

GNG 2101  
**Design Project User and Product Manual**

**Automated T-Shirt Folder**

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# Table of Contents

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1 Introduction	1
2 Overview	2
2.1 Cautions & Warnings	6
3 Getting started	7
3.1 Configuration Considerations	7
3.2 User Access Considerations	7
3.3 Accessing/setting up the System	7
3.4 System Organization & Navigation	9
Folding Actuators	10
Accessibility and Control System	10
3.5 Exiting the System	14
4 Using the System	15
4.1 Perform a fold	15
4.1.1 Fold with button	16
4.1.2 Fold with application	16
4.1.3 LCD display screen	16
5 Troubleshooting & Support	21
5.1 Error Messages or Behaviors	21
5.1.1 T-shirt folder not folding correctly	21
5.2 Bluetooth connection error	22
5.3 Maintenance	22
5.4 Support	23
6 Product Documentation	24
6.1 Product Documentation	27
6.1.1 BOM (Bill of Materials)	27
6.1.2 Equipment list	35
6.1.3 Instructions	38
6.2 Testing & Validation	41
7 Conclusions and Recommendations for Future Work	45
8 APPENDIX I: Design Files	47
9 Bibliography	49

## List of Figures

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- Figure 1: Final Physical Prototype of the ATF - 3*
- Figure 2: Final Prototype of the Mobile App - 4*
- Figure 3: UML State Diagram Representing the Overall Process of the ATF - 6*
- Figure 4: T-shirt Folder Clamped onto the ATF - 8*
- Figure 5: App Displaying that Bluetooth is Connected - 8*
- Figure 6: DC Power Supply Adapter Plugged into the ATF - 9*
- Figure 7: Home Page of Mobile App - 11*
- Figure 8: Notifications Page of the Mobile App - 12*
- Figure 9: Settings Page of the Mobile App - 13*
- Figure 10: Image Showing How To Place The T-shirt Folder - 15*
- Figure 11: Activate Fold Option - 17*
- Figure 12: Folding Progress shown by the bars on the LCD - 18*
- Figure 13: “Options” option - 19*
- Figure 14: Options Menu - 20*
- Figure 15: Housing and Frame of ATF - 39*
- Figure 16: Circuit Diagram of ATF - 40*

## List of Tables

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- |                   |     |
|-------------------|-----|
| Table 1. Acronyms | vii |
| Table 2. Glossary | vii |





## List of Acronyms and Glossary

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Table 1. Acronyms

Acronym	Definition
EEPROM	An EEPROM stands for electrically erasable programmable read-only memory, and it is a non-volatile ROM chip which is used for storing a small amount of data in electronic devices such as computers.
LCD	An LCD stands for Liquid Crystal Display and it is a type of flat-panel display made up of millions of pixels, which uses liquid crystals as its main form of operation.
LED	An LED stands for light emitting diode and it is a semiconductor device that outputs light when an electric current is flowing through it.

Table 2. Glossary

Term	Acronym	Definition
Arduino Nano Microcontroller	-	The Arduino Nano is a small microcontroller board that was designed by Arduino.cc. A microcontroller is a compact integrated circuit that is made to perform a specific operation within an embedded system.
Bluetooth	BLE	Bluetooth is a standardized protocol that is used for sending and receiving data through a 2.4 GHz wireless link.
React Native	-	React Native is a JavaScript framework that is open-source, that is designed for creating apps on many different platforms like iOS and Android. It is also possible to make web applications using React Native.
Resistor	-	A resistor is an electrical component that is used to limit the flow of the electrical current within a circuit.

Servo Motor	-	A servo motor is a rotational or translational motor that applies force to a mechanical system. They are found everywhere from vehicles to robotics.
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# 1 Introduction

This User and Product Manual (UPM) provides the information necessary for patients and caretakers to effectively use the Automated T-Shirt Folder (ATF) and for prototype documentation.

People who have motor deficits are often faced with difficulty in performing day to day tasks. One of these tasks is folding a t-shirt. This is because people with motor deficits have symptoms such as paralysis, spasticity or uncontrolled movements, and difficulty carrying or moving objects. As you could imagine, people with symptoms like this have a hard time folding a t-shirt with their hands or with a regular plastic t-shirt folder. This is a problem, because it has led to the caretakers of people with motor deficits to fold their t-shirts, instead of the people with motor deficits folding their t-shirts themselves.

The main demand for this product comes from people with motor deficits and their caretakers, who would find this product useful for them. The client needs a product that is not built with cardboard pieces, easy to install, reduces the movement of hands, and cleaned with a wipe. We also wanted to go above and beyond by developing an app for the iPad and Microsoft Surface Pro tablets that connected to the t-shirt folder via a bluetooth module, that would allow the the children to activate the t-shirt folder by pushing a button on the app.

Over the course of the past four months, our team drew sketches, made a CAD model, developed a circuit diagram , UML state diagram, a Figma app prototype, and a housing and frame prototype. By using these prototypes, our group was able to develop our final app prototype built with React Native, as well as the physical ATF.

The purpose of this document is to provide instructions for anyone wanting to use the ATF. There is information on how to assemble, use and disassemble the ATF, as well as safety information. This document also shows the key features of the ATF, budget information, troubleshooting and recommendations for future work. The user manual will also point out all of the considerations that need to be stated before moving forward. The manual also walks the reader through the entire process of using the ATF. Next is troubleshooting, where all of the problems that are common to the ATF and their solutions are stated. Then there is the product documentation, and a conclusion.

The intended audience for this document are people that have motor deficits, that want to easily fold their t-shirts without the help of others, or for anyone else that wants to fold their t-shirts easily.

## **2 Overview**

We were tasked with automating a t-shirt folder for Bethany's children's center with the aim of allowing the children, some of whom have motor disabilities, to become more involved in the merch store by allowing them to assist with folding t-shirts. This was an important problem for us to fix as it would make the t-shirt folder accessible for all of the children at the center allowing everyone to participate in the folding of t-shirts by pressing a button.

Our product has been adapted for accessibility so we made sure to implement multiple different ways to activate the ATF. One possibility is by pressing a button that is attached to the ATF which is the standard way of activating a t-shirt folder used by most industry ATF's. The way we differ from others is with our second activation option which is a mobile application. Users can click a button on a mobile application activating the ATF which allows for far more flexibility in its use as this gives users the ability to activate the ATF from a distance.

Another way our product differs from that of the competition are the ways we adapted it for safety. We have included many crucial safety features in our final design such as an emergency stop button, bumpers on the bottom of the device to prevent it from being pushed over and plastic casings that protect the delicate parts of the machine. All of this was crucial as we had to ensure that the children would be at minimal risk of injury when using the device.



*Figure 1: Final Physical Prototype of the ATF*



*Figure 2: Final Prototype of the Mobile App*

Some of the key features offered by our ATF are a mobile application, a menu on a LCD display and a button for activating the ATF.

The mobile application can be used to activate the ATF by pressing the large button that says “Fold” in the center of the first page. The mobile application also includes an accounts feature that allows for the creation of different users. Each user has information associated with their account such as the number of folds.

The LCD display starts off with the Home screen, which simply shows the name of the product, which is the Automated T-shirt Folder or ATF, and a menu to display the options, the Activate Fold, and Options, Once you click on the Activate Fold option, the ATF performs its folding operations on the t-shirt on top of it. When you click on the Options option, the ATF displays all of the other options of the t-shirt folder like the credits option and the Re-Home arms option.

In terms of physical architecture, the exterior of the ATF is made out of aluminum bars, and acrylic plates to cover its sides. There are also movable acrylic flaps that are on the top of the ATF. The plastic t-shirt folder is then held onto the acrylic flaps by PLA clamps. In the interior of the ATF, there are the modified 2 bar linkages made from PLA, as well which are used to fold the acrylic flaps. There is also an Arduino Nano microcontroller attached to a yellow PLA platform that is used to control the LCD display on the ATF, as well as communicate with the React Native app using the HM-10 bluetooth module.

