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# Book and Tablet Team (B.A.T.T.) Final Project Report

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# Executive Summary

The Book and Tablet Team (B.A.T.T.) looks to design a device that simplifies reading from a tablet to assist those with dexterity issues in their hands and arms. The team's main objectives for this project are to design a device that may be used in a functional and useful fashion, construct said device, and finally test the device. This report will consist of an overview of our device and its five subsystems and an evaluation of the final design with respect to the project requirements. The five main subsystems are as follows: the mount, the stand, the tablet holder, the remote controller, and the page turner. The mount, stand, and holder focus on making sure the tablet is in the ideal reading position. These systems only contain mechanical components. Alternatively, the controller and the page turner incorporate electromechanical systems that focus on the actual turning of the page on the tablet.

The design constraints for this project were to protect the safety of the target audience and to stay within the budget provided for the team. The safety of the target audience was addressed by creating three main safety requirements, while also focusing attention on safety applications when considering design changes. The safety requirements look to prevent the following: pinch hazards, sharp edges, and possible falling components. By creating preventive design solutions for these requirements, the team was able to successfully meet the user safety constraint.

The B.A.T.T. team fulfilled all the specific functional and non-functional requirements for their project except for the tablet rigidity requirement. The functional requirements include making the device easily movable, having an adjustable height for optimal reading in various positions, accommodating most tablet reading devices, and allowing page switching with minimal error. Non-functional requirements were also considered to enhance the user experience and make the device safe for the target audience. Tablet size and weight were considered to make the device applicable to more users. The interface of the device and the tablet was also considered by having requirements to keep the tablet in a rigid position, make sure it was not damaged, and the eBook is not blocked by the device. Safety measures were also taken to protect potentially injury-prone users, such as minimizing sharp edges, reducing pinch risks, and installing safety catches for moving components.

The prototype for the tablet holder can perform most of the tasks outlined in the project plan but falls short of meeting one requirement for holding tablets in a rigid position due to the springs being too large for the smallest tablet size. The design team has identified potential solutions to address this design flaw and may need to modify the holder and conduct further testing to ensure all requirements are met. A temporary solution is to mount eh smaller tablet size in a vertical position, where the width of the smallest tablet is the height. For a more permanent solution, the team looks to implement a spring stopper to prevent the springs from losing rigidity, providing more tension. Overall, the prototype is functional and can accommodate a variety of tablet sizes while allowing users to turn pages without physical contact with the device.

# Introduction

The Book and Tablet Holder Team (B.A.T.T.) has identified the target audience for this project as those with dexterity issues in their hands and arms. This issue occurs most often within the elderly community and many potential end users are bedridden or cannot move easily. This target audience often struggles with turning the pages on the device themselves. To address this problem, the B.A.T.T. worked to design a device for the task of holding a book or tablet in a reading position for an extended period of time, while also mimicking the swiping motion of a finger using a mechanical device. The final design goal is to construct a holder for a tablet that the target audience may use in a functional and useful fashion. The ultimate ambition of the project is to create a device that allows readers with dexterity issues to reclaim their passion and be able to read comfortably once again.

The B.A.T.T. team has worked on the project with the goal of meeting the following functional and non-functional requirements that will be discussed in greater detail throughout this report. The functional requirements for the device are as follows. The device shall be mobile or stationary as needed to allow caretakers to easily move the device out of the way. The height of the device shall be adjustable for heights of 20 to 56 inches for optimal reading in both prone and seated positions. The device shall accommodate most tablet reading devices to accommodate more potential users. Finally, the device shall allow the user to switch pages with minimal error, as those with dexterity issues will not be manually turning the pages. There are additional non-functional requirements that are centered around enhancing the user experience and accommodating the target audience for the design. It was imperative that the B.A.T.T. met the following non-functional requirements to make the device both safe and useful for the target audience. To ensure the device is usable by a larger user base, the size and weight of the tablet were considered, along with the design of the device's interface to keep the tablet secure and undamaged while ensuring the eBook is readable. Safety precautions were also implemented to protect users who may be prone to injury, including minimizing sharp edges, reducing the risk of pinching, and installing safety catches for moving components.

