GNG 2101
Design Project User and Product Manual

E-Z Lift Footrest Mechanism

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1 Introduction

This User and Product Manual (UPM) provides the information necessary for mobility impaired individuals and technicians to effectively use and/or install the E-Z Lift footplate raising mechanism and for prototype documentation.

The purpose of this document is to inform the clients and technicians about our product. It was developed to solve an overlooked problem in handicaped people's lives. Detailed information about the conception, the specifications, all features, components, tasks and subtasks can be found in this manual to help the readers to fully understand the operation of the product.

The organization of this document is relatively trivial. It starts with a brief overview of out product as well as some cautions and warnings. This is followed by a section on the considerations of the system and a general walkthrough of the system. Subsequently, the user is taught how to use the product and then how to troubleshoot it in the eventuality of a breakdown. This manual ends on a prototype documentation which contains the bill of materials and other pertinent information about the conception and development. Information about our future work and plans is also included at the very end of this document.

For security and privacy reasons, the names of the team members as well as the name of the client will not be disclosed in this document.

2 Overview

Many mobility impaired people use wheelchairs to move around. Usually, to get in or out of their wheelchairs, they use footplates as support. However, these footplates are close to the ground and hardly accessible to people with disabilities. Our client has also suffered a recent stroke which has worsened her condition. People in wheelchairs need to be able to get in or out of their wheelchairs quickly and effortlessly for safety reasons in case of emergency. They need an automated mechanism to raise or lower their footplates simply by clicking a button. Our product does exactly that. With an average run time of 3 seconds, it is quick and efficient. It is also quiet and very affordable and accessible. It is made out of easily sourceable components and is therefore very easy to repair in case of a break-down. Most importantly, our system is the first of its kind. No other company has ever thought of designing a mechanism to solve this latent problem in disabled peoples' lives.

Our system has two major functions: to lift and to lower the footplates. It is a mechanical automated remote controlled pulley system. It is powered by a 12 V battery which feeds 2 DC motors. These motors will tighten the wire which will eventually lift the footplates. The tension is then released to lower the footplates. A series of limiters is also mounted on the system to ensure that the motor stops running when the footplates reach the desired positions. Weight adjusters were added at the top of every footplate to ensure that the system would actually handle the weight of real footplates. All electrical components are encased in an Acrylic housing to protect them from water and heat.

Our mechanism is controlled by an Arduino Uno board and a series of relays. The Arduino Uno machine has been programmed in advance to control the actuators according to the user's input. The user interface consists of a simple retractable remote which can be stored when not in use. This remote contains an on/off switch and 4 buttons (2 to control the left pedal and 2 to control the right pedal).

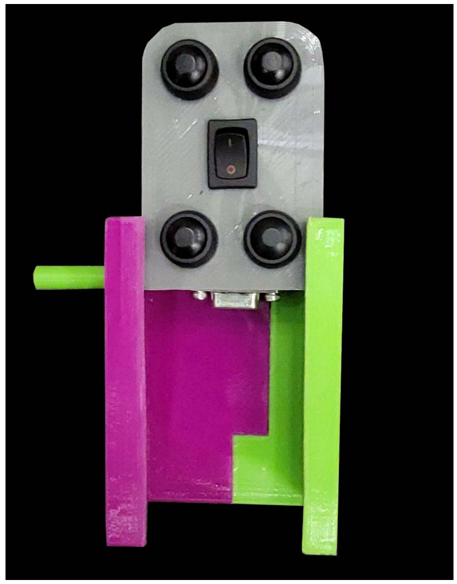


Figure 1: Remote control and sliding remote housing

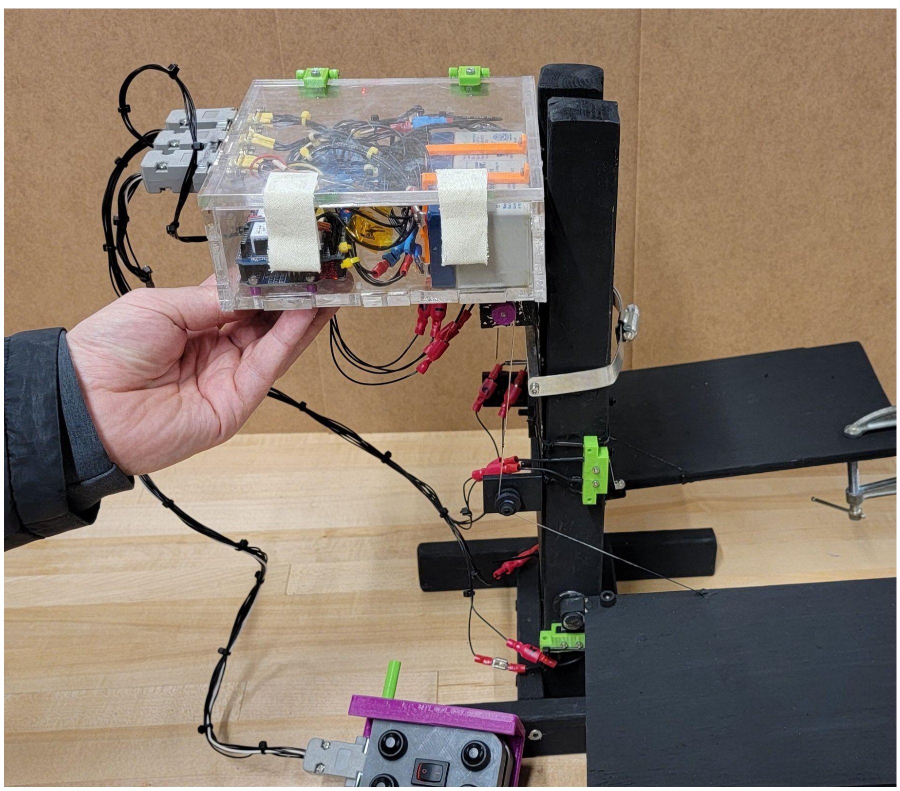


Figure 2: Footrest mechanism

This block diagram shows the main tasks and subtasks of our product as well as their order and their organization.

