a plastic housing for protection. One high intensity red LED and one Tirefly® UV blue LED were sealed in each plastic case and each case was fixed with bolts to the wheel guards on the left and right sides (Fig. 12). The two different color LEDs offer oncoming pedestrians two different effects for noticing the wheelchair. The lights are aligned toward the front because the greatest hazard comes from the front side of the wheelchair and angled upwards so that other pedestrians can more easily identify the wheelchair's presence.

§5.3 Operational Procedure

The final design of the wheelchair warning system allows for quick and effortless activation of both a visual and an audio signal. The two switch consoles located on the right handlebars of the wheelchair allow both the wheelchair user and operator to activate the four lights by a simple toggle of the white rocker switch or activate the audio alarm by a toggle of the black rocker switch (Fig. 13). The absolute positions of the light

Fig. 13 The final design consists of two switch consoles – one for the wheelchair user and the other for its operator. The white switch activates the light system, while the black switch controls the audible output.

switches and the audio switches do not trigger the warnings, rather, the relative positions of each complementary switch. For instance, if both black switches were pressed forward or both were pressed backward, the audio system would be activated. Once both black switches were opposed to each other, the buzzer would be suppressed. This feature allows both the person guiding the wheelchair and the person in the wheelchair to turn on and off the visual and audio components of the system independently. Depending on whoever detects the hazard initially, time would be saved when activating the system.

In order to replace the power source of the warning system, one would need to open the lid of the control box underneath the wheelchair (Fig. 14). This can be performed by removing the four screws with a Philips screwdriver and by replacing the 9 V battery attached to the battery clip.

Fig. 14 The control box of the circuit houses the circuit board, coiled wire, and the 9V power source. It is mounted to the wheelchair frame underneath the seat.

§5.4 Advantages and Disadvantages

The prototype design described has a number of distinct advantages. The factors weighted most heavily when considering possible design alternatives were reliability, safety and effectiveness. The two-way switch design scored well in all three categories (see Table 2: Design Matrix) making it the obvious design choice from which to

construct a prototype. The finished prototype also fits well with the original wheelchair design and does not add considerable weight or bulk. Because of this, the design does not interfere with the day-to-day operations of the wheelchair. The use of SPDT switches provide the obvious advantage of dual activation of either the light or audible output, by both the wheelchair occupant and operator. The final cost of manufacturing and implementing the system was relatively inexpensive compared with the other proposed design alternatives.

Despite the number of advantages our design offers, there are also a few disadvantages worth noting. The main concern with the attached system is the external circuit wires which are exposed to the elements and other debris that may be encountered during the normal use of the wheelchair. Conditions such as these have the potential of tampering with circuit connections and severing wires running from the switch consoles and light housings to the control box. Another disadvantage is the potential of the LEDs burning out or malfunctioning. With the current setup, one would be required to completely remove the old LED from the circuit, including all wiring and solder joints, in order to replace it with a new unit.

§5.5 Cost Analysis

Many components went into the construction of the warning system as shown in Table 3. Some products could be found at local hardware stores, such as RadioShack, while others had to be shipped from electronic warehouses, such as Digi-Key. Plastic project boxes were used for the power center beneath the wheelchair, the housing for the LEDs, as panels for the switches. One must note the expensive LEDs used on this system. Special LEDs were used that are primarily used for mounting on bicycles. The

advantage is that they are extremely bright in all directions. However, cheaper LEDs could also have been implemented. The single-pole double-throw rocker switches would become a cheaper product if they were ordered in bulk as well. The circuitry items listed in Table 3 include the circuit board, all wires, resistors and materials, such as solder, to finish the design. Ultimately, the overall cost of the implemented system remained under $50.

Table 3: Cost Matrix for Warning System

Product	Supplier (Part # if available)	Quantity	Cost
Plastic Housing	ECE Parts Shop	5	$18.00
LEDs	RadioShack (276-086)	2 @	$2.69
	Tireflys® (Blue Valve Stem)	2 @	$6.99
Piezo Buzzer	RadioShack (273-079)	1	$5.29
Rocker Switches	Digi-Key (401-1279-ND)	2 @	$1.38
	Digi-Key (401-1281-ND)	2 @	$1.50
Circuitry	RadioShack (276-150)	1	$3.00
Total			**$48.43**

§6 Future Work

Further testing by the client in various environments must be completed. Actual use of the setup is the only true method by which to determine the effectiveness of the design, and the extent to which the buzzer and lights grasps the attention of those nearby. Development of the external circuit is another aspect that would improve the design. In order to protect the wires running from the switch consoles and light housings to the power source from the elements and other debris, some type of shield or barrier must be considered. This would ensure the safety of the individuals operating the system while allowing the circuit to operate at maximum efficiency. Lastly, the connection of the lights to the circuit must be well established and the placement of the lights in their housing is critical. It remains a possibility that bumps in the road and regular use of the

wheelchair could potentially affect the connectivity of the circuit and dampen the emission of light.

