GNG 2101

# Design Project User and Product Manual

## Breezy Window Closers E1.1

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# 1 Introduction

The product that our group has designed is for opening a window using an app that is on an iPhone. The person that we were making this for had a spinal injury and had minimal function in their arms and hands, they then wanted a way to be able to open their window in their room. The assumptions we had while designing this project is that they can use their hands a minor amount to be able to tap a few bottoms on their phone to be able change some settings on their phone and that there was enough space below the window to be able to attach our mechanical component to. The general overview of the manual is to first talk about how to start building our product and some small details to be warry of, secondly how the whole product was built in more detail, lastly all the materials and equipment needed to be able to build the product. The reason that this document is being built is so that anyone who wants to be able to build this product on their own or with friends would be able to open and close a sliding window automatically. There are not many things to be wary of except to be careful while using all the equipment and the code for the app will not be provided and it will have to be installed and connected to Arduino separately.

# 2  Overview

The problem is that opening a window is not always as simple as going over and then sliding it open. Some people have mobility issues or have physical restraint that make this task very difficult. The Breezy Window Closer is here to help solve the problem. This device will make opening a window as simple as pressing a button on your smart phone. This device is meant to help people get in touch with nature by allowing them to feel the cool breeze outside or hear the birds chirping.

The automatic window opener and closer is far superior to what's on the market right now. With the Bluetooth connection that this device offers opening and closer a window is very easy as simple as open your phone and click close or open on the app. This device will also allow for setting an optimal room temperature as well as opening and closing on a set schedule. Other automated window openers do not offer any of these options, they simply have a button on the device or a controller.



**Figure 1 Prototype**

The prototype is made up of metal gears, a chain that is wrapped around it and a metal braket on the chain that holds the go-pro mounts on it that will move back and forwards. The frame is made of wood for durability. An Arduino is attached to a motor and contains a Bluetooth chip, the motor is then hooked up to the gear to rotate them. The window opener and closer will be fastened to the studs under the window frame, and the go-pro mounts will attach to the window. Then using the Breezy Window Closer app, you can open and close the window.

## 3  Conventions

There are no stylistic and command syntax conventions used in this document.

## 4  Cautions & Warnings

The device is very simple to use and doesn't require a signed waiver for purchase or use. The only thing that the user must be caution about is putting things into the gap that the device is in. This could cause damage to the device and lead to further problems. If something were to fall into the gap unplug the device and call the support help line. Never try to stick your fingers down to retrieve fallen items.

## 5  Getting started

To set up the system the following steps need to be taken:

1. First line up the window opener with the bottom of the window
2. Mount the opener under the window with self-tapping wood screws.
3. Once mounted to the wall, the go pro mounts must be glued to the window itself.

4. Plug in and use.

# 6      Configuration Considerations

The physical configuration involves mounting gears and brackets to a wall and handling bike chains. Here's a simple breakdown:

Description: Use the screwdriver to securely attach gears and brackets to the wall. This ensures stability and support for the system.

Handling Bike Chains:

Tools Needed: Chainbreaker

Description: The chain breaker tool is used to disconnect and connect bike chains. This allows for adjustments and maintenance of the system, ensuring smooth operation.

For a visual representation, imagine a wall with gears and brackets mounted on it. Nearby, there's a depiction of a bike chain being worked on with a chain breaker tool. This illustrates the setup and the tools needed for assembling and maintaining the system.

# 7      User Access Considerations

People who can use our product are basically endless since of the function of the easy-to-use interface in the app. The app can deal with many people in their own situations, the only people that might not be able to use the app directly are ones not able to use their hands at all and not have

someone that could set the app up for them. The only way around this would if they had a system that could go through apps and change it themselves in which they would be able to use the app.

## 8 Accessing/setting up the System

When fixing the gears to the backboard of the opener, the gear sets need to be placed far enough to each other to ensure that the chain will have proper tension. The same goes for mounting the motor to the backboard, each piece that is mounted needs to be properly placed to keep tension on the chain. Once all the chain sets and motor have been mounted then the box needs to be built around it and fixed in place with screws and glue. After the box it around the gears then the device can be mounted to the wall.

For the software prototype the only required setup is to download the app and to upload the code to the Arduino. The app should be able to find the Arduino once it is given power and connected to the adafruit Bluetooth module. Once the device appears in the select devices section of the device selector page, press on its name, and you should be connected.

## 9 System Organization & Navigation

For the software prototype the only required setup is to download the app and to upload the code to the Arduino. The app should be able to find the Arduino once it is given power and connected to the adafruit Bluetooth module. Once the device appears in the select devices section of the device selector page, press on its name, and you should be connected.

