ErgoForm Design

Simon Fraser University, Burnaby, BC. V5A 1S6

March 6th, 2011

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, BC
V5A 1S6

RE: ENSC 440 Design Specifications for the Adjustable Toilet Seat System

Dear Dr. Rawicz,

We are moving along in our development cycle of the Adjustable Toilet Seat. As such, I have attached our design specification document. Our system is to be used by the elderly and or physically challenged when utilizing the toilet. Our system works by allowing the user to customize the height of the seat until it is comfortable for them to use. The system can also be used on any existing toilet with little to no modifications.

This document will outline the components as well as the individual designs. Once all of the parts are completed they will be integrated to form our prototype as specified in our Functional Specification guidelines.

ErgoForm Design is composed of five members: Seyed Abbas Jafari, Ashkan Mirnabavi, Feifan Jiang, Faraz Khan and Nickolas Cheng. If you have any questions or comments regarding our functional specifications, you can contact us through email at nwc@sfu.ca.

Sincerely,

Nickolas Cheng
President and CEO
ErgoForm Design

Enclosure *Design Specification for an Adjustable Toilet Seat*

Simon Fraser University, Burnaby, BC. V5A 1S6

Adjustable Toilet Seat System

Design Specification

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Executive Summary

This document from ErgoForm Design is a technical description that defines the design and development cycle of the Adjustable Toilet Seat. It will provide insight as well as justifications as to why certain decisions will be made during the design/construction cycle of the proof of concept model. Furthermore, designs will adhere heavily on policies set forth in our functional specification marked with I or II [1].

The ATS works by utilizing motors to adjust the vertical height of the seat. This will enable users the ability to utilize their facilities with ease while mitigating risks of injuries. To achieve this, ErgoForm Design has developed the following components:

- Angled seat mechanism
- Fine adjustment mechanism
- Jack screw lift
- Push buttons and user interface
- Casing

The designs of the components above will be discussed further in detail in their respective sections in this document. Once all the components are constructed and integrated into the prototype ATS, tests will be conducted as per the functional design documentation [1].

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Glossary

AC **Alternating Current**
ATS **Adjustable Toilet Seat**
DC **Direct Current**
LED **Light Emitting Diode**
PCB **Printer Circuit Board**
Standard Dimensions **Length x Width x Height**
Standard Toilet **A toilet that is 480mm x 383mm x 460mm**

1. Introduction

ErgoForm Design is proud to present the Adjustable Toilet Seat. This device will enable the elderly or physically handicapped individual the freedom to use the toilet at their desired comfort levels. Currently most seats are mechanically driven and involve no electronics in allowing an individual to customize the orientation of their seats. The ATS will employ a mechanical angled seat that will depress as weight is applied as well as actuators that will adjust the height of the seat when specific buttons are depressed.

1.1 Scope

This design document builds off of ErgoForm's previous specification design document. However, as the finished product this April is a prototype only the requirements of a prototype unit will be adhered to.

1.2 Intended Audience

This document was prepared for ErgoForm Design. This will be used as a guideline as to how the ATS is constructed. Furthermore, a testing plan is also included for fellow Engineers and other interested parties to ensure that the device is able to meet our specifications set forth in our previous document.

2. System Specification

The ATS works by having a user adjust the height of the seat by depressing two buttons; one button controls the upward motion, the other controls the downward translation. The system is constantly on unless a kill switch is flipped on the rear of the ATS. The diagram below depicts the logical flowchart of how the ATS will behave.

