GNG2101 Deliverable I

Design Project User and Product Manual

e-Walker : One Handed Walker Brake System

Submitted by

GNG 2101 Lab Section Z2, Team Z7

Mohammad Ahsan Akhlaque, 8683392

Meghan Brown, 300039235

Wyse Ebbah, 300141935

Christopher Godwin, 8951529

Sandeep Sinha, 300166121

Victor Mercanti, 300005537

July 25, 2021

University of Ottawa

Table of Contents

List of Figures

List of Tables

List of Acronyms and Glossary

Table 1. Acronyms

Acronym	Definition
E.g.	for example
FSR	Force Sensing Resistor or Force Sensor
UPM	User and Product Manual

Table 2. Glossary

Term	Acronym	Definition
Force Sensor	FSR	A force sensing resistor (FSR) is a device used to sense changes in resistance by applying a load, force, weight or through compression. The FSR converts mechanical energy to an electrical output signal.
Servo Winch Wheel	SWW	A servo winch wheel is a device that is used to pull parts with precise control, acceleration and accuracy. Due to the accuracy of servo winch wheels, they are used in most robotic applications.
Brake Cable Splitter	BCS	The brake splitter connects multiple wire cables from different ends. Using the concept of tension, it can allow the pulling of wire cables from one end and the subsequent pulling of wire cable on the other end.

1 Introduction

This User and Product Manual (UPM) provides the information necessary for the user to effectively use the one handed walker brake system and will provide the necessary prototype documentation. The document is divided into seven parts: this introduction, overview of the project and conventions, system setup and organization, the usage of the system, troubleshooting the system, product documentation and a conclusion. The purpose of this document is to familiarize users with the setup, maintenance, use, and error maintenance of the walker brake system and give adequate technical information for reproduction and understanding the mechanics of the system. This document is aimed at the users of the walker braking system as well as the technicians who may want to understand, reproduce, or improve on this one handed walker brake system.

2 Overview

The project is tackling the following problem: The clients require a safe, universal braking system to stop the motion of a walker gradually while using minimal grip strength and a single user interface. The brake system needs to be waterproof and foldable without altering the structural integrity of the walker which creates an unsafe condition for the client. The main difference between our product and standard walker brakes are that ours is optimized for one handed functionality and clients with a lower force threshold.

The brake product is better than the existing ones because it incorporates technology to make the walker come to a stop. The one-hand electrical component ensures that lower force is needed to engage the brakes. There's also a fail safe mechanism served by the mechanical component if the electrical component fails to work at any point. So, the user can engage both brakes simultaneously using 1 hand with either the electrical or the mechanical component. Even with all the technology, the walker can be easily folded so that it fits in the user's car.

The picture of the final prototype is shown below in Figure 1.

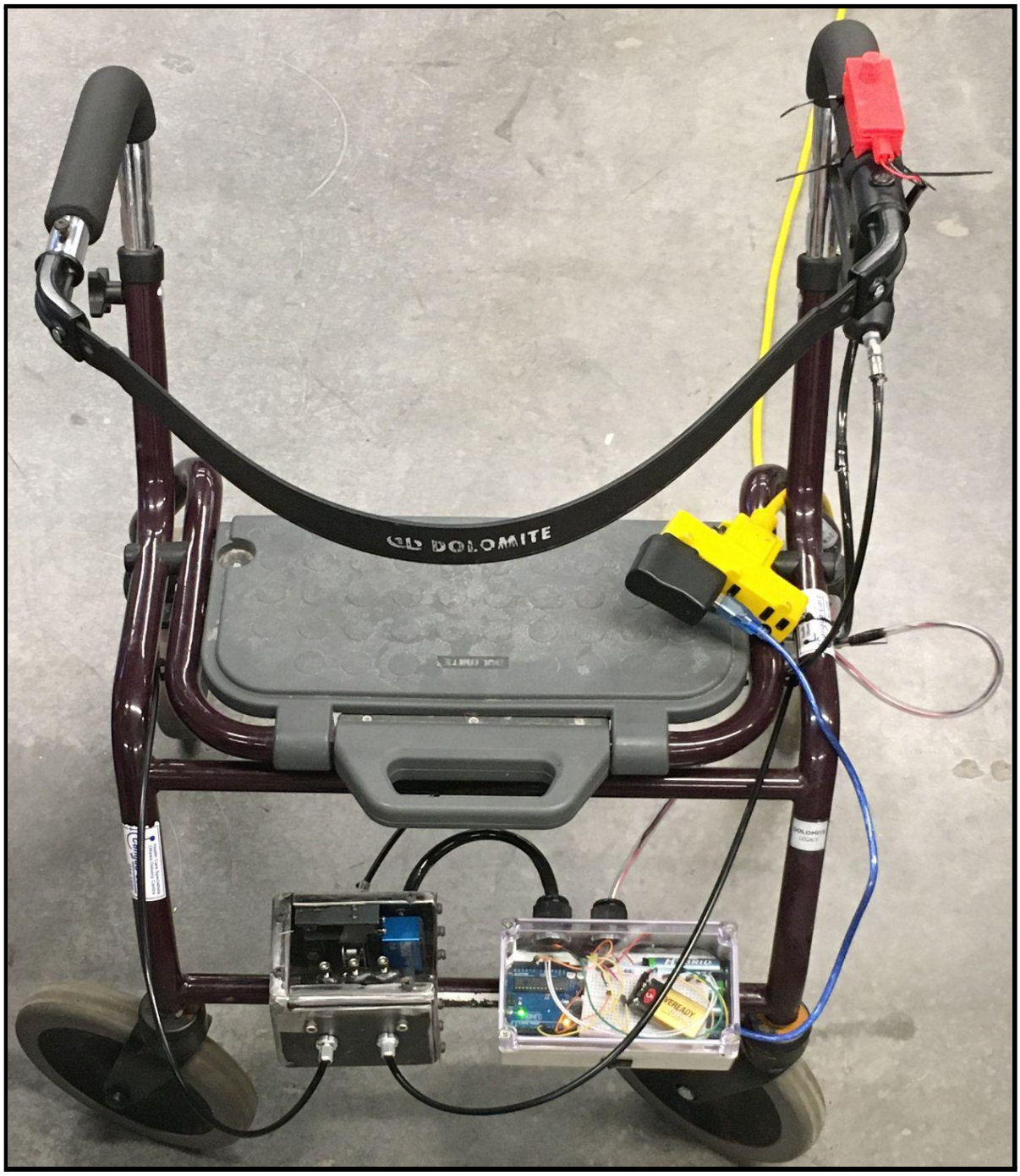
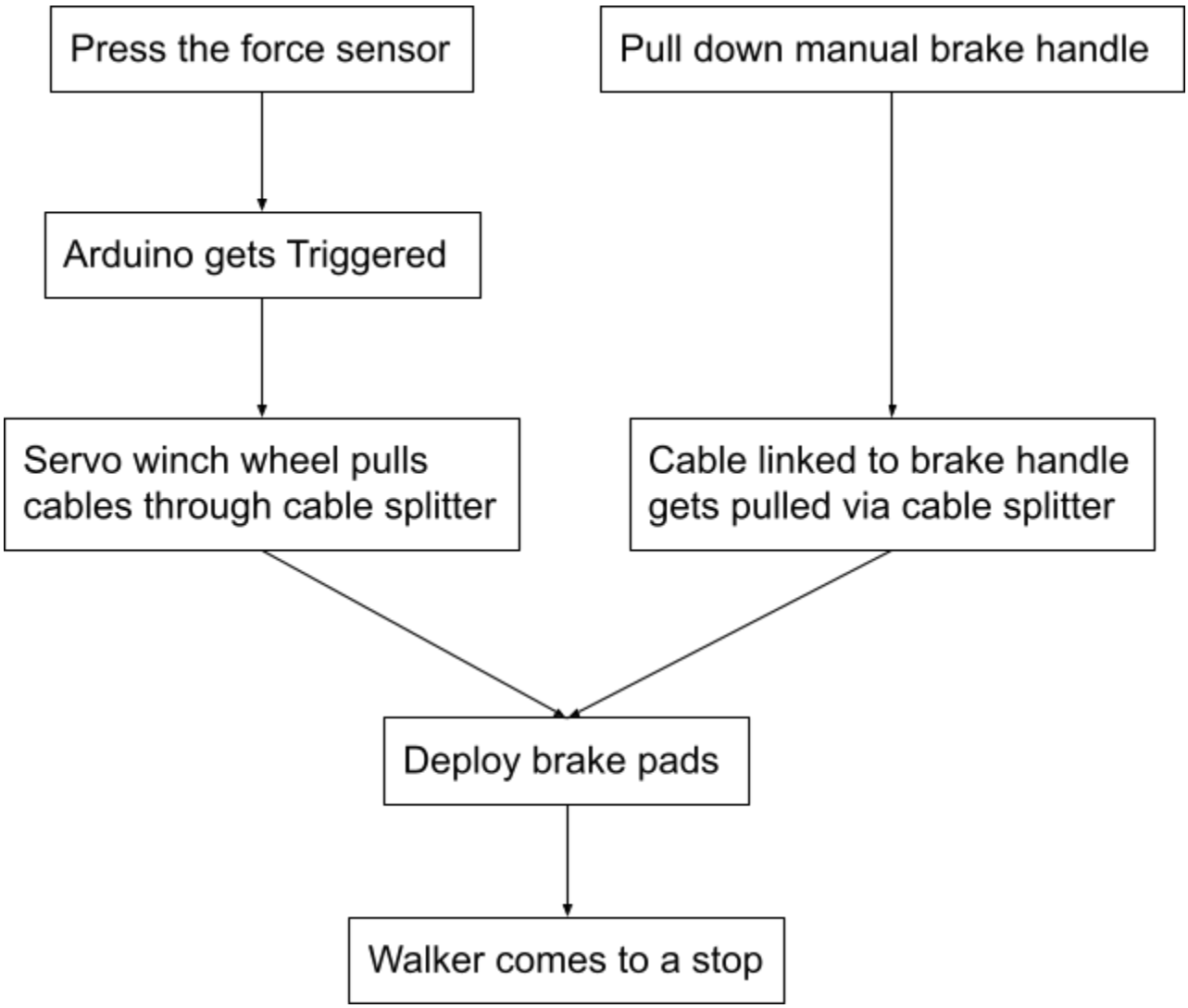


Figure 1 - Final Prototype of Walker Brake System

The product is composed of three major components. A *brake lever handle* which features a button connected to a *force sensor*. The force sensor detects an incident force from the amount of pressure applied to the button by the user. The second part is the *arduino controller* which is the processing part of the system that receives the information, change in resistance, from the force sensor and activates a servo motor, contained in the cable splitter, to pull on two separate brake cables. The last part is the *cable splitter* that connects both a manual brake cable from the brake lever and a separate brake cable attached to a servo motor winch wheel. When either the manual lever is pulled or the force sensor is pressed, the incoming cable will pull on the cable connector which is attached two cables heading to each brake pad. Together these parts cause the walker to brake safely from the activation of only one part.

Block Diagram

Below is a block diagram outlining the procedure in simple blocks.



2.1 Cautions & Warnings

- DO NOT operate this system until this document has been fully read and understood.
- DO NOT exceed the weight capacity of the existing walker.
- DO NOT sit on the walker on an incline.
- DO NOT modify or adjust any brake cable tension without proper guidance from a trained technician certified to work on walkers.
- Periodically check brake handle adjustment screws and adjustment screws on brake splitter for tightness.
- Prior to use ALWAYS VISUALLY INSPECT AND TEST brake functionality by activating the force sensor, manual brake handle lever and parking brake lever to ensure proper functionality prior to each use.
- Prior to use ensure that the battery is adequately charged and that a spare battery is available in the case that the battery charge is fully used during operation.
- ENSURE that the power button located on the electronic enclosure is turned on and the light on the Arduino board lights up prior to use.
- PLEASE REFER to the Walker manufacturer's Safety Warning instructions for all other safe operating procedures.