The ATF process is very simple to follow. This UML state machine diagram shows the overall process of the ATF.

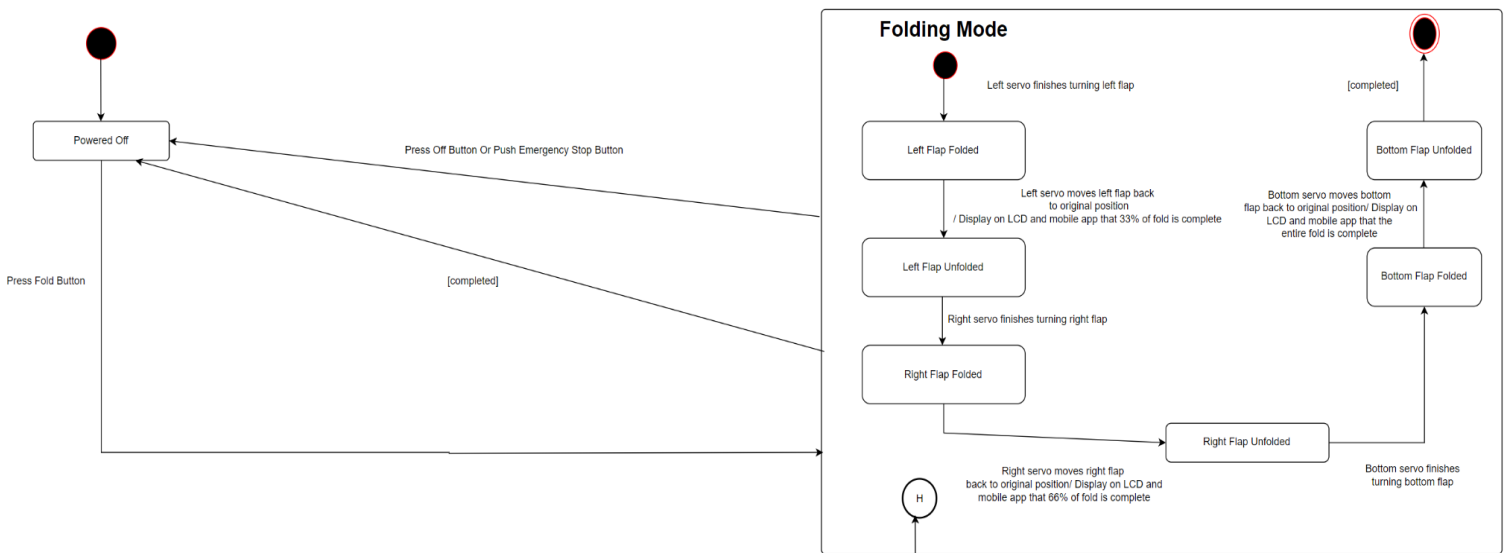


Figure 3: UML State Diagram Representing the Overall Process of the ATF



## **2.1 Cautions & Warnings**

The user should be aware of some of the potential hazards of using this device. Possible injuries that could occur using the device are pinched fingers as the t-shirt flaps fold. The device is heavy and could cause injury if dropped on someone. The user should avoid putting their hands in the interior of the ATF, because he/she could accidentally remove the wires on the breadboard and cause the ATF to break.

## **3 Getting started**

### **3.1 Configuration Considerations**

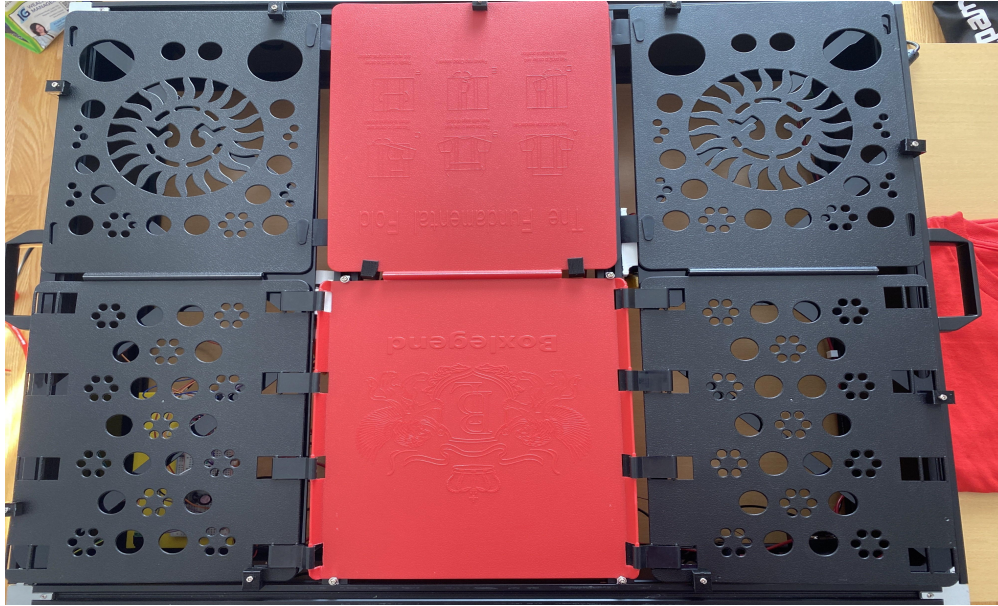
A screwdriver is required to clamp the plastic t-shirt folder onto the ATF. This device is designed to function anywhere that has a wall outlet. The user should use the ATF on a table, but the user could also operate the ATF on the floor as well. As long as the surface is flat, the ATF can operate on top of it. Also, in order to carry the ATF easily, there are plastic handles on its sides. In terms of software, the app is accessible on iPads and Microsoft Surface Pros. For these devices Bluetooth must be on, in order to connect to the ATF's bluetooth module.

### **3.2 User Access Considerations**

The product is designed to be used by an adult or child with motor deficits. However, a caretaker must be present to put on the t-shirt, and take off the t-shirt. Also, a caretaker must be present to screw in the clamps for the plastic t-shirt folder. A caretaker must be present to lift the ATF and move it to different locations. The ATF is a little heavy, so the caretaker needs to be able to lift at least 5 kg to be able to move it around.

### **3.3 Accessing/setting up the System**

1. Grab the plastic t-shirt folder and place it on top of the ATF.
2. Slide the clamps to the spots shown in *Figure 4*.



*Figure 4: T-shirt Folder Clamped onto the ATF*

3. Take a screwdriver and screw in the PLA clamps.
4. If using an iPad or a Microsoft Surface Pro to activate the t-shirt folder, open the t-shirt folder app.
5. Connect to the HM-10 Bluetooth module and check to see if Bluetooth Status is connected, as shown in Figure 5.



*Figure 5: App Displaying that Bluetooth is Connected*

6. Plug in the 5V DC Power Supply Adapter into the wall and the plug in the other end to the ATF.



*Figure 6: DC Power Supply Adapter Plugged into the ATF*

### **3.4 System Organization & Navigation**

#### **Housing and Frame**

The Housing and Frame subsystem is essentially the exterior of the ATF. It is composed of the black Aluminum bars which acts as the skeleton of the ATF, and is what keeps the ATF together. In addition, there are the corner connectors which were made from stainless steel. It is also composed of the double plated black acrylic plates on its sides, to cover up the electronic components of the ATF. The housing and frame subsystem also has acrylic flaps on the top to help push the flaps of the plastic t-shirt folder. In addition, the housing and frame subsystem has rubber

stoppers. Finally, the Housing and Frame subsystem contains the PLA clamps which are used to hold onto the plastic t-shirt folder.

