March 5, 2009

Patrick Leung
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V5A 1S6

Re: ENSC 440 –StandStation System design Specification

Dear Mr. Leung:

The following document, StandStation System Design Specification, gives an overview of the design details that will be included upon the completion of our ENSC 440 (Capstone Engineering Science Project) project. Our project's objective is to help those with limited use of their body by providing a way for them to stand up. The ability to stand up will ease the discomfort that comes from sitting on a wheelchair for an extended period of time, and will also provide a way for a disabled person to use the standing urinal. An additional feature we are considering to include is a convenient way to transport the person in and out of a wheelchair.

This document will outline many key design specifications of the StandStation system. It will cover various aspects of the project such and mechanical design, sensors used, electronics, and ergonomics. The design specifications mentioned in this document only applies to our prototype build of StandStation which is proof of concept model.

New Step Innovations consists of four motivated and talented fifth-year Engineering Science students: Wayne Chan, Gavin Wu, Edward Chan, and Kyuho Cha. We each come from different fields of engineering to provide a diverse expertise, and to bring different insight on to the table. We are committed to our project and will work diligently to accomplish our goals. We will be happy to answer any questions you might have concerning our Functional Specification. I can be reached by phone at 778-241-0709 or by email at wyc3@sfu.ca.

Sincerely,

Wayne Chan
President and CEO
New Step Innovations

Enclosure: StandStation System Design Specification

New Step Innovations

StandStation Design Specifications

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Submitted To:

Patrick Leung
Steve Whitmore
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Date:

March 5, 2009

Version:

1.0

Executive Summary

The ability to stand is very attractive idea for any wheelchair users. StandStation has the ability to manipulate the chair, with minimal alteration to the basic power wheelchair, so that the user will safely translate from sitting to standing position. This will provide more blood flow to the lower body, allow the user to reach higher platforms, and relieve discomfort that comes from prolonged sitting. New Step Innovations is confident that StandStation will meet the needs of many wheelchair users, and allow the users to enjoy a higher standard of life.

This document will go over the design specifications of StandStation. It outlines the design details which our StandStation prototype, proof of concept model is based on. Therefore, only the functional requirements marked as (I) in StandStation Funtional Specification document will be covered.

The key design specifications of StandStation are as follows,

- Mechanical design of the wheelchair frame
- Linear actuators to move the seat of the wheelchair
- Inclinometer to sense the tilt angle of the seat
- Microcontroller to read and process system inputs and appropriately control the actuator

A detailed description of various aspect of the system will be covered through system overview, structure overview, electronic circuit schematic, state diagram, and Solidworks model. Our intended test plan can be found after safety and ergonomics.

New Step Innovation is committed to the production of StandStation prototype to meet the proposed functional requirements. Scheduled completion of the StandStation prototype will be for April 6th.

Table of Contents

1. Introduction

StandStation offers wheelchair users the ability to stand up with a simple click. The use of a mini electric car-jack combining with a well designed chair frame, *StandStation* is able to provide a safe and swift motion that elevates user to a comfortable standing position. Research shows prolonged sitting can cause insufficient blood circulation to the lower body, causing muscle sores and tissue damages. *StandStation* can reduce the risk of muscle sores and tissue damages by assisting the user to stand up, just like a "Standar", which are huge standing machines used by patients at the GF strong rehabilitation center. *StandStation*, over the long term, provides users with effective pressure relief and blood circulation to the lower body. More over, the ability to stand up will further improve users' quality of life in terms of the ability to reach objects and for men, the ability to urinate with ease.

StandStation is a simple add-on to a standard electric wheelchair base; those with the standard base can easily upgrade to a standing wheelchair without the need to spend 20-30 thousand dollars. *StandStation* focuses on using simple design instead of complex integrated design we see on the standing wheelchairs on the market, which yields less cost for the consumer and manufacturer. The development of *StandStation* is separated into two stages; the proof of concept stage and production model stage.

1.1. Scope

The development of *StandStation* is separated into two stages; the proof of concept stage and production model stage. This document is mainly intended to provide the design specifications for the proof of concept stage; however, some production model stage designs are included.

1.2. Intended Audience

This document is intended for use by New Step Innovations members. This document shall serve as a guideline for the development of *StandStation*. Design team shall use this document in conjunction with the functional specification document to ensure that *StandStation* meets the requirements and is on the correct design path. Quality testers will use this document for functionality testing and safety inspections.

2. System Overview

This section of the document outlines the general overview of how the system will operate. The user will be able to make a sitting-to-standing transition (STS) using the provided user interface. Once the user turns on the function, the system will be able to provide the standing function; the user will have full control during the STS transition, and can adjust to a position that is comfortable for him/her. Figure 2.1 shows how the mechanism moves.

When the user press the "up" button the electric car jack under the wheelchair will slowly extend upward. The car jack will push up against the bottom of the seat creating a torque that rotates the seat frame around joint x as seen in Figure 2.1.

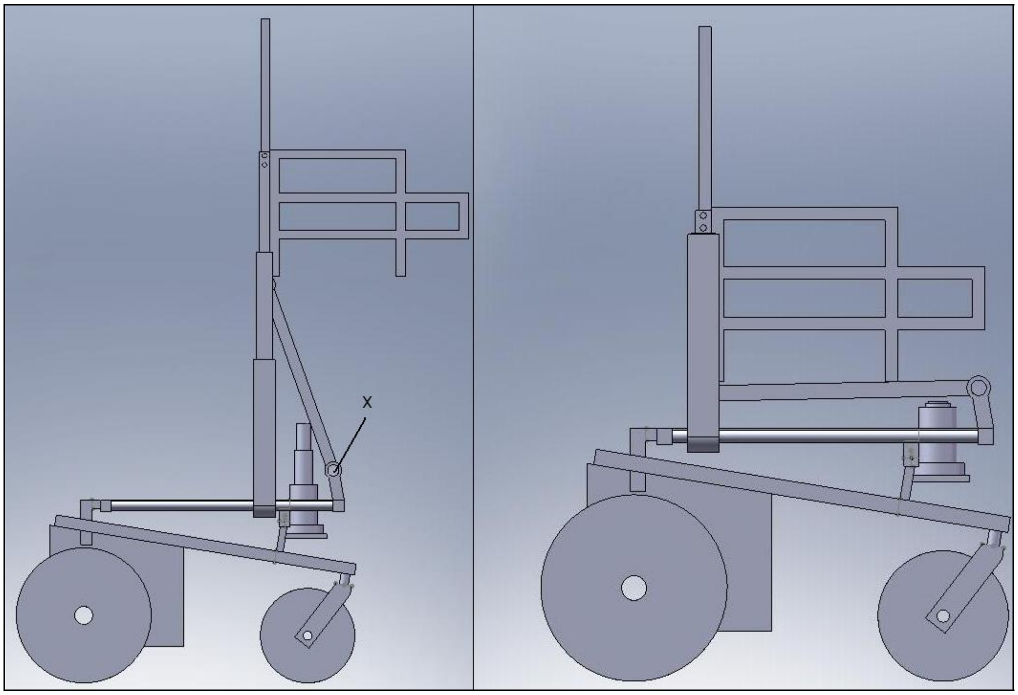

Figure 2.1: Wheelchair Trajectory

While the seat is rotating, the back support will follow the motion of the seat by the use of a back support mechanism (the details of the back support mechanism will be covered in the next few sections). This whole process will take roughly 50-60 seconds and the final sitting angle of the seat will be 70 degrees. Furthermore, the speed of the car jack is controlled by its own electronics to provide a steady raising speed. Lastly the user will be able to pause any time during the STS transition.