The design was separated into five individual subsystems. By doing so, the B.A.T.T. was able to assess specific requirements for each component of the device, while assuring each subsystem met the overall requirements discussed in the previous paragraph. The mount and stand were designed to be easily adjustable in both mobility and height. Lockable caster wheels were implemented to allow for a safe stationary position while maintaining simple mobility. A pin system was designed for the stand to allow for height adjustments over the required range. The holder implements thickness adjustment to ensure that the page turner remains in contact with the tablet across varying tablet models. Sliding rails were used to allow the holder to accommodate different tablet sizes while ensuring that each was held firmly in place. The page turner was designed with a multi-servo system so that the swiping arm can move laterally in both directions. This allows users to progress to the next page or return to a previous page if needed. Finally, the remote controller housing was designed to be ergonomically satisfying for those with dexterity issues to hold. Push buttons were selected to meet the non-functional requirement of low force movements while maintaining the comfortability of the overall design.

## Overview of the Final Design

The tablet holder consists of five subsystems; the mount, stand, holder, remote controller, and page turner. These five subsystems come together to produce the completed prototype seen in Figure 1. The mount is the base piece of the device and consists of a circular base plate with wheels capable of locking. The choice for this design for the mount is straightforward as it provided the device with the necessary mobility and stability to function as intended. The mount is sufficiently heavy that it provides a stable base for the entire device and its wheels with locks enable the device to easily be moved around or anchored in place as needed. The stand is the portion of the device that allows the tablet's height and angle to be adjusted to be viewable by the user. It consists of two aluminum bars and an aluminum pin-ring system that allows the user to lock the height of the device in place. The stand pivots about a central hinge joint to adjust the height of the device and is secured using a pin that runs through the swing arm and the rings on both sides of the stand. The holder is a mechanical system centered around two adjusters that are connected to a base with springs to change the height and thickness of various tablets. The page turner is an electromechanical system centered around two servos used to generate rotation in two separate planes of motion. This rotation is used to create both the actuation force into the tablet screen and the swiping motion across the tablet screen. The remote controller receives user input via two momentary push buttons and wirelessly communicates the appropriate command to the page turner through a radio-frequency link.

**Figure 1. Complete integrated system**

## Subsystem Designs

### Complete System

Many of the functional requirements determined by the B.A.T.T. can be addressed subsystem by subsystem and tested individually. However, the non-functional requirements for the project encompass the complete project and were thus analyzed for the holistic design. These include both tablet size and general safety requirements. Using research completed on the most common reading tablet device currently on the market, the team determined the following two requirements for tablet selection. First, the device should be able to hold a tablet that is a minimum size of 6" X 4" and a maximum size of 14" X 10". Secondly, the device should be able to hold a tablet with a maximum weight of 5 pounds. For the safety of the end user during operation the following requirements were set. The maximum pinching and extended full arm horizontal lateral force should be respectively 4.5 and 7.5 pounds. These values are based on the force standards of the related categories from Ergoweb LLC with a reduction factor of two (Ergoweb LLC, 2013). As the project progressed and design adjustments were made the team considered each of these non-functional requirements alongside the functional ones. These non-functional requirements were essential for the team's goal of creating a device that holds a tablet for the target audience to use in a functional and useful fashion. The B.A.T.T. also made realistic assumptions for the implementation of the device. This included the help of a family member or caretaker when assembling and adjusting some portions of the device, as it is unrealistic to expect someone with dexterity issues to be able to complete this themselves. The possible reading positions of the user were also assumed to be supine or seated. This assumption allowed the group to determine a reasonable height that the stand should be adjustable. A complete description of the system's setup and operation is included in Section 5.1.

Since submitting the preliminary design report (PDR), the B.A.T.T. has made one main adjustment to the overall design requirements. Upon beginning force testing the team became aware that it was unrealistic to expect to move a 50-pound mount with only 3 pounds of applied force. To adapt to this, the team decided to adjust the force requirement to 20 pounds, a more realistic goal that was approved by our sponsor.