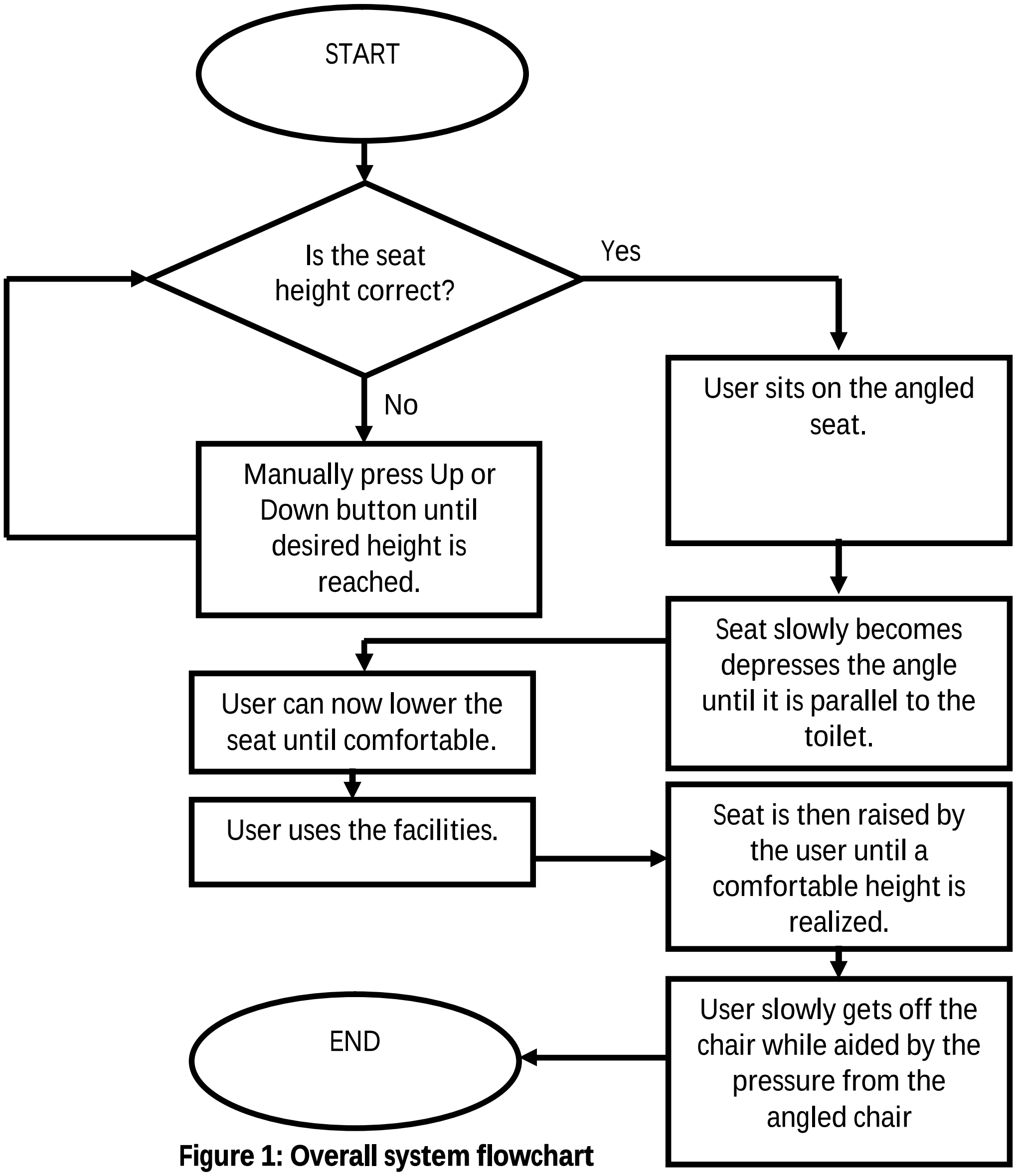

Figure 1: Overall system flowchart

3. Overall System Design

This section will focus on the individual components that make up the ATS. The main components of the system are as follows: i) angled seat mechanism, ii) fine adjustment mechanism, iii) the user interface, and iv) the jack screw lift mechanism with the motors. Each component will be discussed below in their own individual sections.

3.1 Mechanical/Physical System Design

The bulk of the ATS is comprised of mechanical components working together. This includes the jack screw, the angled seat, fine adjustment mechanism and user control box.