# 10    System Organization & Navigation

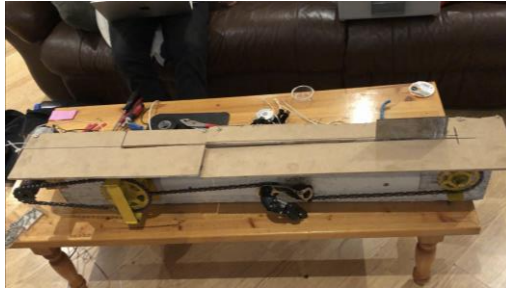The following picture showcases how the components are arranged in the opener:



**Figure 2 Prototype Being Built**

The picture shows that on the device's far left is the motor connected to the center's main gear sprocket. The center sprocket set is attached to the far right set by a chain tensioned by a tensioner placed between them. Welded to the chain is the bracket that the go pro mounts attached to.

To navigate the software, there are five independent screens that all have important functionality. The first screen is the device selector. This is the screen where all device that meet the requirements are visible to be connected with. When a device is selected, the user is directed to the control panel screen. The next screen is the control panel screen. This screen allows the user to view the status and allows the user to access all the other screens. The next screens are the schedule manager, the temperature manager, and the manual control, which allow the user to manage a schedule, manage a temperature limit, and manually control the device respectively.
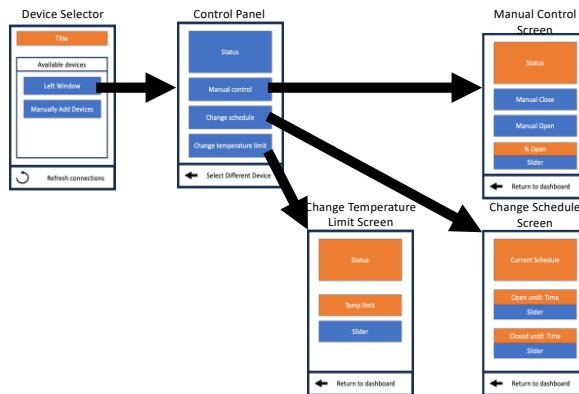
**Figure 3 Iphone App**

## 11    Exiting the System

To exit the software the app can be closed on the user's phone. If the user wishes to deactivate the device, simply remove the power by unplugging it.

# 12 Using the System

## Control Screen

The user has three different options to open and close the window. Firstly, they can manually open and close the window by selecting the "Manual Control" button. Secondly, they can set the window to open and close the window at a specified time by selecting the "Change Schedule" button. Finally, they can have the window open or close based off the temperature of the room by selecting the "Change Temperature Setting" button. More details about the three options are described in the sections below.
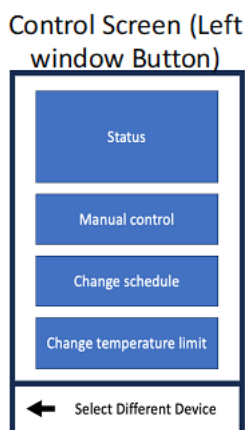


**Figure 4 Control Screen**

## Manual Control

Within the app the user can open and close the window manually by selecting the Manual Control button from the Control Screen. From there, the user has the option to completely open or close the window by selecting the "Manually Open" or "Manually Close" button. The user can also

adjust the slider below "% Open" to open the window part of the way. Finally, the "Status" section

at the top of the screen is used to tell the user if the window is currently open or closed.

**Control Screen (Left window Button)**

Status

Manual control

Change schedule

Change temperature limit

← Select Different Device

**Figure 5 Control Screen**

**Manual Control Screen**

Status

Manual Close

Manual Open

% Open

Slider

← Return to dashboard
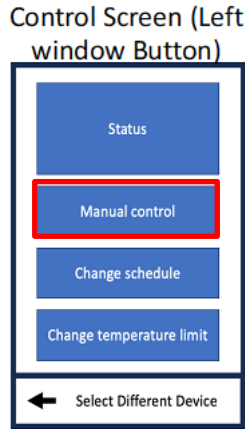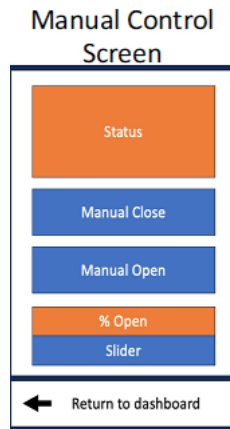
**Figure 6 Manual Control Screen**

## Change Schedule

The user can set a time for the window to automatically open and close. This can be done

by selecting the "Change Schedule" button from the control screen. This will bring the user to the

Change Schedule Screen. Then, the user can set what time the window opens at by adjusting the

slider below the displayed "Closed Until: Time". To change what time the window closes at the user will simply adjust the slider below the displayed "Open Until: Time".
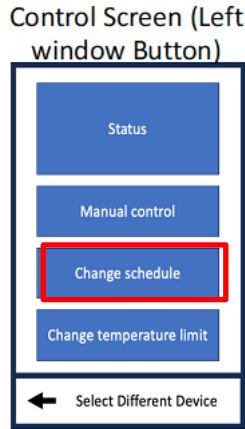