FAILURE TO FOLLOW THESE INSTRUCTIONS CAN LEAD TO SERIOUS INJURIES OR DEATH.

ANY MISUSE OF THE WALKER THAT DAMAGES THE STRUCTURAL INTEGRITY OF THE WALKER COULD VOID THE MANUFACTURER'S WARRANTY. PLEASE CONTACT THE WALKER MANUFACTURE PRIOR TO INSTALLING THIS BRAKING DEVICE.

3 Getting started

This walker brake system is a conversion kit that can be installed on your existing walker. This new and innovative walker conversion kit allows your existing walker to brake both wheels simultaneously by using only one hand.

Electrical Activation of the Brakes Walkthrough

1. This braking is automated by pressing on the force sensor located on the walker's handles.

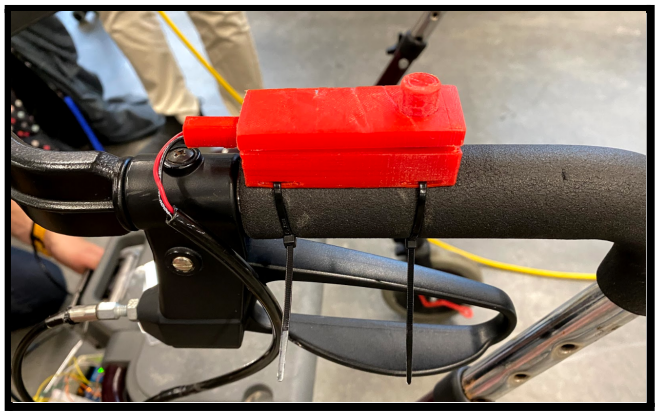


Figure 2 - Force sensor

2. The force sensor electronically sends a signal to the arduino board in the waterproof box.

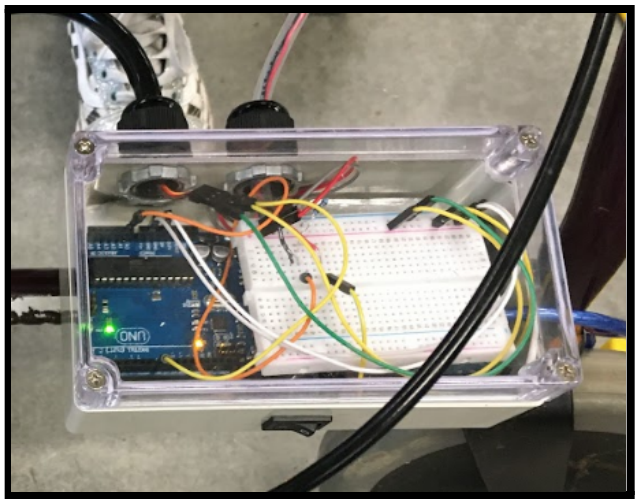


Figure 3 - Arduino in the waterproof box

3. The arduino board is programmed to activate the servo motor when the force sensor is pressed.
4. Then the servo motor activates and turns a cable spool.

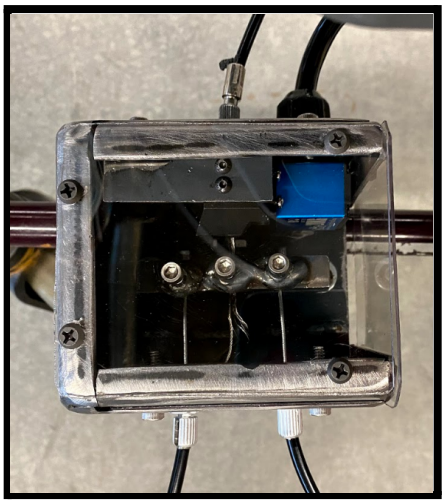


Figure 4 - Brake splitter & servo winch in waterproof enclosure

5. The cable spool pulls a cable inside the brake splitter.

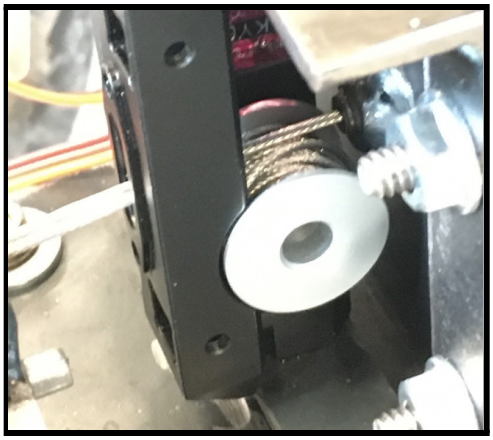


Figure 5 - Cable spool

6. When the brake splitter is pulled, both output cables are tightened which applies the appropriate force on the brake pads to stop the walker.

Manual Activation of the Brakes Walkthrough

1. This braking is activated by pulling up on the brake handle.

Figure 6 - Brake handle to be Pulled Upward

2. The handle will pull on the center brake cable in the brake splitter.

Figure 7 - Brake splitter

3. When the brake splitter is pulled, both output cables are tightened which applies the appropriate force on the brake pads to stop the walker.

Activation of the Parking Brake Walkthrough

1. This braking is activated by pushing down on the brake handle.
2. The handle will pull on the brake cable in the brake splitter.
3. When the brake splitter is pulled, both output cables are tightened which applies the appropriate force on the brake pads to stop the walker.

Figure 8 - Brake Handle Oriented Downwards

3.1 Set-up Considerations

The walker brake system you have purchased is a conversion kit that is installed on an existing walker. The completed installation of the brake kit should resemble the figure below.

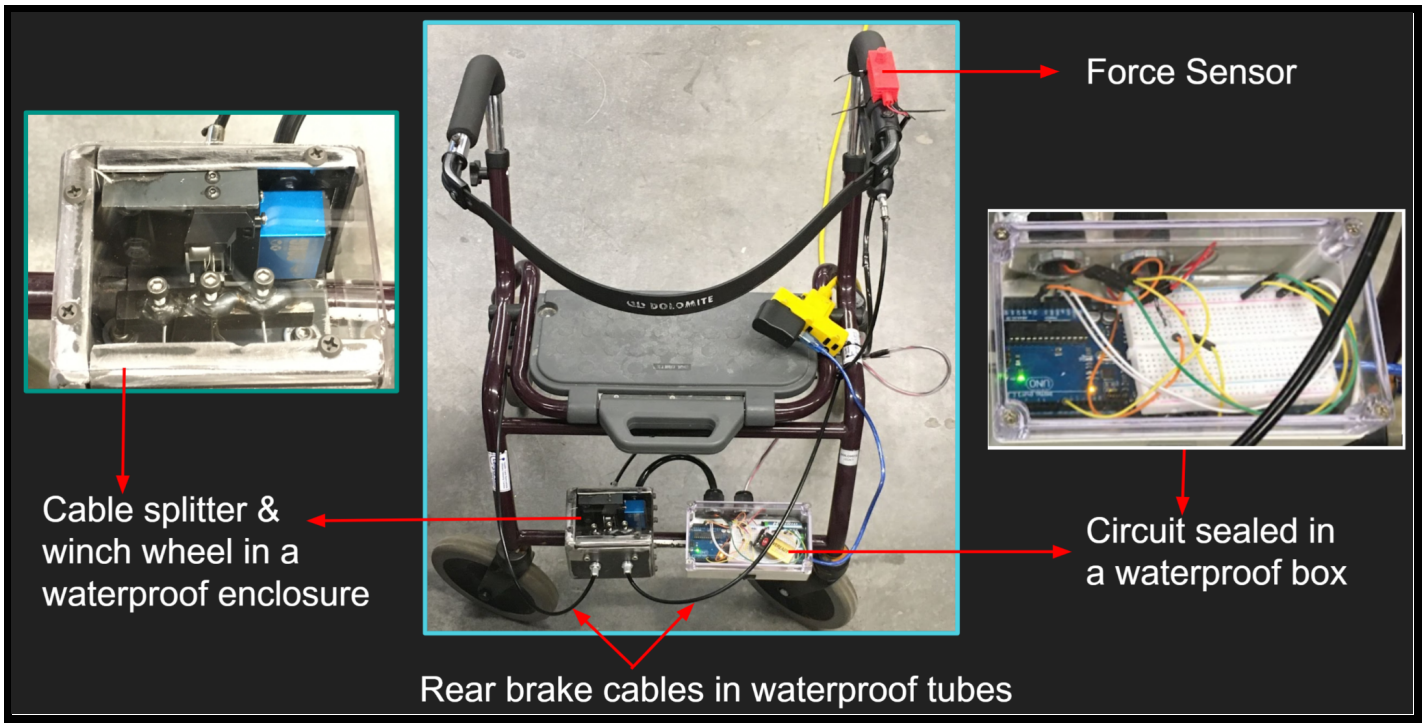


Figure 9 - Completed installation

The walker brake conversion kit you have purchased contains the following components. A force sensor, an arduino board, a battery, a servo motor, a waterproof box, a cable splitter, and cable spool connected to a brake pad.

- Mount the force sensor to the left or right handle depending on the user's healthy hand.

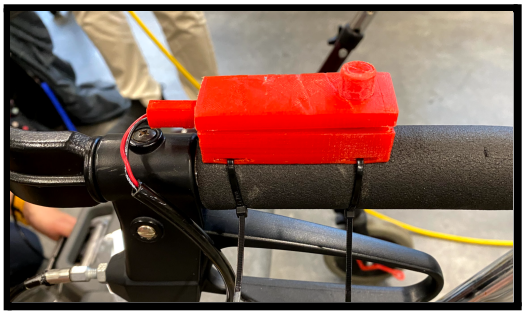


Figure 10 - Force Sensor mounted on handle

- Attach the wiring of the force sensor to the input opening of the waterproof box containing the arduino board and battery supply.

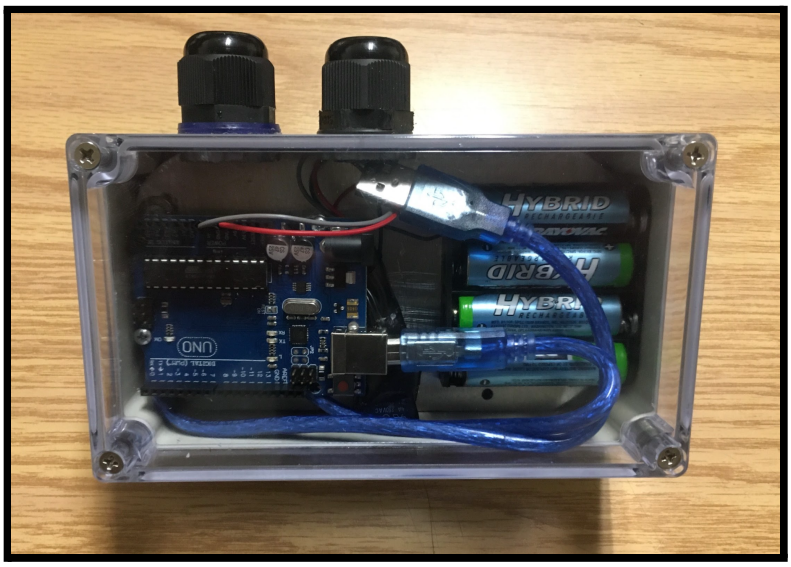


Figure 11 - Waterproof box containing electronics

- Attach the output wires of the waterproof box to the servo motor.