The jack screw lift will be responsible for the vertical translation of the entire system. The two jack screw lifts will be located on the side of the toilet and in turn will be driven independently by their respective actuators. In order to ensure that the motors work on command, two momentary buttons will be used.

The angled seat is a purely mechanical system that utilizes springs and pneumatic jacks. It will be mounted atop of our jack screws. The seat will be naturally angled to allow users the ability to lean and apply their weight slowly onto the system. As more and more weight is applied, the seat will depress and eventually become parallel to the toilet seat.

In order to compensate for the tolerance between the two individual motors we have elected to install fine adjustment mechanisms that will introduce offsets.

A single pole double throw switch is responsible for the vertical translations will be housed in a watertight box unit. It can be mounted on multiple locations depending on the requirements of the user. Allowing this flexibility will enable the ATS to be as intuitive to use as possible.

3.2 Electrical System Design

The entire system will utilize approximately 90W. To meet this requirement we will be using a standard 90W laptop AC Adapter. These adapters are fairly well built and often times never need to be replaced unless misused.

3.3 Mock-up of the device in 2D

The ATS is a less invasive aid when using the toilet. To fully understand the system, the diagram below will illustrate a typical toilet setup with the ATS in place.

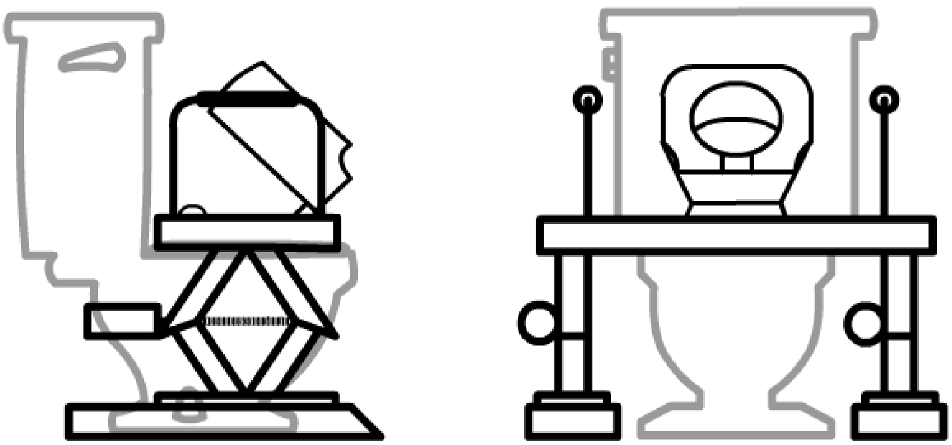

Figure 2: ATS System setup on a standard toilet

To minimize the space occupied by the system we researched into various solutions ranging from pneumatic lifts to a rotation link assembly. Unfortunately, all of those solutions required space that is not normally found in a typical washroom setup. Since most toilets have the water tank facing a wall it was imperative that our device was able to work around that. To solve that issue, the ATS can be slid into place overtop any existing standard toilet.

4. Angled Seat Mechanism

The seat mechanism is the horizontal surface that makes up ATS. It is joined at each ends by the lifting devices and it is the component users will be sitting on. It consists of two major components—the base and the seat support.

4.1 Mechanism Overview

The overall goal of this component in our design is to allow the users to be gently lowered down into the sitting position. For this action to be completed, we considered many possibilities and finally settled with the one seen in figure 3. There are several moving component in the design, they are the hinges (point D) and the hydraulic lift supports (point E).