Since our product is an add-on to a regular power wheelchair, we can custom fit the height and tilt angle of the seat to the user's needs. This will provide an attractive feature for those with special needs.

The power needed to activate this system will come from the 12V batteries on the power wheelchair. We will minimize the power consumption of this system to prolong the life-time of the wheelchair's main driving functions.

3. Structure Overview

Figure 3.1, and Figure 3.2, shows the basic first stage design of *StandStation*. The electric wheelchair was donated by the GF Strong Rehabilitation Center where further modifications were made. We kept the original frame structure for a stable mounting base for our mechanical actuators, electronics, and additional frame.

The main components of *StandStation* system are mechanical actuators, inclinometer, microcontroller, 12V battery, and added frame. The mechanical actuator we are using is an electrical car jack, which runs on 12V power source with wireless controls. The inclinometer will be responsible for sensing the angle of the seat when standing function is being used; the angle reading will be part of the feedback loop to control the height of the car jack's piston. The microcontroller will interface with the user input controls and the inclinometer to provide appropriate responses or signals to the electric car jack.

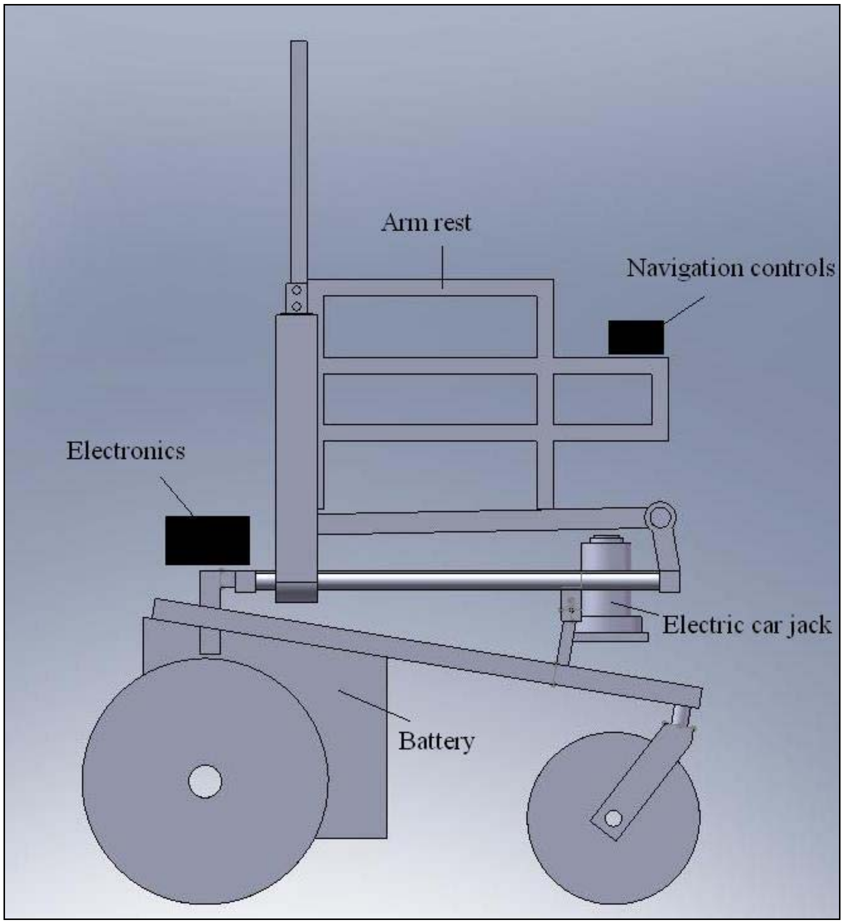

Figure 3.1: Wheelchair Side View (Sitting)

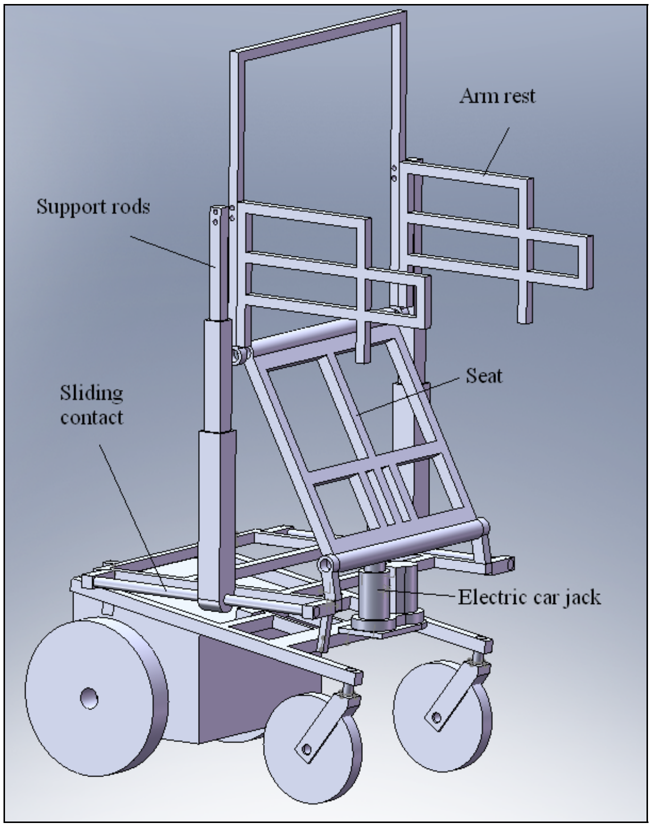

Figure 3.2: Wheelchair Isometric View (Standing)

As illustrated in the above figures, the mechanical actuator is mounted on the bottom of the seat beside the two 12v batteries that are being used to power the electric wheelchair. The electronics will be mounted onto the back of the wheelchair and outside of the structure to avoid interference. In addition to our new standing control buttons, the original navigation controls will still be in use. However, for the proof of concept stage we will not be combining the controls into one unit. The designed chair frame will be our main modification, which will be mounted on top of the original chair frame.

4. Actuator

The actuator used for our StandStation's standing ability is a mini electric car jack, which uses a dashboard cigarette lighter plug, and comes with a remote control. It is the world's smallest electric car jack and has the ability to lift 2 tons vertically as seen in Figure 4.1.

Figure 4.1: Electric Car Jack

The car jack will use power straight from the 12V batteries on the power wheelchair. Load capacity of the jack is 2 tons (4000 lbs), with a weight of 6.25 lbs, and the remote controller's range is 15 ft. We will attach the electric car jack under the seat as illustrated in Figure 4.2.