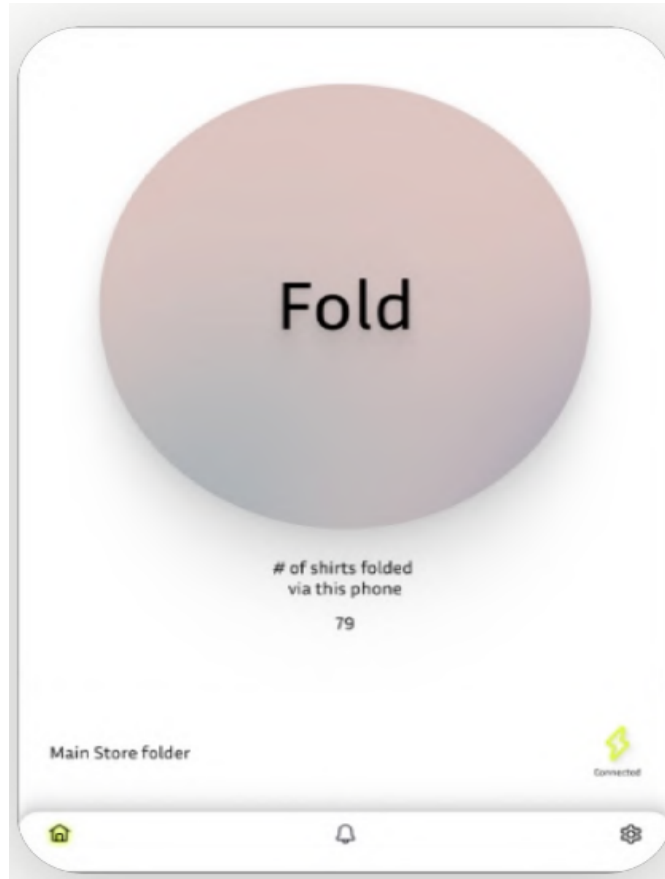
### **Folding Actuators**

The folding actuators subsystem is part of the interior of the ATF. It is the components that allow for the folding of the t-shirt. There are 3 different folding operations that occur on the ATF. There is the left flap fold, right flap fold, and the bottom flap fold. In order for the fold to occur, the actuator needs to make a full 180 degree rotation of the flaps, otherwise, there is a chance that the t-shirt will fold improperly. Also, because the flaps are moving the fabric of the t-shirt, continuous force is required for every folding operation. The 2 bar linkage fills all of these requirements. There are also Servo motors that are used to actually turn the 2 bar linkage, and complete the folding operations.

### **Accessibility and Control System**

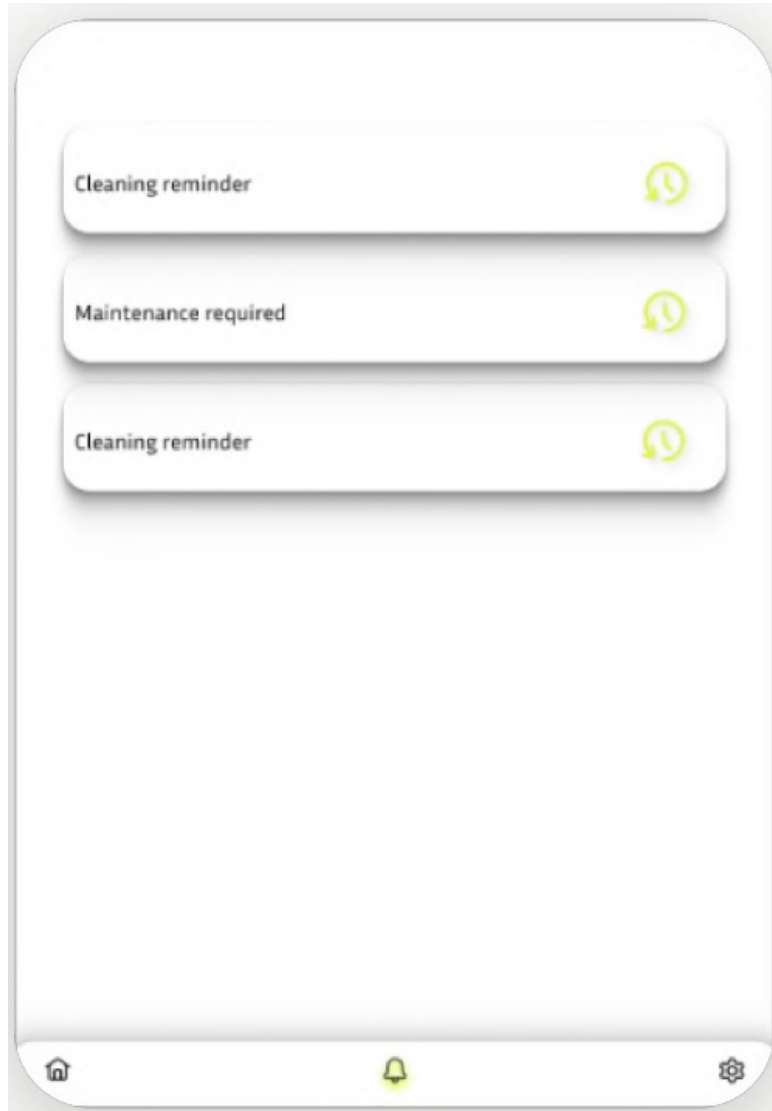
The accessibility and control system is an extremely crucial part of the ATF. This subsystem involves all of the electronic components of the ATF and is what powers it. This involves the 5V DC power adapter, the LCD, the Arduino Nano microcontroller. It also includes the EEPROM which is used to store the total number of cycles, and the 3.5 mm audio jack used to connect the big red button from the Bethany Health Center. It also includes all of the wire connections on the breadboard, as well. The mobile app that could be used to activate a fold on the t-shirt folder is also part of this system.

For the mobile app, there is the home page, that allows the user to press on the button to activate the ATF. The home page also displays whether the Bluetooth is connected or not. In addition, it displays the # of t-shirts that are currently folded.



