GNG2101

Design Project User and Product Manual

PEDAL LIFT MECHANISM

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Table of Contents

Table of Contents ii

List of Figures iv

List of Tables vi

List of Acronyms and Glossary vii

1 Introduction 1

2 Overview 2

2.1 Cautions & Warnings 2

3 Getting started 3

3.1 Set-up Considerations 3

3.2 User Access Considerations 3

4 Using the System 4

4.1 Pedal Lifting/Lowering 4

4.2 Turning off the Device 4

5 Troubleshooting & Support 5

5.1 3D Printed Part Failure 5

5.2 Electrical Component Failure 5

5.3 Support 5

6 Product Documentation 6

6.1 Mechanical Subsystem 6

6.1.1 Instructions 7

6.2 Electrical Subsystem 10

6.2.1 Instructions 10

6.3 Testing & Validation 13

6.3.1 Mechanical Subsystem 13

6.3.2 Electrical Subsystem 16

6.3.3 Prototype test objective 17

6.4 BOM (Bill of Materials) 19

6.5 Equipment list 20

7 Conclusions and Recommendations for Future Work 21

8 Bibliography 22

APPENDICES 23

8 APPENDIX I: Design Files 23

9 APPENDIX II: Other Appendices 24

List of Figures

Figure 1: Final prototype 2

Figure 2: Final Prototype 6

Figure 3: Upper bracket mounting... 7

Figure 4: Upper linear actuator mount installation 7

Figure 5: Lower linear actuator mount bracket... 8

Figure 6: Installed pedal clamps with acrylic 8

Figure 7: Installed pedal clamp.. 9

Figure 8: Installed linear actuator 9

Figure 9: Installed pedals 10

Figure 10: Installed wires... 10

Figure 11: Switch installed into lid 11

Figure 12: Wires aligned with the wire channel 11

Figure 13: Lid tightened to the box.. 12

Figure 14: Switch connected to battery 12

Figure 15: Wires connected from switch to linear actuator 13

Figure 16: Embedded armrest rail system 13

Figure 17: Wheelchair with various lengths [1] 14

Figure 18: Length of member between pedal pin and linear actuator 15

Figure 19: Force required to raise and lower pedals.. 16

Figure 20: Electrical Components 16

Figure 21: Linear Actuator with 10 lbs. Load Attached 17

Figure 22: Double pole double throw (DPDT) switch.. 18

Figure 23: Circuit diagram with and without ammeter... 18

List of Tables

Table 1: Acronyms vii

Table 2: Glossary vii

Table 3: Measured and approximated real dimensions of key distances on the wheelchair 14

Table 4: Loaded and unloaded linear actuator motion 19

Table 5: Bill of Materials 19

Table 6: Equipment List 20

Table 7: Referenced Documents 23

Table 8: List of Product Locations 24

List of Acronyms and Glossary

Table 1: Acronyms

Acronym	Definition
BOM	Bill of Materials
CAD	Computer Aided Design
DPDT	Double pole double throw
PLM	Pedal Lifting Mechanism

Table 2: Glossary

Term	Definition
Arduino	Type of microcontroller
Linear actuator	Device which extends and retracts in a straight-line using electricity
Micro-controller	Integrated circuit designed to run a specific set of commands
Raspberry Pi	Type of microcontroller

1 Introduction

This User and Product Manual outlines the information for technical and non-technical individuals to set up and operate the pedal lifting mechanism. The following design was made for a model that represents the client's chair. Many dimensions were assumed as there was no access to accurate dimensions of the client's chair. In the event the client would like to use the described design, accurate measurements would need to be taken of the client's chair so the design can be rescaled.

To protect the privacy of the client, any information regarding their identity has been omitted from this report.

2 Overview

This system is used to lift and lower the pedals on an electric wheelchair. Wheelchair users may experience discomfort reaching down to fold up or down the pedals on their wheelchair as it puts a decent strain on their backs while doing so. This device, unlike most of its kind, is electric, therefore completely removing the physical strain attached to lifting and lowering wheelchair pedals. The image below is of the most recent prototype.