§7 Ethics

The wellbeing of Jessica and her mother is a top priority. Our goal is to ensure our client that there are no hazards that may interfere with daily operation of the wheelchair. Also, no parts of the prototype will require excessive force from Jessica or include components that could affect her condition. The goal of this project is to alert or notify other people of Jessica's presence. We must take into account the noise levels that will be used so those in the direct vicinity do not receive any damage to their hearing due to any excessive noise levels. From the visual aspect, no blinding lights can be integrated that may affect others. Failure to meet and abide by these standards would be unethical. The audible threshold and visual notification must be within reason. It is our objective to follow these limits by taking into consideration both the users and the people affected by our design.

§8 Conclusion

Despite the need for future modifications and enhancements, the two-way switch design satisfies all design requirements originally proposed by the client. An audible siren has been installed to alert those in the vicinity of the wheelchair user's presence without adding considerable bulk to, or disrupting the daily functionality of the wheelchair. In addition to these initial proposals, visual output through the use of LEDs and bicycle lights has been implemented in order to enhance the effect of audible signals. Both systems, audible and visual, are easily activated by either the wheelchair occupant or operator from switch panels located on the right armrest and right push handle. While

these settings have been designed specifically for our client and her daughter, the basic concept could be manipulated to meet the necessities of other wheelchair users without great difficulty.

§9 References

Bicycle Lights. Tireflys. Date Accessed: 14 Sept 2005 http://www.tireflys.com.

Küschall Mobility. Küschall. Date Accessed: 25 Sept 2005.
http://www.kuschallna.com/.

LED Specifications. RadioShack Corporation. Date Accessed: 26 Nov 2005.
http://www.radioshack.com.

National Institute of Neurological Disorders & Stroke (NINDS). Date Accessed: 06 Oct 2005. http://www.ninds.nih.gov/disorders/cerebral_palsy/ cerebral_palsy.htm.

ParkingSensors.co.uk Sales & Independent Advice. Date Accessed 11 Oct 2005.
http://parkingsensors.co.uk.

Switch Specifications. Digi-Key Corporation. Date Accessed: 10 Nov 2005.
http://www.digikey.com

Trace Research & Development Center. University of Wisconsin-Madison.
2107 Engineering Centers Bldg. 1550 Engineering Dr. Madison, WI 53706

United States Patent & Trademark Office. Date Accessed: 06 Oct 2005.
http://www.uspto.gov/patft.

Wheelchair Picture. Butler Disabilities. Date Accessed: 11 Oct 2005.
http://www.butler.edu/disabilities.

Appendix A

Calculations and Equations

- Ohms Law: Voltage (V) = Current (I) * Resistance (R)
- With a 4 V voltage supply, the measured current through the Tirefly® (blue) LEDs is 0.075A (75 mA) and the RadioShack (red) LEDs have a current of 0.150A (150 mA)
- Therefore, the resistance of a Tirefly® LED is 53 1/3 Ω and a RadioShack LED (red) is 26 2/3 Ω by Ohm's Law
- $1/ R_{LEDs} = 1/ R_{blue} + 1/ R_{blue} + 1/ R_{red} + 1/ R_{red}$; Thus the R_{LEDs} is 8 8/9 Ω
- $V_{LEDs} = V_{battery} * R_{LEDs} / (R_{LEDs} + R)$ where V_{LEDs} is 4 V (optimal operating voltage)
- Thus, the resistor needed is 11.11 Ω. In order to protect against the LEDs from burning out, a 12 Ω resistor was used.