Figure 12 - Servo Motor

- Connect the servo motor to the cable spool

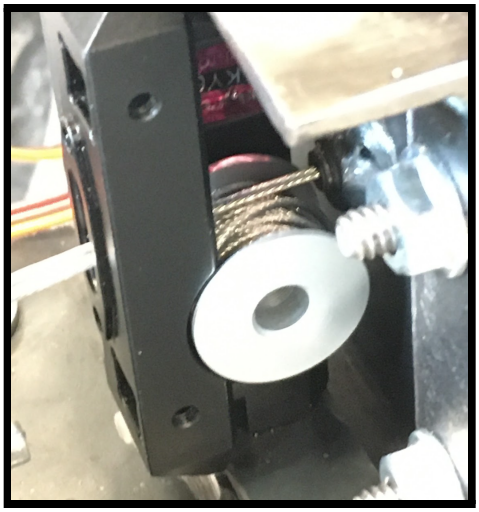


Figure 13 - Cable Spool

- Attach the other end of the cable to the brake splitter by tightening the threaded bolt

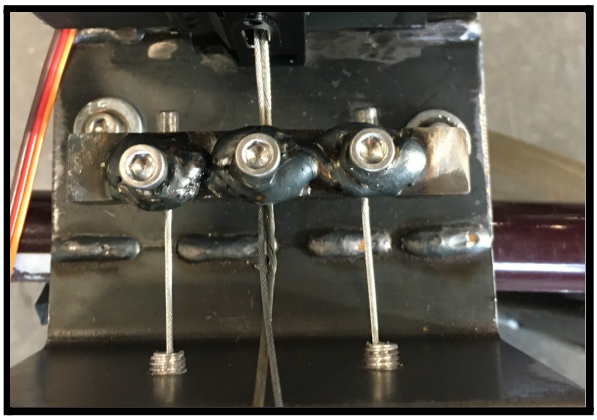


Figure 14 - Cable Splitter

- Attach the ends of the 2 wires on the output side of brake splitter to the left and right brake pads

Figure 15 - Cable attached to brake pad

3.2 User Access Considerations

Table 3. Device User Groups

Different Users	Restrictions
People with mobility issues	These users must keep in mind their mobility limitations.
People with low grip strength	These users must keep in mind their straight limitations. Some actions required some grip straight, E.g. activation of the parking break.

3.3 Accessing the System

To access the system, turn on the switch that's located on the side of the waterproof electronic box. The user must ensure that the walker is not in its folded position before it can function.

3.4 System Organization & Navigation

The system can be broken down into three subsections, the brake splitter, the Arduino activated braking system and the manual braking system.

3.4.1 Brake Splitter

The brake splitter allows the rear brakes to be activated with the use of a single interaction point. The brake splitter is composed of the brake splitter box and of the brake connector attachment. The brake connector attachment is where the three brake cables intersect. The brake cable attached to the handle / servo motor is located in the center of the brake attachment and the brake cables attached to the rear wheels are located on the right and left side of the brake attachment respectively. The brake splitter box encloses the brake attachment and the servo motor. This box is waterproof by design when all joints are sealed with a silicone sealant.

3.4.2 Arduino Braking System

The arduino braking system allows the user to activate the brakes using a force sensor. This system is composed of an Arduino, a servo motor, a force sensor, a breadboard / PCB and a 9V battery. The 9V battery is used to power these components. The force sensor detects how much force is applied on it. Depending on how much force is applied onto the sensor will depend on how far the servo will turn. When the servo motor turns, it pulls on the brake attachment and activates the walker's brakes.

3.4.3 Manual Braking System

The manual braking system can be used as a fail-safe if the Arduino braking system fails, to manually brake the walker, or activate the parking brake. This system is composed of the

walker's brake handle. If the user pulls up on the handle, it will activate the brakes to brake the walker. If the user pushes down on the handle, engage the parking brake.

3.5 Exiting the System

To exit the system, turn off the switch that's located on the side of the waterproof electronic box. This will shut down the power to all the electrical components and the Arduino microcontroller. The user can also fold the walker with ease if he or she desires.

4 Using the System

The functional subsystems of the brake system are outlined below in chronological steps.

4.1 One Hand user Interface

The one-hand interaction component primarily consists of the force sensor. The brake handle is a secondary one-hand interaction component which behaves as a back up if the force sensor fails to function at any point. Both components are mounted on the same 1 side of the walker and both are designed to trigger the connection points within the walker. Thus only 1 hand of the user gets to interact with the two components. The force sensor is mounted on top of the gripping bar while the brake handle, on the contrary, is mounted under the gripping bar.

4.1.1 Force Sensor

The force sensor is depicted below in figure 16 as it's secured in a 3D printed enclosure - one with the opening and the other with the full sealing in place.

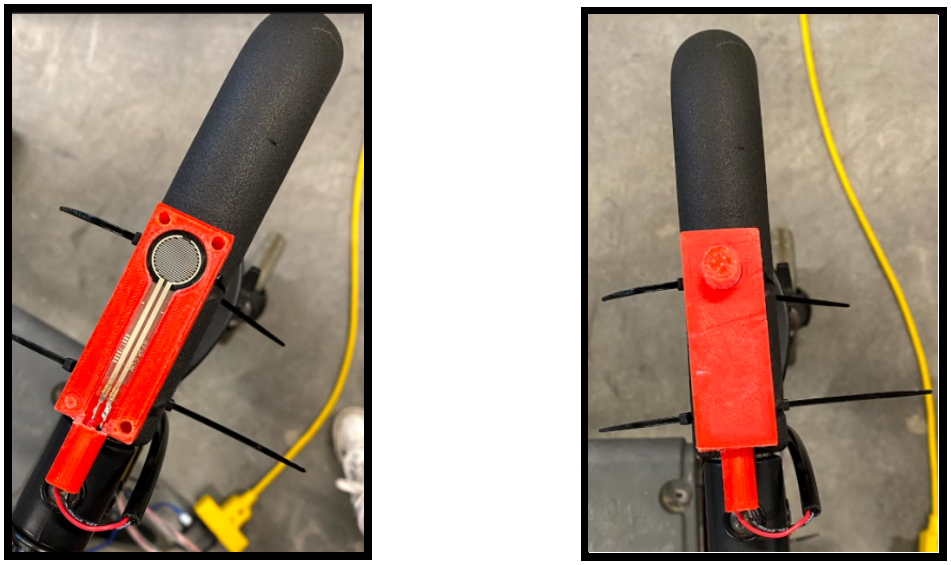


Figure 16 - Force sensor placement

The force sensor is the first major component of the system. It's secured in a 3D printed enclosure. The 3D printed piece is mounted on the gripping bar of the walker, through the use of 2 cable ties, as it secures the force sensor in place. The force sensor is an electrical polymer device used to measure a change in resistance or force. It is mainly described as a circular plastic shape attached to two wire terminals through long metal strips. The force sensor is very flexible and fragile.

The user interacts with the force sensor by simply pressing on the circular region of the 3D printed button. The force that is applied to the sensor is easily passed on to the force sensor. The force sensor measures the force applied to it as its input. The output is the electrical signal that the force sensor sends through its two terminals to the circuitry. This is accomplished because the force sensor is connected to an electronic circuitry system by 2 electrical wires. Each wire is soldered into the respective positive and negative terminal of the force sensor. The wiring is enclosed in waterproof tubes.

There's a condition that must be obeyed for the force sensor to activate. Specifically, the magnitude of the force estimated by the force sensor must exceed the minimum threshold of 4.36 kg. Once the minimum required force has been reached, the two terminals of the force sensor will

send a signal to a circuit through the 2 electrical wires enclosed in waterproof tubes. The user must always ensure that the opening of the force sensor is sealed in the 3D printed piece before usage as shown in the right diagram of Figure 16. The force sensor is protected that way.

4.1.2 Brake Handle

The brake handle, as seen in figure 17, aims to trigger the cable splitter as opposed to the electronic circuitry. Moreover, it helps in locking the brakes for user's safety once pushed down gently. It also gently brakes the walker wheels when pulled up gently. It takes in the user's force as the input just like the force sensor. However, the output of the brake handle is different. Unlike the output of an electrical signal by the force sensor, the brake handle generates a cable pressure and tension at the output. The cable from the end of the brake handle is enclosed in a waterproof tube and connected to a brake splitter. The brake handle must not be pulled or pushed with a high force. That could possibly damage the brake handle itself. The brake handle is depicted below.

Figure 17 - Brake handle

4.2 Electronic Circuit & Signal Transmission

The circuit depicted below in figure 18, consists of electrical components arranged in a waterproof electrical box. In general terms, the input is the signal from the force sensor and the output is the signal from the Arduino. The breakdown of the subsystems of the electrical mechanism will be briefly explained below.

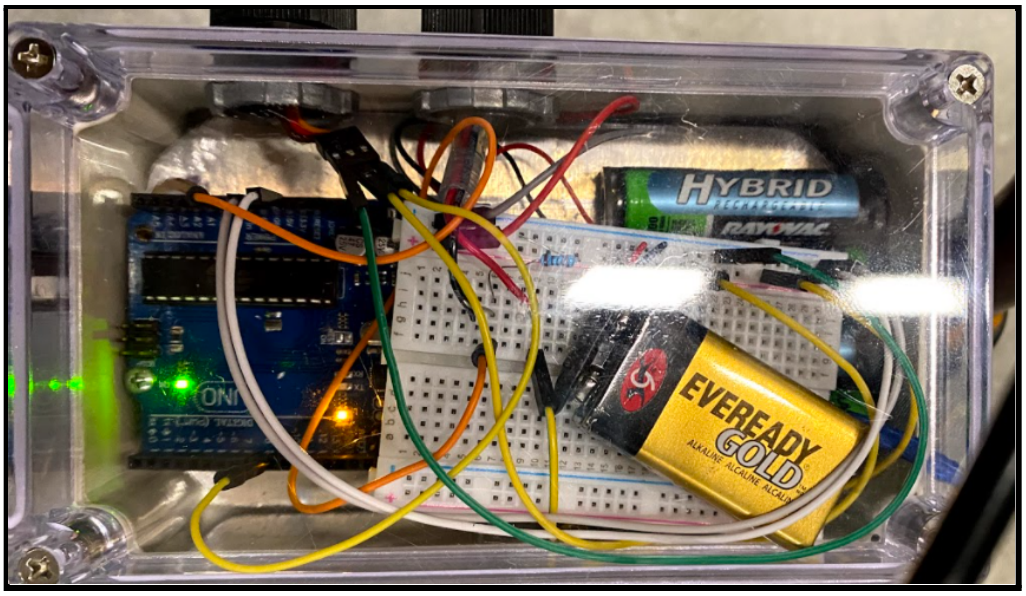


Figure 18 - Electronic Circuit

4.2.1 Arduino UNO

The Arduino microcontroller is depicted below in figure 19. This is a microcontroller based on a hardware and software platform that controls the operation of electronics. The pins of the Arduino are connected to the breadboard via the jumper wires. The microcontroller receives its power from the battery via the jumper wires. The code for Arduino was prepared and uploaded into the microcontroller. The code can be found in section 6.1.3.1. The Arduino receives an electrical signal from the force sensor as the input. It then controls the activation of the servo winch wheel at the output.