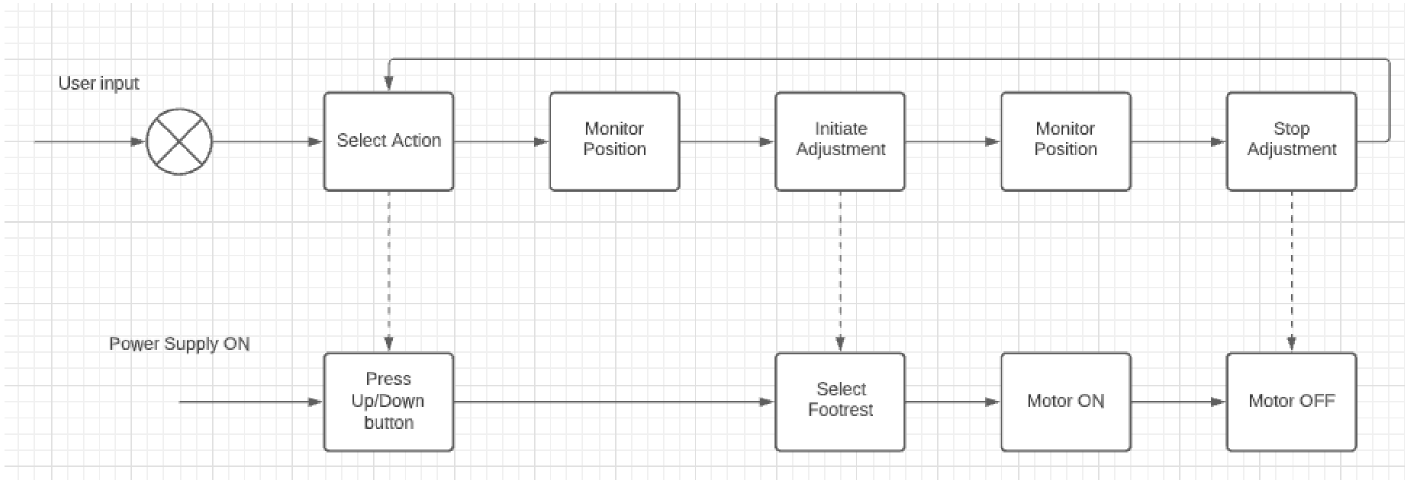


Figure 3: Functional decomposition

2.1 Conventions

If applicable, describe any stylistic and command syntax conventions used within the manual. For example, when an action is required on the part of the reader, it is indicated by a line beginning with the word 'Action'.

2.2 Cautions & Warnings

- Keep all electrical components away from all heat and water.
- Keep all electrical components away from children
- If the system is not working, do not attempt to repair it yourself. Contact your technician as soon as possible.
- Do not place more than 300lbs of weight on the footplates.

3 Getting started

This section will detail the process of setting up the pulley system to affix it to the wheelchair. Removable installation methods have been included with the product, but this system may also be affixed permanently.

3.1 Set-up Considerations

Main plate Set-Up

To install the system, the main plate must be attached to the footplate support arm. This can be easily done with the hose clamp supplied. For a more permanent fixture, this plate can be attached via screws that would go into the support arm.

The hose clamp must first be fully opened. The installer will thread this through the holes in the main plate, then encircle the support arm with it. Once this is in the correct position, the installer will tighten the hose clamp with a screwdriver. Ensure that this hose clamp is tightened as much as possible to ensure a secure connection between the plate and the support arm.

Limiters Set-Up

The upper and lower limiters can be installed with the provided zip ties or can be drilled into the support arm for a more permanent solution. For the upper limiters, the installer will position them on the outside surface of the support arm with the open angle facing the ground. The vertical position of the upper limiters is customizable as this will depend on the minimum angle between the footplates and the support arm. On the Premobil M3 model, it is recommended to install the upper limiters at **XX in (cm)** below the hose clamp.

The lower limiters are to be installed on the outside surface of the support arm, with the open angle facing forwards. The vertical position of these limiters are also customizable and depend on the maximum angle between the footplates and the support arm. On the Premobil M3 model, it is recommended to install the upper limiters at **XX in (cm)** below the hose clamp.

Cable Set-Up

To secure the position of the cables in place, the footplate clamps provided can be used to attach them to the footplates or a hole may be drilled into the footplates for a more permanent solution. For the Premobil M3 Corpus model, it is recommended to be drilled at **XX in (cm)** from the support arm.

These cables will come pre-affixed to pulley 1. The installer will run the free length down around the outside of pulley two and then to the attachment site on the footplates. The cables will be threaded through the hole and secured in place using the crimps provided. Before crimping the cable in place, ensure that it is taut but not too tight, as it will be difficult to secure the cables in place.

Cable Set-Up

For this product, there are three cables that will need to be installed. The first two connect the motors to the main electronics box, and the third connects the electronics box to the user remote. To set this up, the installer will simply connect the numbered red plug sockets on the cable to the corresponding numbered red plug on the pulley system. There will be a total of 12 plugs to connect, 6 per side. There will be two plugs per motor, two plugs per upper limiter, and two plugs per lower limiter.

Once the cables have been wired to the pulley system, they must be attached to the ports in the electronics box. The cables for the left pedal connect to the port on the **XXX**, and the cables for the right pedal connect to the port on the **XXX**. The last cable to connect will be the one that runs from the remote to the electronics box. This will connect to the port on the **XXX**.

When all the cables have been attached, the installer should do a trial run to ensure that all the cables have been attached correctly. When they have confirmed the system to be in working order, the installer will then attach the electronics box to the base of the wheelchair, and run the remote cable up the left side of the wheelchair seat and then under the left armrest.

Remote Set-Up

The remote will come pre-affixed to the remote housing. This housing will allow the remote to slide forwards and backwards within a certain distance. This housing will be attached to the underside of the left armrest with the velcro strip provided. The installer should ensure that this housing is placed as close to the front edge of the armrest as possible.

3.2 User Access Considerations

The user of this system will only need to adjust the remote housing placement as needed. The installer of the system will position the main plate, the cables, the electronics box, and the wiring system.

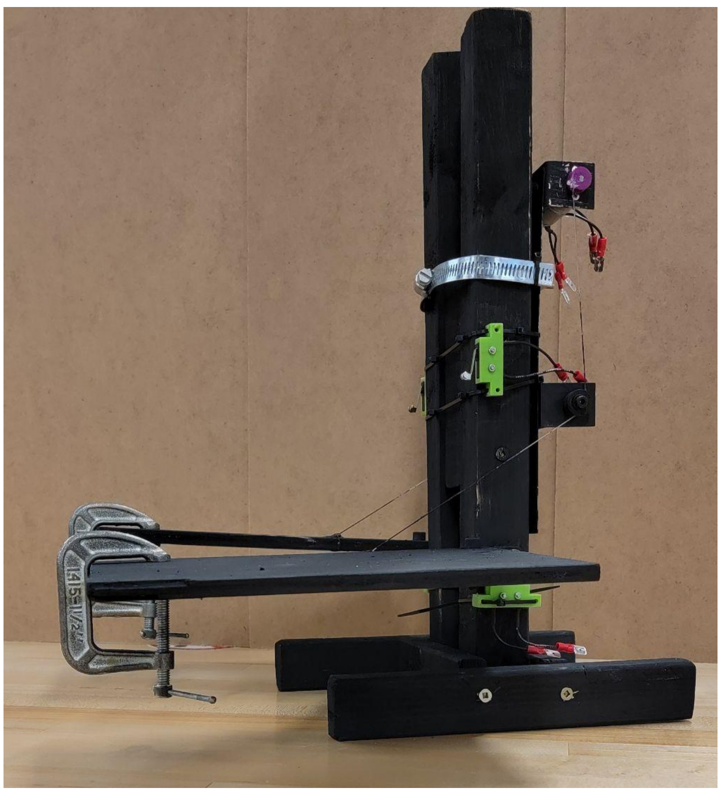


Figure 3.1: Side profile of Pulley System

4 Using the System

This chapter aims to provide you with basic information to quickly get started with your E-Z lift, and also provide you with information you may need in your everyday use of the lifting system. The following subchapters describe how to use the remote, charge the battery, and use the footplates manually

4.1 Remote Control

The remote control has 5 buttons, the center On/Off button, which turn the entire system on with one click and off with another. It also has two black buttons and two red buttons, for left foot plate up, right footplate up, left footplate down, right footplate down. This allows the user to move the footplates at the same time, or one at a time.