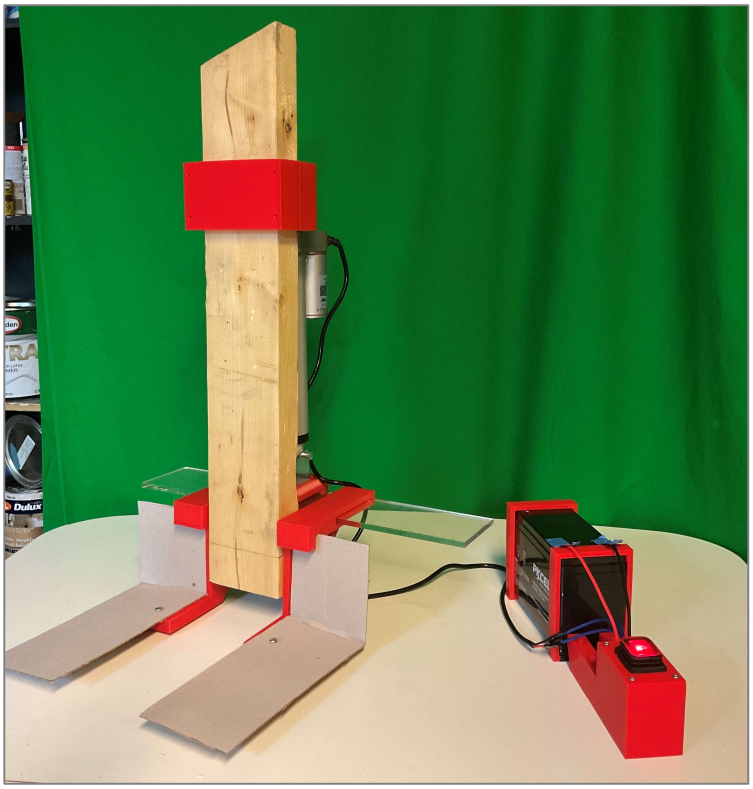

Figure 1: Final prototype

This system is comprised of a few major components working together to accomplish the task. The linear actuator is the most significant part of this system and is the component responsible for lifting and lowering the pedals. The switch on the right of the image above is responsible for controlling the power and direction of the linear actuator and is powered by the battery located behind it. All red components in this assembly are 3D printed.

2.1 Cautions & Warnings

When using the mechanism, ensure that nothing is in the way of the pedals while they are moving. This may add extra stress to the mechanism which may cause it to break as the PLM is only designed to withstand the weight of the pedals.

3 Getting started

With the footrests starting in the flat position, hold the back of the switch (side closest to the seat) until the footrests are completely vertical. Once the footrests are in place, sit in the chair and ensure that nothing is blocking the pedals (including legs). Hold the front of the switch (side closets to the pedals) until they are completely flat. With this design, the system is always on as such there is no on/off switch.

3.1 Set-up Considerations

It is recommended that the setup be done by a trained technician as any minor modifications made to the chair can void the warranty.

3.2 User Access Considerations

The system is designed to be accessible by users with a wide variety of disabilities. Once assembled the only limiting factor will be whether the user is able to press the button controlling the mechanism. Since the button is placed on the opposite arm rest to the controls, there should be no accessibility issues with the button.

Regardless of age or disability the designed system should be accessible to all.

4 Using the System

The following section describes the operation. The following sub-sections provide detailed, step-by-step instructions on how to use the various functions or features of the pedal lifting mechanism.

4.1 Pedal Lifting/Lowering

The lifting and lowering of the wheelchair's pedals is accomplished using the switch installed on the wheelchair. This switch has three positions: forward, center and backwards. In the center position, the pedals will not move. If the switch is pushed forward (away from the armrest), the pedals will lower, however if the pedals are already in their lowest position nothing will happen. If the switch is pressed backwards (towards the armrest), the pedals will raise, however if the pedals are raised completely, nothing will occur.

4.2 Turning off the Device

In the event the client would like to completely turn off the system, one must disconnect the wires connected to both battery terminals. This cuts off the current in the wires and in turn the whole system. It is recommended that the client contact a trained technician to turn off the device for them.

5 Troubleshooting & Support

Troubleshooting & support has been broken into two main categories; 3D printed part failure and electrical component failure as these are the two most common types of malfunctions with the PLM.

5.1 3D Printed Part Failure

The components most likely to break are the plastic pedal clips if something were to resist the motion of the pedals. In the event that one or both clips break, simply reprint the components using the appropriate CAD file from the MakerRepo, slide them onto the acrylic and reclip them to the pedal. The same applies with any other 3D printed components that fail; simply reprint them and reattach them.

5.2 Electrical Component Failure

In the event that one or more of the electrical components fails it is likely that if replaced the system will function as it did previously. These would include the battery and switch. If one or more of the wires needs to be replaced the circuit can easily be recreated with the schematics provided in **Error! Reference source not found.**.

5.3 Support

If assistance is required, it is recommended the service technician is contacted first. In the event a mechanical or electrical component is beyond basic repair, please contact Patrick Baril at pbari010@uottawa.ca as he has the necessary components available to make any repairs.

6 Product Documentation

This section of the document will go in detail on the mechanical and electrical construction of the prototype as well as the testing and validation of the components.