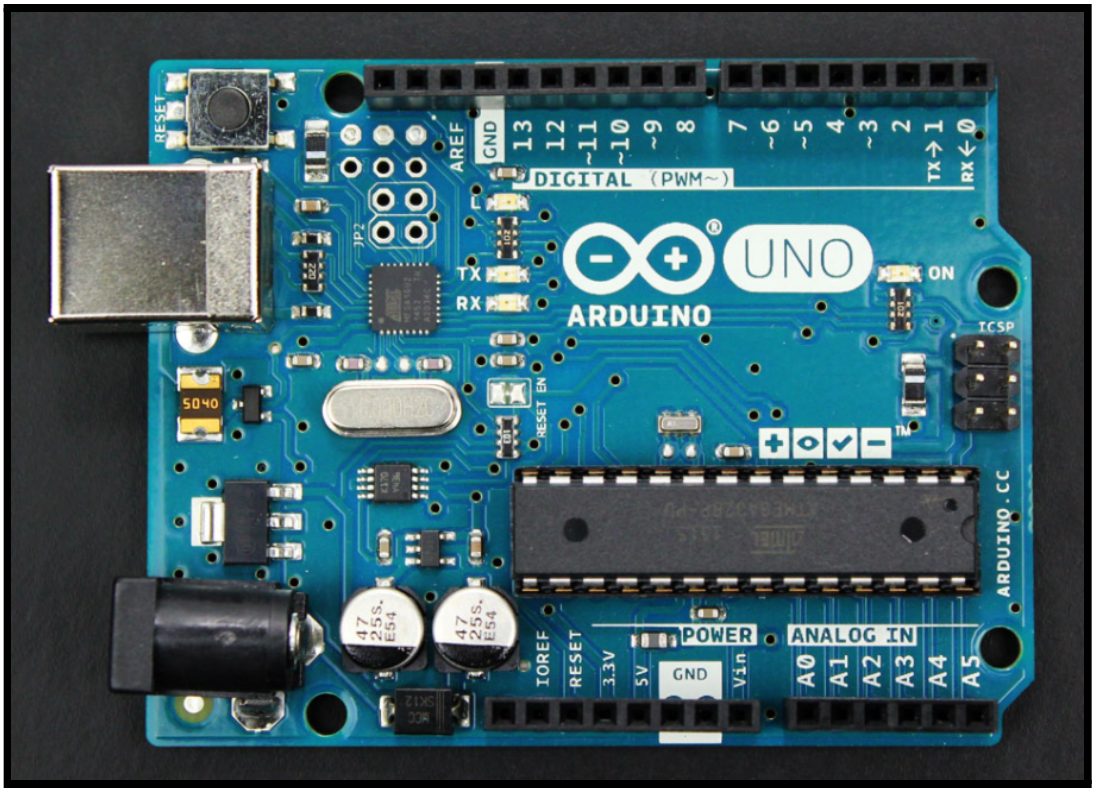


Figure 19 - Arduino board

4.2.2 Battery

Below are pictures of a 9 volt battery and a 1.5 volt battery, figure 20. They don't have any input. They're connected to the Arduino through the jumper wires. That way, the batteries distribute power at the output to the microcontroller and the breadboard.

Figure 20 - 9V and 1.5V batteries

4.2.3 Breadboard

The breadboard is depicted below in figure 21. The circuit was built and tested on the breadboard. The breadboard is connected to the Arduino and the battery via the jumper wires.

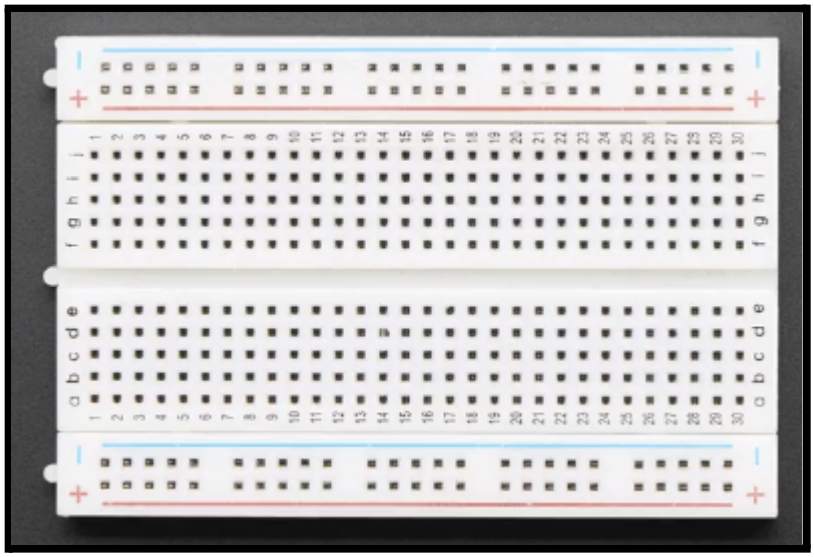


Figure 21 - Breadboard

4.2.4 Jumper Wires

The jumper wires are shown below in figure 22. They were connected on the pins of the Arduino and the battery as well as the breadboard. They take in electrical signals at the input and transfer them to other electrical components. Some commonly used ones include male - male connector, female - male connector or female - female connector.

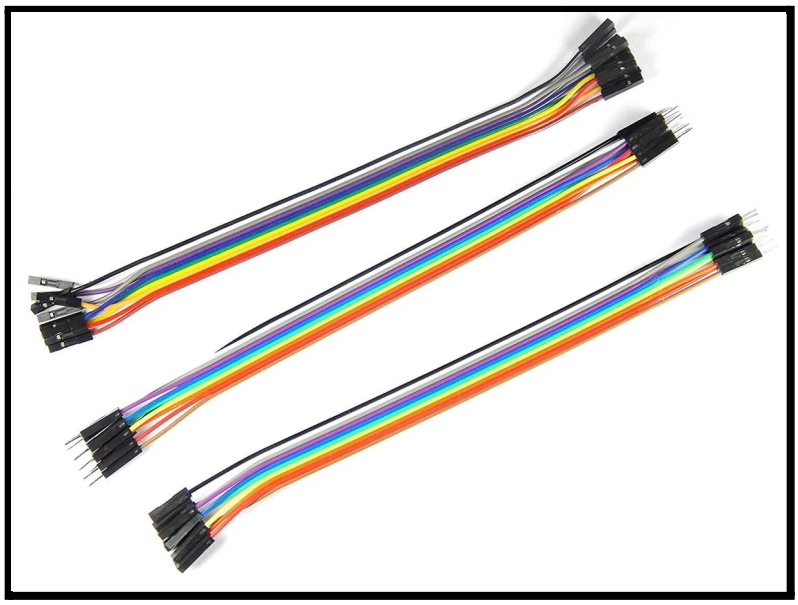


Figure 22 - Female-female, male-male and female-male jumper wires

4.2.5 Waterproof Box

The waterproof box for the circuit is depicted below in figure 23. As its name suggests, it protects the entire electrical circuit from water. Thus, the circuit can function without any disruption. As seen in the right diagram in figure 23, the box has 2 openings so that the 2 wires in enclosed cables branching from the force sensor can get through the waterproof box to reach the destination pins in the circuit.

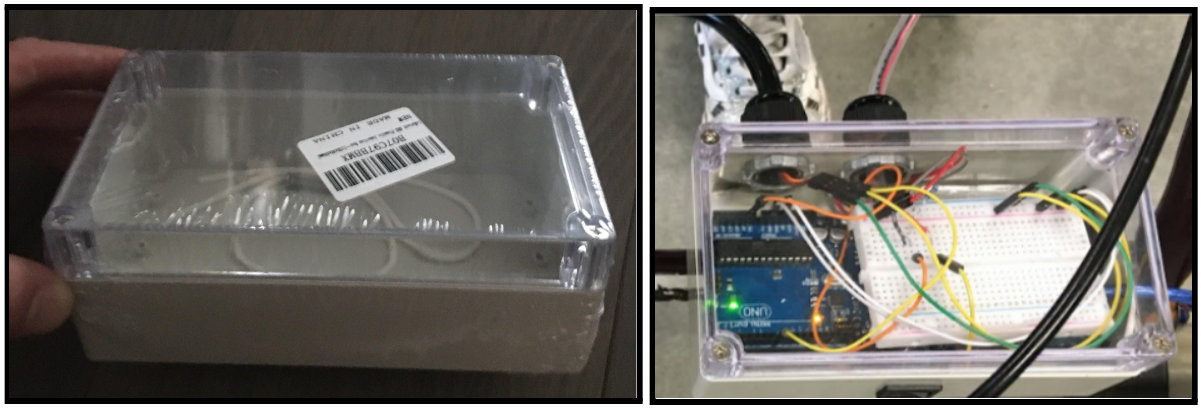


Figure 23 - Waterproof box

4.3 Mechanical Braking System

The cable pulling mechanism is one of the most important subsystems in making the walker come to a stop. The main components will be discussed below.

4.3.1 Servo Winch Wheel

The servo winch wheel is depicted below in figure 24. It's purpose is to generate torque and pull in the rear brake cables through the brake splitter. The cable of the servo winch wheel is connected to the cables which link to the brake pads. The servo winch wheel is a pulley with a metal wire cable wound around it. The cable has to be wound up before the servo winch wheel starts pulling. If the cables are unwound from the beginning, this could cause the cable to jam inside the brake splitter enclosure causing excess rubbing and poor tension. The servo winch wheel is mounted to a bracket so that it remains fixed in place. The input of the servo winch wheel is the electrical signal from the Arduino microcontroller. The output is the tension that the servo winch wheel generates once it pulls the cables leading to the brake pads through the brake splitter.

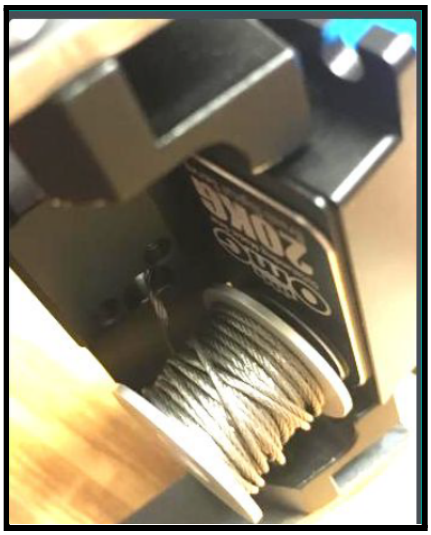


Figure 24 - Servo Winch Wheel

4.3.2 Cable Splitter Connector

The cable splitter connector is depicted below. It consists of a ½" square piece of key stock with 3 holes drilled into one side and out the opposite side. The purpose of the 3 drilled central openings are to allow the cables to pass through it. As the wire cables pass through the openings, the cables can be secured to create a connection point. The 3 drilled and tapped holes directly above the drilled opening allow the cables to be adjusted with tension and securely fixed, preventing the cables from moving. The wire cable linked to the servo winch wheel as well as the cable linked to brake handle pass together directly through the middle opening of the keystock. The cables linking the brake pads pass through the far left and right openings of the piece. The input of the cable splitter connector is the tension from the pulling of the wire cable by the servo winch wheel in the middle opening or by manually lifting up on the brake handle which tensions a separate cable from the one attached to the servo winch wheel. The output is the tension and pressure that the cable splitter actually generates by pulling the rear cables in the far left and right openings as seen in figure 25. This tension and pressure at the output is transferred by the cable

splitter to the brake pads through the two cables enclosed in waterproof tubing. For safety reasons, if the waterproof plexiglass cover ever gets removed, the user is strongly encouraged to wear cut resistant gloves before touching the sharp cables and should use extreme caution as the tension created by the cables could cause serious harm. It is discouraged to fix or modify any components within the brake splitter housing unless under the supervision of our technical support team.