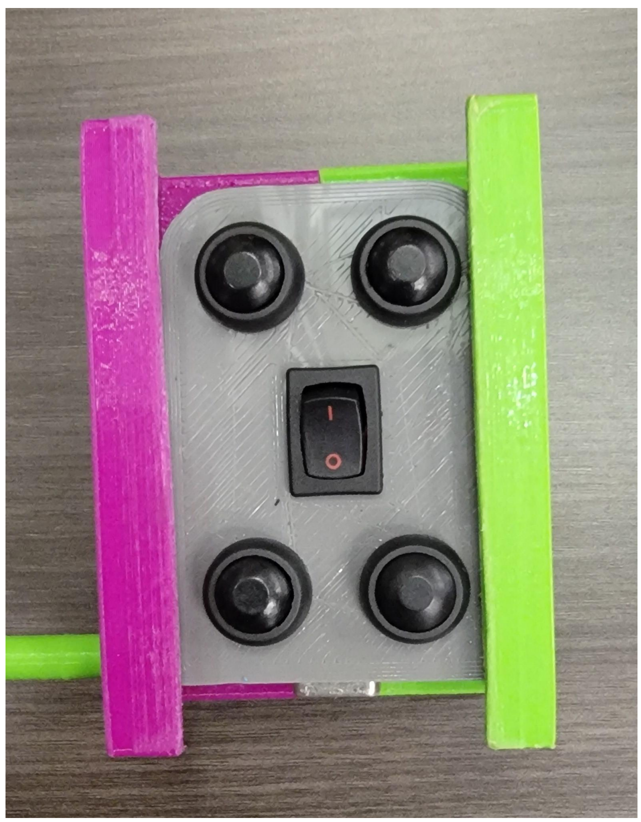


Figure 4: Remote control

4.2 Charging The Battery

The battery needs to be charged very little, in case it ever needs to be, it is very easy and can be done overnight, simply by plugging the battery box into the nearest power source.

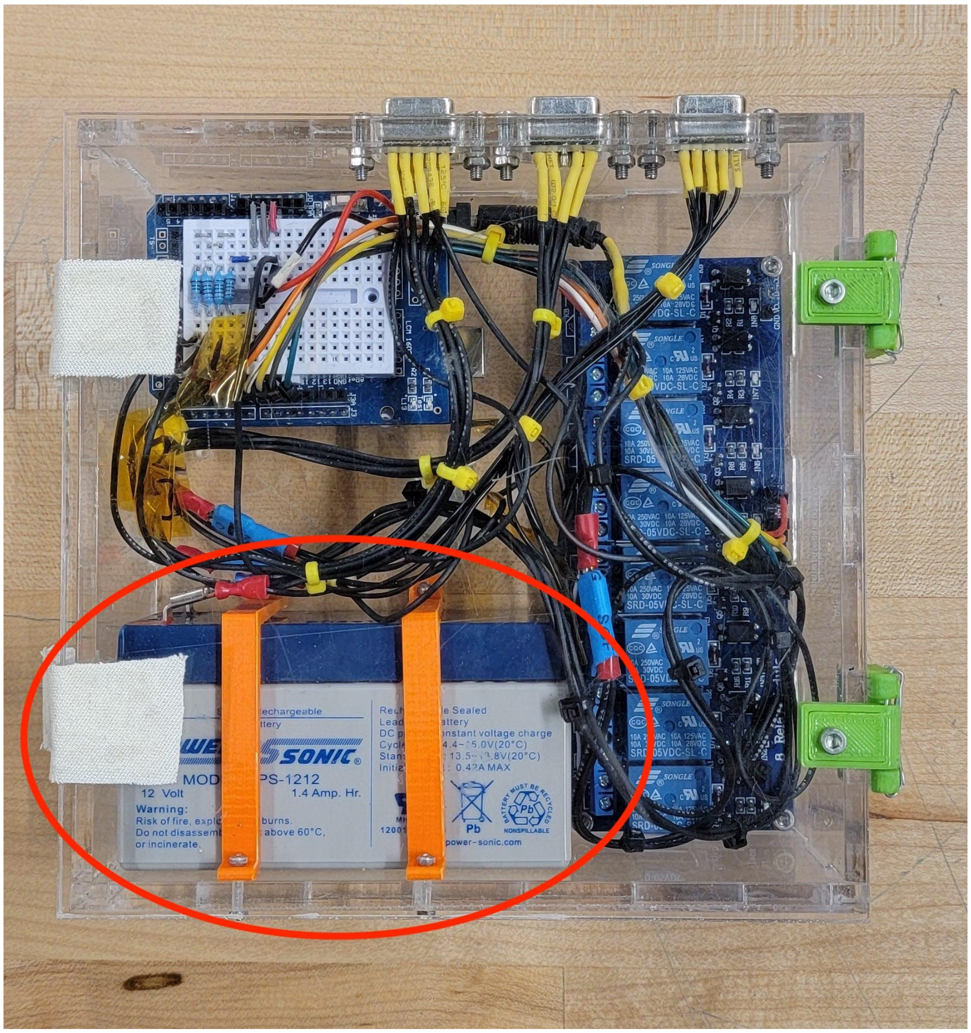


Figure 5: Electrical components in housing unit

4.3 Manually Moving The Footplates

In case the system stops working, the battery dies, or you just desire to not use the mechanism, by simply turning the E-Z lift off, you can still move the foot plates manually with your hands.

5 Troubleshooting & Support

This section will describe the recovery procedures. This section should be consulted concerning general maintenance and device malfunctions. It is important to read the troubleshooting and support section before attempting to repair any components in the lift system.

5.1 Error Messages or Behaviors

The following troubleshooting guide describes a number of faults and events which can occur when you use the lift system, including suggested solutions.