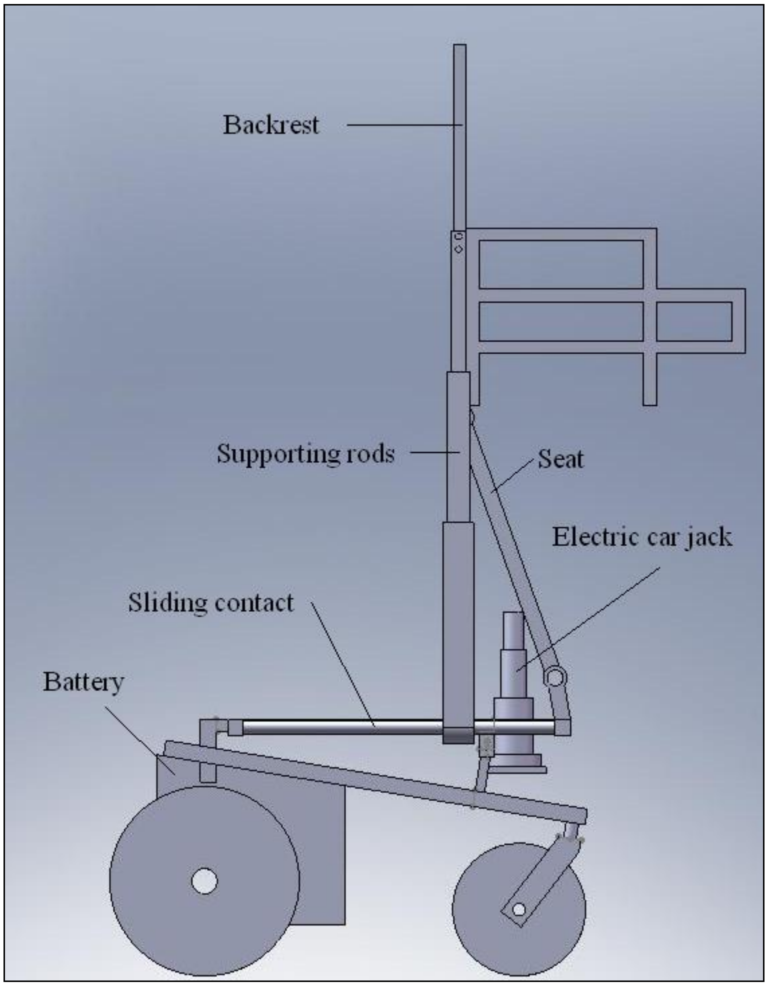

Figure 4.2: Wheelchair Side View (Standing)

The current rating of the car jack during operation is tested to be around 1.5~1.7 Amps. However, current spikes occurs when the motor is starting and changing directions. The dimensions of the car jack are 7 x 4 x 5.5 in. where 5.5 inch is the original height of the jack and it is capable to raise to 11 inches.

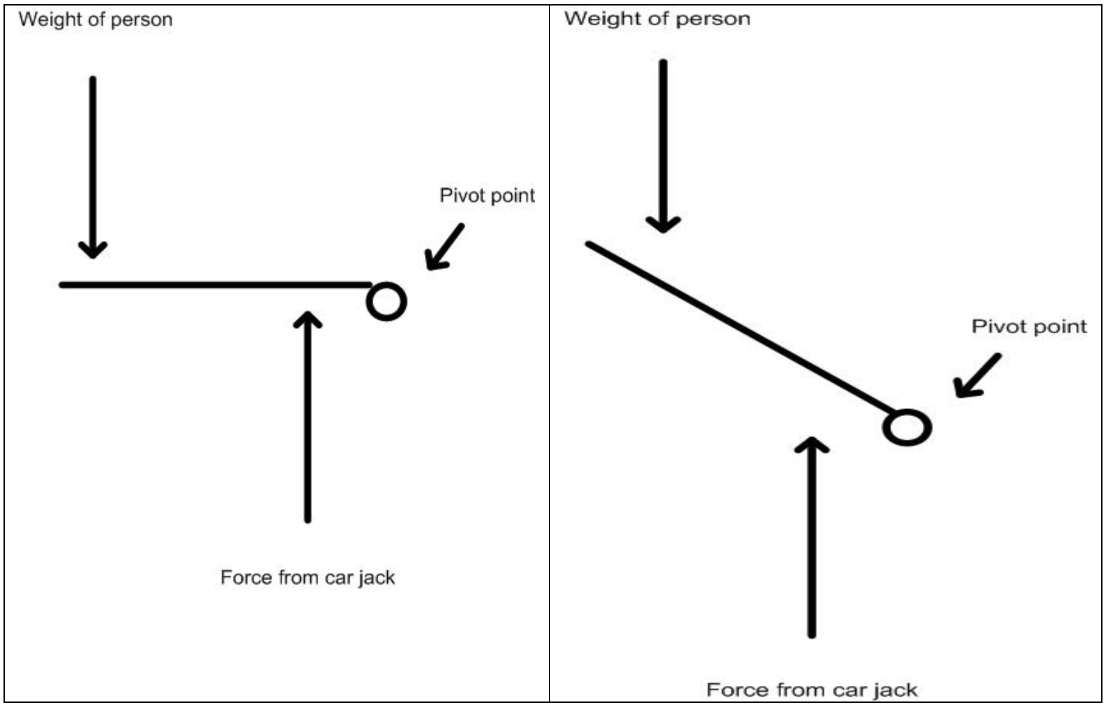

Figure 4.3: Torque Calculation Diagram

As seen in Figure 4.3, the bottom chair rest is 50 cm long; therefore, the torque required to pivot the chair can be calculated.

(The below equations eliminate the gravitational acceleration term as well as the conversion from lb/cm to kg/m for ease of calculation)

Assuming the weight of the user is at 400lb, the torque from the weight will be:

50 cm x 400 lb = 20,000 cm-lb

The torque generated from car jack is:

10 cm x 4000 lb = 40,000 cm-lb

Therefore through the above simple calculations, we determine that the car jack is sufficient for our functions. Figure 4.3 (Left) shows the starting torque and Figure 4.3 (Right) shows the chair during the standing process. Notice the torque from the weight of the person will never exceed of that generated from the electric car jack.

The car jack has its own controller to control the input speed, therefore we do not have to monitor the weight of the person and control the speed of the jack accordingly.

4.1. Robustness of the Car Jack

Since the device is made to lift cars, we are not too worried that the device will break. However, we took into account of the possibility that the bracket holding the electric jack may break. Since the electric jack is not resting on a strong surface like the ground, the bracket will be the only ground support baring the reaction force from pushing against the seat.

Assuming our user's weight is 400lbs, the maximum generated opposing force will be roughly the same as the person's weight. Therefore, our welding will have to be able to bare a lot more than 400lb for safety and robustness.

4.2. Locking

The electric car jack is able to pause during the lifting process without consuming constant power to sustain the weight; therefore the power consumption is fairly small and it will not move.

5. Sensors

We require a sensor to measure the tilt of the seat so we can have a real-time feedback as to where the seat is; since the electric car jack's piston length is not perfect for our application it will overshoot our required length. The microcontroller will interfere with the car jack's controller so when maximum safety angle is reached, the jack will be stopped.