### Mount

The mount is the base piece of the device with a heavy, wooden circular base plate and five 1.5" castors with locks underneath, as displayed in Figure 2. The circular base plate of the mount is fabricated from wood and was machined using the CNC router along with various hand tools in the Makerspace. The mount has several requirements that must be met to satisfy the acceptance criteria. Firstly, it must not exceed a total weight of fifty pounds to be considered not excessively heavy. This requirement stems from the desire to keep the final product reasonable to ship to consumers in case it ends up being commercialized or mass-produced. Additionally, the mount must be mobile, which is defined as allowing the device to be moved out of the way with a force not exceeding twenty pounds when the wheels are unlocked. This mobility requirement is extremely important for several reasons, including the functionality of the device and the target audience. The device being mobile allows its position to be adjusted, which is critical given that the tablet is meant to be held in the desired position of the user. The target audience for this device is individuals with manual dexterity issues, who are typically older

members of the population. Due to this, the device will likely be implemented within assisted living facilities and other healthcare settings where the ability to move the device out of the way as needed is of the utmost importance.

Lastly, the mount must be able to maintain its position with locked wheels with an applied force of up to twenty pounds. This requirement is essential to the function of the device as it is very important that the position of the tablet can be maintained as desired by the user. Evaluating the force needed to move to move the mount with locked wheels ensures the wheel locks are performing as desired and that end users will receive a reliable device. A major concern of the mount was the stability it would provide for the device as a whole, specifically ensuring that it does not tip over easily when an external pushing or pulling force is applied. Tipping calculations were conducted while designing the mount to evaluate whether a counterweight should be implemented to make the mount more stable (Appendix 5.2). However, the calculations indicated that by making the mount sufficiently heavy and carefully selecting the location of the wheels underneath the mount it would be stable enough to support the device without easily tipping. The first prototype of the mount included castors with a 0.5” diameter, however these were switched to the 1.5” castors due to the high level of difficulty to engage the locks on the smaller castors.

**Figure 2. The mount subsystem**

## Stand

The stand is the principle means of adjusting the height and angle of the tablet. Two rectangular aluminum bars pivot around a central hinge joint, with a pin-ring system in the center

that allows the height of the device to be locked into place, as shown in Figure 3. It was constructed from aluminum due to the high strength-to-weight ratio of the material and the pin-ring system was implemented as the locking mechanism due to its reliability. Machining the raw aluminum to fabricate the stand required the use of the CNC cutter for the rings, the mill for the aluminum bars, and various hand tools in the Makerspace to configure the final design. The requirements that must be met by the stand to satisfy the acceptance criteria include its height adjustment, angle adjustment, and ability to lock into a fixed position. The stand height adjustment requirement entails the height measurements of the stand being able to accommodate a range from thirty to sixty inches off the ground. This requirement is important as the device is designed to be utilized in a multitude of positions ranging from sitting in a chair to laying down on a bed that is raised off the ground. Therefore, the stand must allow the height of the tablet to at least be adjusted within this range so that it is functional for users in a variety of settings.

The angle adjustment requirement means that the protractor measurements of the angle the stand allows the tablet to move within must have a range of 120 degrees in both the horizontal and vertical directions. Once again, this requirement stems from the need to accommodate the multitude of different positions and settings that the device may be utilized within. Depending on where the device can be positioned relative to the user, adjusting the angle of the tablet is critical to ensure that the device is even able to function as intended. For each set of measurements, of the height and angle adjustment, the average plus or minus one standard deviation must meet the acceptance criteria to be considered satisfactory. Lastly, the stand must allow the tablet to be fixed into a rigid position. Essentially, the height and angle of the tablet must be locked into a rigid position once the user has found their ideal operating position for the tablet. This requirement is extremely important as well, as the device would not be functional if the height and angle of the tablet could not be fixed at a set position that the end user would like to read at.

**Figure 3. The stand subsystem**

## Holder

The holder in Figure 4 was specifically designed to accommodate tablets within a range of sizes, from 6" x 4" x 0.1” to 14" x 10" x 0.5” (width, height, thickness), with a maximum weight of 5 lbs. This holder consists of three main components - the base, vertical adjuster, and thickness adjuster – each was 3D printed on an Ultimaker S5 and connected with springs. The base connects both adjusters and supports the back of the tablet, while the vertical adjuster allows the user to adjust the height, and the thickness adjuster is responsible for changing the thickness of the tablet being used. To reference the motion Figures A7 and A8 show the motion of the vertical and thickness adjusters respectively. An additional view from the side of the tablet is shown in Figure A9.