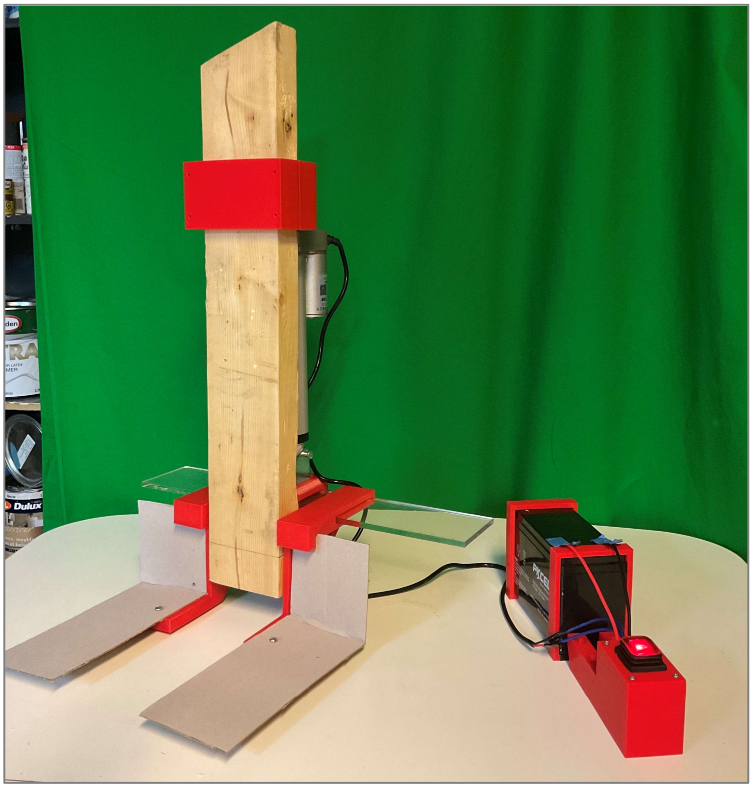

Figure 2: Final Prototype

6.1 Mechanical Subsystem

This final prototype is designed to fit and function around a two-by-four as the precise dimensions for the actual wheelchair are unknown. Some of the parts included are modified to fit this model. The upper linear actuator mount is made to fit the piece of lumber. The pedal clamps are modified such that they can be mounted to the wood directly rather than being mounted to the wheelchair's pedals as well as being shortened in width to lower its print time.

All red parts in the figure are 3D printed in PLA. This material was chosen because it is inexpensive, lightweight, and provides the necessary strength and weatherproof requirements. Aluminum or steel would also work; however, these materials would significantly increase costs and weight while providing more strength and potentially more durability. The two-by-four used to join all the parts together was there to mock the actual wheelchair's structure which connects the seat to the pedals. This material was used since its size seemed to be similar to the dimensions of what is found on the wheelchair. Wood is also easy to work with and facilitated the mounting of the various components used. The linear actuator chosen was of relatively low quality due to the cost of comparable ones of the same form factor.

Given the opportunity to measure the user's wheelchair, the parts may be modified to fit and work in accordance with the wheelchair.

6.1.1 Instructions

To put together this prototype, all 3D printed parts must be printed and ready to install along with the rest of the parts. Once everything is ready for assembly, the first step is to install one of the metal linear actuator brackets to the back of the upper linear actuator mount. This can be done by sliding the part down into the slot at the bottom of the part and then using two #4 – 1/2" screws to secure the part in place. The below figure shows what this looks like. Note that the images used to describe the assembly are taken with the assembly complete.

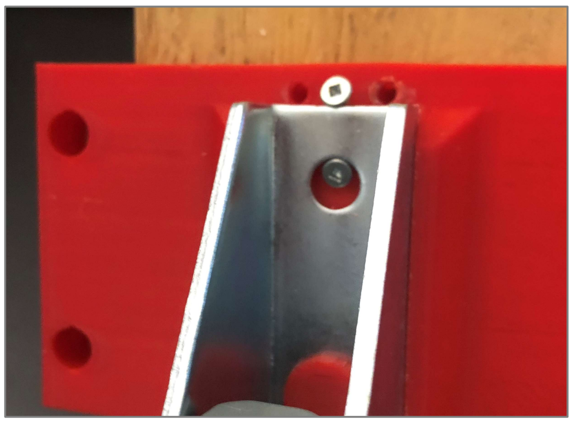

Figure 3: Upper bracket mounting

The next step is to install both parts of the upper linear actuator mounts to the two-by-four using four #8 – 1 ½" screws in their respective corners as shown in the image below. Do not tighten these screws too much as it is likely the upper mount's position will need to be modified.

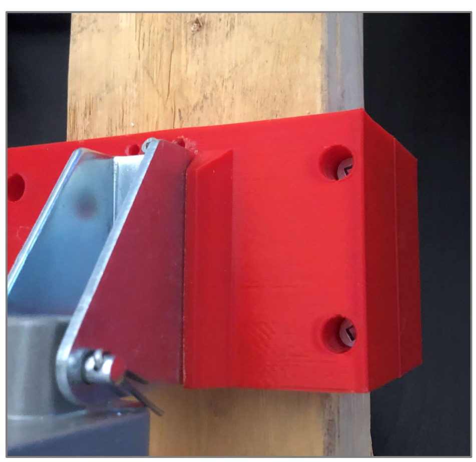

Figure 4: Upper linear actuator mount installation

The lower linear actuator mount can then be put together. This is done by sliding the metal bracket into the 3D printed part and then installing the part and bracket onto the acrylic using a #8 – ¾” screw as per the image below.

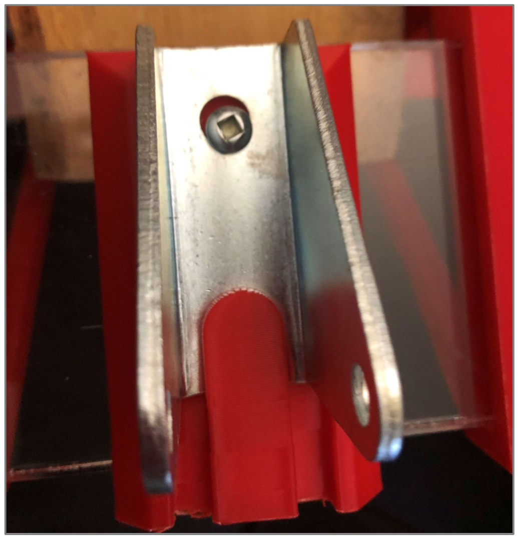

Figure 5: Lower linear actuator mount bracket

The next step is to install the pedal clamps to the two-by-four. This is done by marking and drilling two holes into the short sides of the two-by-four. This is done to ensure the axis at which the pedals rotate is concentric, facilitating their rotation in accordance with the rest of the system. Next, place the linear actuator into the upper bracket and mark the holes 3 inches below the lowest point of the linear actuator (the linear actuator must be fully retracted for this step). Install one of the pedal clamps using a #8 – 1 ½” screw ensuring there is a 5/16” washer in between the clamp and the wood. Once one of the pedal clamps is installed, the acrylic and lower linear actuator mount can then be installed by sliding the acrylic into the square hole of the pedal clamp. The other pedal clamp can then be installed ensuring the acrylic also passes through this part as well. The second pedal clamp can then be fastened using a #8 – 1 ½” screw ensuring there is a 5/16” washer in between the pedal clamp and the wood. See the two below figures.