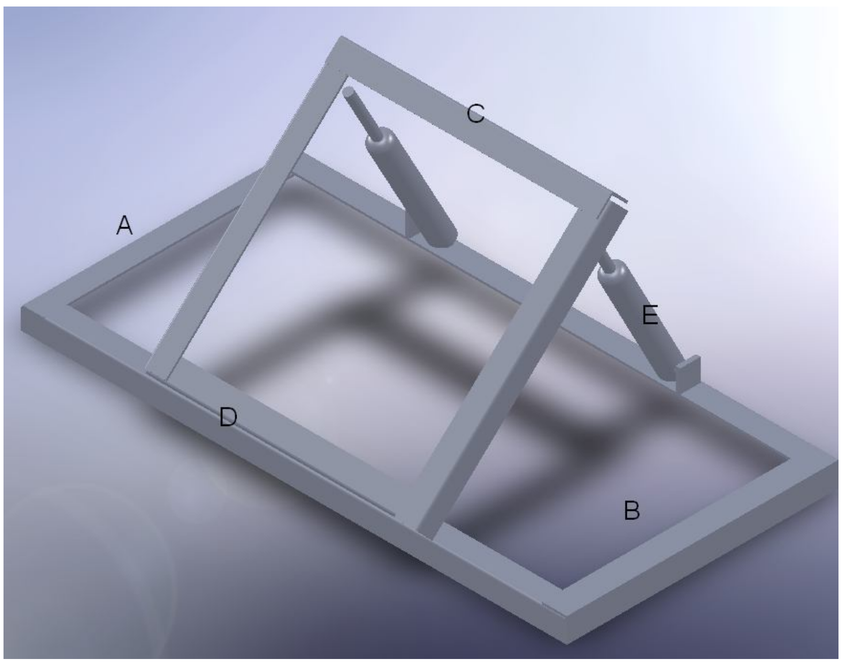

Figure 3: Final design of the sitting surface

4.2 Physical Design

The material used to construct the frame is angled iron (figure4). It was from the research and development stage of the project that we decided to choose this material. It had the physical strength but also was malleable enough to be worked on with amateur tools. The base frame (point A) has the dimension of 30 by 60 cm and the sitting surface is 30 by 30 cm. At point D, there are two hinges to allow the base seat to pivot about the base frame. The pivoting action is limited by the hydraulic cylinders. These cylinders allow the seat to be gently lowered to point A/B. The hinges also serve another purpose. They allow a gap between base and the seat such that when the two parts come together there is no pinching hazard to one's body.

Figure 4: The angled iron we used in our design

4.3 Lift Cylinders

To lift and lower the sitting surface with ease, the design employs gas-charged cylinders (also called gas spring). It was after much trial and error that we got the product to work as per the functional specification document. To fulfill the requirement of being able to lift at least 80 kilograms we chose the StrongArm 4420 gas-charged cylinder. The StrongArm cylinder had the correct length needed to fit in our enclosure with the dimensions of 2.5 cm diameter with a 5.5 cm rod and a 5 cm piston (the part that extends). This provided the correct angle of 60 degrees and range of motion needed for our design. The second and most important feature of this lift cylinder is that it requires 30 pounds of force to be depressed. This is because with two, it provides a gentle motion as the cylinder compressed. The manufacture also claimed that the cylinder sports a temperature/humidity O-ring. This is good for our project since it will be exposed to water.

Figure 5: The gas-charged cylinder used to support the sitting surface

Our choice of lift was based on the following calculations to determine extension force [3]:

$$F_E = F_1 * \frac{W R_W}{L_G n}$$

Definitions:
W - Force due to weight of the lid
R_W - Radius of the center of gravity
L_G - Distance from pivot to spring
s - Center of gravity
D - Pivot point
n - Number of gas springs in parallel

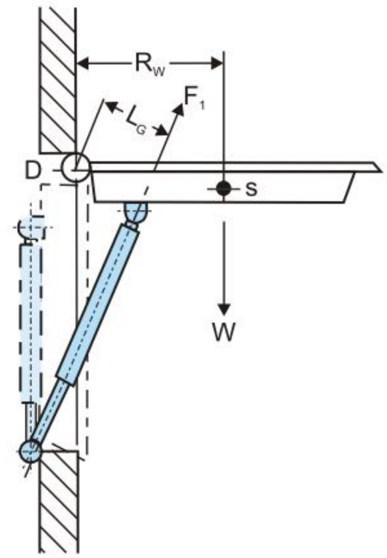

Figure 6: The definitions and diagram of a spring cylinder

5. Jackscrew Lift

To perform the actual lifting motion, we chose a 1-Ton, 12V jackscrew lift[2]. Since the overall system relies heavily on the jackscrews, it was imperative that we overcompensated for instances of load imbalance or abuse. Furthermore, most jackscrew applications are found in the automotive world where several tons of imbalanced loads are placed on the lifting mechanism. We were also quite fortunate to find that the jackscrew utilized only 12V and approximately 3A and less than 10 A [2]. In our application we will be utilizing two jackscrew lifts with one on each side of the toilet respectively.