Note that the guide cannot describe all the problems and events which may occur and you should always contact E-Z Lift or your local authorized service provider for technical support if you need additional assistance. Troubleshooting and repairs of electronics must always be performed by qualified personnel with abilities to read and understand wiring diagrams.

Table 1: Troubleshooting Guide

Event	Cause	Solution
The lift system does not start	Low battery charge	Charge the battery
	Loose connection from the remote to the control box	Unplug and plug the remote cable back into the remote.
	Loose connection inside the box	Contact E-Z lift or your local authorised service provider for immediate assistance.
The battery cannot be charged	The battery does not hold charge	Contact E-Z lift or your local authorised service provider for immediate assistance

The lift system starts but pedals do not move	Broken drive cable	Feed through a new drive cable, secure it onto the designated anchor points on the drive pulley and footrest, **refer to 5.3.3** For further assisgtance, contact E-Z lift or your local authorised service provider.
	Loose limit switch connection	Check all connections, related to the limit switch cable. If all connections are secure, contact E-Z lift or your local authorised service provider for immediate assistance
Footrest pedals movie but do not fold or unfold fully.	Low battery charge	Charge the battery
	Limit switches are not aligned properly.	Loosen mount and adjust limit switches to achieve proper folded and unfolded position, **refer to 5.3.4.** For further assisgtance, contact E-Z lift or your local authorised service provider.
Lyft system does not stop automatically when the footrests are folded or unfolded fully	Limit switches are not aligned properly.	
Pedals operate when turned ON but without any buttons pressed.	Electronics malfunction due to water contamination	Contact E-Z lift or your local authorised service provider for immediate assistance
	Electronics malfunction due to possible defects	

5.2 Special Considerations

It is important to note that all repairs and troubleshooting must be performed when the system is turned off.

If it is necessary to troubleshoot the system when it is ON, make sure to wear proper PPE to avoid hazards such as: pinch points, laceration and electrocution. It is recommended to use cut resistive gloves and safety glasses.

5.3 Maintenance

For the footrest lift system to work properly, it is important that you use it correctly and maintain it regularly. Only carry out basic maintenance and minor adjustments specified in the user manual. All other service and repairs must be performed by a qualified personnel only

5.3.1 Maintenance Schedule

E-Z Lift recommends compliance with the following maintenance and inspection schedule. Contact your local dealer for all service-related needs or questions.

Table 2: Maintenance Schedule

Maintenance and inspection schedule	Daily	Weekly	Monthly	Yearly
Check battery level charge the lift if necessary	x			
Make sure that the remote is plugged in and not damaged	x			
Make sure that the remote housing is secured properly	x			
Clean the moving parts		x		
Check drive cable for wear and tear			x	
Check all electrica cables for wear and tear			x	
Complete inspection, safety check, and service performed by authorized contractor.				x

5.3.2 Cleaning

Acrylic and Plastic can be damaged by harsh solvents and cleaners, including abrasive kitchen supplies. Use a commercial plastic cleaner or mild soap and water to remove dirt and debris, utilizing a soft cloth only.

All metal parts are coated in a protective layer for optimum corrosion resistance. To maintain the coatiung intact, use a soft cloth or sponge, hot water and a mild detergent for normal cleaning. Wipe down carefully with a cloth and water, dry off.

All cables are insulated with a polymer material and can be damaged by abrassive chemicals. To clean the cables, miox soap or mild detergent with warm water, clean it with sponge or cloth and dry off.

5.3.3 Replacing drive cable

If drive cable requires replacement, it can be accomplished by a user or authorized service provider.

A replacement drive cable can be ordered from E-Z Lift or an authoriser local distributor, refer to **section 4.4** for contact information.

Replacement steps:

1. turn ON the lift
2. lower footrest to unfolded position
3. turn off the lift
4. remove used drive cable using side cutters
5. clean anchor points
6. feed new drive cable through the drive pulley, secure one end, feed via guide pulley and through the footrest achour point, secure the end to the footrest anchor point.
7. turn on the lift
8. using the remote, start lifting the footrest to create the tension in the system.

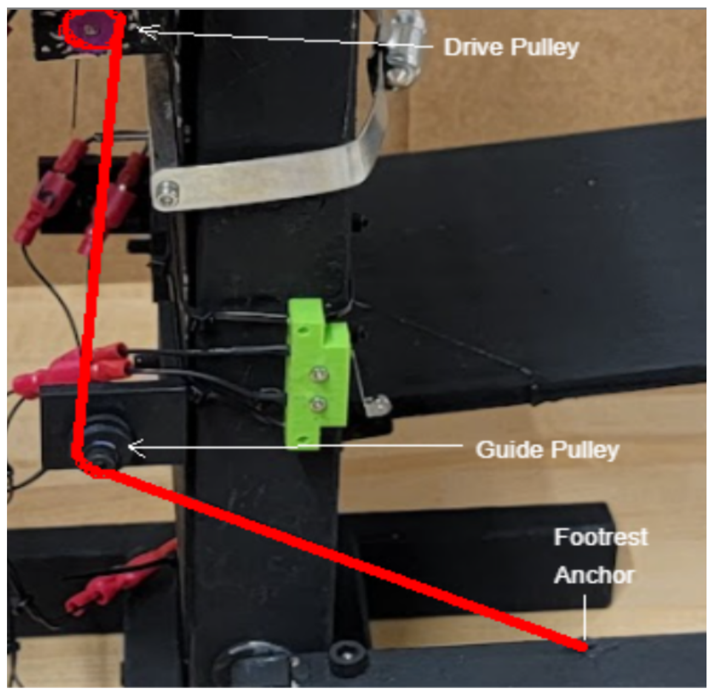


Figure 6: Drive cable

9. ensure that the cable is wound on the drive pulley.

Note: drive cable is highlighted in RED.

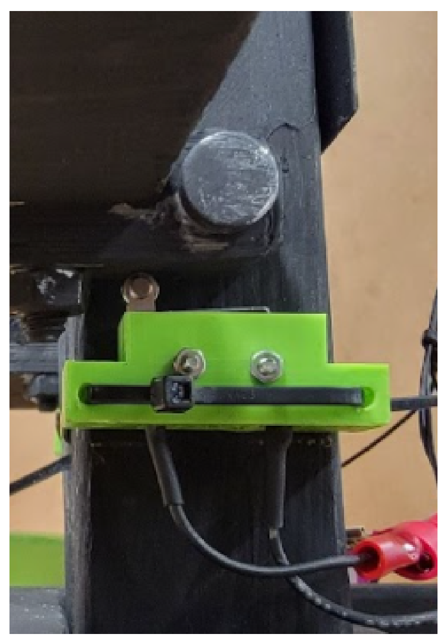
5.3.4 Adjusting limit switches

It is important to always have the limit switches properly calibrated so that the footrests are folded and unfolded fully to maximise user comfort.