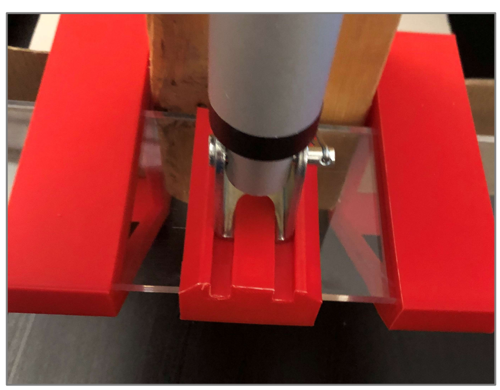

Figure 6: Installed pedal clamps with acrylic

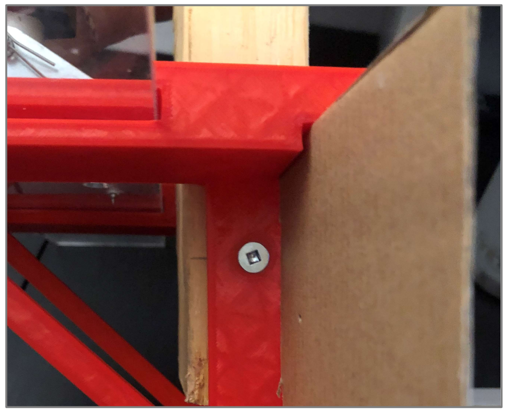

Figure 7: Installed pedal clamp

While the linear actuator is still fully retracted, while referring to the image below, position the linear actuator such that the pin holes of the linear actuator and metal brackets are aligned. Once they are aligned, put the pins into the pin holes and use cotter pins to ensure the pins do not fall out.

Figure 8: Installed linear actuator

Upon installing the linear actuator, slide the upper linear actuator mount such that the pedals are perpendicular to the wood. Once this is done, the screws holding the upper linear actuator mount can then be tightened. In this model, cardboard was used to mock the actual wheelchair pedals. they are not required, and their dimensions do not have to be very accurate. The image below shows what they should look like once they are installed. They use one screw per pedal to secure them into place.

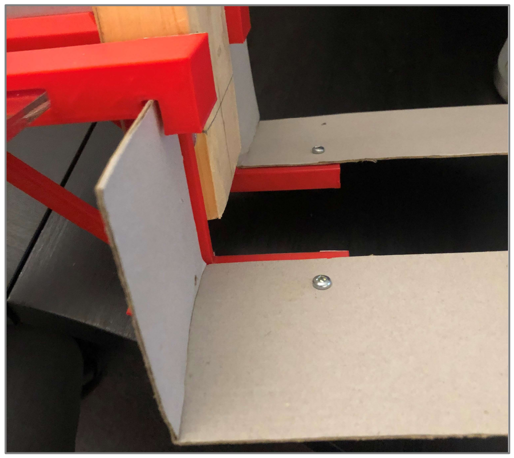

Figure 9: Installed pedals

6.2 Electrical Subsystem

Unlike the mechanical system, the electrical system is likely not to change as a result of getting the measurements of the wheelchair. This system is comprised of only 4 components, these are the Switch, battery, linear actuator, and the wires.

Due to the nature of the linear actuator, a microcontroller (i.e., Arduino, Raspberry Pi, etc.) is not required to control the actuator's motion. The linear actuator can simply be controlled using a DPDT switch, inverting the direction of DC current depending on the position of the switch. This greatly reduces the cost and complexity of the system. The power is routed from the battery to the switch and finally to the linear actuator. The following is the set of instructions used to assemble the electrical system used in the final prototype.

6.2.1 Instructions

It is recommended to use the wires supplied with the switch and insert them into the switch as per the image below.

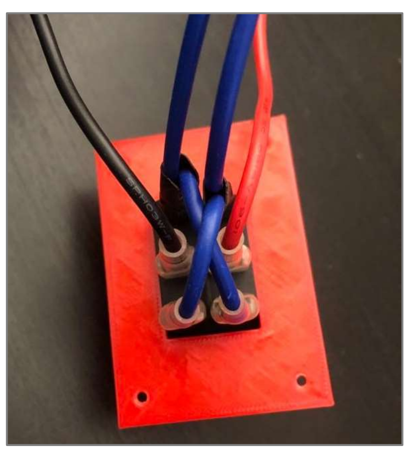

Figure 10: Installed wires

Once the wires are placed into the switch, the switch can then be inserted into the switch box's lid as per the figure below. The wires should be fed through the hole and the switch should snap into place. Its orientation does not matter.