5.1. Inclinometer

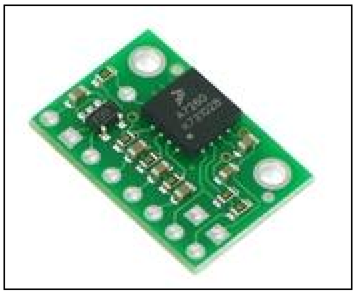

Figure 5.1.1: Inclinometer [1]

The inclinometer we are using is the MMA7260QT 3-axis accelerometer as seen in Figure 5.1.1. The accelerometer operates in the range of 2.2 to 3.6V, but is able to be powered by high voltage up to 16V through the Vin pin, which connects to a low-dropout 3.3v voltage regulator. The output reading from all 3-axis are in volts, ranging from 0 to 3.3V, which can be easily feed into our voltage reader on the butterfly board to decode the tilt angle and all 3 axis' sensitivity can be changed from 1.5g to 6g. The dimension of the chip is 0.8" by 0.6", which is fairly small and easy to mount. The device will likely be attached to the bottom of the seat or on the side of the seat to measure tilt angle.

6. User Interface

The user will have 2 sets of controls, the original navigation control from their electric wheelchair, which is a simple toggle switch with joy stick and the StandStation user interface buttons. Figure 6.1 shows the original toggle switch with joystick to control the wheelchair movement.

Figure 6.1: Wheelchair Controls

Figure 6.2 shows the user interface for standing applications; it consists of 3 buttons and a toggle switch.

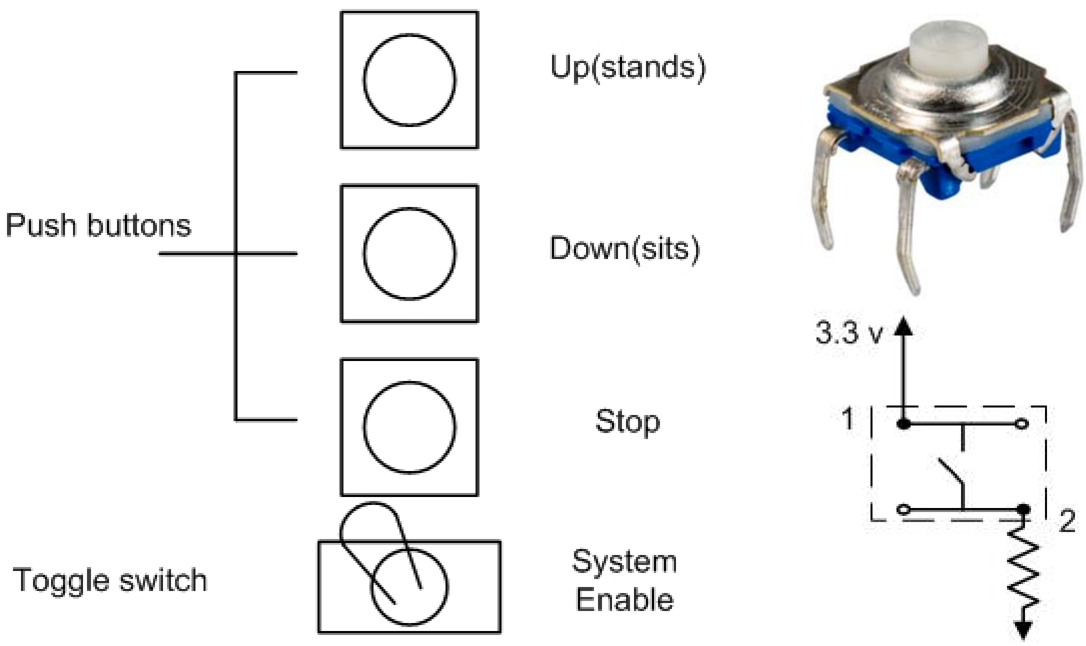

Figure 6.2: User Interface [1]

The up, down, and stop buttons generate control signals to the electric car jack. Figure 6.2 (Lower right) shows the circuitry for a single switch. When the switch is close a logic one will occur at terminal 2, which is connected to the Butterfly's input pin. A pull down resistor is used between the pin connection and the ground to ensure that the pin stays at logic zero when the switch is not activated.

Since our targeted users are paraplegic and quadriplegic, we will need to modify our control buttons to fit their limitation, however, for proof of concept we will not implement those features.

7. AVR Butterfly

The AVR Butterfly is used to control the main electronic components of our system. It is a development board for the microcontroller, ATmega169. The main features of Butterfly include:

1. An ATmega 169 AVR microcontroller with the following technologies:
    - 16 Kbyte self-programming Flash Program Memory
    - 1 Kbyte SRAM
    - 512 Byte EEPROM
    - 8 Channel 10-bit A/D-converter
    - Timer/Counters

2. 4Mbit Dataflash
3. Voltage reading 0-5V

The Butterfly comes with a bootloader which allows re-programming of the board to be done via RS232 cable from any host PC. The board provides a 32 kHz crystal oscillator as the system clock; it is also used for the timers, counters.

7.1. Inputs/Outputs of the AVR Butterfly

Figure 7.1.1 shows the main inputs and outputs for the Butterfly.

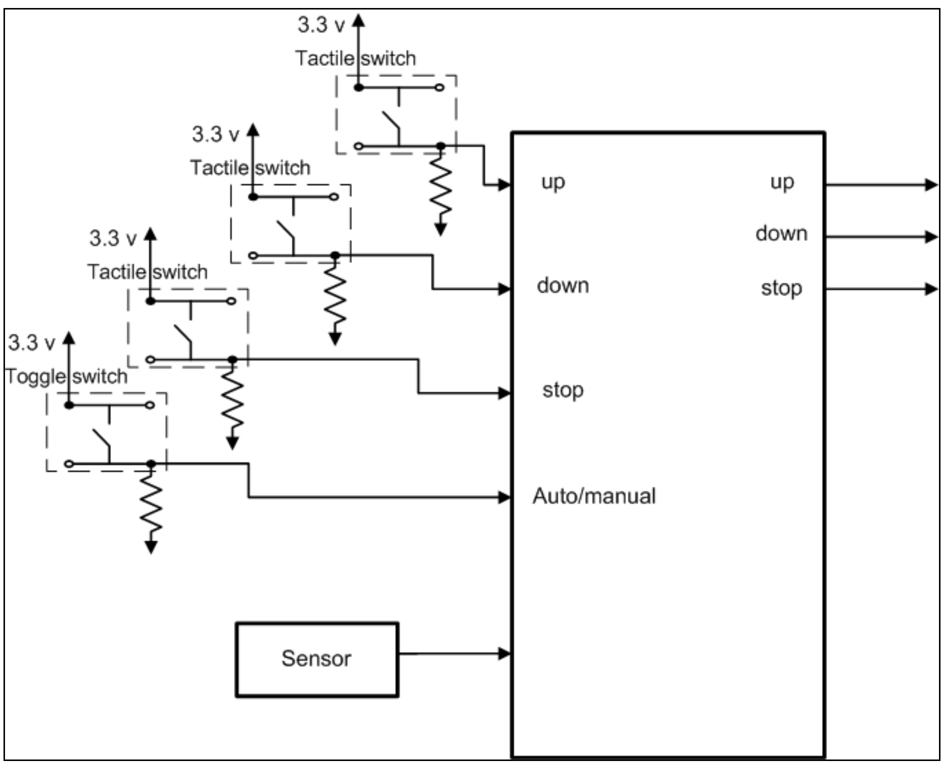

Figure 7.1.1: Input/Output for the Butterfly

The main inputs for the Butterfly includes four switches and the sensor input. The four switches discussed in section 6, are used as primary user controls. The main outputs consist of 3 control signals to the remote control of the electric car jack.