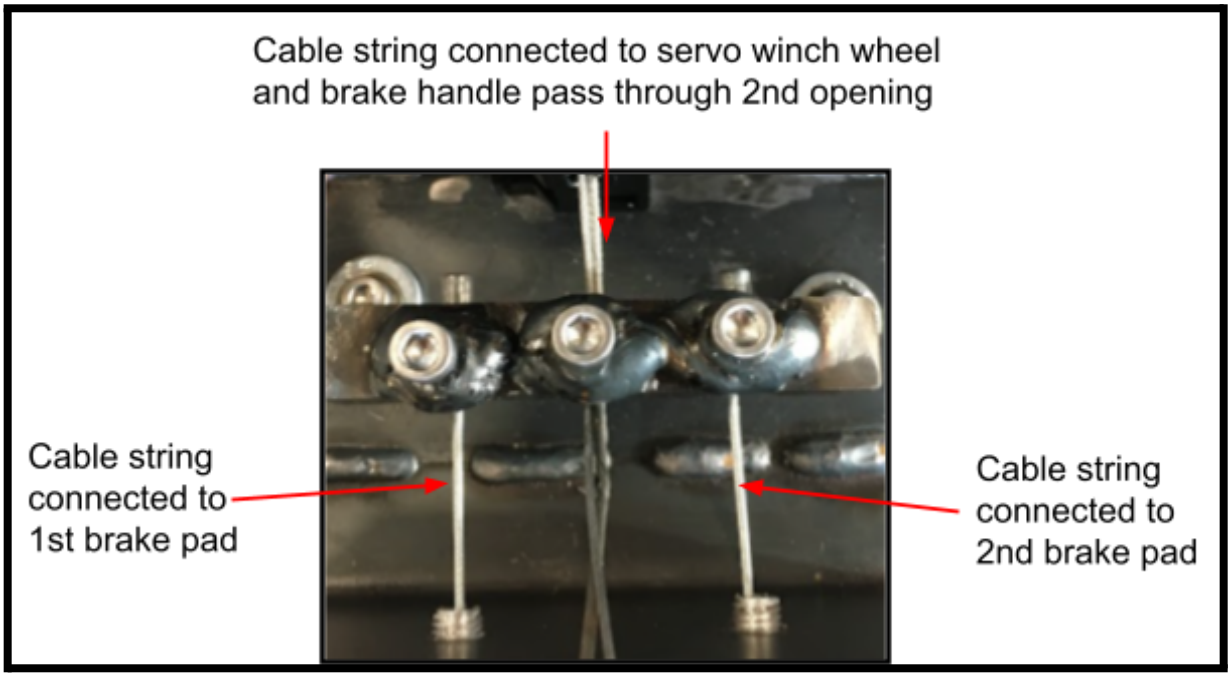


Figure 25 - Connection of the cables into the cable splitter

4.3.3 Waterproof Enclosure

The waterproof enclosure is depicted below in figure 26. As its name suggests, the waterproof enclosure secures the brake splitter and the servo winch wheel mechanisms. This enclosure is a simple square shaped box with a square glass on the top and side face. Inside the square box, the cable splitter and the servo winch wheel are all secured tightly. The glass is then placed on the opening of the enclosure. The 4 corners of the glass have small openings and screws

are used here to bolt the glass to the metal frame. A silicone sealant would be used to prevent water from entering in through any holes or seams of the enclosure. Looking at the diagram in figure 26, there are 2 cables on the outer right and 2 cables on the outer left. The black cable with a larger diameter on the right contains an electrical wire which connects from the servo winch wheel to the circuit in a separate waterproof box, figure 23. The thinner cable on the right is linked to the emergency brake handle, figure 16. The remaining two cables on the left in the diagram connect to the rear brake pads, figure 26. All 4 of these cables pass through the waterproof enclosure.

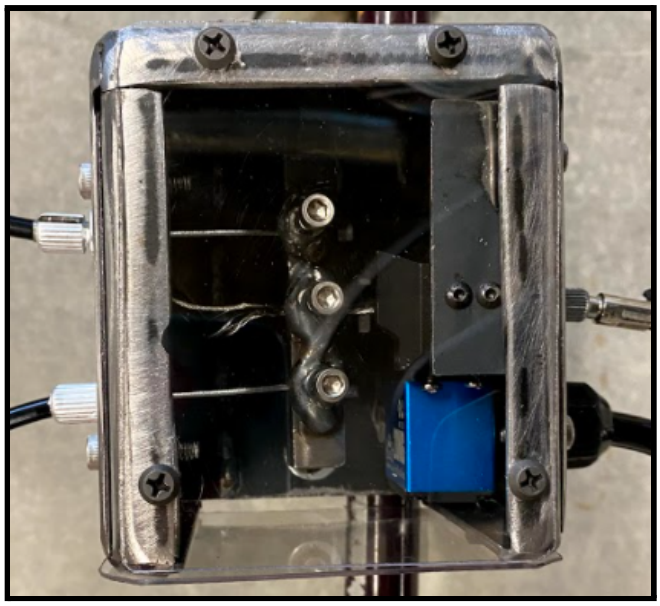


Figure 26 - Waterproof enclosure

4.4 Brake Pads

The brake pads are the final part of the walker's brake system. The front and side views of the brake pads are depicted below. There's a jointed structure on top of the wheels and the frames of the walker. In the interior region of the structure, the brake pads are sandwiched in between the

two ends of the structure itself through a small pipe. The brake pads look square in shape and slightly curved on one end. Both rear brake pads are connected by a waterproof cable to the cable splitter. On top of each brake pad, there's a small opening. The wire cable goes through this opening and is securely fixed by screwing in a socket head cap screw which compresses the cable as shown on the picture to the left in figure 27. This maintains every brake pad's connection to the cable splitter. The brake pads receive cable pressure and tension as the input from the functioning brake splitter connector. The brake pads then get pushed down to create friction on the rear wheels at the output. In the right diagram in figure 27, the brake pad can be seen in action to reflect this output. Thus, the walker comes to a stop. The brake pads can be released by either letting go of the manual brake lever handle, figure 17, or by letting go of the force sensor button, figure 16. Once the brakes are pushed down, they can also stay in contact with the wheels to make the brakes lockable. This is accomplished when the brake handle, figure 16, is gently pushed down by the user.

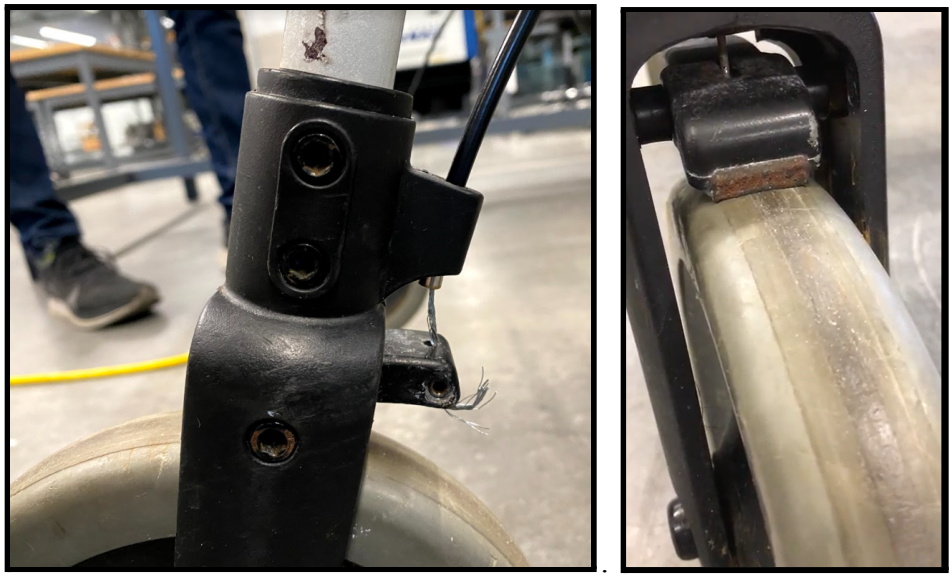


Figure 27 - Brake Pads

5 Troubleshooting & Support

In this section you will find the necessary information to properly care and maintain your e-Walkers electro-mechanical one hand brake system. In the case that either the electronic brake system or manual lever operated brake system malfunctions, please refer to Table 4 for some probable causes prior to contacting for service of the unit. If service is required to the brake system, please contact the e-Walkers certified technician for support and service. DO NOT attempt to repair or open the sealed brake splitter box as this could lead to SEVERE INJURY due to the brake cable tension. DO NOT open the electronic enclosure to change the battery unless the power switch has been turned off as an ELECTRIC SHOCK could occur if any exposed wiring is touched.

Table 4. Troubleshooting of Electro-Mechanical Braking System

Malfunction	Probable Cause	Corrective Action
Force Sensor not working when pressed.	● Power to the electronic sensor not turned on. ● Battery dead or not charged. ● Wire damage from the sensor to the Arduino Controller.	● Turn the power switch to the on position and ensure the light on the Arduino lights up. ● Replace battery with a fully charged one. ● Contact for service of the unit.
Arduino unit not turning on when switch is in the on position.	● Battery is dead. ● Damage to the Arduino. ● Damage to the circuit wiring.	● Replace battery with a fully charged one. ● Contact for service of the unit. ● Contact for service of the unit.

Manual brake lever not activating brakes.	• Stretched brake cable. • Broken cable. • Disconnected cable inside the mechanical brake splitter connection.	• Tighten adjustment screws at the handle, infeed of brake splitter and outfeed of brake splitter. • Contact for service of the unit. • Contact for service of the unit.
Brakes not equally braking at the same time causing the walker to twist.	• Loose or stretched cable going to one side of the walker brake.	• Tighten the barrel adjustment screw on the outfeed of the brake cable splitter by turning one rotation at a time and testing until equal braking of both rear brakes is achieved. • Contact for service if the problem continues.
Servo motor not activating to stop the walker.	• Power switch to the electronic system is not in the on position. • Battery discharged. • Damage to wiring.	• Turn the power switch to the on position • Replace Battery with a new one. • Inspect wiring from the electronic enclosure to the servo for damage. If damage has occurred contact for service of the unit.
Light on the Arduino is on, but the servo is still not activating when the force sensor button is pressed.	• Battery charge is too low. • Damage to wiring or Servo failure. • The Arduino circuit board is damaged or software is corrupted. • Brake cable on the winch wheel to the cable splitter connector is disconnected.	• Replace battery with a new fully charged one. • Contact for service of the unit. • Press the reset button and wait for 30 seconds and try activating the force sensor to see if this corrected the problem. If problem persists , contact for service of the unit or reload the program to the arduino board.

		• Contact for service of the unit.

5.1 Error Behaviours

Potential errors in components may occur suddenly and unexpectedly during the operation of the brake system. Two of these include:

- The electrical circuit in the waterproof box is prone to damage if the walker has been bumped with a heavy object. For example, the crashing of the walker into a wall may crack the waterproof box and possibly break the pins of the Arduino microcontroller. A break in the jumper wires is also possible, causing signal disconnection from the circuit.

- A failure in the battery supply can also occur. The battery pack has a lifespan after which it will cease to provide the necessary power. The Arduino microcontroller will stop working as a result, thus disrupting the electronic braking mechanism.

5.2 Maintenance

- Check if wiring connections are tight to maintain good electrical connection.
- If any of the electrical wires are loose, either push back into place or tighten fastening screw depending on connection type
- Replace batteries in a waterproof box if the servo motor is slow or not moving.
- Check if brake cable connections are tight by ensuring that the lock nut on the barrel adjustment screw is locked against the housing of the brake lever or brake splitter enclosure.

- If brake cables are loose, tighten the appropriate adjustment screws located on the handle, and at both the input and output of the brake splitter. To tighten, loosen the lock nut and turn the adjustment screw one full turn at a time in the counterclockwise direction until proper tension is obtained. Once the desired tension is reached, retighten the lock nut and ensure that it is secure to prevent any loosening or tightening of the brake cables.

5.3 Support

For any support or emergency assistance regarding the brake product, the user can contact e-Walkers certified technician Christopher Godwin by email at cgodw034@uottawa.ca or visit https://makerepo.com/victor123/913.gng-2101-team-z7-ewalkers.

6 Product Documentation

Below are the design considerations and testing methods used to arrive at the final product.

6.1 Materials and Components Used

Materials were used after verifying their usage on the 3D SolidWorks model shown in Figure 28.