5.1 Physical Design

The jackscrews will be ordered and used as is. The overall dimensions of the lift is 20 cm x 7cm x 15 cm. The actuation by the motor will be performed by a 3/8" screw. Minor adjustments include filing off any sharp corners as well as ensuring that the screw is well lubricated. To prevent water damage from the humid environment of the toilet, the entire jackscrew lift mechanism will be housed in a uni-body plastic chassis in the final product. The image below is a 3D render of our jackscrew unit.

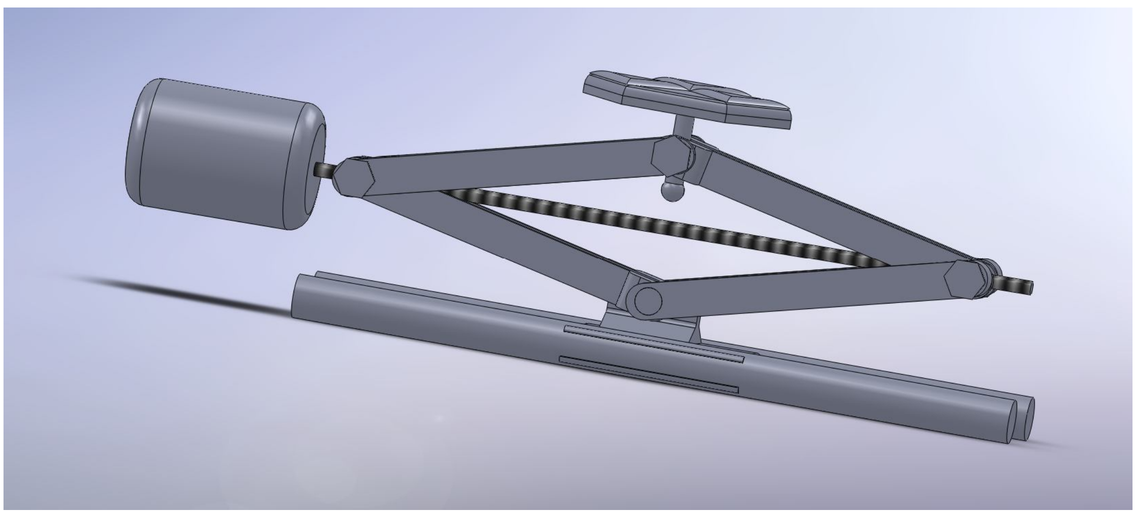

Figure 7: The jackscrew lift used in the ATS

The lifting mechanism works by having the screw turn clock/counter-clockwise in the midsection of the lift. Depending on the orientation of the spin, the lift will compress or extend. The screw is the most important part of the lift and as such is made of hardened steel.

The rest of the jackscrew unit is composed mainly of steel and brass. Due to the materials used and with the motor directly mounted to the jackscrew lift, the weight of the mechanism is 5kg. This is desirable as the weight will ensure that the unit is stable when a load is applied. The jackscrew lift maintains a minimum height of 5 inches to a fully extended height of 14 inches.

5.2 Electrical Design

The motors in our jackscrew will be limited to a total of 90W. This ensures that the vertical actuation occurs at a mediocre speed of 2cm per second. The two motors will be connected in series along with the momentary buttons that control the current flow that drives the movement. We have verified the power reading with a digital multi-meter as well as through practical stress tests (applying weight and allowing the lift to operate in the opposite direction).