The StandStation system consists of three states: Moving_up, Moving_down and Idle states as shown in Figure 7.1.2. The transitions between different states depend on the 3 control inputs and the information from the sensor.

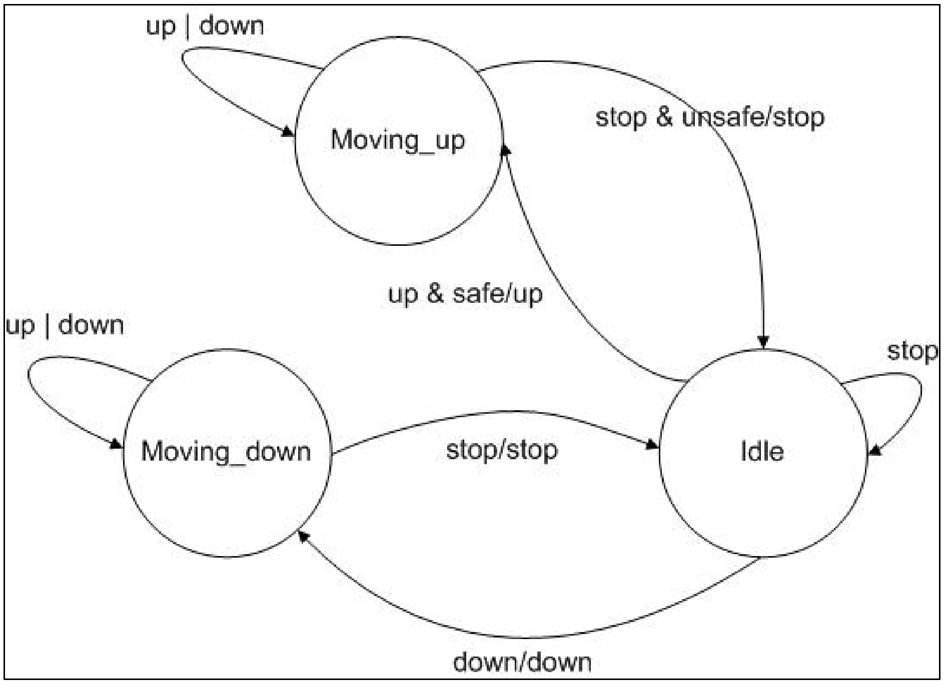

Figure 7.1.2: State Diagram of Modes

The corresponding input pins of the Butterfly are initialized as external interrupt inputs during the start of the program. When the user presses any control button, it sends a logic 1 to the pin, which will generate an interrupt to the program. Since ATmega169 only supports 1 external interrupt service routine, all the user inputs will have to be taken account in the interrupt handler. Figure 7.1.3 shows the flow chart for the external interrupt service routine.

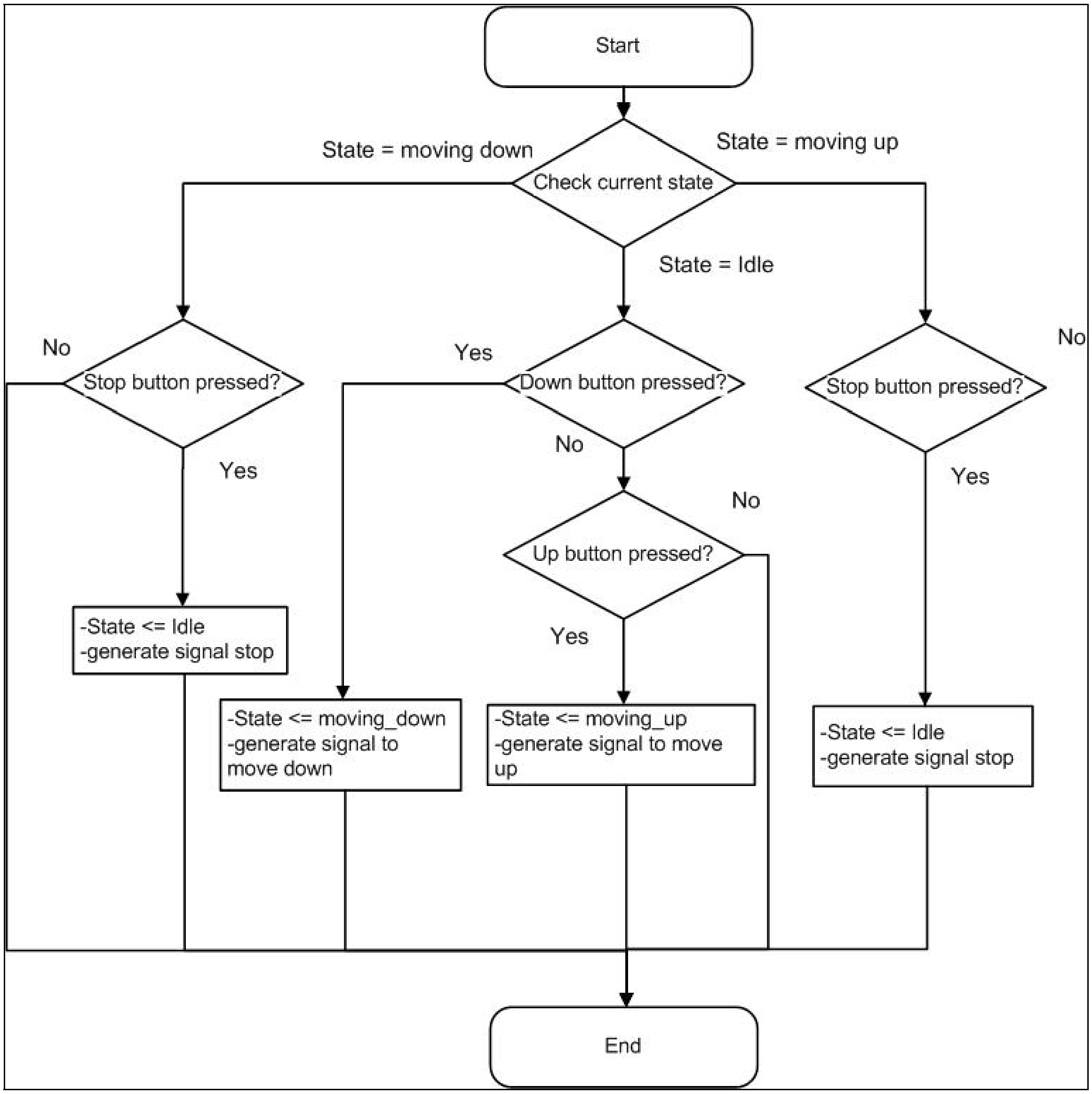

Figure 7.1.3: Flow Chart of External Interrupt Service Routine

The sensor input data is retrieved by the ADC. The StandStation system must have fast response time because the sensor inputs determine the safety angle. A timer is initialized to generate an interrupt to the program so it can constantly sample the sensor inputs during the STS transition Figure 7.1.4 shows the flow chart for the timer interrupt handler.