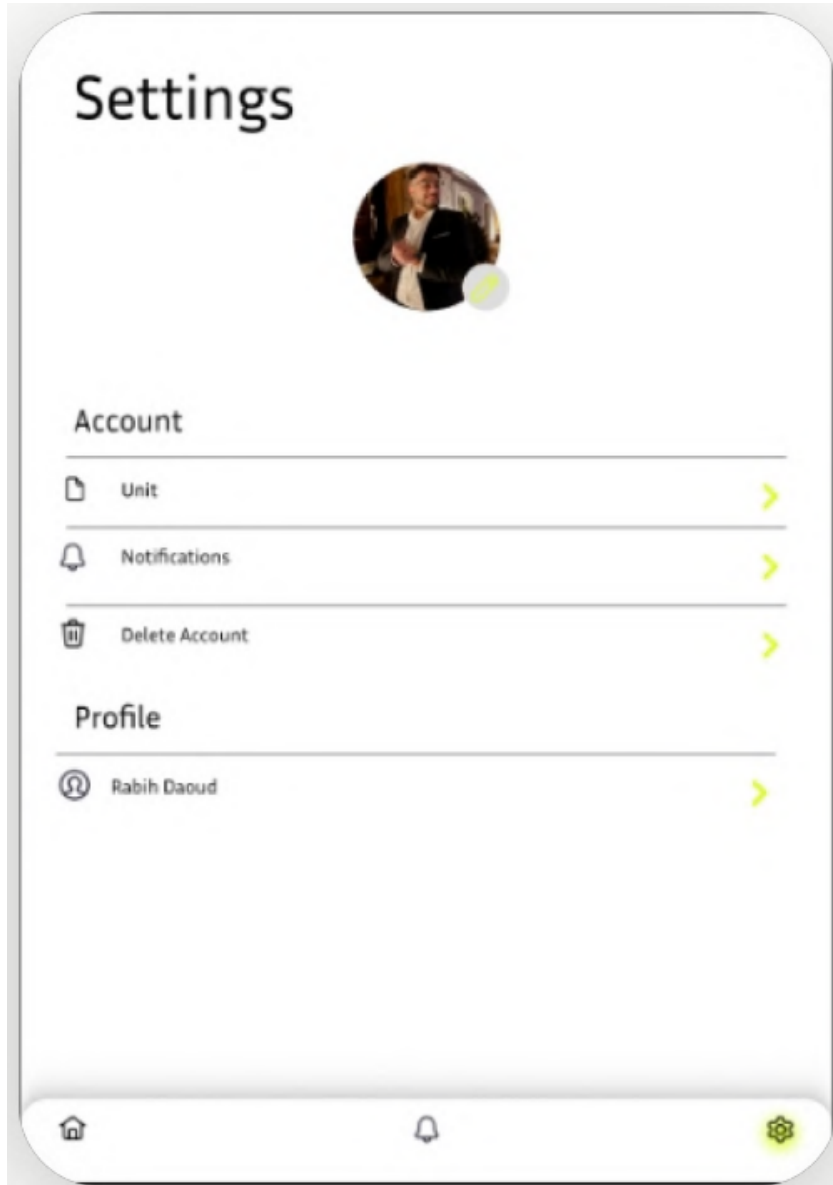
*Figure 7: Home Page of Mobile App*

In the mobile app, there is also the notifications page, which is used to remind the user to regularly clean the t-shirt folder, or to repair the t-shirt folder.



*Figure 8: Notifications Page of the Mobile App*

In the mobile app, there is also the Setting page, which allows the user to turn on or off their notifications, delete their account, and personally track the number of t-shirts that are folded.



*Figure 9: Settings Page of the Mobile App*



### **3.5 Exiting the System**

1. Reset the ATF's flaps by pressing the Re-Home Arms option on the LCD.
2. Unplug the 5V DC Power Supply Adapter.
3. Carry the ATF to a safe location by holding onto the handles on its two sides.
4. If you need to remove the plastic t-shirt folder on top of the t-shirt folder, grab a screwdriver and unscrew the PLA clamps on the edges of the t-shirt folder.
5. On the mobile application, sign out of your account by navigating to the Settings page.

## 4 Using the System

### 4.1 Perform a fold

To perform a fold with the ATF, you must first place the t-shirt on the t-shirt folder with the t-shirt laying in the middle of the t-shirt folder. The arms of the t-shirt should be positioned over the right and left upper black flaps of the t-shirt folder. The bottom of the t-shirt should be positioned over the bottom red flap of the t-shirt folder. Make sure the t-shirt does not hang over the edge of the flaps. If this is the case, you can fold parts of the t-shirt to ensure that it always remains on top of the t-shirt folder.



*Figure 10: Image Showing How To Place The T-shirt Folder*

#### **4.1.1 Fold with button**

Once the t-shirt is properly positioned on the t-folder you can begin the fold. To do this press the large button attached to the ATF through the 3.5 mm audio jack. If at any point you wish to stop the fold, press the emergency stop button. You could also fold the t-shirt folder by selecting the “Activate fold” option using the LCD screen, instead of using the big red button.

#### **4.1.2 Fold with application**

To use the mobile application first open the application on an android or IOS device. After opening up the application, you should see a display that consists of a button with the text “fold” and a t-shirt icon on it. Click this button to perform a fold.

#### **4.1.3 LCD display screen**

The LCD display starts off with the Home screen, which simply shows the name of the product, which is the Automated T-shirt Folder or ATF, and a menu to display the options, the Activate Fold, and Options, Clicking on the “Activate Fold” option will allow you to perform the fold with the automated t-shirt folder. it.



*Figure 11: Activate Fold Option*

When a fold is occurring, the LCD shows the folding progress. You could stop the folding progress by selecting the Stop the Fold option.



*Figure 12: Folding Progress shown by the bars on the LCD*

The LCD display could also be used to go into the Options option as well.



*Figure 13: "Options" option*

The image below shows all of the options that are available in the other options. This includes the Re-Home Arms option, which resets the Servo motors to its original position. Then there is the Credits option which simply shows all of team member's names. Then there is the Back button which brings you back to the home page of the LCD.





*Figure 14: Options Menu*

## **5 Troubleshooting & Support**

### **5.1 Error Messages or Behaviors**

#### **5.1.1 T-shirt folder not folding correctly**

This could be caused by incorrect placement of the t-shirt on the ATF. Make sure the t-shirt is placed at the center of the ATF and that the sleeves are folded back before starting the folding process.

#### **5.1.2 Application error**

If at any point you encounter an error with the application, exit the application and restart it. If the error persists then turn off your device and turn it back on and try running the application for a second time.

#### **5.1.3 ATF not turning on**

Ensure that the t-shirt folder is plugged into a working power outlet and that the power cord is properly plugged into the ATF.

#### **5.1.4 ATF flaps not folding all the way.**

If the flaps on the ATF are not folding all the way, you may have to reset the t-shirt folder, by selecting the Re-Home Arms option on the LCD. This will reset the servo motors back to its original default position.



## **5.2 Bluetooth connection error**

If the bluetooth status on the application says “not connected” then take the following steps to resolve the issue.

1. Check to see if your bluetooth setting is turned on. On IOS devices, this can be done by swiping up from the bottom of the screen and checking if the bluetooth icon is colored. On windows 11, search “bluetooth and other device settings” in the search bar at the bottom of the screen. Then check to see if your bluetooth is turned on.
2. If the bluetooth status still says “not connected”, then you may need to manually connect to the ATF. To do this on IOS, first go to settings > bluetooth. Here you should see a device called “DSD TECH”. Click on this to connect. On windows 11 search “bluetooth and other device settings” in the search bar at the bottom of the screen then look under “Other devices” for “DSD TECH” and click on it.
3. If your device still cannot connect to the ATF via bluetooth then there are still a few steps you can try. You can try exiting out of the application and starting it back up again. If the bluetooth connection still does not work, then you can try restarting your device itself as there may be a device error. You can also try unplugging the ATF and plugging it back in.

## **5.3 Maintenance**

Make sure to regularly clean the ATF to remove any debris that may have accumulated on the device. Use a dry cloth to wipe down the device, making sure not to get any liquids inside the device.

Ensure that the ATF is properly calibrated before each use. This means that the flaps should all be flat and touching the frame of the ATF. This will help to ensure that the device is operating correctly and will help to prevent any incorrect folds.

## 5.4 Support

For any additional support, please email us at: [support@foldamatics.com](mailto:support@foldamatics.com). Our team is available 24/7 to assist with any issues that may arise. The following individuals are responsible for system support:

- Jeyason Jeyaparan, [jjeya091@uottawa.ca](mailto:jjeya091@uottawa.ca)
- Ryan Dick, [rdick080@uottawa.ca](mailto:rdick080@uottawa.ca)
- Rabih Daoud, [rmura096@uottawa.ca](mailto:rmura096@uottawa.ca)
- Joshua Labelle, [jlabe096@uottawa.ca](mailto:jlabe096@uottawa.ca)
- Jordan Malench, [jmale053@uottawa.ca](mailto:jmale053@uottawa.ca)

To report any problems with the system, please send an email to [support@foldamatics.com](mailto:support@foldamatics.com) with a detailed description of the issue you are experiencing. Please include any error messages that may have been displayed, as well as any steps you have already taken to resolve the problem.

## 6 Product Documentation

The Automated T-Shirt Folder (ATF) was built using a combination of mechanical, electrical, and software components. Each of these components was carefully considered and tested to ensure proper functionality and safety. This section will provide detailed information on the design considerations, calculations, and the various elements that make up the final prototype.