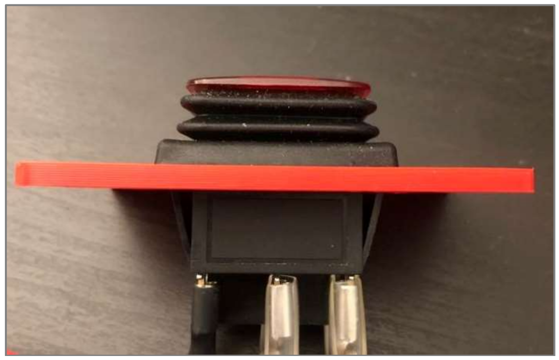

Figure 11: Switch installed into lid

The switchbox lid can then be installed onto the switchbox using four screws. Before tightening the #4 - 1/2" screws. The wires must be placed in their respective channel to ensure they do not interfere with the lid's ability to close properly.

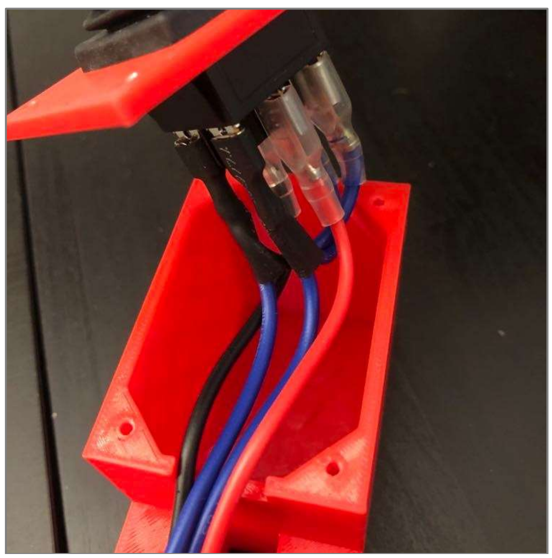

Figure 12: Wires aligned with the wire channel

Once the wires are aligned, the #4 - 1/2" screws can then be inserted and be used to tighten the lid to the rest of the box.

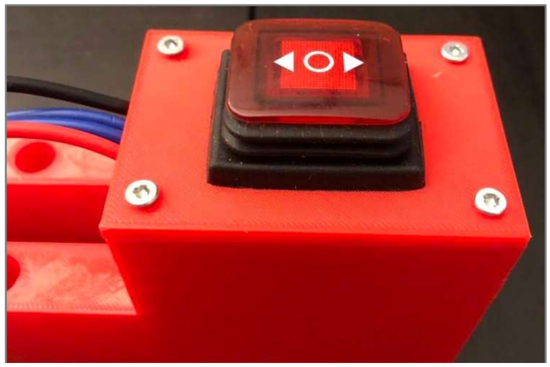

Figure 13: Lid tightened to the box

The red and black leads from the switch box can then be connected to the battery. This prototype does not use solder to make connections as it is not intended to be a permanent solution. The wires were loosely connected to the battery and covered using tape to ensure the leads stay connected.

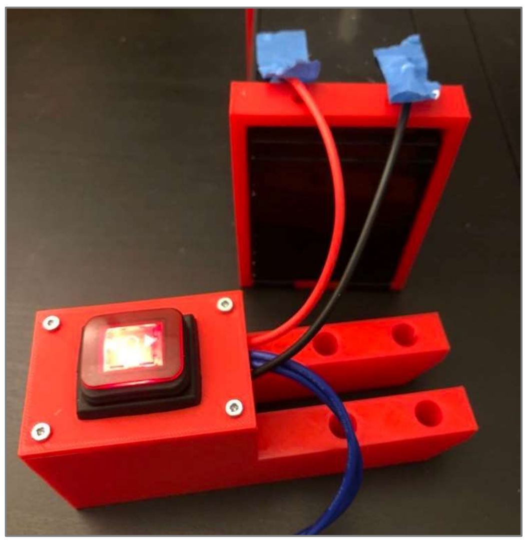

Figure 14: Switch connected to battery

The blue wires from the switch box can then be connected to the leads from the linear actuator. The orientation of the wires only affects the direction of the DC current given a specific switch direction; these wires can be connected in the user's preferred orientation (i.e., "I want the linear actuator to extend when I push the switch in this direction"). The wires are folded together and wrapped in electrical tape to prevent shocks and shorting.

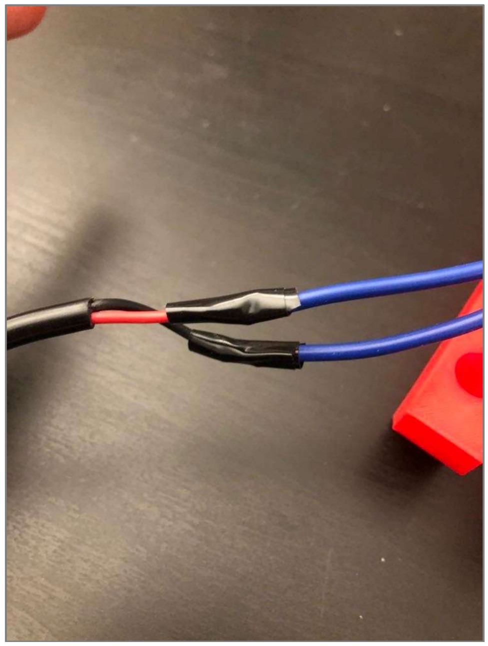

Figure 15: Wires connected from switch to linear actuator

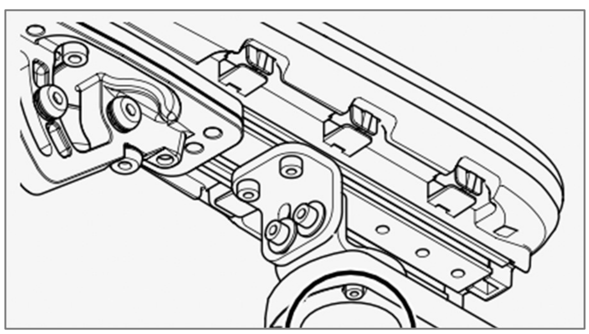

Figure 16: Embedded armrest rail system

6.3 Testing & Validation

This section encompasses the testing of the components as well as necessary calculations and measurements made which were used to further the project.