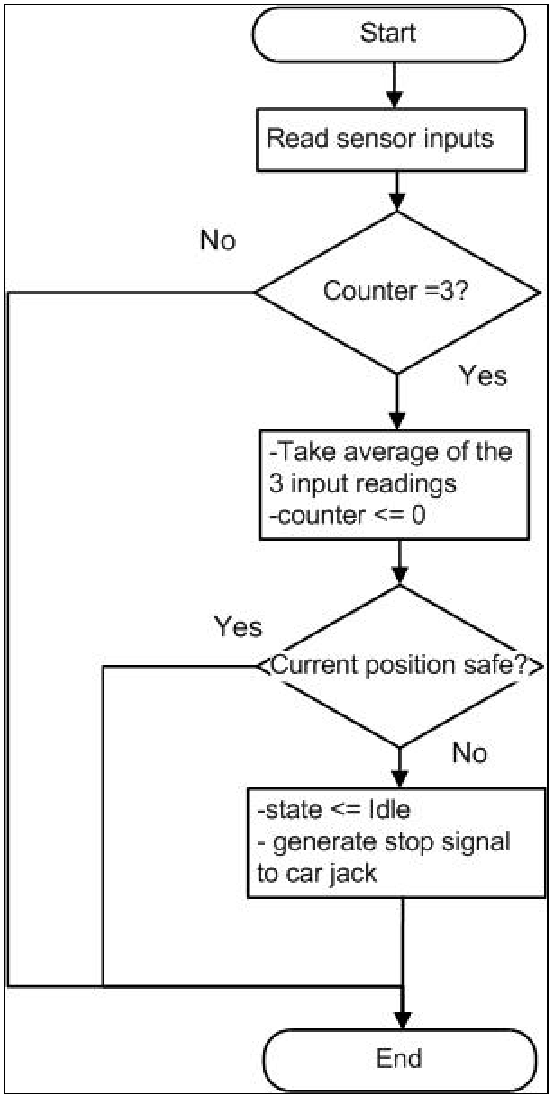

Figure 7.1.4: Flow Chart of Timer Interrupt Handler

The main program first runs the necessary initialization, and then enters an infinite loop to wait for the user interrupt shown in Figure 7.1.5. Note that the timer for sampling the sensor input is only activated while the system is moving to a standing position.

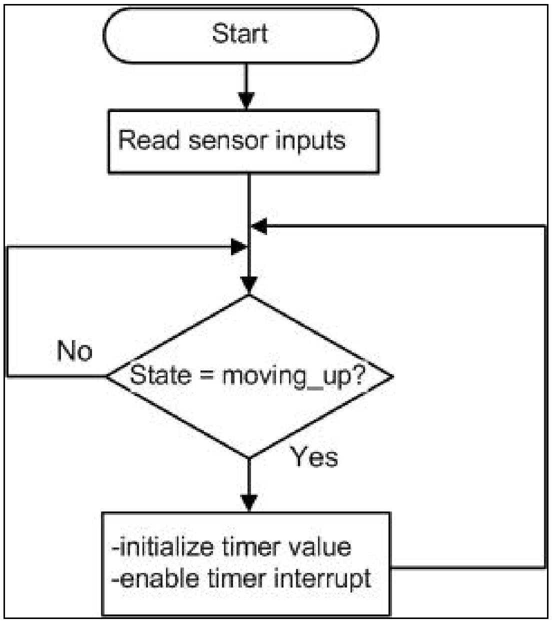

Figure 7.1.5: Flow Chart of Infinite Loop

8. Back Support Mechanism

The back support will stay straight during the standing process to ensure safety and body stability. This is achieved by the back support mechanism shown in Figure 8.1

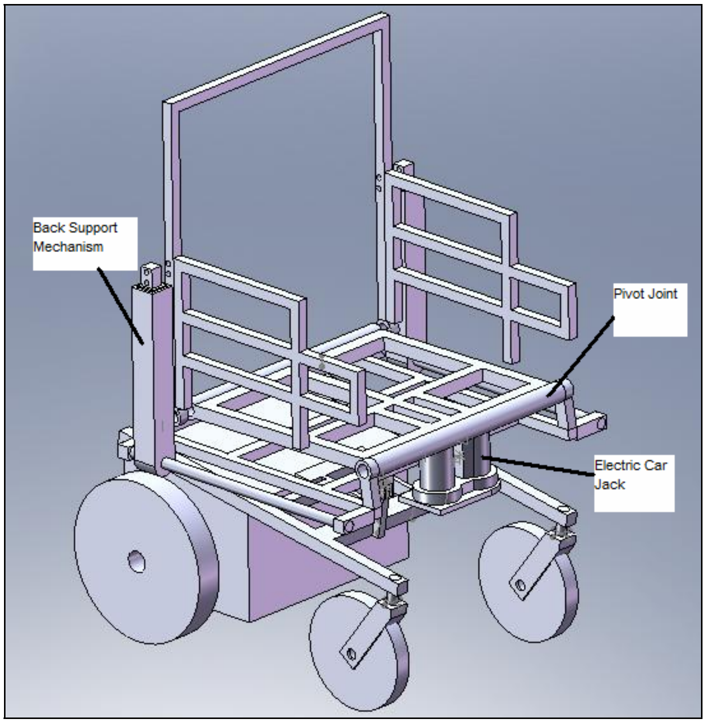

Figure 8.1: Isometric View of Back Support Mechanism

The Back support mechanism has two degrees of freedom; it consists of a prismatic joint which moves vertically and a cylindrical joint which moves horizontally. The prismatic joint is attached to the back support at two places, providing constraints to ensure that the back support is always perpendicular to the ground. As the chair elevates by the car jack, the seat will rotate forward and the back support will follow in an up-right fashion. By mounting guiding rods on the sides of the wheelchair, the back support mechanism can follow the movement of the back support. Example of how our back support mechanism work is shown in figures 8.2 and 8.3.