### Mechanical Components:

The primary mechanical structure of the ATF includes the aluminum frame, acrylic plates, movable acrylic flaps, and PLA clamps. The aluminum frame provides structural support and stability, while the acrylic plates offer protection for the delicate interior components. The movable acrylic flaps are responsible for the actual folding process, and the PLA clamps hold the plastic t-shirt folder in place.

### Material Selection:

Aluminum frame: We chose aluminum due to its lightweight, strength, and resistance to corrosion. Alternative materials, such as plastic or wood, could be considered if cost or availability becomes a concern. However, these materials might not provide the same level of strength or resistance to corrosion.

Acrylic plates: Acrylic was chosen for its transparency, lightweight, and ease of fabrication.

Alternatives include polycarbonate or glass, but they may have different properties and fabrication requirements.

Electrical Components:

The electrical components include an Arduino microcontroller, an LCD display, the HM-10 Bluetooth module, and a breadboard for wiring connections. The microcontroller is responsible for controlling the ATF and communicating with the mobile app. The LCD display provides a user interface, while the Bluetooth module enables wireless connectivity.

Software Components:

The software includes a React Native mobile application and the firmware running on the Arduino microcontroller. The mobile app serves as an alternative interface for activating the ATF and allows users to create accounts and track their folding progress. The firmware controls the ATF's mechanical components and communicates with the mobile app.

Material Substitution Considerations:

In case a material needs to be swapped due to unavailability or cost-effectiveness, the basic requirements should be met. For instance, the frame material should be lightweight, strong, and corrosion-resistant, while the plate material should be transparent and easy to fabricate.

## Design Files:

To provide a comprehensive view of the ATF design, the following design files are included:

- Mechanical Diagrams: CAD models of the frame, plates, flaps, and clamps
- Circuit Diagram: A detailed diagram of the electrical components and their connections
- Software Code: The source code for the mobile app and Arduino firmware
- Flowchart: A visual representation of the software logic
- 3D Models: Files for 3D printing components such as PLA clamps
- Laser Cutting Files: Files for cutting the acrylic plates and flaps

These files should be used as a reference for anyone interested in building or modifying the ATF prototype. Detailed images, diagrams, and step-by-step instructions will help guide the assembly and configuration process.

In conclusion, the Automated T-Shirt Folder (ATF) was carefully designed to provide an accessible and efficient t-shirt folding experience for individuals with motor deficits and their caretakers. By considering various materials, components, and design aspects, we have developed a functional and safe product that meets the needs of our target audience. This product documentation serves as a comprehensive guide for understanding the construction and operation of the ATF prototype.

## 6.1 Product Documentation

For the Housing and Frame of the assembly, the acrylic panels were

### 6.1.1 BOM (Bill of Materials)

Item Name	Description	Quantity	Unit Cost	Bulk Cost	Source	Link
Arduinio Nano	Microcontroller	1	\$0.00	\$0.00	Ryan	n/a
Servos			\$38.00	\$38.00	Amazon	<a href="https://www.amazon.ca/RG-BZONE-Control-Angle180-Digital-Helicopter/dp/B07RFRLRV8/ref=sr_1_7?crid=UG40IDI06Q7U&amp;keywords=Servos&amp;qid=1678298302&amp;srefix=servo%2Caps%2C130&amp;sr=8-7&amp;th=1">https://www.amazon.ca/RG-BZONE-Control-Angle180-Digital-Helicopter/dp/B07RFRLRV8/ref=sr_1_7?crid=UG40IDI06Q7U&amp;keywords=Servos&amp;qid=1678298302&amp;srefix=servo%2Caps%2C130&amp;sr=8-7&amp;th=1</a>
Breadboard	Wiring	1	\$0.00	\$0.00	Jordan	n/a

3.5mm Aux Female f	Audio Jack	1	\$2.50	\$2.50	Adafruit	<a href="https://www.adafruit.com/product/2791">https://www.adafruit.com/product/2791</a>
Piezo Buzzer free	Buzzer	1	\$1.50	\$1.13	Adafruit	<a href="https://www.adafruit.com/product/160">https://www.adafruit.com/product/160</a>
5 V PSU -stock	Power	1	\$20.00	\$20.00	Amazon	<a href="https://www.amazon.ca/JOVNO-Converter-Transformer-100-240V-5-5x2-5mm/dp/B08CZV3CX3/ref=sr_1_1_sspa?keywords=5v+power+supply&amp;qid=1677726576&amp;srefix=5v+power+%2Caps%2C120&amp;sr=8-1-spons&amp;psc=1&amp;spLa=ZW5icnlwdGVkUXVhbGlmaWVyPUExMUFFSl03N0RF SzJOJmVuY3J5cHRIZEikPUEwNzA0MTg3MIFXRkITNzVDUTRBQSZlbnNyeXB0ZWRBZEikPUEwODY3ODI3MIIXWIRGMzVZVzUyUyZ3aWRnZXR">https://www.amazon.ca/JOVNO-Converter-Transformer-100-240V-5-5x2-5mm/dp/B08CZV3CX3/ref=sr_1_1_sspa?keywords=5v+power+supply&amp;qid=1677726576&amp;srefix=5v+power+%2Caps%2C120&amp;sr=8-1-spons&amp;psc=1&amp;spLa=ZW5icnlwdGVkUXVhbGlmaWVyPUExMUFFSl03N0RF SzJOJmVuY3J5cHRIZEikPUEwNzA0MTg3MIFXRkITNzVDUTRBQSZlbnNyeXB0ZWRBZEikPUEwODY3ODI3MIIXWIRGMzVZVzUyUyZ3aWRnZXR</a>

						<a href="https://www.amazon.ca/POWERTEC-71651-Paddle-Installation-Hardware/dp/B095HTCW42/ref=sr_1_42?crid=OLWP7Z1WVE4H&amp;keywords=start+and+emergency+stop&amp;qid=1678326242&amp;refinements=p_85%3A5690392011&amp;rnid=5690384011&amp;rps=1&amp;prefix=start+and+emergency+stop%2Caps%2C136&amp;sr=8-42">OYW1IPXNwX2F0ZiZhY3Rpb249Y2xpY2tSZWRpc mVjdCZkb05v dExvZ0NsaW NrPXRydWU</a> <a href="#">≡</a>
Start/E-Stop maybe	Switch	1	\$28.25	\$28.25	Amazon	<a href="https://www.amazon.ca/POWERTEC-71651-Paddle-Installation-Hardware/dp/B095HTCW42/ref=sr_1_42?crid=OLWP7Z1WVE4H&amp;keywords=start+and+emergency+stop&amp;qid=1678326242&amp;refinements=p_85%3A5690392011&amp;rnid=5690384011&amp;rps=1&amp;prefix=start+and+emergency+stop%2Caps%2C136&amp;sr=8-42">https://www.amazon.ca/POWERTEC-71651-Paddle-Installation-Hardware/dp/B095HTCW42/ref=sr_1_42?crid=OLWP7Z1WVE4H&amp;keywords=start+and+emergency+stop&amp;qid=1678326242&amp;refinements=p_85%3A5690392011&amp;rnid=5690384011&amp;rps=1&amp;prefix=start+and+emergency+stop%2Caps%2C136&amp;sr=8-42</a>
RGB LED yes	LED	1	\$9.95	\$7.96	Adafruit	<a href="https://www.adafruit.com/product/848">https://www.adafruit.com/product/848</a>
24LC32 I2C EEPROM	Memory	1	\$3.95	\$3.16	Adafruit	<a href="https://www.adafruit.com/product/5146">https://www.adafruit.com/product/5146</a>