**Figure 7 Control Screen**
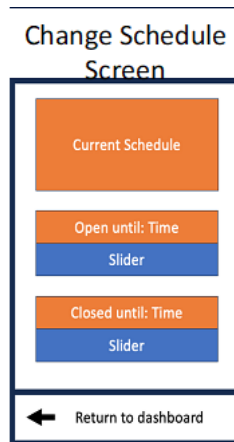


**Figure 8 Schedule Screen**

## Change Temperature Limit

The user can also open and close the window based off specified temperature limits. This can be done be selecting the "Change Temperature Limit" option from the control screen.

Afterwards the user can adjust the slider under the "Temp Limit" to set the temperature limits for

when the window should open and close.
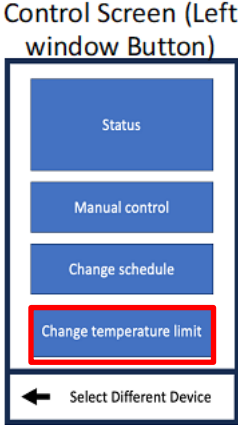


**Figure 9 Control Screen**
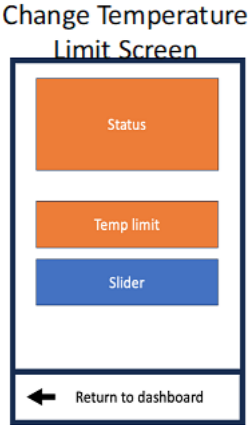


**Figure 10 Temperature Screen**

## Open By Hand

Also, if for any reason the window needs to be opened or closed by hand the person opening or closing the window can simply push or pull on the window without disconnecting anything from the window itself or adjusting any settings within the app.

## 13 &lt;Given Function/Feature&gt;

The device will open and close a window by using an app on the iPhone. If you refer to Using the System section of the user manual, you will find everything you need on how the device functions and how to operate it. If there are any questions or concerns, please contact the support team.

## 14 Troubleshooting & Support

Power-cycle the device, and if issues persist replace the device.

## 15 Error Messages or Behaviors

There are none.

## 16 Special Considerations

When trouble shooting the first option you can try is power-cycling the device back in. If the chain falls off the gears or something internally comes lose you can fix it, but you must make sure the device is unplugged as not doing so can lead to injury. If in doubt, please contact our support line. We are here to help our clients and ensure a safe and speedy fix.

## 17 Maintenance

For the maintenance of the prototype the person will not have to take care of it too often since we built it to function all the time under almost any conditions. The only thing that someone would need to check would be the chain and gears of the system since they are the things that would most likely fail first. This would be done by making sure that there is no rust over the components as well as maybe lubing up the mechanism if the motions become stiff.

## 18 Support

To get support you can email Jordan DeRose at jdero078@uottawa.ca. Make sure you include the exact problem you have, and we will do our best to get back to you as soon as possible. If your product is damaged, please discontinue the use until we can confirm that it is safe to use, or we have a chance to fix the problem. Thank you.

## 19 Product Documentation

The final prototype was built by building the mechanical, software, and electrical components individually and then piecing them together once they were all done. Details about each section are outlined below.

### Mechanical

The mechanical system was meant to be as simple as possible, our first idea was to make a product that used a rotating arm to open and close the window similar to that of a automatic door opener.
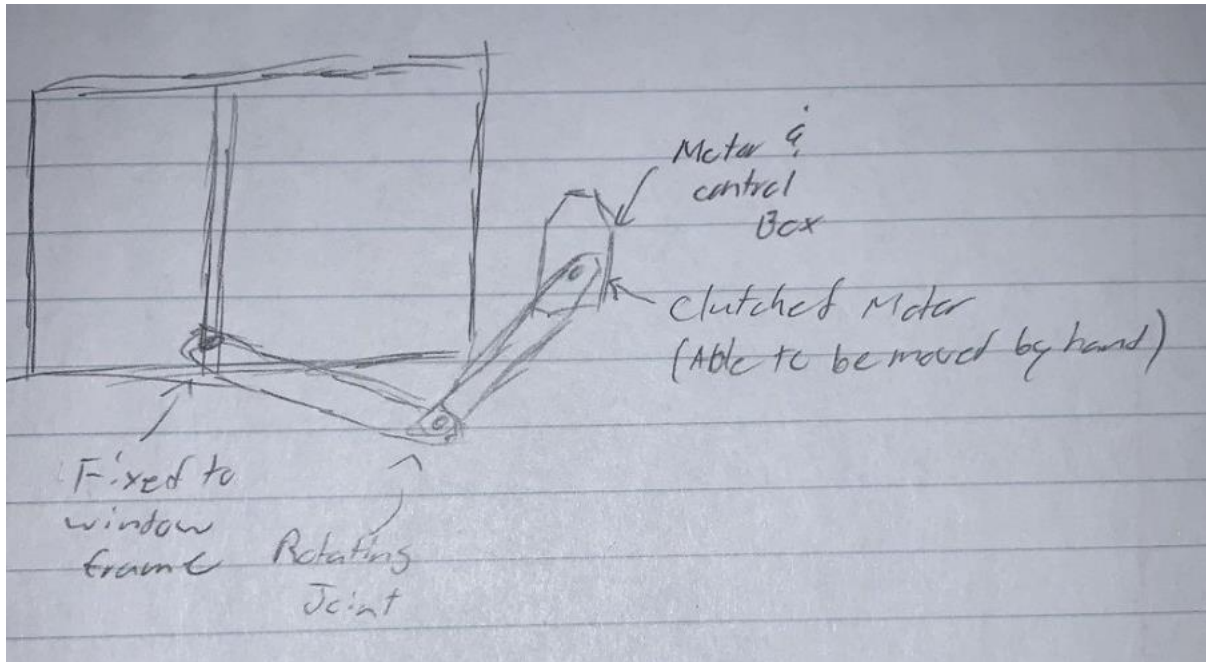
**Figure 11 First Prototype**