To ensure that the two lifts work at the same time, they will be connected in series. The logic behind this orientation is that if a motor fails, the ATS does not function. This prevents injuries from uneven loading.

6. Switches and User Interface

Since this product will be used by the elderly and the physically challenged, it is important to have a large and intuitive user interface. The switch on the console that will be used is of the double pole, double throw variety. This switch is similar to a joystick and will enable the user to manipulate the chair with ease.

6.1 User Interface Hardware

The double pole double throw switch will be housed in a plastic housing and connected to the overall circuit via a PCB. As the switch is moved to one of the three positions the seat will adjust accordingly. Depending on the state of the switch an image illuminated by an LED will light up indicating the action. Furthermore as there are defined height limits for the jackscrew lift, it is imperative that the user is notified via illuminated LEDs. The image below illustrates how our console will look like.

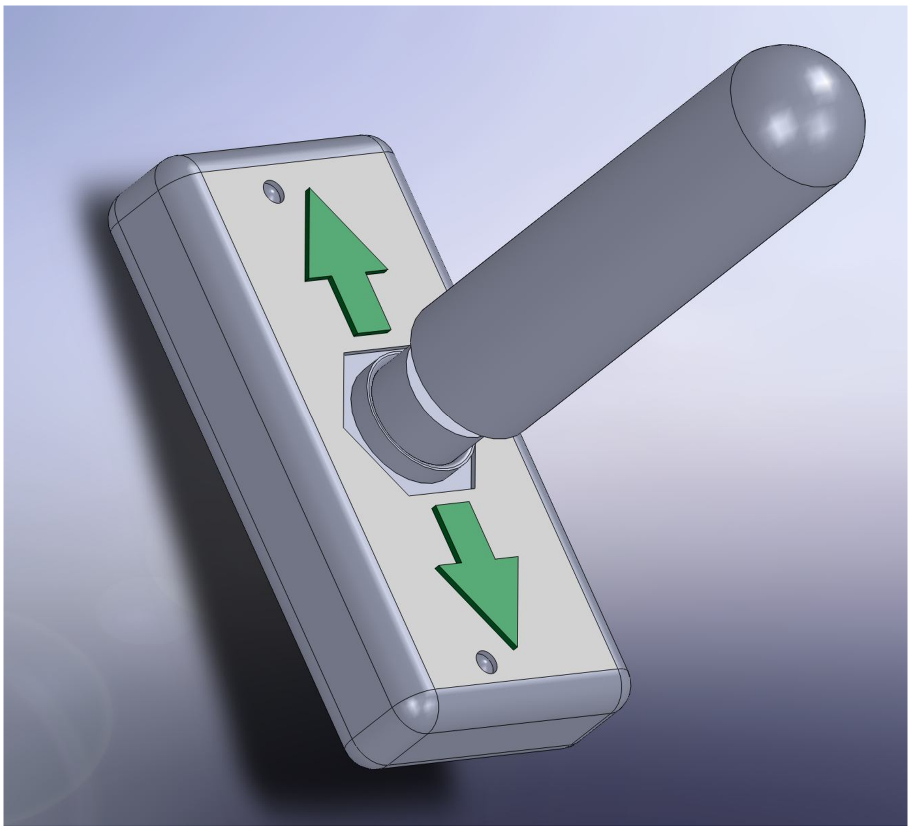

Figure 8: The user control interface of the ATS

The justification behind a single pole, double throw switch to control the actuation was based on field experience from an acquaintance in the health services industry. Since many of the elderly often suffer from debilitating conditions such as arthritis or under routine blood testing on their fingertips they would lack the strength to operate buttons.

6.2 Emergency Shutoff Switch

A switch located on the underside of the console is available during times of emergencies or when maintenance is being carried out. Unlike the other switches the emergency shutoff switch has a protective covering to deter tampering and is a state switch. The image below is a 3-dimensional render of our switch which includes the tamper-proof cover.