Pushbuttons	Button	4	\$0.95	\$3.80	Adafruit	
20x4 LCD and I2C Backpack	LCD	1	\$15.00	\$15.00	Amazon	<a href="https://www.amazon.ca/HiLetgo-HD44780-Character-Backlight-InterfaceAdapter/dp/B082Y37WXG/ref=sr_1_9?crid=JNH8A9Q703QT&amp;keywords=i2c+lcd+backpack&amp;qid=1677689956&amp;srefix=i2c+lcd+backpack%2Caps%2C80&amp;sr=8-9">https://www.amazon.ca/HiLetgo-HD44780-Character-Backlight-InterfaceAdapter/dp/B082Y37WXG/ref=sr_1_9?crid=JNH8A9Q703QT&amp;keywords=i2c+lcd+backpack&amp;qid=1677689956&amp;srefix=i2c+lcd+backpack%2Caps%2C80&amp;sr=8-9</a>
Wires/Dupont Connectors	Wiring	Unknown	\$0.00	\$0.00	Ryan/Electronics Store	
HC-06	Bluetooth	1	\$16.99	\$16.99	Amazon	<a href="https://www.amazon.ca/DS-D-TECH-Wireless-Bluetooth-Transceiver/dp/B01FCQZ8VW/ref=sr_1_1_sspa?crid=40TMZSI2O9UK&amp;keywords=bluetooth+hc-06&amp;qid=1675973235&amp;srefix=bluetooth+hc%2Caps%2C95&amp;sr=8-1-spons&amp;p">https://www.amazon.ca/DS-D-TECH-Wireless-Bluetooth-Transceiver/dp/B01FCQZ8VW/ref=sr_1_1_sspa?crid=40TMZSI2O9UK&amp;keywords=bluetooth+hc-06&amp;qid=1675973235&amp;srefix=bluetooth+hc%2Caps%2C95&amp;sr=8-1-spons&amp;p</a>

						<a href="https://www.amazon.ca/gp/product/B09F2WKY46/ref=ox_sc_act_title_1?smid=A1YHW98JPGEZ14&amp;th=1">sc=1&amp;spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUEzSzdlNUFaMTY1TEITJmVuY3J5cHRIZElkPUExMDIzNTI0MjdaQzk5Nk5ISEoxVSZlbmNyeXB0ZWRBZEIkPUeWUjI1MzI4MU5QV0tIV1VENU0yVSZ3aWRnZXROYW1IPXNwX2F0ZiZhY3Rpb249Y2xpY2tSZWRpcmVjdCZkb05vdExvZ0NsaWNrPXRydWU=</a>
300 Ohm Resistors	Resistors	12	\$0.00	\$0.00	Ryan/Electronics Store	n/a
Aluminium Extrusions		1		\$125.00	Amazon	<a href="https://www.amazon.ca/gp/product/B09F2WKY46/ref=ox_sc_act_title_1?smid=A1YHW98JPGEZ14&amp;th=1">https://www.amazon.ca/gp/product/B09F2WKY46/ref=ox_sc_act_title_1?smid=A1YHW98JPGEZ14&amp;th=1</a>
2020 Corner Connectors		1		\$18.21	Amazon	<a href="https://www.amazon.ca/gp/product/B07VXPCZSV/ref=ox_sc_act_title_1?smid=A1YHW98JPGEZ14&amp;th=1">https://www.amazon.ca/gp/product/B07VXPCZSV/ref=ox_sc_act_title_1?smid=A1YHW98JPGEZ14&amp;th=1</a>

						<a href="https://www.amazon.ca/uxcell-Single-Hole-Clevis-Pins/dp/B0816N1PF3/ref=sr_1_4_sspa?crid=3618FEE3EIL8R&amp;keywords=5mm+clevis+pin&amp;qid=1677897962&amp;sprefix=5mm+clevis+pin%2Caps%2C99&amp;sr=8-4-spons&amp;psc=1&amp;spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUExTkZCRjVXRUhOMIdOJmVuY3J5cHRIZEIkPUEwNDQ0NTAyMzM2Q0wwNzIOMFVTWSZlbnNyeXB0ZWRBZEIkPUeWwNiYxMzUyMIFINVQyMEE5RzdMMSZ3aWRnZXROYW1lPXNwX2F0ZiZhY3">e_1?smid=A246N7U5PREMZD&amp;psc=1</a>
Acrylic thick 1/8		1		\$36.00	MakerStore	
Clevis Pins				\$14.00	Amazon	<a href="https://www.amazon.ca/uxcell-Single-Hole-Clevis-Pins/dp/B0816N1PF3/ref=sr_1_4_sspa?crid=3618FEE3EIL8R&amp;keywords=5mm+clevis+pin&amp;qid=1677897962&amp;sprefix=5mm+clevis+pin%2Caps%2C99&amp;sr=8-4-spons&amp;psc=1&amp;spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUExTkZCRjVXRUhOMIdOJmVuY3J5cHRIZEIkPUEwNDQ0NTAyMzM2Q0wwNzIOMFVTWSZlbnNyeXB0ZWRBZEIkPUeWwNiYxMzUyMIFINVQyMEE5RzdMMSZ3aWRnZXROYW1lPXNwX2F0ZiZhY3">https://www.amazon.ca/uxcell-Single-Hole-Clevis-Pins/dp/B0816N1PF3/ref=sr_1_4_sspa?crid=3618FEE3EIL8R&amp;keywords=5mm+clevis+pin&amp;qid=1677897962&amp;sprefix=5mm+clevis+pin%2Caps%2C99&amp;sr=8-4-spons&amp;psc=1&amp;spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUExTkZCRjVXRUhOMIdOJmVuY3J5cHRIZEIkPUEwNDQ0NTAyMzM2Q0wwNzIOMFVTWSZlbnNyeXB0ZWRBZEIkPUeWwNiYxMzUyMIFINVQyMEE5RzdMMSZ3aWRnZXROYW1lPXNwX2F0ZiZhY3</a>

						<a href="https://www.amazon.ca/uxcell-Interior-Connector-Aluminum-Extrusion/dp/B07VP59DY5/ref=sr_1_24_sspa?crid=2Y4J2GQV9EGO7&amp;keywords=2020+connectors&amp;qid=1677898492&amp;srefix=2020+connector%2Caps%2C101&amp;sr=8-24-spons&amp;psc=1&amp;spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUFMUIJISUJLSU5PNjQmZW5jcnlwdGVkSWQ9QTAxMzAxMzUzVkkYTOkyQIRUUjMmZW5jcnlwdGVkQWRJZD1BMDgxNDE4MzFVR0g4MIE5RUJYWjkmd2lk">Rpb249Y2xpY2tSZWRpcmVjdCZkb05vdExvZ0NsaWNrPXRydWU=</a>
2020 90 Connectors				\$18.49	Amazon	<a href="https://www.amazon.ca/uxcell-Interior-Connector-Aluminum-Extrusion/dp/B07VP59DY5/ref=sr_1_24_sspa?crid=2Y4J2GQV9EGO7&amp;keywords=2020+connectors&amp;qid=1677898492&amp;srefix=2020+connector%2Caps%2C101&amp;sr=8-24-spons&amp;psc=1&amp;spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUFMUIJISUJLSU5PNjQmZW5jcnlwdGVkSWQ9QTAxMzAxMzUzVkkYTOkyQIRUUjMmZW5jcnlwdGVkQWRJZD1BMDgxNDE4MzFVR0g4MIE5RUJYWjkmd2lk">https://www.amazon.ca/uxcell-Interior-Connector-Aluminum-Extrusion/dp/B07VP59DY5/ref=sr_1_24_sspa?crid=2Y4J2GQV9EGO7&amp;keywords=2020+connectors&amp;qid=1677898492&amp;srefix=2020+connector%2Caps%2C101&amp;sr=8-24-spons&amp;psc=1&amp;spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUFMUIJISUJLSU5PNjQmZW5jcnlwdGVkSWQ9QTAxMzAxMzUzVkkYTOkyQIRUUjMmZW5jcnlwdGVkQWRJZD1BMDgxNDE4MzFVR0g4MIE5RUJYWjkmd2lk</a>