To ensure the holder is suitable for its intended purpose, specific requirements must be met. Firstly, the holder must be capable of securely holding the tablet in a rigid position without causing any damage. Secondly, the method of securing the tablet must not obstruct the screen and provide easy access to the display. Thirdly, the holder should allow for easy rotation of the tablet in both the horizontal and vertical planes, enabling optimal viewing angles. Fourthly, the angle of the holder must be adjustable, with a maximum user force of 5 pounds, following ergonomic guidelines.

After the first prototype, a significant design flaw was identified in the thickness adjuster. The previous design had two major issues - difficulty removing it from the base and falling out after pulling it 0.3 inches. This was due to a t-shaped connection that constrained the motion, and lack of support after a specific distance. To resolve these issues, a new horizontal plate with supports was created to connect the thickness adjuster to the base, and the thickness adjuster itself was modified to fit the new connection. Additionally, minor changes were made to the vertical adjuster to align it with the acrylic panels.

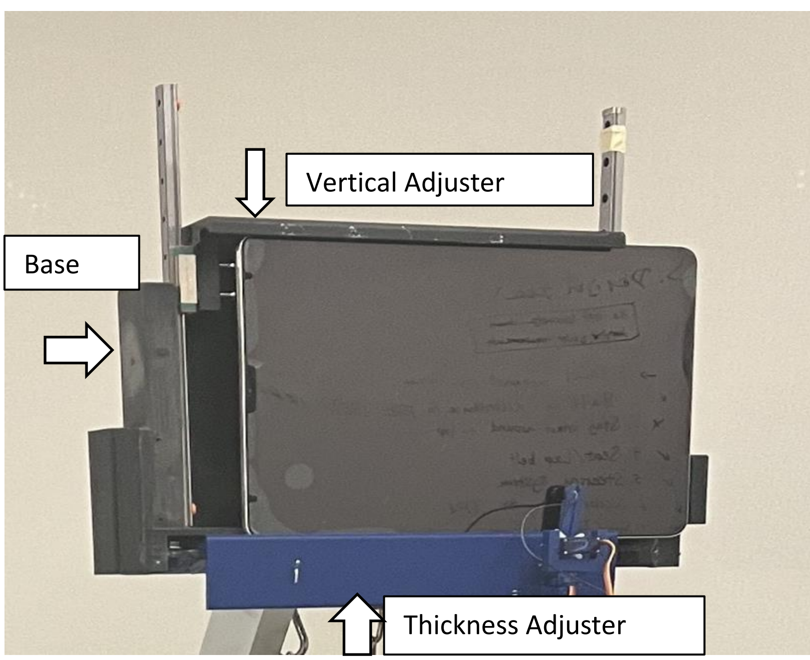


**Figure 4. The holder subsystem.**

## Page Turner

The page turner is designed to recreate a swiping motion across the screen of a tablet to change the page. To create this motion two servos were implemented, one creating the actuation pressure onto the tablet face, and the second creating the swiping motion across the screen. Mounts for each servo were created using Prusa and Ultimaker S5 3D printers, allowing for the two to be joined as one mechanical system as seen in Figure 5. Most modern tablets are equipped with capacitive touch screens which require conductive material to be used to contact the screen. To accomplish this a soft conductive foam tip was implemented with an accompanying ground wire running down a channel on the page turning arm. The functional requirements for the page turner subsystem were two-fold. The first of these is that the page turner shall successfully complete a page turn upon receiving a command from the user 98% of the time. The second is that the swiping motion must be able to be completed within 2 seconds of receiving the signal. To address both requirements, the page turner was designed with a hard-coded servo swiping sequence that reliably turns pages with consistent, predictable timing. It is important to note that the user will not be interacting with the page turner itself, which allowed the team to focus on meeting the functional requirements as the non-functional requirements do not particularly apply to this system.