The client told us that the design was visually unappealing. A new design was pitched. This design consisted of gears enclosed in a box connected by a chain. A piece would be connected from the chain to the window so that moves as the gears spin the window will open and close.
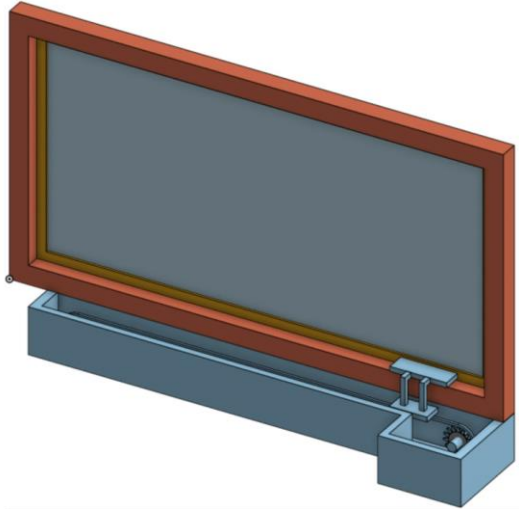
**Figure 12 Prototype CAD**
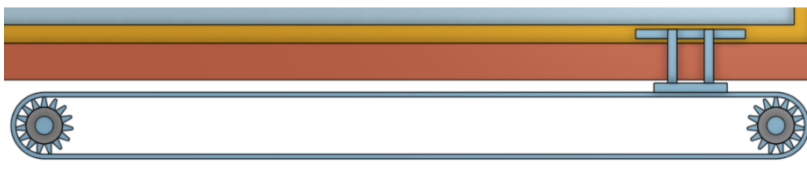


**Figure 13 CAD Mechanical for Prototype**

The client approved of the design but asked us to extend the box so that it spans the whole length of the window even if it full of empty space.

An advantage of this design is we could construct our mechanism using old bike parts which we were accustomed to. We also had significant budget restrictions while building the prototype and we had access to old free bike parts.

The build was initiated by sourcing some old bike parts for free. These parts included some individual gears, a free wheel, some chain, and a derailleur. With a larger budget and some more

time we would have bought new gears, some new chain and we would have explored more ways to tension the chain. Such as using a single sprocket instead of the derailleur.

We felt that the bike parts would be suitable based off the following simple calculation. A cyclist on Quora named Branko Dodig shared his cycling data. With his data he calculated his force output during an endurance ride to be 28lbs[1]. This, however, is not equivalent it the maximum force a bike can tolerate. He produced this force resulting in an average power output of 171 watts, but professional cyclists are capable of averaging over 400 watts of power[2] . A free body diagram was created in order to calculate the tension on the chain when someone is applying 28lbs of force to the pedal. The radius of the smallest gear of a crankset is about 150 mm (using the smallest gear results in the greatest tension force on the chain). From there, the moment about the center of the freewheel was calculated. With the moment an estimation for the chain tension can be made. With 28lbs of force applied it is estimated that 44lbs of tension is in the chain and it is highly probable that the bike components can withstand much higher forces. Also, from manually opening and closing the window it is safe to say that it does not take 44lbs of force to do so. This is not a perfect calculation, however it does tell us that the bike components will be sufficient for opening and closing the window.