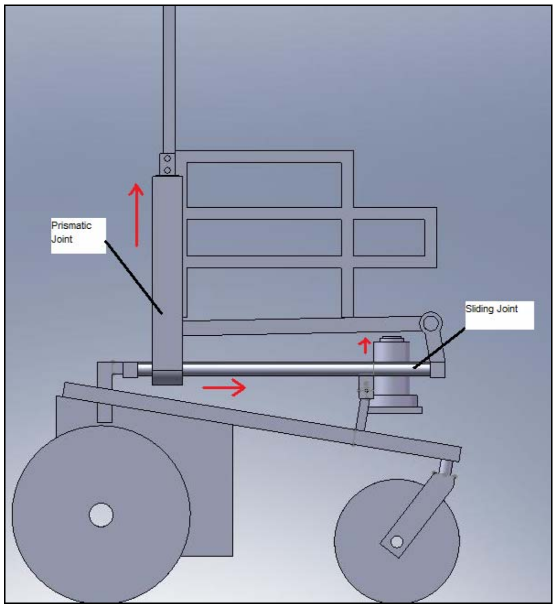

Figure 8.2: Trajectory of Mechanism (Sitting)

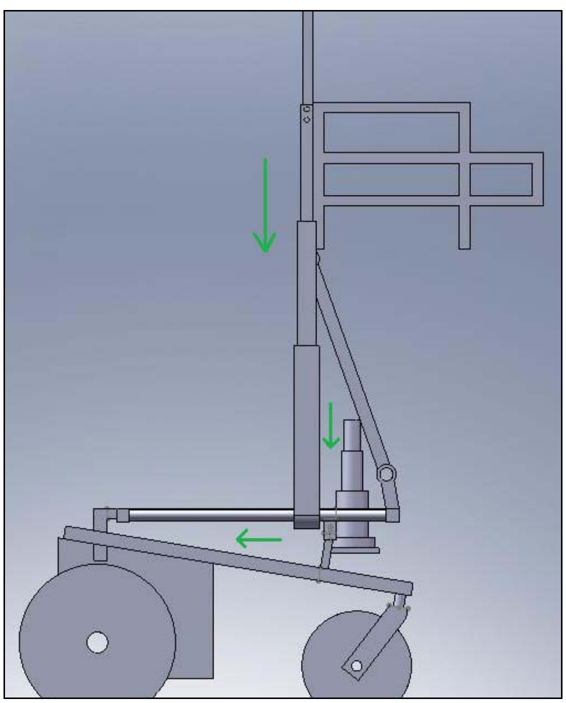

Figure 8.3: Trajectory of Mechanism (Standing)

By limiting the use of extra actuators and motors we were able to simplify our design and make it more robust. Furthermore, less electrical components yield less power consumption, which is crucial for our proof of concept design.

9. Power

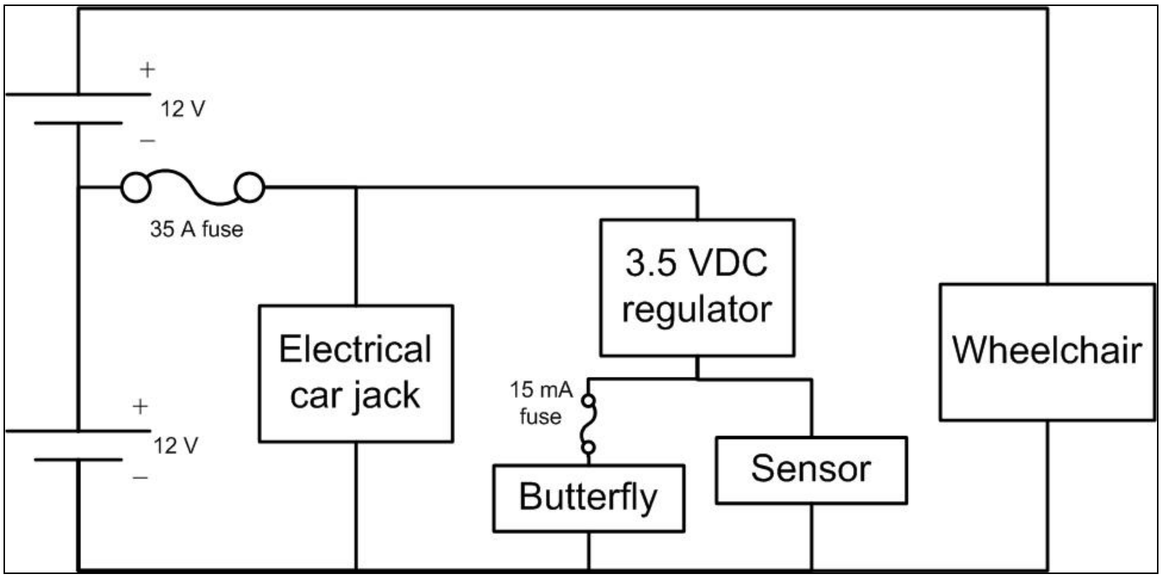

Figure 9.1: Power Circuit

All the electronics will draw power from the on board 12V batteries. For the microcontroller and sensor we will use adjustable voltage regulators so no additional battery is needed for the user to replace or recharge (User usability); for the purpose of proof of concept we will drive our microcontroller and sensor using separate battery source. To prevent high current surges, we will have a 15mA fuse attached on the input side of the microcontroller.

10. Safety & Ergonomics

Safety and ergonomics aspects are accounted to take in the user's capabilities and limitations to guarantee a suitable product environment. To allow a wide range of users with different body size and shape, StandStation will use an adjustable harness to safely secure the user. The harness will be attached to the back frame of the wheel chair and will assist the user's back to stay in an upright position. Moreover, with the safety harness in place, users will be secured into the StandStation device even in the full standing position. As seen in Figure 10.1, the chest harness is fully adjustable in sizes:

Figure 10.1: Yates, Rescue Chest Harness [2]

To avoid and relieve pressure placed on the chest through the harness as transitions are made to the standing position; the arm rests will move along with the user to counteract parts of the vertical force on the harness. As shown in Figure 10.2, the arm rests will be attached to the frame structure on the wheelchair and will stay in a usable position throughout the whole process.

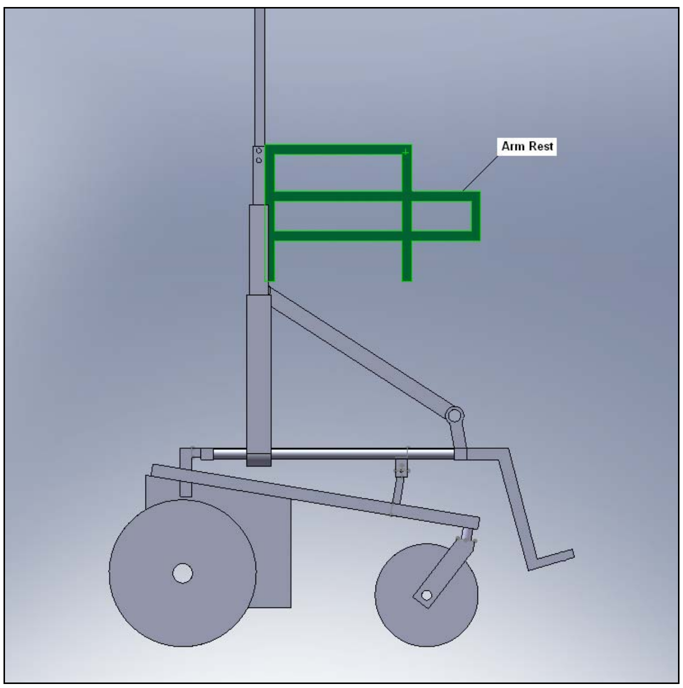

Figure 10.2: Wheelchair Arm Rests

10.1. Weight Characteristics

Safety concerns exists where the possibility of the StandStation wheelchair flipping over when the user is at a standing position. At a full standing position, the user's weight converges to the front side of the wheelchair and therefore precautions and limitations exists to prevent the wheelchair from flipping over during normal operation. The wheelchair is 112 cm in length with two sets of wheels touching the ground acting as pivots as shown in Fig. 10.1.1.