6.3.1 Mechanical Subsystem

$$Scale = L/L'$$

Where,

L (true length of wheelchair) = 1016 mm
L' (measured length of wheelchair) = 240 mm

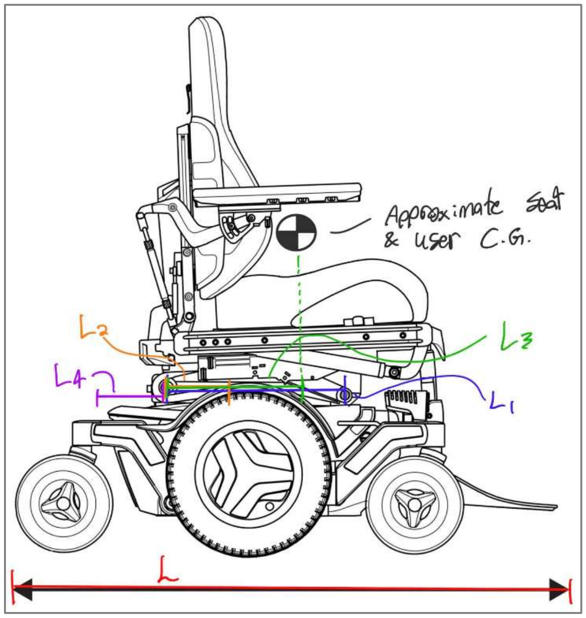

Figure 17: Wheelchair with various lengths [1]

Using this scale, any measurements taken on screen could be scaled up to approximate the real distances of said measurements. The table below shows the various measurements taken as well as their scaled approximate real values. L is the total length of the wheelchair; this real value is given and was used to create the scale as per the sample equation above. L1 is the approximate distance between the slider pin in its rear-most position and the reclining piston. L2 is the approximate length of the slider. L3 is the approximate horizontal distance between the slider pin in its rear-most position and the center of gravity of the user and chair combined [2]. L4 is the approximate distance between the pin in its rear-most position and the approximate location of the spring. These distances will be used to find an appropriate spot for the battery to be mounted.

Table 3: Measured and approximated real dimensions of key distances on the wheelchair

Length ID	Screen measurement (mm)	Approximated real distance (mm)	Approximated real distance (in)
L	240	1016	40
L1	80	339	13.35
L2	30	127	5

L3	35	148.2	5.83
L4	30	127	5

The following calculation was done to find the length of the member between the pedal pin and the linear actuator. This value was calculated assuming the pedal would be rotating 90º between its raised and lowered positions as well as for a stroke of 4”.

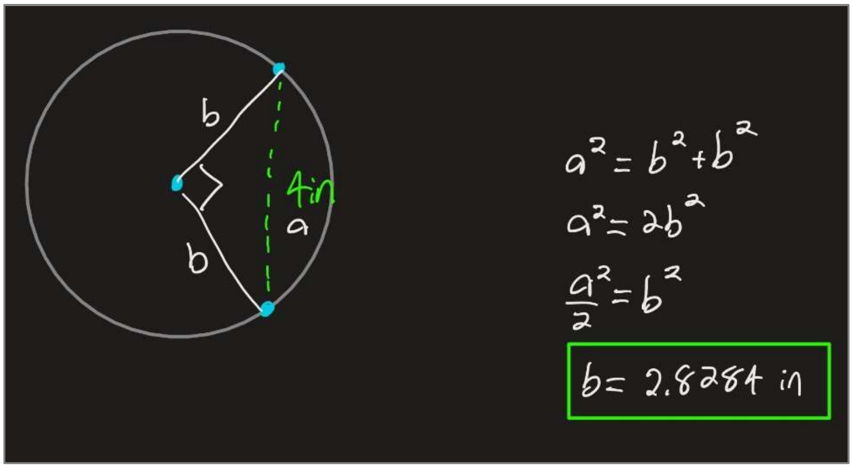

Figure 18: Length of member between pedal pin and linear actuator

The image below is a sample calculation which was used to find the required force to move the pedals. It is estimated that the required force to pull up each pedal is about 3 lbs. This would add up to 6 lbs. as a combined load, though a value of 10 lbs. was used to be conservative. Due to not having access to real measurements, the length of the pedal was estimated to be 12” from the end to the pin from which they rotate. Using the length b from the calculation above, the estimated required force to move the pedals is roughly 45 lbs., conservatively.