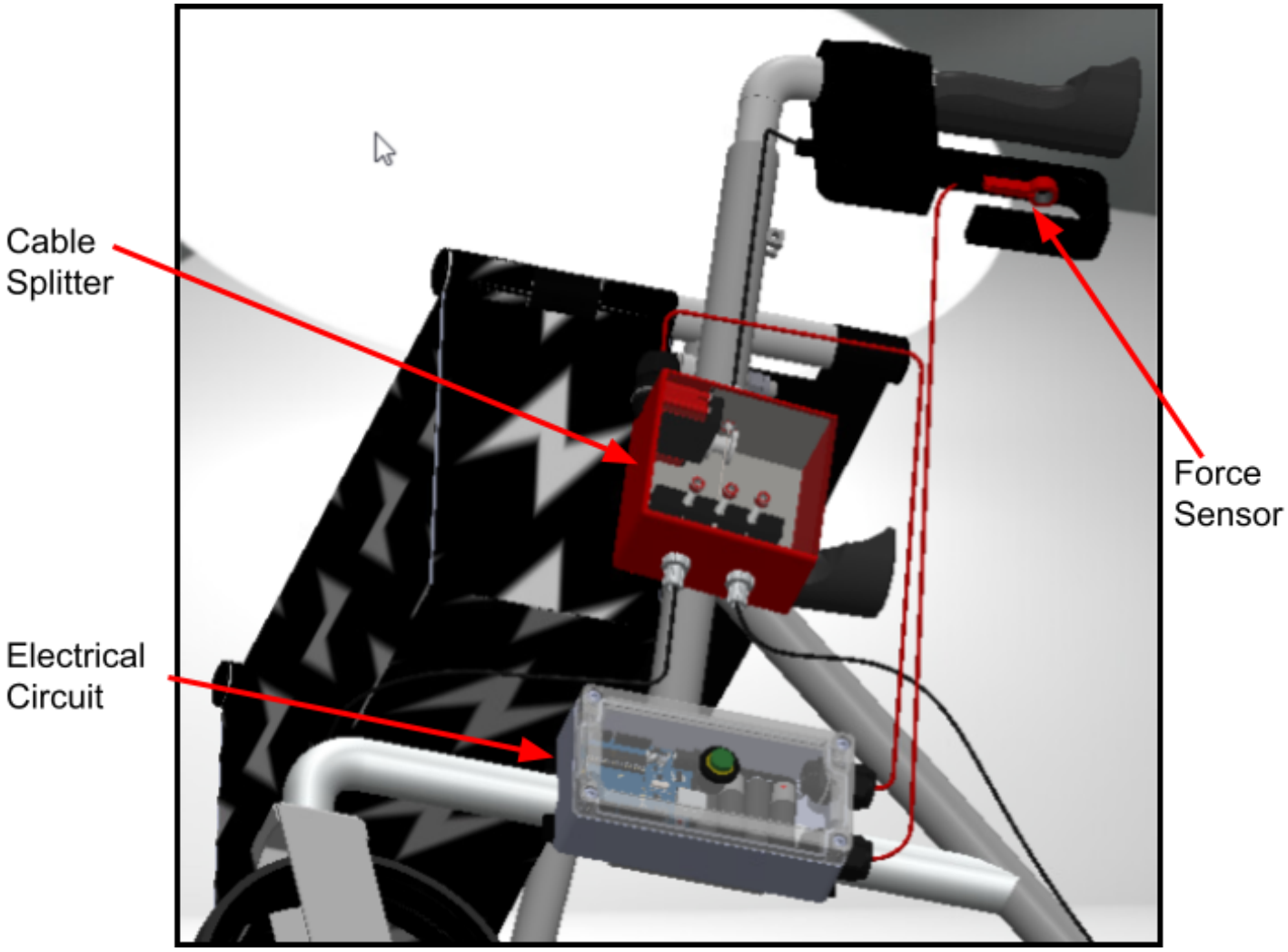


Figure 28 - SolidWorks 3D Modelled Prototype

6.1.1 B.O.M (Bill of Materials)

Table 5. Bill of Materials

QUANTITY	Part #	DESCRIPTION	UNIT PRICE	TOTAL

1 ea.	1	Metal Gear Servo Motor 4.8-6V Link	$6.00	$6.00
1 ea.	2	Arduino Uno Link (Reuse from Lab Kit)	$20.00	$20.00
1 ea.	3	AA 4x Battery Pack Link (Reuse from Lab Kit)	$1.00	$1.00
1 ea.	4	Force Sensor Link	$3.00	$3.00
1 ea.	5	25T Servo Winch Wheel Link	$4.47	$4.47
1 ea.	6	Polyethylene Tubing ¼”OD x 0.170” ID x 25 ft. Link	$7.99	$7.99
1 ea.	7	Waterproof Box 6.2”x3.5”x2.4” Link	$14.99	$14.99
1 ea.	8	5 ft. Red 22awg Wire Link	$1.60	$1.60
1 ea.	9	5 ft. Black 22awg Wire Link	$1.60	$1.60
1 set	10	Brake Cable and Casing Link	$8.49	$8.49
1 ea.	11a	3” Wide Cable Splitter Assembly (Custom built) 3” wide C-Channel Link and 3” wide 0.5x0.5 sq. stock Link	$4.78	$4.78
1 ea.	11b	Brake Cable Connector	$0	$0
1 Bag of 5	12	3/4” Metal Strap (2 hole) Link	$2.31	$2.31
6 ea.	13	M4 x 20 Socket Head Cap Screw Link	$0.10	$0.60
6 ea.	14	M4 Hex Nut – Zinc Plated Link	$0.17	$1.02
12 ea.	15	M4 Washer – Zinc Plated Link	$0.10	$1.20
1 ea.	16	Cable Ties (Black) 3-5/8” (16 Pack) Link	$2.49	$2.49
2 ea.	17	Latching Push Button Switch Link	$0.70	$1.40
3 ea.	18	Connector Strain Relief 0.23-0.47” Link	$1.68	$5.04
			Subtotal	$88.24
			Sales Tax	$11.47
			Total	$99.71

6.1.2 Equipment List

Cable Brake Splitter and Enclosure Equipment Required

1. Mig Welder
2. Metal Cut-off Wheels
3. Metal Flat Disc
4. Mini-Grinder
5. Vise
6. Drill Press
7. Measuring Tape
8. Sand Paper
9. Hand Tap and Die Set
10. Metal Grinding Wheel
11. Combination Square
12. Drill Bit Set
13. Phillips Screwdriver
14. Metric Hex Key Set
15. Electric or Cordless Hand Drill
16. Ball Peen Hammer
17. Center Punch
18. Bastard Hand File
19. Side Cutting Pliers
20. Slot Head Screwdriver

Force Sensor Enclosure

1. 3D Printer

Electronic Enclosure and Circuits

1. Philips Screwdriver
2. Hand Drill
3. Solder and Soldering Iron
4. Adjustable Wrench
5. Drill Bit Set
6. Utility Knife
7. Slot Headed Screwdriver

6.1.3 Instructions

The instructions below have to be followed to set up the electrical mechanism.

6.1.3.1 Arduino Setup

1. Upload the following code to the Arduino. You can find the code under *Project Files* at https://makerepo.com/victor123/913.gng-2101-team-z7-ewalkers.

```
#include <Servo.h>
#define FORCE_SENSOR_PIN A0

Servo servo;

void setup()
{
  servo.attach(9);
  servo.write(0);
  delay(2000);

  Serial.begin(9600);
}

void loop()
{
  int analogReading = analogRead(FORCE_SENSOR_PIN);

  Serial.print("Force sensor reading = ");
  Serial.print(analogReading);

  if (analogReading < 10)
  {
    Serial.println(" -> no pressure");
    servo.write(0);
  }
  else if (analogReading < 200)
  {
    Serial.println(" -> light touch");
    servo.write(45);
  }
  else if (analogReading < 500)
  {
    Serial.println(" -> light squeeze");
    servo.write(90);
  }
  else if (analogReading < 800)
```

```
 {
   Serial.println(" -> medium squeeze");
   servo.write(135);
  }
   else
  {
   Serial.println(" -> big squeeze");
   servo.write(180);
  }
  delay(1000);
}
```

2. Attach the force sensor to analog pin A0 and the servo motor to digital pin 9. Refer to Figure 29 on Tinkercad on how to set up the force sensor and servo motor.

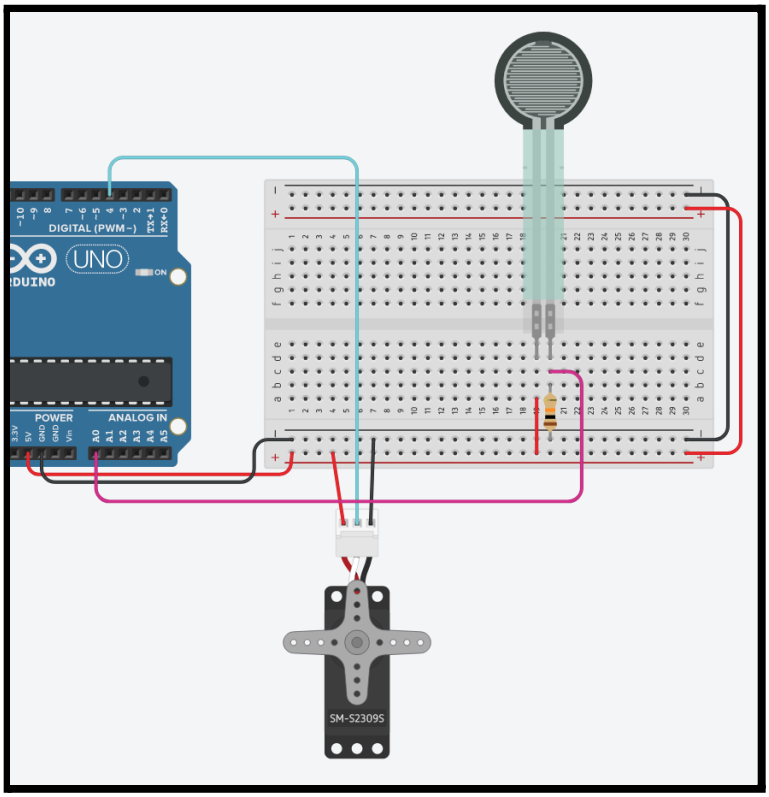


Figure 29 - Force sensor diagram setup

3. Attach the winch wheel to the servo motor.

4. Attach the servo motor in the brake splitter box.

5. Put the cable through the center hole of the brake attachment. Make sure the cable is tight before tightening the screw.

6.2 Mechanical Braking Subsystem

The brake splitter enclosure and assembly were custom built based on the SolidWorks drawings and dimensions. Note that some drawings were modified from the original for design day presentation. Please find the SolidWorks drawings located on the MakerRepo website: https://makerepo.com/victor123/913.gng-2101-team-z7-ewalkers

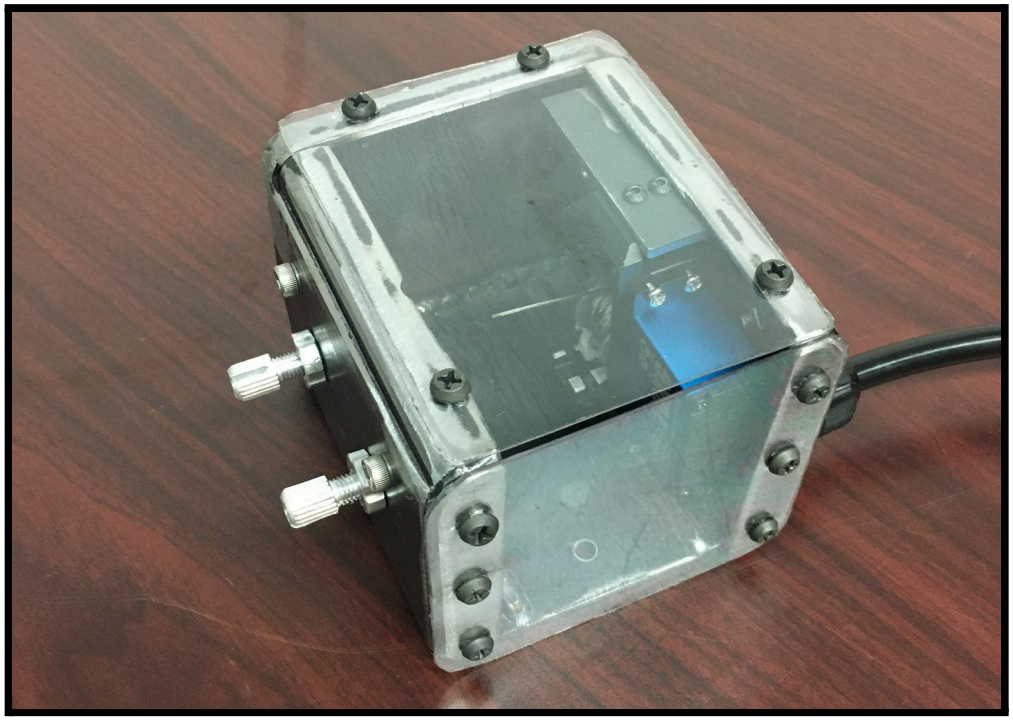


Figure 30 - Brake Splitter Complete Assembly

Figure 30 (Brake Splitter Complete Assembly) -- shows the complete brake splitter assembly. The material selected for the brake splitter enclosure was steel due to its easy

manufacturing abilities, weldability, low cost, strength and durability. Due to the corrosion of steel when exposed to water, a suitable primer and rust resistant oil based paint should be used to coat both the inside and outside of the exposed metal to prevent rust and preserve the strength and longevity of the material. Once the paint has cured, based on the recommended cure time provided by the paint manufacturer, all seams and openings to the brake splitter housing should be sealed with a waterproof silicone caulking to act as a gasket material and prevent water from entering inside the housing and causing any potential damage to the cables or servo motor. Any threaded openings could be sealed with a teflon thread sealant to also prevent water from entering in through the threads.