- Appendix B

Wheelchair Warning System

Product Design Specification

Team Members: YikNing Wong (Team Leader), Jimmy Fong (BSAC), Farshad Fahimi (BWIG), Tyler Witt (Communications)

Date Last Updated: October 7, 2005

Abstract: A major problem for wheelchair users is their inability to alert others of their presence. This problem is magnified when users are unable to vocally identify themselves. Such is the case for our client's daughter who suffers from cerebral palsy. This impairment not only affects her vocal capabilities, but also restricts the movements in her left hand. Her mother, Sandra Rodriguez, assists her daughter around on a daily basis. Currently there is no system that can be attached to Jessica's wheelchair to alert the public of her presence. Ms. Rodriguez has requested that we develop an audible warning system to inform others of her daughter's presence.

Function: The expected device needs to alert others of the wheelchair's presence to reduce confusion and potentially harmful accidents.

Client Requirements:

- Specific to Jessica's wheelchair but may be tweaked to fit all wheelchairs
- Audible warning system to alert others and Jessica's mother
- Mechanism may not disrupt daily use of wheelchair
- Device can be used by both Jessica and her mother
- Easily activated by Jessica's right hand
- Must not require an 'extensive' amount of force to operate

Design Requirements

1. **Physical and Operational Characteristics**
    a. *Performance Requirements*: The warning system should be able to be activated by both the person in the wheelchair and the person guiding the wheelchair. The activation system for the person in the wheelchair must be such that only a simple press or slide of a switch is necessary. Once engaged, the device should emit an audio warning and a visual beacon to pedestrians in the immediate vicinity warning them of the wheelchair's presence. A signal should also be sent to the person guiding the wheelchair alerting him or her of the activated warning. The warning system should be attached to the wheelchair, but also should have the ability to be removed and attached to a different wheelchair.

b. *Safety*: The system should be kept sealed, clean and free of debris. It also should not interfere with the path of the wheels when the system is mounted. When engaged, the system should not startle the pedestrians, but should just alert them.

c. *Accuracy and Reliability*: The audio warning should be at a constant tone and at a constant volume every time the system is activated. The system should be able to withstand the vibrations caused by the terrain and not be affected by it. The light on the system should be bright enough such that if the audio warning were ineffective, the light would be able to compensate. If the power source for the audio warning fails, the visual warning should still function on its separate power source.

d. *Life in service*: The desired device should last as long as possible allowing for wear over time. However, the batteries will run out of power and must be replaced.

e. *Shelf life*: Should be able to keep for a number of years. Client should be able to change the battery easily.

f. *Operating Environment*: The product would be used mostly at outdoors which it will be exposed to heavy sunlight or rain. The device should be able to withstand the high temperature and be water proof. This device will also be used in crowded and noisy environments. The light source and alarm should be strong enough to grasp attention

g. *Ergonomics*: Activating the button should be fairly simple and not require much force. The client should not have a hard time replacing the batteries no matter where they are located. The device should be attached securely to the wheelchair handle and act as part of the wheelchair and not an obstacle.

h. *Size*: The switch or button should be large enough so that Jessica can use it right away. The compartment for the power source should be small enough so that it does not interfere with use of the wheelchair.

i. *Weight*: The product must be light enough so that Jessica can place the box in her lap and move it with ease. The final device should not make it any harder for Ms. Rodriguez to advance the wheelchair.

j. *Materials*: Plastic covering for the power source box and for the switch. Insulated wire will stretch from the power source to the switch box. Small LED lights are to be used that will shine bright enough to attract attention. A piezo-electric speaker will be attached to the circuit.

k. *Aesthetics, Appearance, and Finish*: No blinding lights or painful noises must emanate from the device. The design should be integrated and fitted into the wheelchair well so that it does not attract too much attention when not in use.

2. Production Characteristics

a. *Quantity*: One device that has the ability to be activated in two separate locations.

b. *Target Product Cost*: No specific target cost was established; however, one can assume lowest cost method to efficiently and effectively provide a solution would be preferred.

3. Miscellaneous

a. *Standards and Specifications*: None.

b. *Customer*: Any audible output must be somewhat appealing. Monotone, annoying responses are strongly discouraged.

c. *Patient-related concerns*: Any design must incorporate right hand activation due to loss of motor skills in left hand. Conceivably, activation methods could be modified in different scenarios.

d. *Competition*: A patent search provides Patents: 6,163,249; 5,791,761; 6,160,493 as comparable devices. Also, research reveals device employing proximity sensors in order to detect stationary objects producing audible output varying in tone intensity.