& assume the chain (and thus the tension forces run horizontally, and perpedicular to the applied force)

Small crankset gear

$$T_1 + T_2 = T$$
$$\frac{1}{2}T + \frac{1}{2}T_2 = T$$

28 lbs

$R \approx 105\ mm$
$R = 0.105\ m$

0.165 m

$M_{applied\ force} = 28 \cdot 0.165 = 4.62\ lb \cdot m$

$M_{applied\ force} = M_{tension}$

$M_{tension} = \frac{1}{2}T \cdot R + \frac{1}{2}T \cdot R$

$M_{applied\ force} = T \cdot R$

$T = \frac{M_{applied\ force}}{R}$

$T = \frac{4.62}{0.105}$

$\boxed{T = 44\ lb}$
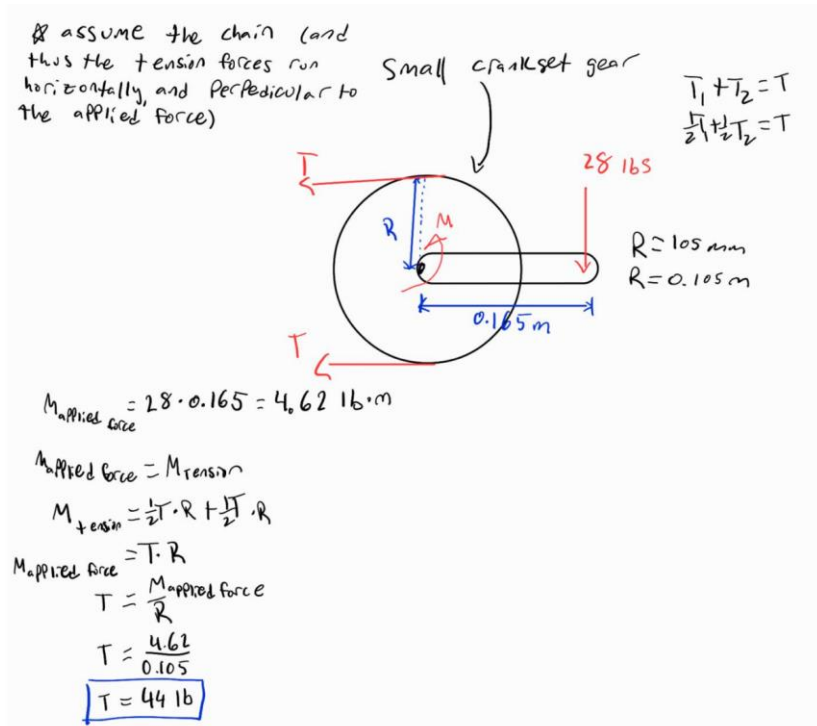
**Figure 14 Engineering Mechanics of Prototype 1**

Afterwards, balls bearings were welded to the insides of the gears and large bolts with a diameter of ½" were welded to the bearings, these bolts acted as axles. Ideally, we would have used a regular ½" solid steel rod to use as the axle. After, a steel frame was constructed for the gears so that they could be mounted to the board.

**Figure 15 Gear for Prototype**

The frames were then fastened to a scrap piece of 10" x 2" x 4' piece of wood. A smaller and higher quality 8" x 2" x 4' piece of wood would have been ideal to make the box smaller and make it more aesthetically pleasing. A derailleur was then fastened to the board using a screw and an extra piece of scrap wood to raise the height of the derailer. After, a bike chain was looped through the derailer and 2 gears. Finally, a bracket was welded to the chain. This bracket had GoPro mounts attached to it and the mounts would attach directly to the window.
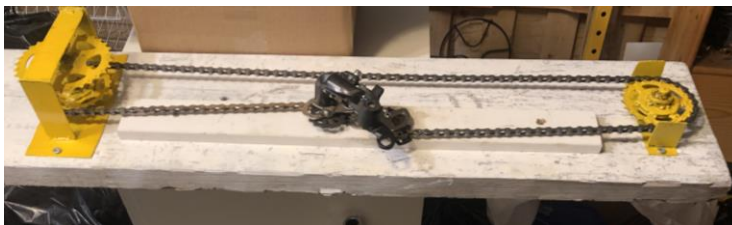


**Figure 16 Chain set up for Prototype**

**Figure 17 Slider for Prototype**

We sourced an old drill for free to drive the chain. The drill was mostly made of steel so a gear was welded to the chuck of the drill and a bracket was welded to drill casing. From there the bracket was screwed into the wood and a second chain was put into the drill and on of the gears on the closest frame. The gear on the drill was not aligned properly so we put a zip tie around the drill and screwed the two ends of the zip tie into the board. With more time and a larger budget we would have bought a smaller motor which would have fit inside the box. From there we would have attached a gear to an axle coming off the motor. This would make the whole design look a lot nicer.

**Figure 18 Motor for Prototype**

## Box

Once the mechanical system was complete, we were able to build the box. The box is important because it improves the aesthetics of the design and it prevents anyone or anything from getting caught in the system. The box was made of 18" x 24" x 0.25" MDF particle board and scrap acrylic. The box had two acrylic viewing windows on the front side so that observers could see the mechanical workings on design day. A slot was made on the top of the box so that the bracket attached to the chain could freely move back and forth. We also did not cover the bottom, so we had easy access in case something broke. The MDF and acrylic was held together using super glue.