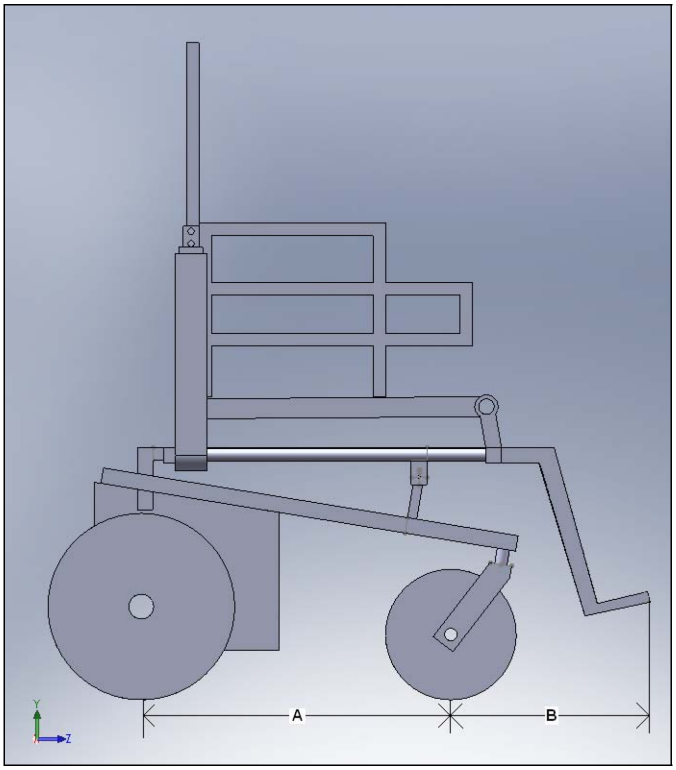

Figure 10.1.1: Wheelchair Dimensions

Since the wheel chair frame is quite light compared to the other major components of the system (batteries, motor, user), the frame is ignored in our calculations. Therefore the weights and the positions of the major components can be seen in Table 10.1.1:

Component	Weight	Position
Battery (x2)	45.89 Kg	A
Motor	9.07 Kg	A
User	X Kg	B

Table 10.1.1: Weight & Positions of Different Wheelchair Components

The weights of the battery and motor components are situated at position A. The lever arm from the pivot to position A is almost 3 times longer than the lever arm of the pivot to position B. Therefore the weight of the major components can counteract a larger weight of the user situated at position B.

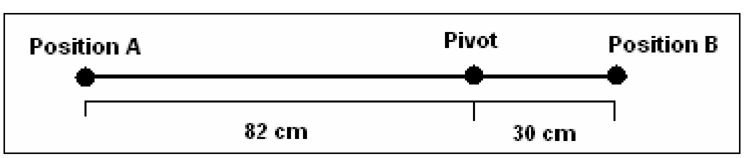

Figure 10.1.2: Moment Diagram

Force at Position A = (45.89 Kg + 9.07 Kg)* 9.81m/s^2 = 539.16 N
Moment from Weight at Position A = 539.16N * 82 = 44210.92

Limitation Force at Position B = 44210.92/30 = 1473.70
Max Weight at Position B = 150.22 Kg

Through the torque and moment calculations, we can see that the maximum weight the user can place at position B is 1473.70 N, therefore generally our system is limited to users weighing at 150.22 Kg and below. However, since we assumed in these calculations that the user is standing straightly upright at position B which is not possible with our system configuration. In our system configurations, the user may only stand partly upright; therefore this allows a safe zone to our limited user weight and to the actual limit of the user weight.

10.2. Additional Safety

On top of the stop button to control the height, there is also an emergency stop button which disconnects the power to the car jack in the case of an emergency. The disconnection and reconnection are all electronically done, so user does not have to reconnect the wiring.

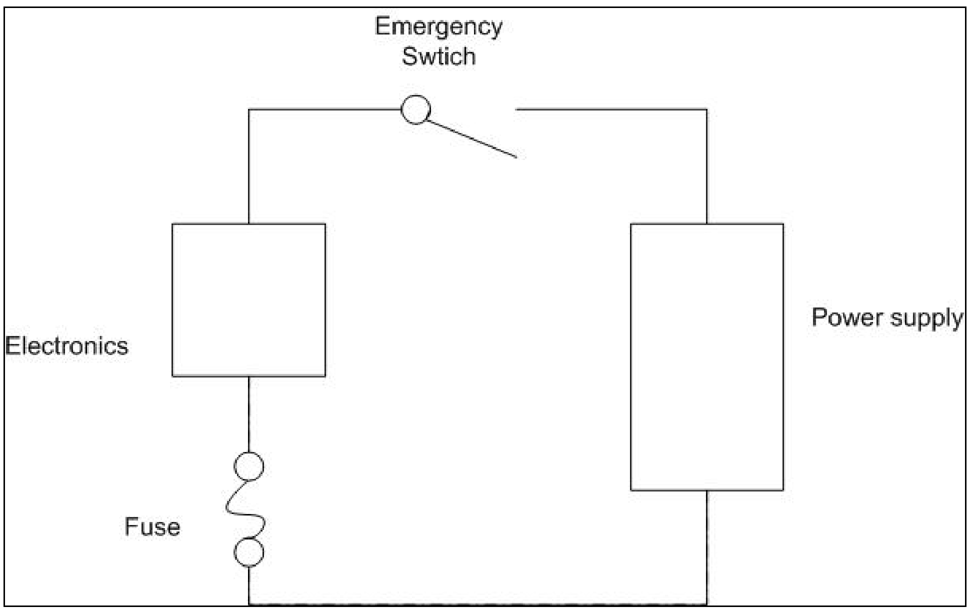

Figure 10.2.1: Emergency Safety Circuit

The emergency switch is normally closed so it is a closed circuit. The fuse is there to prevent large current spikes from damaging the electronics, mainly the microcontroller.

11. System Test Plan

While the Station system normal operations, different aspects and modes must be tested. Each mode consists of different testing procedures to ensure secure operable conditions.

11.1. Automatic Mode

The effectiveness and the different safety components will be tested when the StandStation system is in the automatic mode. To test for these, a user will be asked to use the StandStation to go from a sitting to a standing as well as a standing to a sitting position. During which the different safety components including the emergency stop button and the weight characteristics are tested as discussed in Section 10.

11.2. Safety & Ergonomics

Safety and ergonomic aspects will be studied per user's requirements. Different users will be allowed to adjust the positions of the StandStation system. During operation of the system, safety and comfort levels will be tested. Moreover, the ease of use of the manual controls we allow us to test for intuitive and easy to use controls.

12. Conclusion

In conclusion, different specifications on the design for the mechanical and electrical components have been discussed. Through these design specifications, the StandStation prototype will be completed to meet the proposed functional requirements. Scheduled completion of the StandStation prototype will be for April 6th.

13. References

[1]
http://www.pololu.com/catalog/category/7

[2]
http://www.urbanhart.com