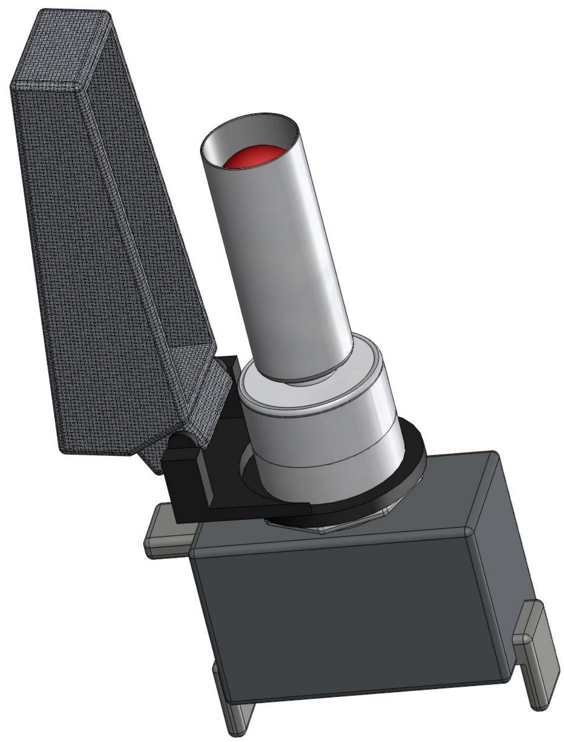

Figure 9: The emergency shutoff switch

6.3 Electrical System of the Switches

To ensure that the overall system performs within specific limitations we will be using numerous switches in the mechanisms to trigger alternate states. For instance, momentary switches are used within the jackscrew chamber to detect when the minimum or maximum levels of the lift is reached. Once the limiters are triggered, current is cut and using the single pole double throw switch to continue with the action will fail.

Since our overall system consumes approximately 90W, all of our switches will have to have an operational rating of 90W or more. All of our switches are selected with the tolerance of 25A at 12V which exceeds our needs.

6.4 Electronic Circuit

Since the ATS is a mechanical and electrical system we will have a fairly sophisticated circuit design that will address many of the systems limitations and requirements. As mentioned, the actuators will be set up in a parallel configuration with a series of switches that control when current flows to drive the motors.

6.5 Motor Control

The purpose of the steering diodes is to give the device an effect of auto reset once the normally closed limit switches have opened up. Once the contact limit switch is activated for which ever direction, the user will then apply power in the opposite direction and with the diodes the circuit will be complete. This allows the motors to move and the switch contacts will close again and be ready for the next time. Figure 10 illustrates the circuit that will be responsible for the proper function of the ATS.

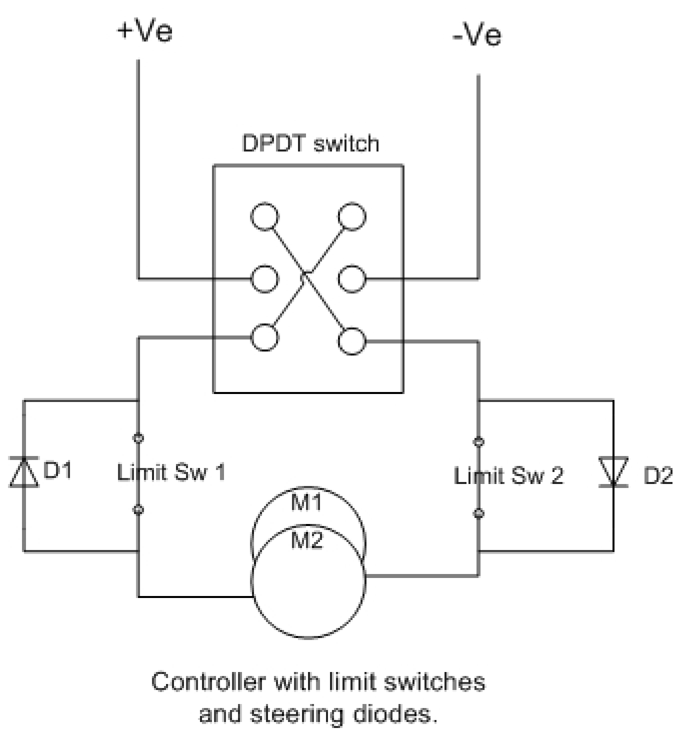

Figure 10: The circuit used to control the motors

7. Chassis and Housing

As the unit will be working in a washroom it is necessary to ensure that all of the hardware is stored in a watertight housing unit. The chassis of the ATS will also need to be constructed from durable materials that can withstand misuse and other unforeseen abuse.