Figure 7: Upper limit switch

Upper limit adjustments:

1. lossen mounting ties to allow free movement of the limit switch assembly
2. adjust to desired position
3. lift the footrest using the remote and verify that the footrest stops automatically when fully folded
4. tighten mounting ties to secure the limit switch assembly



Lower limit adjustments:

1. loosen mounting ties to allow free movement of the limit switch assembly
2. adjust to desired position
3. lower the footrest using the remote and verify that the footrest stops automatically when fully unfolded

4. tighten mounting ties to secure the limit switch assembly

Figure 8: Lower limit switch

5.4 Support

For any emergency, or in the case of fire or electrocution, please contact 911

For general assistance with E-Z Lift, please direct any questions or concerns to your support team at mseli086@uottawa.ca. You might be asked to provide a serial number or order number for the support team to provide assistance so please have this information ready for faster response. It is advised to contact the team before attempting any repairs. The support team will be able to properly assist you and maintain the warranty on the product.

For immediate assistance, contact out toll-free 24 hour help centre at 1-888-212-1212. Questions related to the immediate functionality or device failure can be directed to our help centre.

Any authorized wheelchair dealership can be contacted for immediate support as well such as "Motion", located in Ottawa, ON, Canada. They can be reached via email: contact@motioncares.ca or cell: 1-888-222-2172.

6 Product Documentation

As described under the problem statement, an automatic foot plate raiser was made to assist client in raising foot plates to ease client in day to day life function. 3 designs were initially selected to be turned into a functioning prototype from the brainstorming phase. The 1st idea was a total mechanical design including a crank lever which is attached to the foot plate to raise it by manually rotating the lever. The 2nd design was to use straps which would be tied to the footplate and pulling it would raise the foot plate. 3rd design which is a pulley system that is operated by a 12V dc motor attached to a fishing wire which is tied to the foot plate.

From the brainstorming phase 3rd design (pulley system) was finalised. This design includes a pulley system which is operated by a 12V DC motor and powered by a 12V battery which is wired to Arduino relays and Arduino UNO which has been coded so that it can be controlled using a user-friendly remote to lift and lower the foot plate.

Mechanical aspect of this prototype includes a stainless steel frame which holds 2; 12V dc motor and 2 guiding pulley frame which holds a fishing wire on which one end is attached to footplate and other to the motor pulley. 4 limit switches are used to detect the position of both foot plate; two for fully raised and other two for fully lowered. Limit switches are enclosed in a 3D printed cover to protect and also be used to tie on the desired location on a wheelchair. A controller box which includes: 12V battery, 8 channel relay and an Arduino Uno is tied under the wheelchair to protect the box and closer to the pulley mechanism to power it.

Figure 9: Stainless steel frame

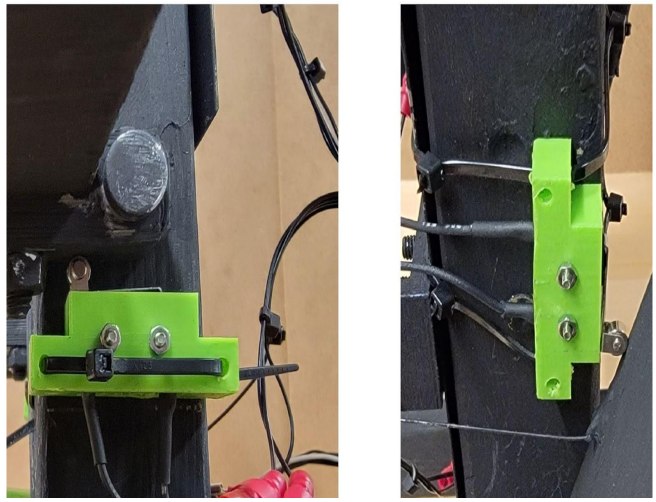


Figure 10: lower/upper limit switch frame

Electrical aspect of this prototype includes wiring of relays, battery, motor, limit switch and Arduino Uno itself. Here an electrical schematic diagram is used to explain how the wiring is done to protect the pulley mechanism. It can be seen that the prototype is fully modular which is indicated to be easy to troubleshoot and have less maintenance. The controller box contains 3 output connector plugs; 1st one goes to the remote, 2nd goes to the motor and 3rd goes to the limit switch.

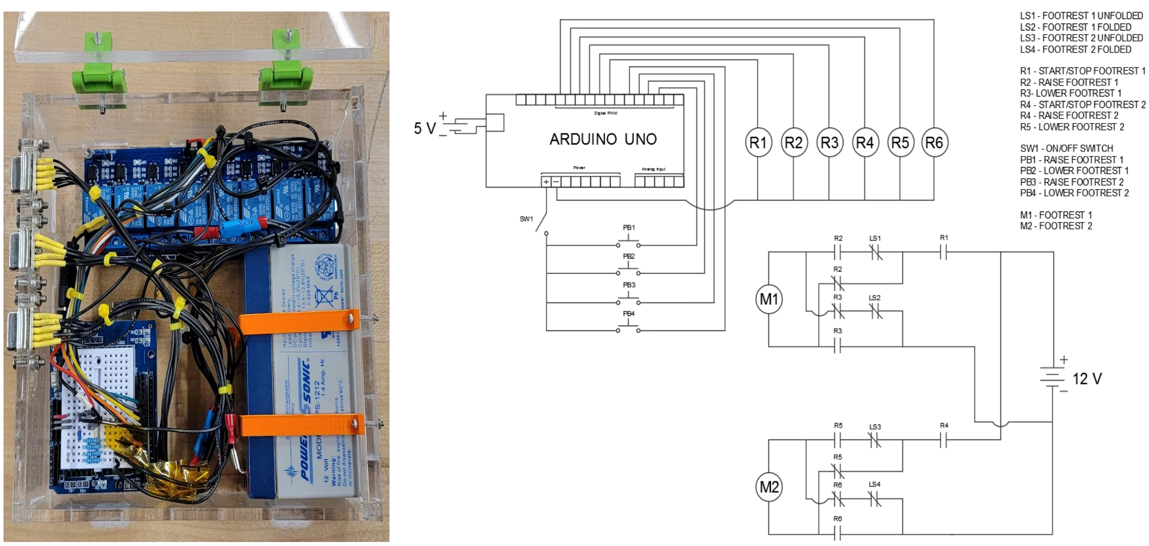


Figure 11: Wiring diagram

Arduino Uno is used to code for this pulley system which is attached under the appendix. The main function of the code is when the user presses the upper/lower button it raises/lowers the selected foot plate and makes sure that limit switch is not actuated for that footplate to over travel from its position. A power button is also present in the remote for turning on/off before using the mechanism.