						<a href="https://www.amazon.ca/uxcell-Stainless-Cylindrical-Support-Elements/dp/B07Z1MG2BN/ref=sr_1_4?crd=7T6LMCE8Y0WC&amp;keywords=10x30+diameter+dowel+pins&amp;qid=1678293787&amp;prefix=10x30+diameter+dowel+pins%2Caps%2C85&amp;sr=8-4">Z2V0TmFtZT1zcF9tdGYmYWN0aW9uPWNSaWNrUmVkaXJlY3QmZG9Ob3Rmb2dDbGljaz10cnVl</a>
Dowel Pins		6	\$3.04	\$18.24	Amazon	<a href="https://www.amazon.ca/uxcell-Stainless-Cylindrical-Support-Elements/dp/B07Z1MG2BN/ref=sr_1_4?crd=7T6LMCE8Y0WC&amp;keywords=10x30+diameter+dowel+pins&amp;qid=1678293787&amp;prefix=10x30+diameter+dowel+pins%2Caps%2C85&amp;sr=8-4">https://www.amazon.ca/uxcell-Stainless-Cylindrical-Support-Elements/dp/B07Z1MG2BN/ref=sr_1_4?crd=7T6LMCE8Y0WC&amp;keywords=10x30+diameter+dowel+pins&amp;qid=1678293787&amp;prefix=10x30+diameter+dowel+pins%2Caps%2C85&amp;sr=8-4</a>
Acrylic thick 1/4				\$81.00	Amazon	<a href="https://www.amazon.ca/Falke-Design-BK2025-1-4-2436-Acrylic/dp/B01DYSTYBA/ref=sr_1_4?crd=35VVI9IEM83BN&amp;keywords=1%2F4+inch+acryl">https://www.amazon.ca/Falke-Design-BK2025-1-4-2436-Acrylic/dp/B01DYSTYBA/ref=sr_1_4?crd=35VVI9IEM83BN&amp;keywords=1%2F4+inch+acryl</a>

						<a href="https://www.amazon.ca/PZ-RT-Aluminium-Rectangular-Industrial-Accesories/dp/B07QP6G9BS/ref=sr_1_7?crid=180GSFRYJAE2A&amp;keywords=2020+aluminum+extrusion+handle&amp;qid=1678327706&amp;prefix=2020+aluminum+extrusion+handle%2Caps%2C96&amp;sr=8-4">ic+sheet+24+black&amp;qid=1677899158&amp;sprefix=1%2F4+inch+acrylic+sheet+24+blac%2Caps%2C111&amp;sr=8-4</a>
Handles				\$19.73	Amazon	<a href="https://www.amazon.ca/PZ-RT-Aluminium-Rectangular-Industrial-Accesories/dp/B07QP6G9BS/ref=sr_1_7?crid=180GSFRYJAE2A&amp;keywords=2020+aluminum+extrusion+handle&amp;qid=1678327706&amp;prefix=2020+aluminum+extrusion+handle%2Caps%2C96&amp;sr=8-7">https://www.amazon.ca/PZ-RT-Aluminium-Rectangular-Industrial-Accesories/dp/B07QP6G9BS/ref=sr_1_7?crid=180GSFRYJAE2A&amp;keywords=2020+aluminum+extrusion+handle&amp;qid=1678327706&amp;prefix=2020+aluminum+extrusion+handle%2Caps%2C96&amp;sr=8-7</a>

### 6.1.2 Equipment list

- Soldering Iron

- For soldering wires and components onto the Arduino Nano and other electronic components.
- Solder
  - Needed for soldering connections between electronic components.
- Wire Stripper
  - For stripping insulation from wires before soldering or connecting.
- Wire Cutter
  - For cutting wires to the desired length.
  
- Screwdriver Set
  - For tightening screws and fastening components together.
- Pliers
  - For gripping, bending, and cutting wires and other components.
- Hex Key/Allen Wrench Set
  - For tightening bolts and nuts on aluminum extrusions and other parts.
- Drill and Drill Bits
  - For creating holes in acrylic sheets and other materials as needed.
- Digital Multimeter
  - For testing electrical connections and verifying proper voltage and current levels.

- Heat Gun or Lighter
  - For heat-shrinking wire connections (if using heat-shrink tubing).
- Tweezers
  - For handling small electronic components.
- Magnifying Glass or Loupe
  - For closely inspecting solder joints and small components.
- Protective Eyewear
  - For safety when working with tools and materials.
  
- Antistatic Wrist Strap
  - For grounding oneself while working on sensitive electronics to prevent static discharge.
- Workspace with Proper Lighting
  - To facilitate proper assembly and soldering.
- Tape Measure or Ruler
  - For measuring and cutting materials to the correct dimensions.
- Box Cutter or Acrylic Cutting Tool
  - For cutting and scoring acrylic sheets.
- Deburring Tool



- For removing burrs from cut edges of aluminum extrusions and other parts.
- Sandpaper
  - For smoothing edges of cut materials, if necessary.
- Clamps or Vise
  - For holding materials securely in place during cutting, drilling, or assembly.

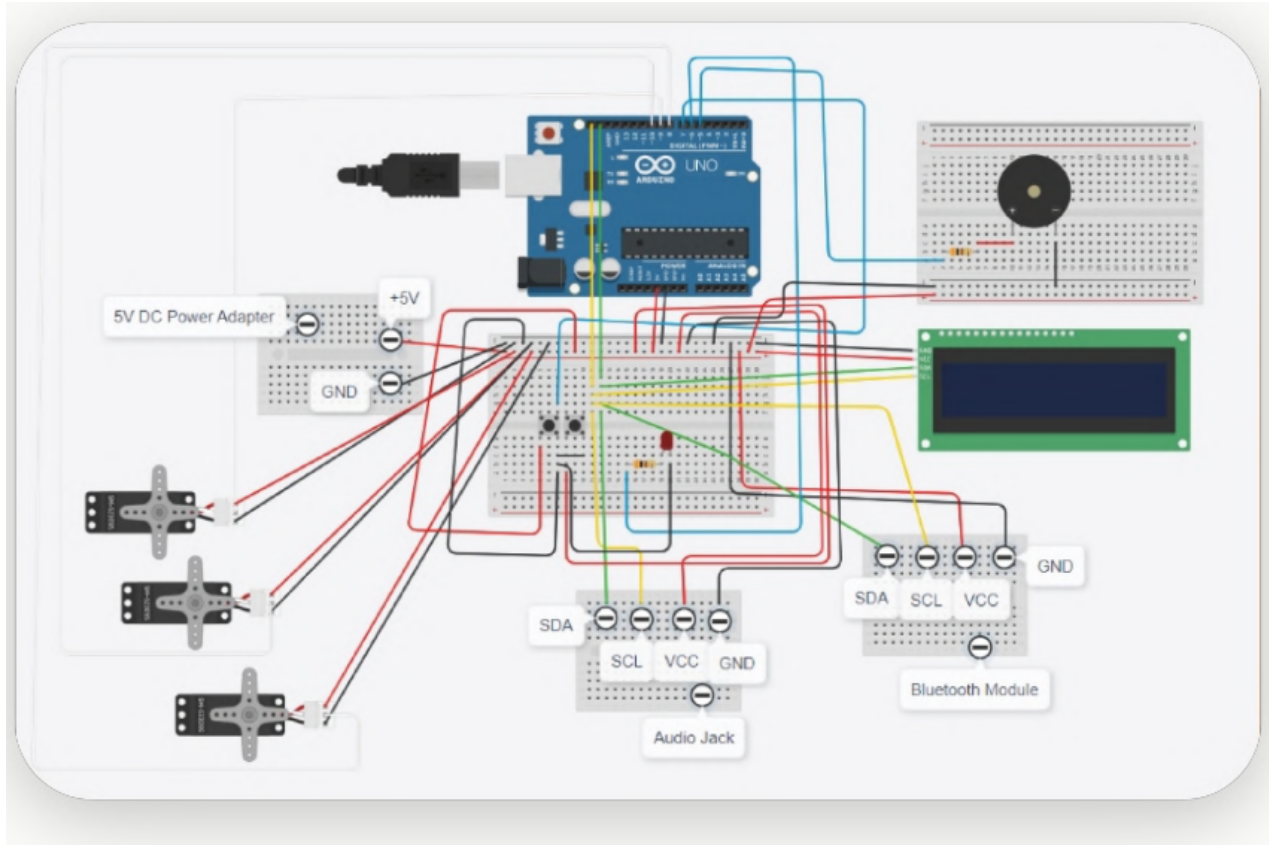
### **6.1.3 Instructions**

1. Grab a screwdriver.
2. Create the frame of the ATF by putting screws into all of the aluminum bars and then tightening them together. It should look like Figure 15.