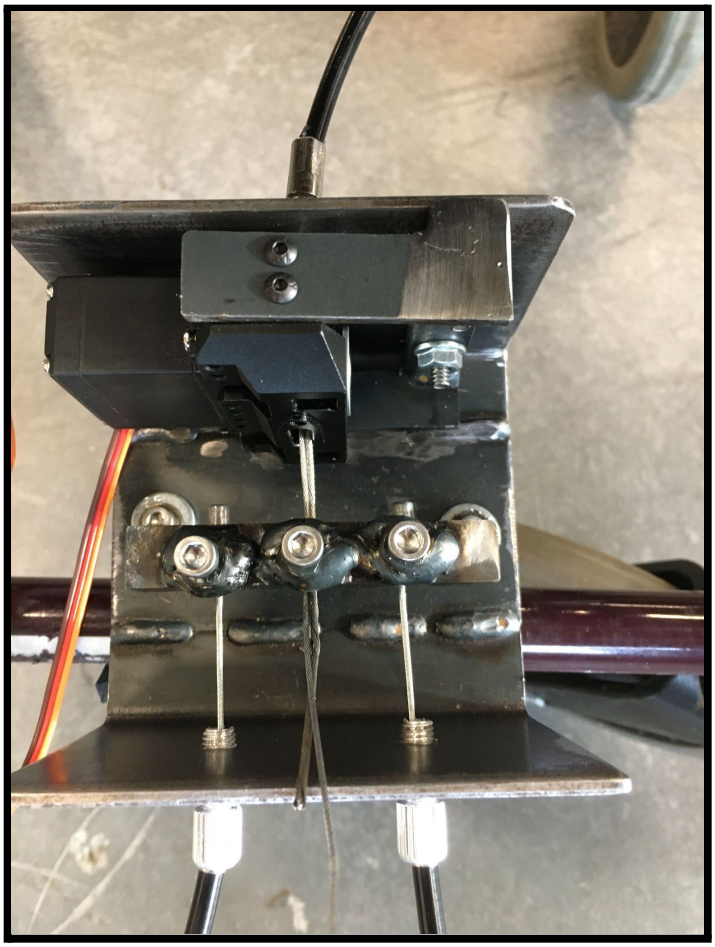


Figure 31 - Inside view of Brake Cable Splitter Connections

In Figure 31 (Inside view of Brake Cable Splitter Connections) the cable on the left and the cable on the right will lead to either brake pad located at the rear wheel of the walker. The center connection will have two cables, one from the servo motor winch wheel and the other from the manual brake lever. Proper tension is necessary to provide equal and accurate braking of the walker braking system.

In Figure 32 (Part 11a. Brake Splitter Enclosure Drawing.) is the drawing for the brake splitter enclosure. For a more detailed description, please refer to the SolidWorks part on the makeRepo website as stated previously in the link at the top of this section.

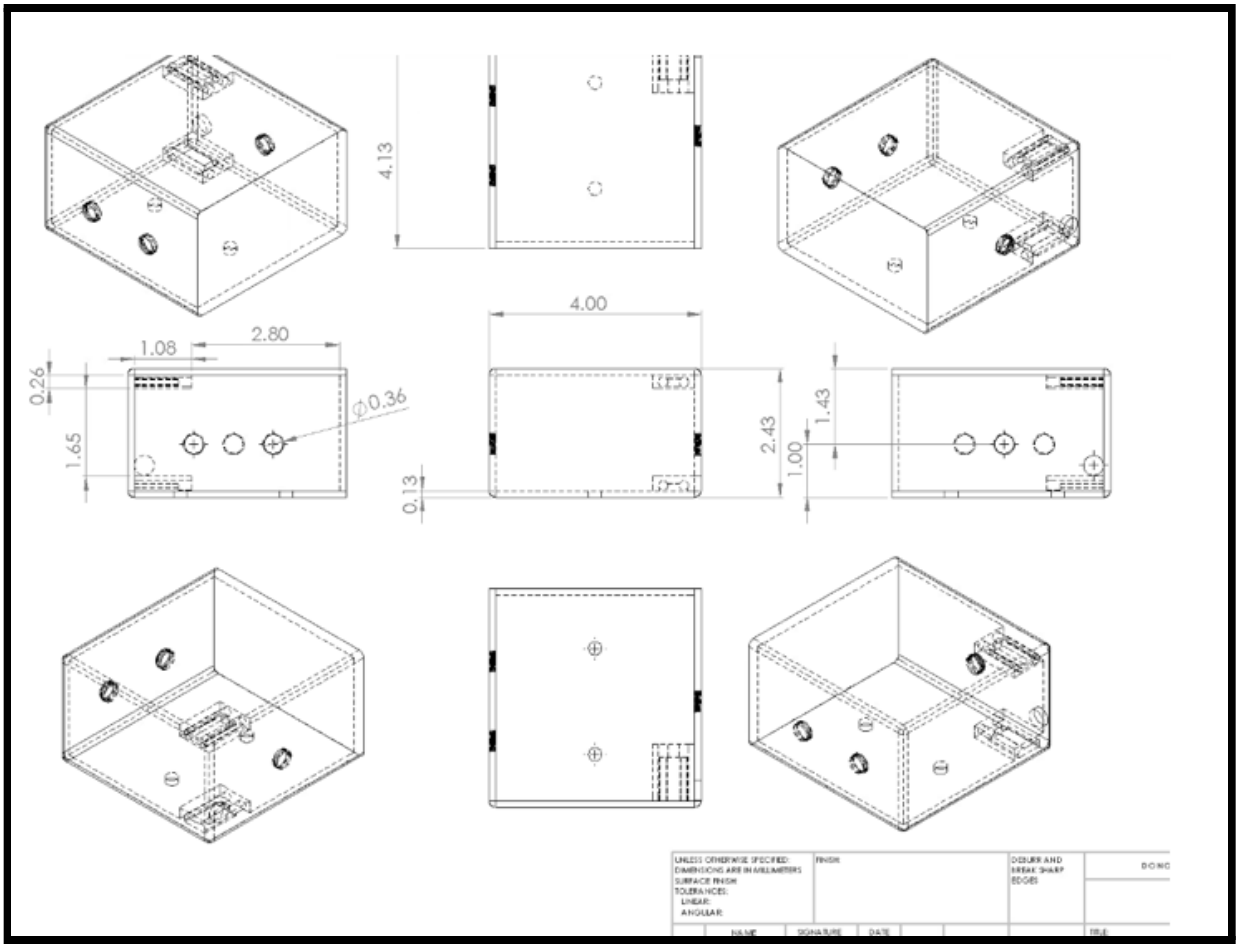


Figure 32 - Part 11a. Brake Splitter Enclosure Drawing

In Figure 33 (Part 11b Brake Cable Connector.) is the detailed drawing for the brake cable connector. This part was made out of ½" x ½" steel key stock which will resist wear of the cables rubbing against the surface of the connector.

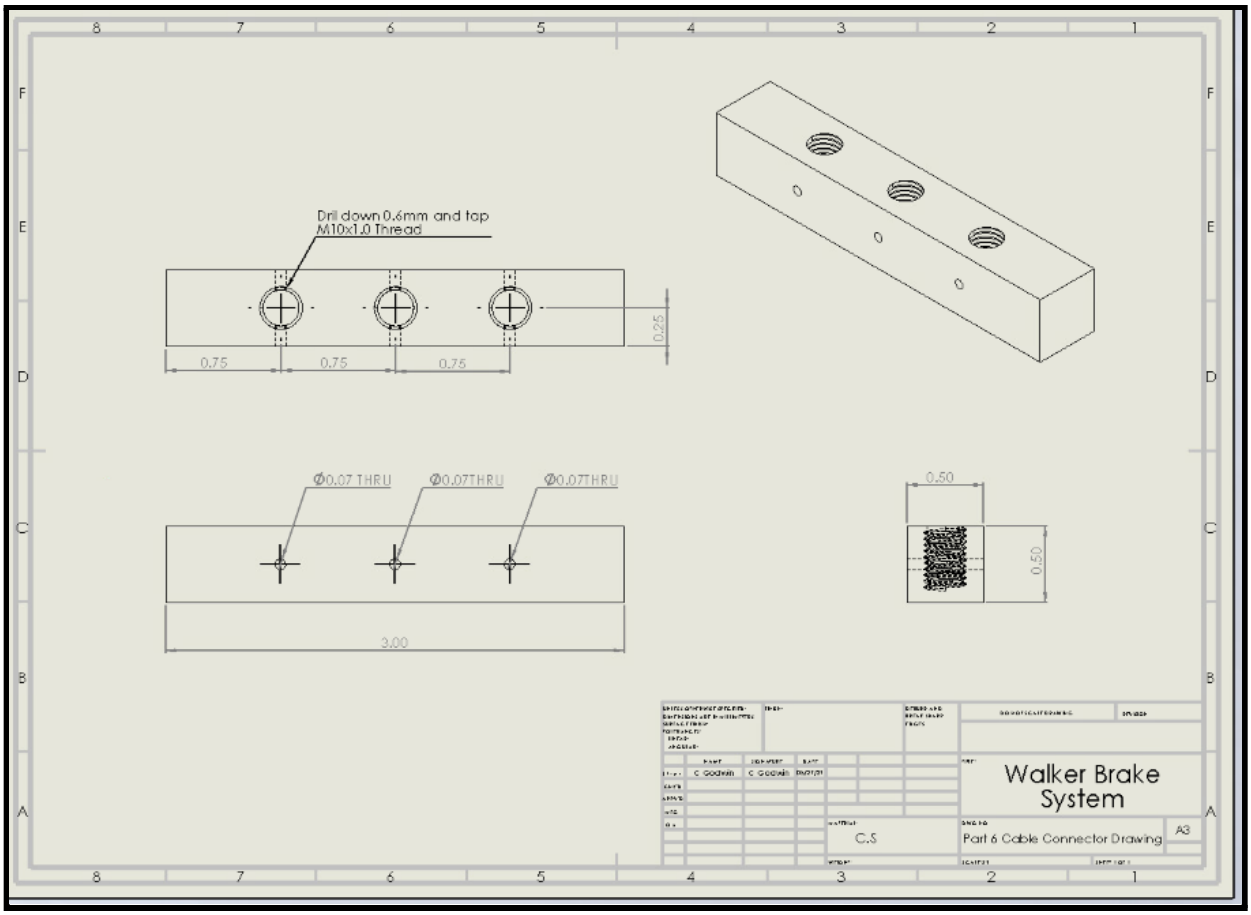


Figure 33 - Part 11b Brake Cable Connector

In Figure 34 **(**Part 1 Servo Motor and Part 5 Winch Wheel Assembly) and Figure 35 (Part 5 25T Winch Wheel Servo Attachment) is the electronic servo motor and wheel. The servo motor is secured to the frame of the enclosure by four screws and the winch wheel is secured to the servo motor by one screw, which also secures the wire cable to the winch wheel.