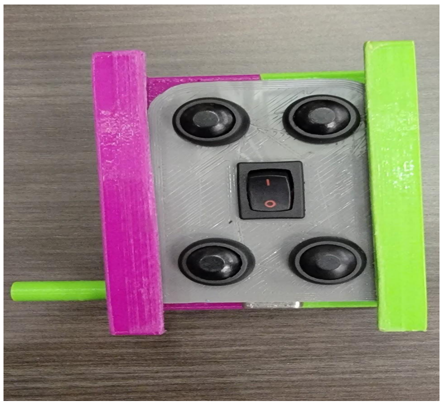


Figure 12: Remote with slider

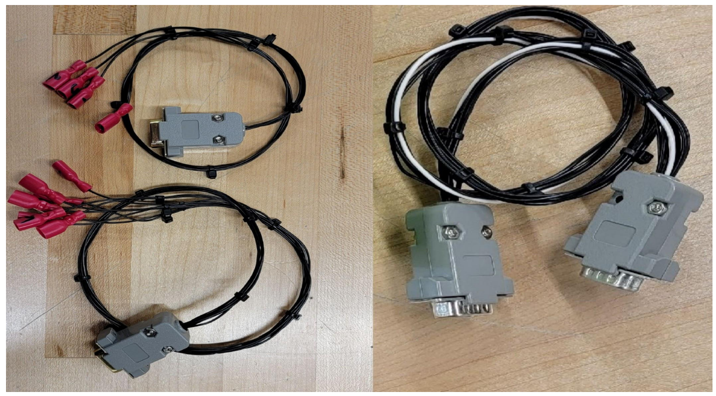


Figure 13: Cables

From the cost perspective 3D printed PLA material is used for limit switch cover, guiding pulley frame, remote, remote holder and pulleys. The PLA material is hard and has high endurance against the wheelchair vibrations and it's easy to customise and 3D print for low cost. Fishing wire is used on the footplate and is guided through the pulley due to its strength, flexibility and size. As initially a belt was considered to be used which is bulky in comparison to the fishing wire, also belts are hard to replace and are expensive while on the other hand fishing wire is low cost and durable.

6.1 Product Details & Equipments

6.1.1 BOM (Bill of Materials)

As seen from the table below it shows a detailed list of all the equipment that were bought for this prototype. The total cost for this prototype is $194.11 CAD. All the other equipment that were used were either 3D printed or manufactured in the machine shop.

Table 3: Bill of material

Bill of Materials					
Item #	Description	Quantity	Link	Unit Price	Amount (Inc. Tax)
1	Micro LimitSwitch	4	https://www.accessotronik.com/product_p/47-403-0_m256.htm	2.65	11.9
2	Push Button	4	https://edu-makerlab2021.odoo.com/shop/product/push-button-switch-81?search=waterproof+momentary#attr=147	0.71	2.84
3	Power Switch	1	https://www.accessotronik.com/product_p/46-102j-0_m256.htm	2.8	3.2
4	Arduino Uno	1	https://edu-makerlab2021.odoo.com/shop/product/arduino-5?search=arduino#attr=5	20	20
5	Arduino Relay	1	https://edu-makerlab2021.odoo.com/shop/product/relay-49?search=relay#attr=52	24	24

6	12V Battery	1	https://www.accessotronik.com/product_p/ps-1250-f2_p228.htm	26	29.4
7	22 AWG wire	1 (25ft)	https://www.accessotronik.com/product_p/8822-0_p176.htm?1=1&CartID=0	5.7	6.4
8	12V motor	2	https://www.amazon.ca/Torque-Turbo-Geared-Motor-100RPM/dp/B01M4K8A1B/ref=sr_1_5?keywords=12V%2Bdc%2Bmotor&qid=1636502126&sr=8-5&th=1	23.59	53.3
9	9-Pin-Connector-plug	8 (4M & 4F)	https://www.amazon.ca/Yosawa-Connectors-Connector-Assortment-Accessories/dp/B07JFJ5RYZ/	38.12	43.07
Total (CAD)					$194.11

6.1.2 Equipment list

For the following table below, it clearly shows all the equipment that were used for this prototype which were built from the 3D printer or manufactured in a machine shop. Link section is specifically shared to recreate the item as needed.

Table 4: Equipment

Item #	Description	Link	Manufactured
1	Remote	https://cad.onshape.com/documents/3df583843749b4b9cf726576/w/9bf8dc9949754ad0410cd2b4/e/f23423702ab28bdf6c19f90c?renderMode=0&uiState=61ad25103d0fd5454fd1d2a1	3D Printed
2	Remote Slider Cover	https://cad.onshape.com/documents/3df583843749b4b9cf726576/w/9bf8dc9949754ad0410cd2b4/e/f1277a07bfb9a10fbb353019?renderMode=0&uiState=61ad24d93d0fd5454fd1d27e	3D Printed
3	Limit Switch Cover	https://cad.onshape.com/documents/3df583843749b4b9cf726576/w/9bf8dc9949754ad0410cd2b4/e/68798549b3acb351d5c2013d?renderMode=0&uiState=61ad24a33d0fd5454fd1d25e	3D Printed
4	Guiding pulley face plate	https://cad.onshape.com/documents/3df583843749b4b9cf726576/w/9bf8dc9949754ad0410cd2b4/e/99f9165b9345ee6cea01a30b?renderMode=0&uiState=61ad24ec3d0fd5454fd1d28a	3D Printed
5	Motor face plate	https://cad.onshape.com/documents/3df583843749b4b9cf726576/w/9bf8dc9949754ad0410cd2b4/e/	Machine shop

		99f9165b9345ee6cea01a30b?renderMode=0&uiState=61ad24ec3d0fd5454fd1d28a	
6	Motor Pulley	https://cad.onshape.com/documents/3df583843749b4b9cf726576/w/9bf8dc9949754ad0410cd2b4/e/bbb720ca3b56f3a187778ad1?renderMode=0&uiState=61ad25873d0fd5454fd1d2d0	3D Printed
7	Guiding Pulley	https://cad.onshape.com/documents/3df583843749b4b9cf726576/w/9bf8dc9949754ad0410cd2b4/e/694e586f39437d5fbc2bb2c4?renderMode=0&uiState=61ad255a3d0fd5454fd1d2b4	3D Printed
8	Hinge	https://cad.onshape.com/documents/3df583843749b4b9cf726576/w/9bf8dc9949754ad0410cd2b4/e/d286e0f8c67a7daf0c16370a?renderMode=0&uiState=61ad25a13d0fd5454fd1d301	3D Printed
9	Controller Box-Acrylic	https://cad.onshape.com/documents/1921b9afefe96637e58de4a9/w/dc65d1fd2429fe0ae38b3f55/e/6cd56b14db54e5aa0ca4ff5c	Machine shop
10	Battery holder	https://cad.onshape.com/documents/3df583843749b4b9cf726576/w/9bf8dc9949754ad0410cd2b4/e/57c1ac349457df3583750750?renderMode=0&uiState=61ad25e13d0fd5454fd1d5df	3D Printed