This worked well for design day however there are many improvements that could be made. Firstly, there would be a bottom build into the box and there would be no viewing windows. We would also have to explore way to make a removable top so that repairs can be made if needed. For example, a shallow slot could be cut into the large board and the top could slide into the slot. Also, the client asked for the box the be white so the box would either have to be painted white or some white wood could be used to construct the sides of the box.

## Software

One of the client needs was to be able to open and close the window from her phone. We explored many options such as using an Arduino Bluetooth controller app, a web application, or integrating our system with an app already available that allows user to control multiple systems. We felt that these options limited us and that we would not be able to meet all of our client's needs. Instead, we developed an iOS app using Apple's developer software, provided to us by the University of Ottawa.

Developing a new app allowed us the meet the following client needs. The user could manually open or close the window either completely or partially. The user could have the window open or close based on a specified time. Finally, the user could have the window automatically open or close when based on the temperature of the room.
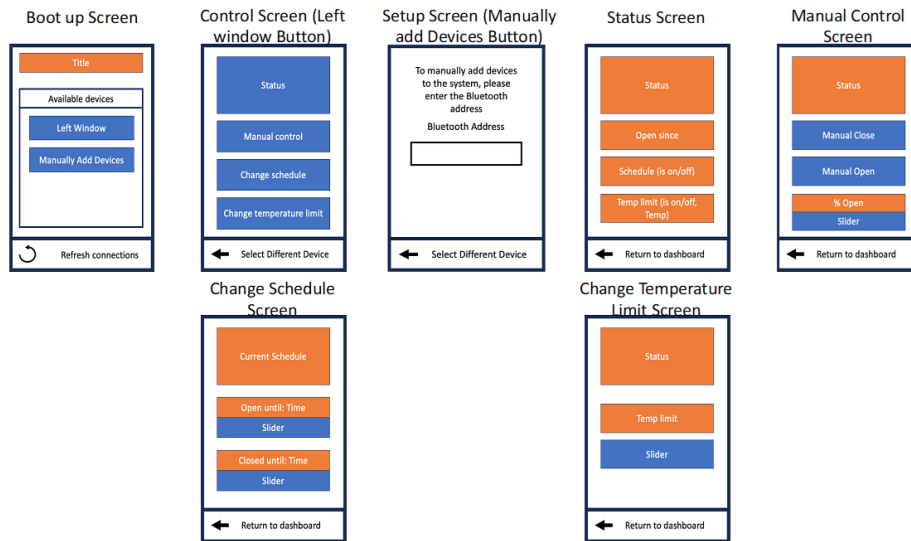


**Figure 19 App Layout**

## Electrical

The circuit was centred around the use of an Arduino due to the abundance of information available online and the customizability of them. Within the circuit there was a temperature sensor used to measure the temperature of the room so that the user could open and close the window at specified temperatures. There was also a magnetic sensor used to tell if the window was fully open or closed so that the motor would not try to fight against the window. The sensors were plugged into the

Arduino's 5V pins for power and plugged into the Arduino's analogue pins for data input. The Arduino also had two digital output pins which went to a motor controller which was also connected to a 32V charger for power and the motor. These pins can be activated by the Arduino code when we want to change the state of the window, and the motor controller will then activate the motor.
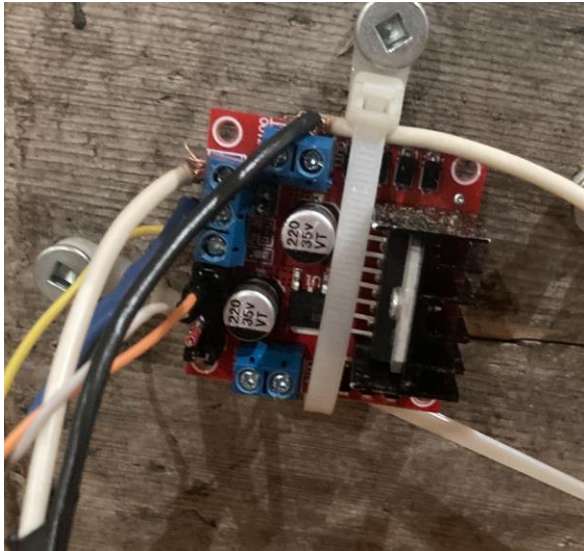


**Figure 20 Wire to Arduino**

## Communication

To communicate between the phone and circuit we decided to use Bluetooth. We also explored using WIFI and infrared light however, we identified key problems with these two options. WIFI would not have been ideal because there was no ethernet port close to the window and in the event of a network crash there would be no way to communicate with the window. Infrared would not have been a good solution because the client already had a lot of infrared devices in the room, and

we were worried about interference from the other devices. Using Bluetooth avoided the problems from WIFI and infrared but it also simple and allowed the user to control the window from almost anywhere in her house with the ~100m range of Bluetooth Low Energy.