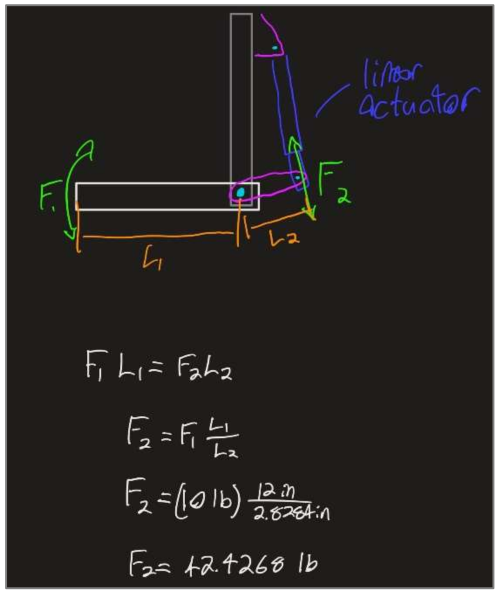

Figure 19: Force required to raise and lower pedals

6.3.2 Electrical Subsystem

The following section focuses on testing the electrical system of the product.

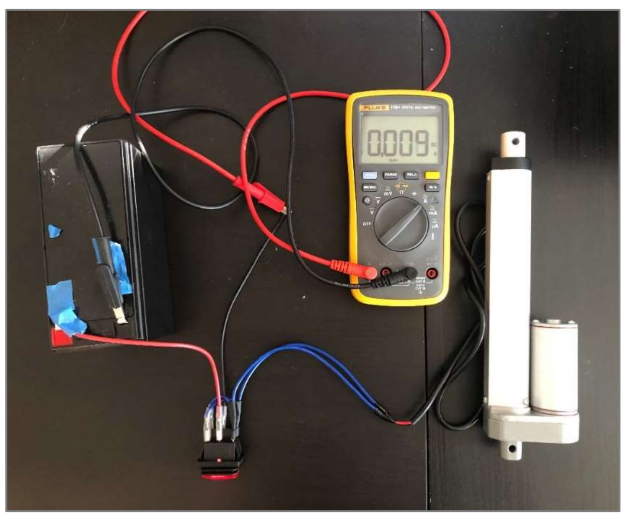

Figure 20: Electrical Components

Figure 21: Linear Actuator with 10 lbs. Load Attached

To accurately test how the actuator would behave under the estimated load of the pedals, a 10lb weight was secured to the actuator with rope. The results found are displayed in table 2.

6.3.3 Prototype test objective

The main goal of this prototype is to communicate and show the client a visual demonstration of how the electronic system of the pedal lift will work. The prototype's results and feedback will determine how the group will adjust/customize the wiring to better improve the final product.

6.3.3.1 Testing Plans

The prototype used in this test is a wiring schematic of the final product. The prototype needs to have the basic requirements that the team identified in the previous deliverable. The prototype will use the linear actuator, the wires, and the battery used to build the final product.

6.3.3.2 Results Summary

Confirm all electronic components such as the linear actuator, the switch, and the battery all work together.

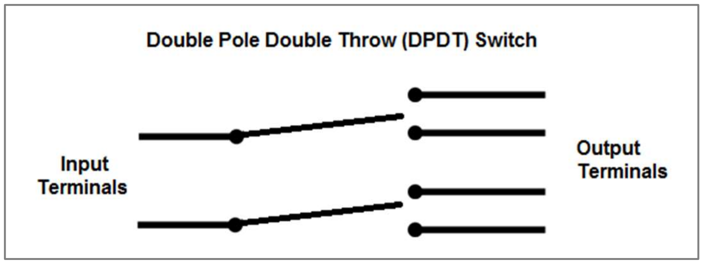

Figure 22: Double pole double throw (DPDT) switch

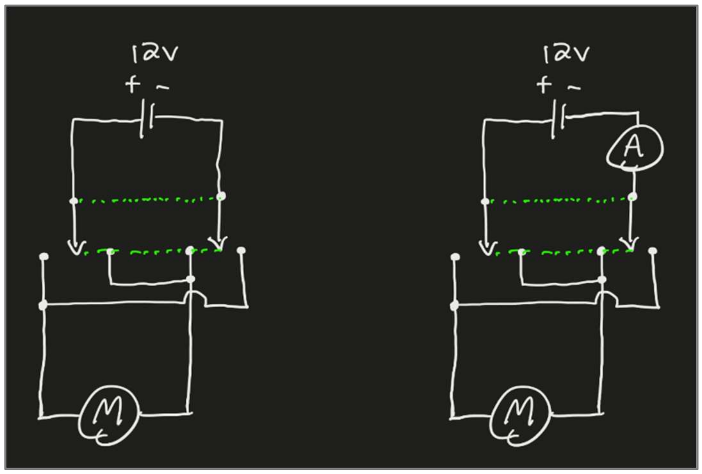

Figure 23: Circuit diagram with and without ammeter

*Note: The green dotted lines indicate a mechanical connection; the switches will always switch synchronously. When a switch orientation is changed it inverts the direction of current.

- Measure the speed of the actuator, and act accordingly. If the actuator is too fast, use a microcontroller to control the speed.
    - Upon testing, the actuator's speed was 0.97 mm/s which is reasonable for lifting the pedals slowly, without breaking anything or causing any sort of injury to anyone in the vicinity of the wheelchair. Since the speed is slow there is no need to include a microcontroller into our design.

- Measure the amperage draw, and act accordingly. The amperage was decreasing with every run, which might indicate that the battery was dying, or that the lubricant within the linear actuator is spreading around and reducing friction within its mechanism.
    - The voltage of the battery was still at its rated voltage, indicating that the battery was not drained.