*Figure 15: Housing and Frame of ATF*

3. Slide the acrylic panels for the side slots of the frame. Make sure to add another layer of acrylic panels to make the ATF stronger and more durable.
4. Follow the circuit diagram below to make all of the electronic attachments.



*Figure 16: Circuit Diagram of ATF*

5. Attach the Arduino to the yellow piece of plastic and attach it to one of the panel sides.
6. Arrange the buttons and LCD to be outside of the frame, and screw them in with the screwdriver to the ATF.
7. Add screws to the Servo motors and attach them to the opposite sides of the middle aluminum bars.
8. Attach the acrylic panels meant for folding the plastic t-shirt folder to the servo motors on top of the ATF.
9. Rest the plastic t-shirt folder on top of the acrylic panels on top of the ATF.
10. Attach the 8 PLA clamps between the acrylic panels and the plastic t-shirt folder.

## 6.2 Testing & Validation

Testing and validation of the Automated T-Shirt Folder (ATF) prototype was a crucial step in ensuring its functionality, safety, and overall performance. We conducted a series of tests on the mechanical, electrical, and software components of the prototype. The following sections outline the tests performed, their results, and any issues or special requirements for sustained usage.

### 1. Mechanical Testing:

To validate the mechanical components and overall stability of the ATF, we conducted load-bearing tests and repetitive folding tests. Load-bearing tests involved applying weight to the frame and flaps to ensure they could support the intended loads during operation. Repetitive folding tests ensured that the ATF could perform multiple folds without mechanical failure or excessive wear.

Results:

- Load-bearing test: The aluminum frame and acrylic flaps supported the intended loads without any signs of deformation or failure.
- Repetitive folding test: The ATF successfully performed 100 repetitive folds without any noticeable wear or mechanical failure.

### 2. Electrical Testing:

We tested the electrical components, including the Arduino microcontroller, LCD display, and Bluetooth module, for proper functionality and reliability. These tests involved powering on the ATF, checking for correct display output, and ensuring a stable Bluetooth connection with the mobile app.

Results:

All electrical components functioned as intended, with the LCD display providing accurate output and the Bluetooth module was faulty by not maintaining a reliable connection with the mobile app.

### 3. Software Testing:

To validate the software components, we tested the mobile app and firmware on the Arduino microcontroller. This included checking the app's user interface, account creation, and communication with the ATF via Bluetooth. Additionally, we tested the firmware's ability to control the mechanical components and respond to commands from the mobile app.

Results:

The mobile app functioned smoothly, providing a responsive user interface and successfully creating and managing user accounts.

The firmware successfully controlled the mechanical components and accurately responded to commands from the mobile app.

#### 4. Safety Testing:

We tested the safety features, such as the emergency stop button and the stability of the device with bumpers. The emergency stop button test involved initiating a fold and then activating the stop button to check if the ATF would halt its operation. Stability tests evaluated the device's resistance to tipping over when pushed from different angles.

Results:

- The emergency stop button worked as expected, immediately stopping the ATF's operation when activated.

- The bumpers provided enough stability to prevent the device from tipping over during testing.

#### Issues and Special Requirements for Sustained Usage:

- Regular maintenance: To ensure the ATF's longevity, users should periodically inspect and clean the mechanical components to prevent dust or debris buildup.
- Software updates: The mobile app and firmware may require updates over time to maintain compatibility with newer devices or to fix potential bugs.
- Electrical component replacement: In the case of component failure, users may need to replace faulty electrical parts, such as the Arduino microcontroller or Bluetooth module.

In conclusion, the testing and validation process of the Automated T-Shirt Folder (ATF) prototype demonstrated its functionality, safety, and reliability. By addressing potential issues and special requirements, users can expect sustained performance and a seamless t-shirt folding experience.

## 7 Conclusions and Recommendations for Future Work

Throughout the development of the Automated T-Shirt Folder (ATF) prototype, our team learned valuable lessons related to mechanical design, electrical engineering, and software development. We successfully built a functional and accessible t-shirt folding solution for people with motor deficits and their caretakers.

Our experience led to the following key lessons:

1. Ensuring accessibility and safety features were top priorities in the design process.
2. Rigorous testing and validation were essential for determining the prototype's reliability, efficiency, and usability.
3. Collaboration and clear communication across different fields of expertise, such as mechanical, electrical, and software engineering, were vital for the project's success.

For future work, we suggest the following avenues to improve and expand upon our current prototype:

1. Enhance the Bluetooth module functionality: In our current design, the Bluetooth module can only write data and not read it. Future iterations should address this limitation,



enabling bidirectional communication between the ATF and the mobile app for enhanced features and usability.

2. Implement additional folding patterns: The ATF currently supports only one t-shirt folding method. By expanding its folding capabilities to accommodate different garment types and sizes, the ATF could better serve a wider range of users.
3. Explore alternative materials and manufacturing methods: Investigate the feasibility of using other materials or production techniques to reduce cost, improve durability, or increase the device's overall performance.
4. Develop a more compact design: Create a more compact ATF that is easier to transport and store without compromising its functionality.
5. Enhance user feedback and interaction: Incorporate additional sensors and user feedback features, such as audio cues or vibrations, to provide a more interactive and engaging user experience.
6. Improve energy efficiency: Research and implement energy-efficient components or power management systems to minimize the ATF's energy consumption during operation.

If we had a few more months to work on the project, we would focus on addressing the limitations of the Bluetooth module and enhancing the ATF's overall performance and functionality by incorporating the suggestions mentioned above.

By considering these conclusions and recommendations, future teams can continue to improve the Automated T-Shirt Folder, making it more accessible, efficient, and user-friendly for those who need it most.

## APPENDICES

### 8 APPENDIX I: Design Files

MakerRepo link: <https://makerepo.com/jjeya091/1602.foldamatics>

**Table 3. Referenced Documents**

<b>Document Name</b>	<b>Document Location and/or URL</b>	<b>Issuance Date</b>
Deliverable A	MakerRepo/Brightspace	Jan 15, 2023
Deliverable B	MakerRepo/Brightspace	Jan 26th, 2023
Deliverable C	MakerRepo/Brightspace	Feb 9th, 2023

Deliverable D	MakerRepo/Brightspace	Feb 14th, 2023
Deliverable E	MakerRepo/Brightspace	Mar 22nd, 2023
Deliverable F	MakerRepo/Brightspace	Mar 29th, 2023
Deliverable G	MakerRepo/Brightspace	Mar 30th, 2023
Deliverable H	MakerRepo/Brightspace	Apr 5th, 2023
Deliverable I	MakerRepo/Brightspace	Apr 12th, 2023
Mechanical Diagrams, Circuit Diagram, Software Code, Flowchart, 3D Models,	MakerRepo	Apr 12th, 2023

Laser Cutting Files		
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