Figure 34 - Part 1 Servo Motor and Part 5 Winch Wheel Assembly

Figure 35 - Part 5 25T Winch Wheel Servo Attachment

6.3 Testing & Validation

6.3.1 Force Test Plan

This test consisted of measuring the amount of weight required to activate the brakes using a single brake lever, both with and without the use of a cable splitter. For this test a cable brake system on a bicycle was used, which is similar to that of the cable brake system used on a walker. To measure the force, an empty bucket was mounted onto the top of a brake lever, Figures 37 & 39 and filled gradually with water. The tire of the bicycle was then spun manually by hand until the first initial braking of the wheel(s) was found. The bucket of water was then removed from the handle and placed on a scale, Figure 38. The weight value, in kgs, was then recorded as the weight needed to begin the brake activation. Once the weight was recorded, the bucket was returned to the top of the lever and was continued to be filled with water, while turning the wheel of the bicycle until the brakes were fully activated and the wheel could no longer be turned by hand. The bucket of water would then be removed and weighed once more recording the weight required to fully brake the wheel(s).

Sequence of tests performed:

Braking Force Test 1

- Braking of only the front wheel of the bicycle using a single hand lever.
- Three tests performed in total.
- Three weight values recorded for the amount of force needed to begin braking.
- Three weight values recorded for the amount of force applied to fully brake the front wheel only.

- Results found in Table 6.

Braking Force Test 2

- Braking of only the rear wheel of the bicycle using a single hand lever.
- Three tests performed in total.
- Three weight values recorded for the amount of force needed to begin braking.
- Three weight values recorded for the amount of force applied to fully brake the front wheel only.
- Results found in Table 7.

Braking Force Test 3

- Braking of both the front and rear wheels on a bicycle, with the brake splitter, using a single hand lever.
- Three tests performed in total.
- Three weight values recorded for the amount of force needed to begin braking.
- Three weight values recorded for the amount of force applied to fully brake the front wheel only.
- Results found in Table 8.

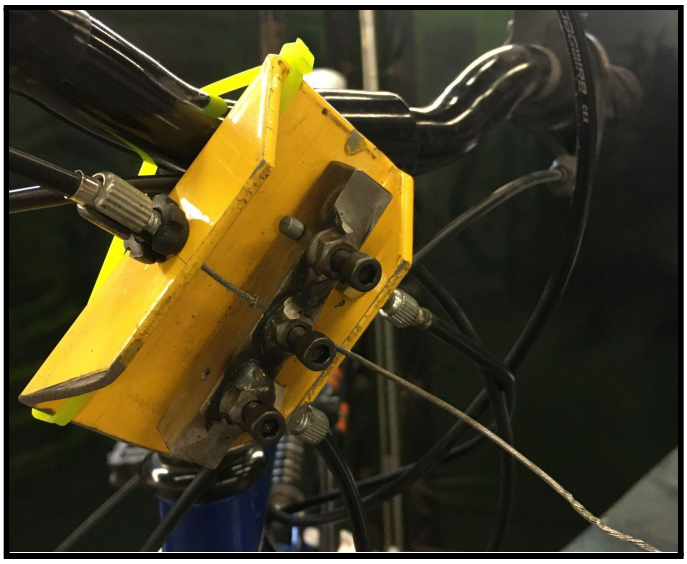


Figure 36 - Force test using the cable splitter

Figure 37 - Force test using a bucket filled with water to measure the braking force

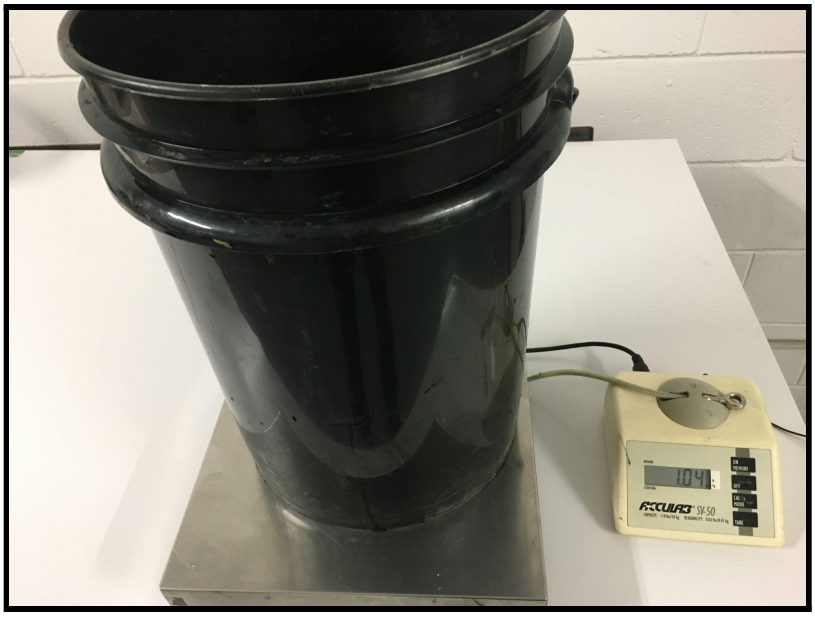


Figure 38 - Weighing of a bucket of water during force test

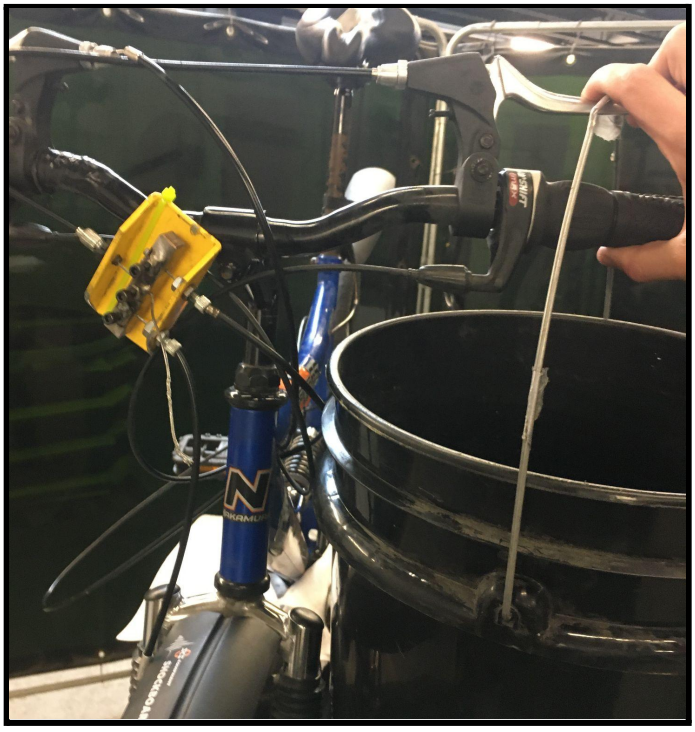


Figure 39 - Force test using the cable splitter

6.3.2 Observations and Results

After the completion of the three series of tests, the results, as seen in Table 6, Table 7 and Table 8, were compiled and compared. From these results, it was noted that the average kilogram-force needed to begin the activation of the brakes using the brake splitter was 4.89 kg, average values calculated using Table 8, which was less than half of the force required to begin the activation of the front and rear brakes, 2.21 kg, when averaging the six results found from Braking Force Test 1, Table 6, and Braking Force Test 2, Table 7. It was also found that the average kilogram-force needed to fully brake both wheels was 10.28 kg, which was approximately equal to slightly higher, 9.37 kg, when combining the average values from Test 1, Table 6 and Test 2, Table 7, respectively.

Table 6. Braking Force Test 1 – Braking of front wheel of bicycle using a single hand lever.

Test	Force Required to Begin Braking (KG)	Force Required to Fully Brake (KG)
1	1.98	4.37
2	1.84	3.53
3	1.64	3.98

Table 7. Braking Force Test 2 – Braking of rear wheel of bicycle using a single hand lever.

Test	Force Required to Begin Braking (KG)	Force Required to Fully Brake (KG)
1	2.86	5.59
2	2.57	4.98
3	2.38	5.67

Table 8. Braking Force Test 3 – Braking of both front & rear wheels of a bicycle with a single hand lever using the brake splitter.

Test	Force Required to Begin Braking (KG)	Force Required to Fully Brake (KG)
1	4.36	11.01
2	5.47	9.44
3	4.84	10.39

From these results, it was confirmed that approximately double the amount of force is required to activate both brakes using the cable splitter with one single brake handle. As the client noted that his hand strength in his good hand was average, the additional force required to manually activate the hand brake should not be unreasonable. To compensate for this extra amount of force, the electronic braking system will be used a majority of the time and the manual system only used as a failsafe, back-up system in case the electronic system were to fail.

Based on the average force of 10.28 kg required to fully brake both wheels using the brake splitter, a suitable servo motor rated above 10.28 kg will be needed to have enough force to pull a cable within the brake splitter, without failure.

Also measured during this test was the linear travel of the cable from rest to gradual braking to fully activating the brakes, which was found to be from ½" to ¾" inside the brake splitter. This measurement will be used to calculate the distance the servo motor would need to pull a single cable within the brake splitter to activate both brakes. This measurement will also be used in the redesign of the cable splitter to accommodate the mounting of the servo motor within the cable splitter box.

Found in Table 9, are the final test results achieved based on the set Metrics for the one handed braking system.

Below are the final test results. In the first row, the force sensor requires a little force to engage the braking system. That's good because the force won't be activated inadvertently if the user accidentally touches it. As discussed above, the force is measured by a bucket of water physically. Electrically, the code in the Arduino estimates the force applied by the user. The force of 4.36 kg is low for people with minimal grip strength. As shown in figure 1, the interaction is 1-hand for both electrical (i.e force sensor) and mechanical (i.e. brake handle) preferences. As shown in figures 23 & 26, both the electrical circuit and brake splitter are protected within the waterproof boxes. Pouring droplets of water on the boxes had no effect at all. The cable strings themselves are enclosed in waterproof tubes as shown in figure 1. Most importantly, there's a fail safe mechanism. I

Table 9 - Final Test Results

Metric	Units	Marginal Value	Ideal Value	Measured Value
Force Required to Begin Braking	kg	-	< 5	4.36
One-hand interaction with brake	Yes/No	Yes	Yes	Yes
Waterproof	Yes/No	Yes	Yes	Yes
Fail safe mechanism	Yes/No	Yes	Yes	Yes

7 Conclusions and Recommendations for Future Work

7.1 Lessons Learned

In the course of completing this project work, some lessons learned were that building the brake splitter enclosure was time consuming and could have started this task earlier. Tensioning of the brake cables was challenging to balance the braking of both wheels at the same time using both the manual and servo activated brake system.

7.2 Future Ideas

Future work to the project would include the following:

- Install permanent connections for the circuits and arduino controller.
- Do further testing on battery life.
- Test different size servo motors to reduce the power requirements on the system and extend battery life.
- Paint and seal the brake splitter assembly.
- Reduce the overall size of the brake splitter assembly and combine with the waterproof electronic enclosure.
- Build the electronic enclosure and brake splitter enclosure with a light weight material such as aluminum that would remove weight of the overall system.
- Test different mounting brackets to better secure the brake components to different styles of walkers.

APPENDICES

8 APPENDIX I: Design Files

Table 10. Referenced Documents

Document Name	Document Location and/or URL	Issuance Date
Servo Specs	MakerRepo, under PROJECT FILES (Link)	07/25/2021
Walker Brake System Design and BOM	MakerRepo, under PROJECT FILES (Link)	07/25/2021
Force Sensor Code	MakerRepo, under PROJECT FILES (Link)	07/25/2021
User Manual	MakerRepo, under PROJECT FILES (Link)	07/25/2021
Force Sensor Holder (part 1)	MakerRepo, under PROJECT FILES (Link)	07/25/2021
Force Sensor Cover (part 2)	MakerRepo, under PROJECT FILES (Link)	07/25/2021
Force Sensor Button (part 3)	MakerRepo, under PROJECT FILES (Link)	07/25/2021
Deliverable B-J	MakerRepo, under PROJECT FILES (Link)	07/25/2021

9 APPENDIX II: Other Appendices

Table 11. Other Relevant Documents

Document Name	Document Location and/or URL
Device Listing Application Package – Manufacturers and Distributors	Ontario Health Government website, Assistive Devices Program (Link)