An Arduino Bluetooth module was attached to the Arduino. We felt this was the best way to implement the use of Bluetooth because it was easy to add it to the circuit and there are a lot of resources available online to help us set up and troubleshoot problems.

# 20 &lt;Subsystem 1 of prototype&gt;

## 20.1.1 BOM (Bill of Materials)

**Table 1 Bill of Material**

| Item | What it is? | Amount | Cost ($) | Source |
|---|---|---|---|---|
| 1 | Arduino Uno | 1 | 15.25 | Maker store |
| 2 | Gears (2.5 inches in diameter) | 2 | 13 | Amazon |
| 3 | Chain (1 meter bike chain) | 1 | 18 | Amazon |
| 4 | Brushed Motor (18V) | 1 | 25 | Amazon |
| 5 | Wires (1 meter red 1 meter black) | 2 | 10 | Amazon |
| 6 | Bluetooth Chip | 1 | 13 | Amazon |

| 7 | Screws (self-tapping hardware screws, 2.5 in) | 4 | 14 | Amazon |
|---|---|---|---|---|
| 8 | Wood sheets (3x3 foot) | 2 | 9 | Amazon |
| 9 | Metal Sheets (2x2 foot) | 1 | 20 | Amazon |
| 10 | GoPro Mount | 1 | 15 | |
| Total | | | 174 | |

### 20.1.2  Equipment list

Welding: This is needed to mount the metal parts like the hears to the chain of the system

Metalworking: This is needed to be able to manipulate the metal pieces to fit on the system

Woodworking: This is used to build a box around the chain system

Coding: Needed to program the app in which the client will use daily to operate the window and the Arduino to interact with the app and control the window.

CAD designing: This is for testing purposes of the mechanical portion of the project.

### 20.1.3 Instructions

Firstly, disassemble two bike free wheels and keep one 117 mm 28 tooth gear, two 79 mm 20 tooth gear and a single 60 mm 14 tooth gear. From there, weld ½" x 1 – 1/8" x 5/16" deep grove ball bearing into the centre of all the gears except for the 60 mm gear. After, slide a ½" x 4" bolt through the 117 mm gears and through one of the 79 mm gear (so that they are on the same axle). Weld the 79mm gear 1" from the head of the bolt and weld the 117 mm gear 1" from the other end of the bolt. Weld the second 79 mm gear in the same position on the other bolt. Next, weld the axles onto frames using the schematics below.
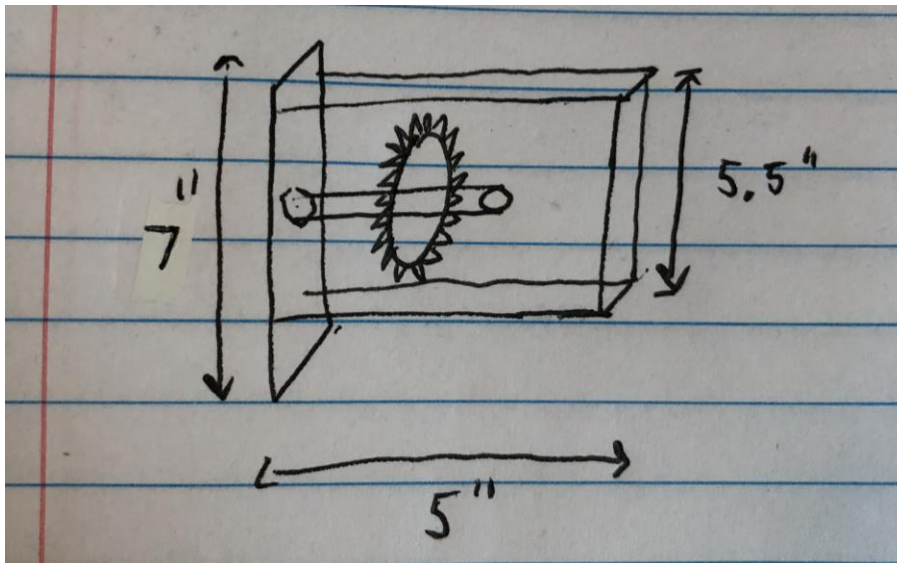


**Figure 21 Gear Setup**

Once the frames have been made, they can be fastened to the 10" x 2" x4' back board. They should be placed 26" apart and the frame with 2 gears should be 1' from the left side. Once, frames are fixed to the board screw a ½" board roughly centred between the bottom section of the two frames.