7.1 Construction Guidelines

To cut down on costs, the prototype unit will be utilizing a wood housing with a layer of varnish for the jack screws. We elected to go with solid oak that we salvaged from a cabinet for our housing. To provide a protective covering, a layer of varnish was applied on the inside and outside of the wood. The entire casing will be fastened with 1/8" wood screws along with wood glue.

The final model will be constructed from polyvinyl chloride which is extremely durable and a cost effective. To ensure that there are no seams for bacteria and other grime to cling to, the PVC will be machined from a single piece to cover the components of the ATS.

7.2 Leveling Adjustment

To ensure the device is level and to prevent tipping, we have included a leveling system. The design is a common one that one can easily see in appliances for example. Bolts placed at the four corners of the frame can be adjusted in or out such that if the surface is uneven, the ATS will maintain stable.

8. Test Plan

The two adjustable parts of the ATS will be tested first. After individual component testing, we will test the whole device in its normal operating conditions and in extremes cases.

Unit Verification

To verify the safety and accuracy of our product, we will run strict tests. To confirm with our expectations and the functional specification, the following test will be performed.

1. Lift motor automatically stops when the lift is fully extended.
2. Lift motor automatically stops when the lift is fully closed.
3. Seat closes in a smooth consistent motion.
4. Seat does not "fire" back up from the closed position
5. The motors can handle the weight and unloaded conditions with same speed.
6. The control is responsive.
7. The control provides the correct feedback to the user.
8. Simulate a power outage during use.

8.1 Normal Case 1: User is in correct sitting position

User Input
The user raises the seat and gets onto it.

Test Condition
From the standing position, the user pushes back onto the seat, and proceeds to sit down such that their weight is in the device's center of gravity. The seat is then lowered until it is parallel with the toilet bowl.

Expected Output
The seat comes to the home position when called by the user. The LED indication function as expected letting the user know that there command is being executed. The system works as per the flowchart in figure 2.

8.2 Normal Case 2: Users' weight is not centered

User Input
The user places their weight off center.

Test Condition
The user sits off center on the device. The user sits too far forward or backwards on the seat thus making the device more susceptible to tipping over.

Expected Output
Because the device has the potential to become top heavy (similar to a bookcase with books only on the top shelf) tipping is a concern. When the device is in the fully extended form, it should be remain stable and resist any inclinations to tip over.

8.3 Extreme Case 1: The limit switches are activated

User Input
User presses the up/down button until the limits are reached

Test Condition
The motors are driven until the upper/lower limits are reached.

Expected Output
This test is essential to ensure that the device does not destroy itself. With contacts placed strategically on the device, the limits should be detected and the power to the motor should be cut. A red LED on the control panel should be lit indicating an abnormal state of the device.

8.4 Extreme Case 2: Power failure during use

User Input
In the process of being lifted or lowered

Test Condition
When the user is on the device, the power will be removed from the system.

Expected Output
The system should freeze. The motors should not collapse, dropping the user and seat to the toilet bowl suddenly.

9. References

[1]
N.Cheng et al.. “Functional Specification,” ErgoForm Design, B.C., Rep 1, 2011

[2]
“Electric Jack 1 Ton (2,000 lbs) Assembly and operating Instructions ,“ whitepaper BuffaloTools Corp., Mar. 2008.

[3]
ACE Control Inc., Gas Springs & Hydraulic Dampers. Farmington, MI: ACE World Wide, 2003, pp 4.