6.1.3 Instructions

1. Manufacturing steel base plate that contains a bar attached to an adjustable hose clamp
2. Attaching motor face plate and guiding pulley face plate on the steel base plate
3. Inserting motor and guiding pulley
4. Attaching both motors on motor face plate
5. After following these 4 points, base plate is attached to the wheelchair
6. Tighten up adjustable hose clamp to secure base plate
7. Securing limit switches at desired position at fully raised and lowered footplates
8. Attaching fishing wire on foot plate and other end on the motor pulley
9. Attaching remote slider under the armrest of wheelchair by velcro straps or zip ties
10. Securing controller box under wheelchair
11. Attaching cables from controller box to limit switch, motor and remote control
12. Full prototype is now assembled and ready to use

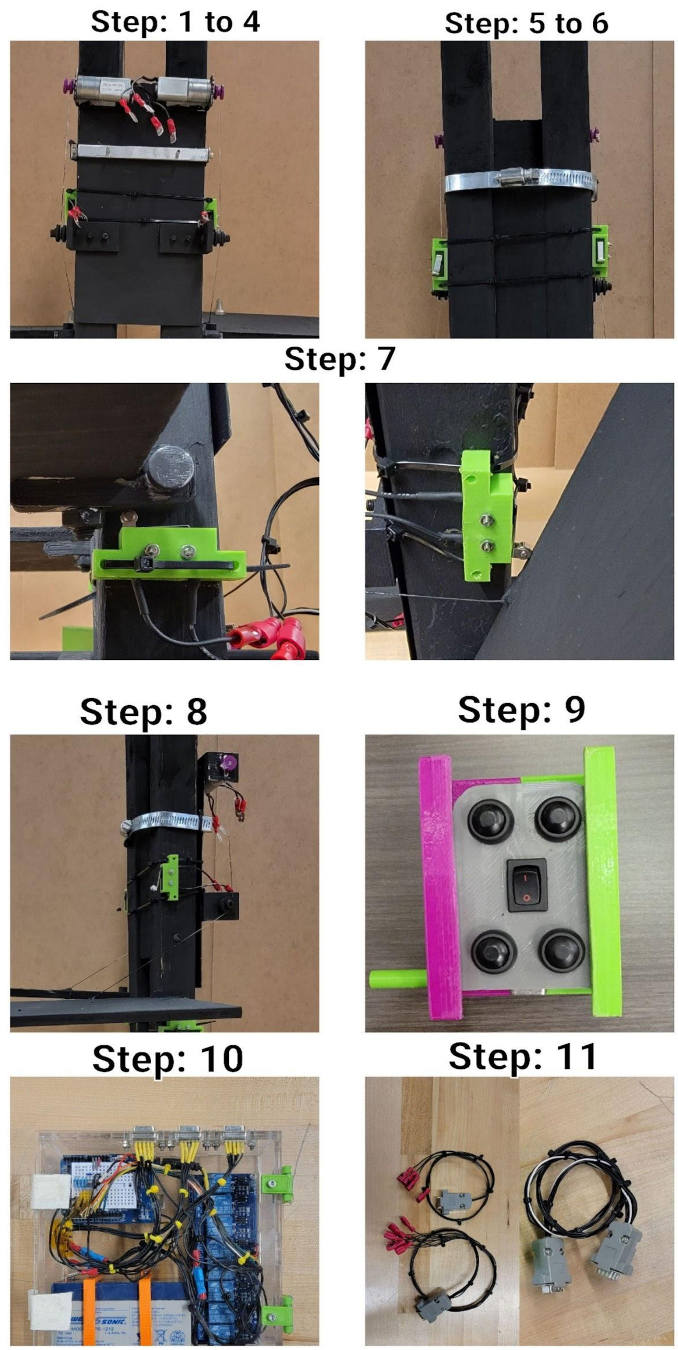


Figure 14: Assembly instructions

6.2 Testing & Validation

Due to time and financial constraints not many tests were performed but a limited number of tests were performed to check durability of the prototype. Calculations indicated in using a 100 RPM motor that it takes 3-4 sec to lift and lower the footplate which is safe compared to other higher RPM motors which can damage the components of the prototype.

$$\Sigma M_o = FD - mg(\frac{L}{2})$$

For the footplate to be able to move, we need to have a positive sum of moments about point A. Let's assume the length of the footplate is 9.5in (0.2413 meters) and that it weighs approximately 5lbs (2.27 kg).

We know that the distance that the footplate must cover is equal to the quarter of the circumference circle of radius L.

$$C = 2\pi r$$

$$\frac{C}{4} = \frac{\pi r}{2}$$

$$D = \frac{(0.2413m)\pi}{2}$$

$$D = 0.379 \text{ m}$$

Let's say we want the footplate to raise in 4 seconds. We know that the force is the product of the mass and the acceleration. To find the acceleration we use the following formula.

Average speed of the footplate:

$$v = \frac{D}{t}$$

$$v = \frac{0.379}{4}$$

$$v = 0.095 \text{ m/s}$$

Initial speed of the footplate= 0 m/s

Acceleration:

$a = \frac{v - v_o}{t}$

$a = \frac{0.095 - 0}{4}$

$a = 0.02369$ m/s²

$F = ma$

$F = 2.27 * 0.02369$

F = 0.05378 N

The vertical force required to lift the footplate in 4 seconds is approximately 0.054 Newtons.

We want a torque of 0.054 N.m to keep this time of 4 seconds.

The torque generated by the weight of the footplate is equal to:

$M_F = mg\frac{L}{2}$

$M_F = (2.27)(9.81)(0.12065)$

$M_F = 2.6867$ N.m

The final calculation to determine on how much time it takes to lift/lower the footplate:

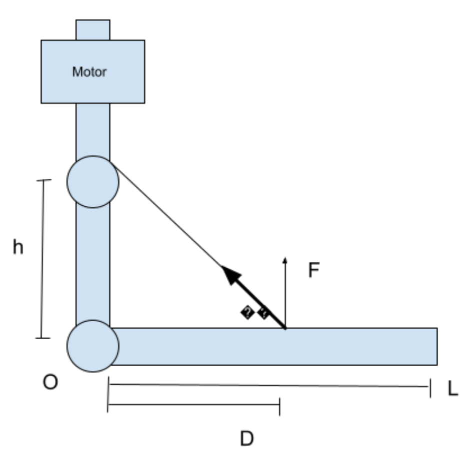


Figure 15: Free body diagram

$c = 2\Pi r = 2 * 3.14 * (0.250/2) = 0.785\ inches$

$F = \sqrt{h^2 + D^2} = \sqrt{3^2 + 3^2} = 4.24\ inches$

Motor = 100 RPM;

No. of rev. req= $4.24 * 0.785 = 3.33\ rev$

$\frac{100\ Rev}{60\ Sec} = \frac{3.33\ Rev}{x\ sec}; x = \frac{3.33 * 60}{100}\ sec; x = 2\ seconds$

The electrical and circuit testing aspect is explained below by showing calculations that were performed.