**Figure 5. Comparison of Fall 2022 (left) and Spring 2023 (right) Page Turner Prototypes**

The main electrical components of the page turner subsystem are included in the functional diagram shown in Figure 6. The full electronic schematic is also included in appendix section 5.5. In the fall iteration of the page turner design, the entire page turner system was run on a single Arduino Micro, however this design was unable to both receive RF signals and drive the servos due to conflicts between the VirtualWire RF library and the official Arduino servo library. To resolve this issue, we chose to use an Arduino UNO to interface the RF receiver which would then communicate via digital I/O to an Arduino Nano Every controlling the page

turning mechanics of the servos. The code for both microcontrollers is contained in appendix section 5.4. This iteration of the page turner circuitry was built on a breadboard as shown in Figure 7. The electronics are powered by a 7.5-volt DC wall outlet adapter which connects to a power switch to toggle the board on/off. All the components operate at a 5-volt supply, so the wall power is stepped down from 7.5 to 5 volts using an LM7805 with coupling capacitors. The circuit also includes an RGB LED to show the user a brief red, green, then blue flashing sequence when the device is powered on, and green and red flashes for forward and backward page turns, respectively.

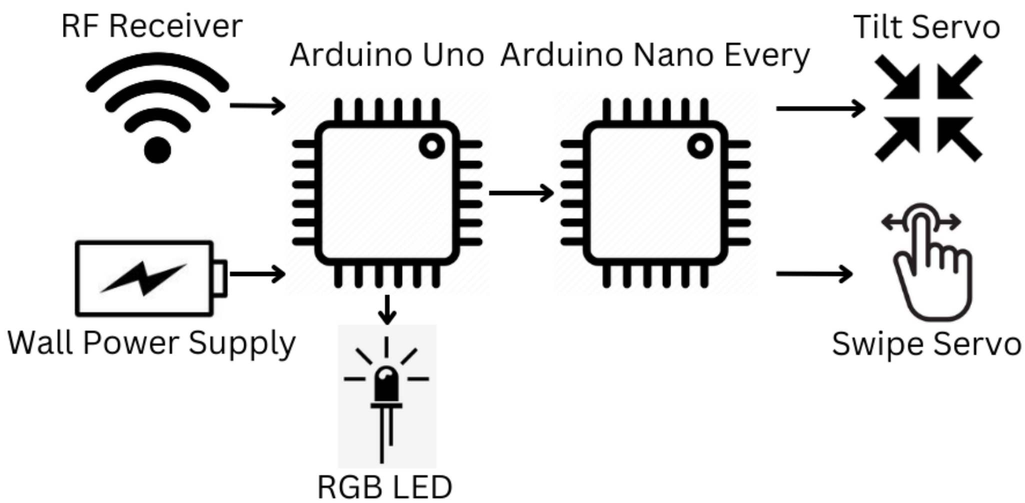


**Figure 6. Page turner functional diagram**

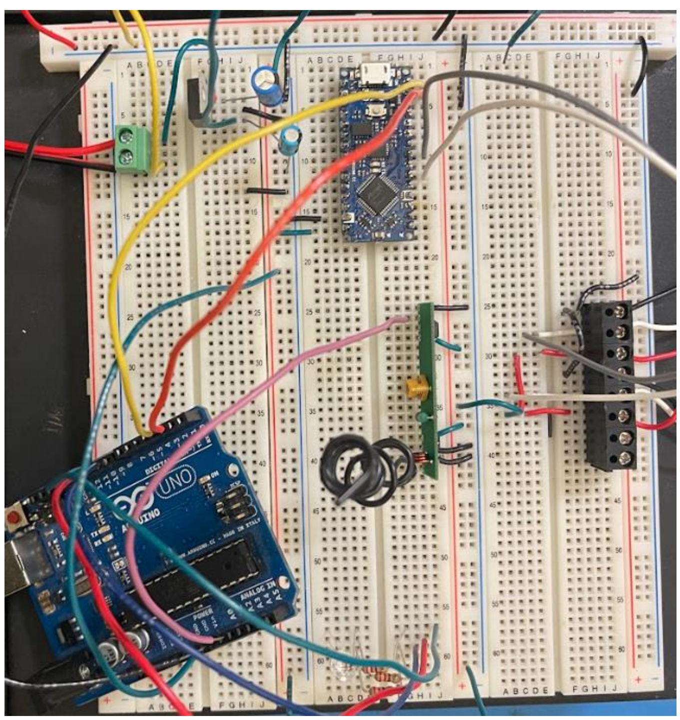

**Figure 7. Page turner electronics breadboard prototype**

The page turner subsystem was the chosen prototype for testing during the fall 2022 semester. By analyzing the results of this testing two main mechanical design adjustments were made. The first was a transition to a swiping arm tip that better fit our final design goals. The initial page turner prototype implemented a stripped wire tip, as seen in Figure 5. The flaw in this design was the potential damage that the wire would cause to a tablet screen. By switching to a conductive foam tip the page turner was able to create a better connection with the tablet face while also reducing any potential damage risks. The second design change was to create a more rigid design. The initial prototype was created using hot glue to connect each component, this created consistency issues that made the successful swipe requirement harder to achieve. For the final design form factor holes were designed into each servo mount, allowing for the servos to be screwed into place.