Table 4: Loaded and unloaded linear actuator motion

	Load Applied (10 lb.)	Without load
Travel Time (s)	20 down. 16 up	15.5 both ways
Distance (mm)	15	15
Current Draw (mA)	1100-760	770
Speed (mm/s)	0.75	0.97

*Results collected with the linear actuator in a vertical orientation under a load of 10lb.

This test determined that all the components work together as intended. The multimeter found 770mA was drawn while the actuator was in motion as seen in figure 1. When a load of 10lb was applied to the actuator a current draw of 1.1A was initially found, then reduced to 760mA once the actuator was in motion. The 10lb load was chosen because it represents roughly the mass as both foot pedals. The travel time was estimated using a stopwatch.

As seen in figure 1, the button draws a constant 9mA due to the led. This current draw is very low and should not cause too much drain on the battery.

6.4 BOM (Bill of Materials)

The below is a table of the bill of materials.

Table 5: Bill of Materials

Material	Place	Cost per unit	Number of units	Total cost (CAD)
Linear Actuator	Amazon	$67.39	1	$67.39
3 Pin Button Switch	Amazon	$16.99	1	$16.99
12V-5Ah Battery	MakerLab	$1.00	1	$1.00
3D Printer Filament	MakerSpace	$0.00	0	$0.00
22awg Electric Wire (5ft)	MakerLab	$2.50	2	$5.00
Scrap Acrylic	MakerSpace	$0.00	1	$0.00
#4 – ½” screw(s)	Patrick’s	$0.00	6	$0.00
#8 – 3/4” screw(s)	Patrick’s	$0.00	3	$0.00

#8 – 1 ½” screw(s)	Patrick’s	$0.00	6	$0.00
5/16” Washers	Patrick’s	$0.00	2	$0.00
*Tax not included in price **Links for the products in the bill of materials are found in appendix II.			**NET COST:**	**$90.38**

6.5 Equipment list

The below is the equipment list used to manufacture and assemble the PLM.

Table 6: Equipment List

Equipment	Use
3D Printer	Used to print many components of the PLM such as the pedal clips
Laser Cutter	Used to cut the acrylic to the correct size
Hand Drill	Used to drill holes into various components of the PLM

7 Conclusions and Recommendations for Future Work

With additional time to work on the project, proper dimensions would be obtained, and the parts created would be able to properly integrate with the client's chair. Proper dimensions were unable to be obtained because the team was unable to examine the wheelchair in person or contact the manufacturers about the dimensions of the wheelchair.

With accurate dimensions, the parts would be sized correctly to the user's wheelchair. For the components of the PLM, a box would be created to house the battery compared to the clips currently made to provide additional protection of the battery from the elements and to better protect the electric poles. Additionally, the acrylic piece would be changed as currently there is a PLA part that attaches the acrylic piece to the linear actuator. Thus, changing the acrylic piece would remove the need of the 3D printed part and simplify the system.

8 Bibliography

[1] Permobil, "M3 Corpus user manual," 09 07 2020. [Online]. Available: https://www.permobil.com/us/wp-content/uploads/2020/08/M3_Corpus-User_manual-eng-US-v1-337261.pdf. [Accessed 28 9 2021].

[2] "Determination of centers of gravity of man," 08 1968. [Online]. Available: https://www.faa.gov/data_research/research/med_humanfacs/oamtechreports/1960s/media/AM62-14.pdf. [Accessed 3 10 2021].

APPENDICES

8 APPENDIX I: Design Files

Table 7: Referenced Documents

Document Name	Document Location and/or URL	Issuance Date
PDB	https://makerepo.com/Hghannoum/1041.the-pedal-lifters-b11	Sept 23, 2021
PDC	https://makerepo.com/Hghannoum/1041.the-pedal-lifters-b11	Sept 30, 2021
PDD	https://makerepo.com/Hghannoum/1041.the-pedal-lifters-b11	Oct 7, 2021
PDE	https://makerepo.com/Hghannoum/1041.the-pedal-lifters-b11	Oct 13, 2021
PDF	https://makerepo.com/Hghannoum/1041.the-pedal-lifters-b11	Nov 11, 2021

9 APPENDIX II: Other Appendices

Table 8: List of Product Locations

Product	Product Location and/or URL
Linear Actuator	https://www.amazon.ca/gp/product/B07TKXQ5H1/ref=ppx_yo_dt_b_asin_title_o00_s00?ie=UTF8&psc=1
3 Pin Button Switch	https://www.amazon.ca/Twidec-Momentary-Miniature-Waterproof-MTS-123-MZ/dp/B07VR93FS1/ref=mp_s_a_1_17?keywords=3+pin+switch&sr=8-17
12V-7Ah Battery	https://edu-makerlab2021.odoo.com/shop/product/battery-90#attr=158
22awg Electric Wire (5ft)	https://edu-makerlab2021.odoo.com/shop/product/wire-5ft-45?category=9#attr=213,217
#4-½" screw	https://www.mcmaster.com/91771A110/
#8-¾" screw	https://www.mcmaster.com/91771A197/
#8-1 ½" screw	https://www.mcmaster.com/91771A203/
5/16" washer	https://www.mcmaster.com/92141A030/

*For the screws and washer the URLs are to similar items used but it may or may not be exactly the same as they were not bought from any source