Power Consumption of the Control Unit (5 Vdc power source)

- 80 mA per Relay = 480 mA total
- Arduino Uno = 200 mA

$$P = V x I$$
$$I = 480\, mA + 200\, mA = 680\, mA = 0.68\, A$$
$$V = 5\, V$$
$$P = 5\, V\, x\, 0.68\, A = 3.4\ \text{W}$$

The system is designed around two motors that operate independently to actuate the pedals. Each motor has 3 designated relays:

- 2 relays control the polarity of the motor allowing forward and backward motion
- 1 relay is permissive and will initiate movement when all conditions are satisfied.

The operating conditions are:

- The power switch is ON
- The user must input the desired command
- The pedal must be in between set limits

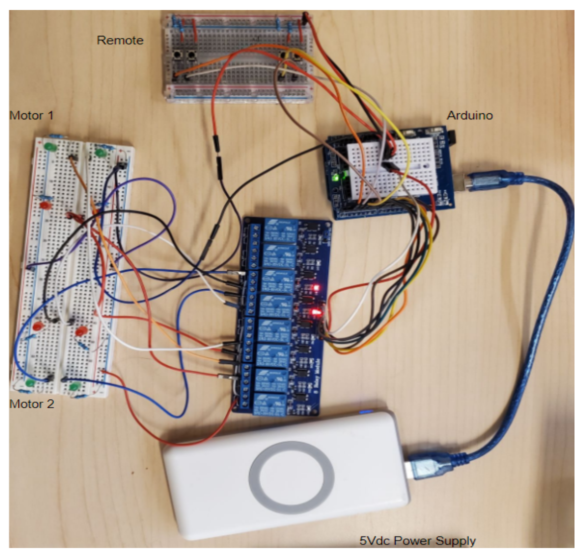


Figure 16: Test circuit

The test circuit is wired closely to the final product wiring diagram. The only difference is that the motors are represented by LEDs: Red - up, Green - down.

It was observed that all LEDs are OFF and they turn On only when one of the push buttons is pressed. The LEDs stay ON only when the pushbutton is held down which is a positive test for the push-to-run functionality. Arduino also displays what action is enabled via Serial Port. It is important to note that during testing, we discovered that if more than one pushbutton is pressed for each pedal, the Arduino only reads 1st signal received and does not induce any glitches.

7 Conclusions and Recommendations for Future Work

To conclude, our prototype has been a success in which we have managed to create an automated wheelchair footplate mechanism that can be removable, lightweight, and user friendly. We have learned that learning from mistakes and failure is a key to success. We wished to further develop the project by adding sensors to limit the footplate's movement, make the footplates withstand additional weight, reduce the size of the housing unit and use wheelchair power source instead of a battery for the lift system, have a force sensor to eliminate limit switches, and a stepper motor for a more accurate operation but due to the lack of time and limited budget , we were not able to develop the project as far as our ambitions. As for future work, we would like to add a feature to the footplate mechanism where it can be fully automatic without using any buttons or control panels when raising and lowering the footplates by adding sensors that can detect the feet distance to avoid the client from being hit by the footplates and a system that can consume less energy and have long-lasting battery life.

7 Bibliography

1. *Welcome to Permobil*. https://www.permobil.com/us/wp-content/uploads/2017/03/UM_US_M3_Corpus-2.pdf.
2. Team, The Arduino. “Button.” *Arduino*, https://www.arduino.cc/en/Tutorial/BuiltInExamples/Button.
3. “Arduino - Relay: Arduino Tutorial.” *Arduino Getting Started*, https://arduinogetstarted.com/tutorials/arduino-relay.

APPENDICES

1 APPENDIX I: Design Files

All documents and technical drawings are resented in **Section 6.1.2**

1.1 Makerrepo

https://makerepo.com/Samba058/1018.gng2101a12midnight-automation

2 APPENDIX II: Other Appendices

Arduino Code

```
int footrest1up=2;
int footrest1down=3;
int footrest2up=4;
int footrest2down=5;
int motor1=11;
int motor1cw1=10;
int motor1cw2=9;
int motor2=8;
int motor2cw1=7;
int motor2cw2=6;
int rightup, rightdown, leftup, leftdown;

void setup()
{
  Serial.begin(9600);
  pinMode(footrest1up, INPUT);
  pinMode(footrest1down, INPUT);
  pinMode(footrest2up, INPUT);
  pinMode(footrest2down, INPUT);
  pinMode(motor1cw1, OUTPUT);
  pinMode(motor1cw2, OUTPUT);
  pinMode(motor2cw1, OUTPUT);
  pinMode(motor2cw2, OUTPUT);
  pinMode(motor1, OUTPUT);
  pinMode(motor2, OUTPUT);
}
void motor1CW()
{
  digitalWrite(motor1cw1, HIGH);
  digitalWrite(motor1cw2, HIGH);
}

void motor1CCW()
```

```
{
  digitalWrite(motor1cw1, LOW);
  digitalWrite(motor1cw2, LOW);
}




void motor2CW()
{
  digitalWrite(motor2cw1, HIGH);
  digitalWrite(motor2cw2, HIGH);
}

void motor2CCW()
{
  digitalWrite(motor2cw1, LOW);
  digitalWrite(motor2cw2, LOW);
}
void inputs()
{
  rightup=digitalRead(footrest1up);
  rightdown=digitalRead(footrest1down);
  leftup=digitalRead(footrest2up);
  leftdown=digitalRead(footrest2down);
}

void loop()
{
 inputs();
 if (rightup==1 && rightdown==0)
 {
  Serial.print("\nRIGHT UP");
  delay(50);
  digitalWrite(motor1,LOW);
  motor1CW();
 }

 if (rightdown==1 && rightup==0)
 {
```

```
 Serial.print("\nRIGHT DOWN");
 delay(50);
 digitalWrite(motor1, LOW);
 motor1CCW();
}




if (leftup==1 && leftdown==0)
{
 Serial.print("\nLEFT UP");
 delay(50);
 digitalWrite(motor2, LOW);
 motor2CW();
}



if (leftdown==1 && leftup==0)
{
 Serial.print("\nLEFT DOWN");
 delay(50);
 digitalWrite(motor2, LOW);
 motor2CCW();
}

if(rightup==0 && rightdown==0)
{
Serial.print("\nRIGHT STOP");
delay(50);
digitalWrite(motor1, HIGH);
}

if(leftup==0 && leftdown==0)
{
Serial.print("\nLEFT STOP");
```

```
 delay(50);
 digitalWrite(motor2, HIGH);
 }
}
```