This will raise the derailleur up so that it is in line with the two 79 mm gears. Loop a bike chain through the derailleur and the two 79 mm gears so that the derailleur can be positioned vertically, but don't connect the ends together. Then, roughly centre the derailleur in between the frames and secure it to the board using screws. Finally, the length of the chain can then be set, and the two ends of the chain can be connected. At this point the window opener should resemble the following image.



**Figure 22 Chain and Gear Layout**

Once all this is assembled, weld a 6" x 6" piece of steel to the chain in between the long length of chain between the two gears.

Now, take the 60 mm gear and weld it the very end of the chuck of the drill. Then a bracket can be made by cutting a semicircle into a 4" x 3" piece of steel. The base of the chuck should be comfortably sit in the semicircle. The bracket can then be welded to the drill and screwed into the back board. As shown below. Finally, a bike chain can be looped between the 60 mm and 117 mm gear.

**Figure 23 Motor and Chain Setup**

A box made of MDF and acrylic can now be constructed to cover the mechanical system. The top of the box will need a piece of wood that is the length of the back board and 5 – ½" wide. Mark where the bracket welded to the chain will intersect with the top of box and cut a slit. Fasten the top of the box to the back board using screws. The long side of the box can then be made by cutting a piece of MDF to be the length and height of the back board. Using scrap acrylic cut out holes smaller than the pieces of acrylic so that they can be super glued in place. Once the windows are in place use super glue to attach the side of the box to the top of the box. Finally cut a 9.5" x 5.5" piece of wood to cover the left side and use screws and super glue to secure it to the back board and rest of the box.

## Construction of Circuit

To begin building the circuit attach the Bluetooth module to the Arduino. Then, the temperature and magnetic sensors were plugged into the analogue pins on the Arduino. From there, the Arduino was connected with the motor controller and wires were ran from the motor to the motor controller. After testing the motor to ensure it ran properly everything was soldered and mounted to the back of the back board. Finally, electrical tap was used to bundle all the wires together to tidy it up.

## 21    Testing & Validation

Tests that were done to ensure the components were working before the prototype was build were; ensuring the app worked, ensuring the motor was compatible with the Arduino, and ensuring the chain and the gears would work with the motor to open and close the window.

The app was tested by hooking up an LED to the Arduino and then pressing open and close on the app to see if it received a signal. This was successfully done since the LED would light up when the app was given a command.

The next test that was performed was to test if the motor was compatible with the app, this was done by hooking the motor up to the Arduino and seeing if the app could make the motor spin. This was also successful since the motor would spin clockwise when opening the window and then spin counterclockwise to close the window.

The next thing that needed to be done was to ensure that the chain being hooked up to h motor would work and have enough tension. The chain was connected, and the motor was started

to see if it could be moved back and forward without any problems. This was successfully done and there were no issues.



**Figure 24 Prototype**

# 22 Conclusions and Recommendations for Future Work

There were many things that our group has learned from making this project in which was the amount of work that is needed to make the physical model as well as the amount of teamwork needed to make sure that everything goes smoothly from the people doing the deliverables and the people making the products themselves. For people who would be taking on this project after us, the main things would be to make the final product earlier so that they can do more testing. As well as to be able to make the final product more appealing since the product that we produced was not the most aesthetically pleasing but was the best we could do with the amount of time we had to make it.

If we had a few more months to do this project we believe that the physical model would be a lot cleaner and would have a more permeant way for the mechanism to attach from the chained system to the window. There were not many things that we had to abandon because of time, but the main thing would have a temperature sensor on the build to be able to detect the temperature since our app had the function to do so but we did not have to physical thing.

# 23 Bibliography

[1] Dodig, B. (n.d.). Re: How much force do you apply on a bicycle pedal? [Comment on the forum question How much force do you apply on a bicycle pedal?]. Quora. https://www.quora.com/How-muchmaximum-pedal-force-would-the-leg-of-an-average-person-generate-while-cycling

(BOM links)

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Bibliography

# APPENDICES

# 24 APPENDIX I: Design Files

The Bill of Materials came form Deliverable D.

**Table 2. Referenced Documents**

| Document Name | Document Location and/or URL | Issuance Date |
|---|---|---|
| Deliverable D | rilptxmqxh4qrcw4j3dgk7igvyfo (amazonaws.com) | March 4, 2024 |

MakerRepo- GNG2101-E1.1-Breezy Window Closers | MakerRepo (makerepo.com)

# 25 APPENDIX II: Other Appendices

BOM for box and mechanical system – https://uottawa-my.sharepoint.com/personal/etrai055_uottawa_ca/_layouts/15/guestaccess.aspx?share=Ef_FTfTye8hBqp0KVsnOLqEBMYk_2X6arZ3-t7UOo0Mf0Q&e=ACfRUo

Basic CAD Model- https://cad.onshape.com/documents/8f412b386e6e65828ee96681/w/e9439b37e8c5301572fc8675/e/6d52ee962551f0fa48a2edcc