### Remote Controller

The remote controller shown in Figure 8 is designed to take user input and transmit it to the page turner subsystem to swipe on the tablet screen. There are two functional requirements that apply to the remote controller subsystem, including that the force required to depress the user inputs should not exceed 2.5 pounds and that the page turning mechanism must operate without error 98% of the time. There is also a design constraint that user inputs must be held for one second before transmitting page-turning signals to mitigate accidental inputs.

**Figure 8. Remote controller prototype**

While the remote controller design retained the 434 hertz radiofrequency (RF) transmitter to communicate wirelessly to the page turner from the fall semester design, the interfacing system was changed significantly for the final iteration. Originally, the user input was processed by a series of digital logic integrated circuits and then parsed as a serial message via a serial encoder before being sent to the page turner by the RF transmitter. We ran into several development issues while trying to implement the delay timing functionality and decided to pivot to a microcontroller-based design using an Arduino Micro. This decision reduced design

complexity and development time while improving overall functionality as the VirtualWire RF Arduino library used for the page turner receiver could also be adopted for the transmitter. This RF library is deprecated and only supports Arduinos with the ATmega32 family of processors, so we chose the Micro specifically to minimize the space required to house the microcontroller.

The functional diagram for the remote controller is shown in Figure 9 and the full circuit schematic is included in appendix section 5.5. The RGB LED was included to provide feedback to the user when the remote controller is sending signals to the page turner based on the National Disability Authority IT accessibility guidelines (2020). A green flash represents a forward page turn while a red flash indicates a backward turn. The circuit is powered by four AA batteries in series providing a 6-volt DC supply voltage. The battery pack is connected to a power switch to manually turn on/off the device as well as an LM7805 to step down the power supply to 5 volts for the logic level components. The battery pack is able to power the entire remote controller for an estimated 80 hours using average performing Duracell alkaline coppertop batteries. The two pushbutton inputs are connected in an active low configuration. The final circuit was constructed by soldering the components onto a project board as shown in Figure 10. We considered a custom printed circuit board; however, we decided the project board was the best option to retain modularity for follow-up work while still incorporating more robust connections than a breadboard circuit.

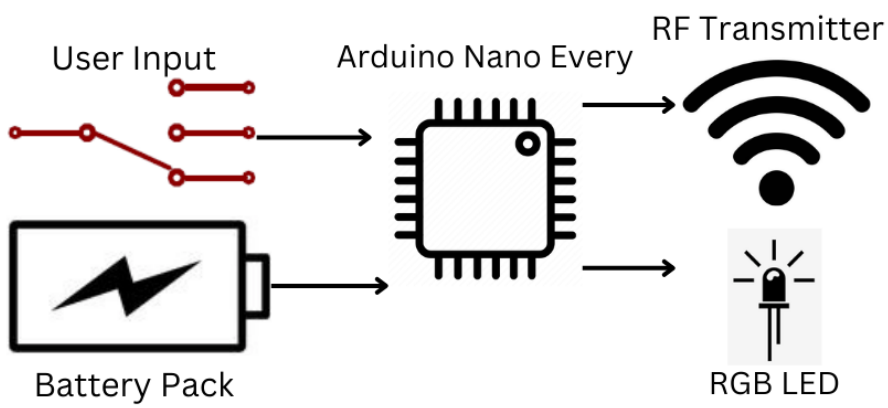


**Figure 9. Remote controller functional diagram**

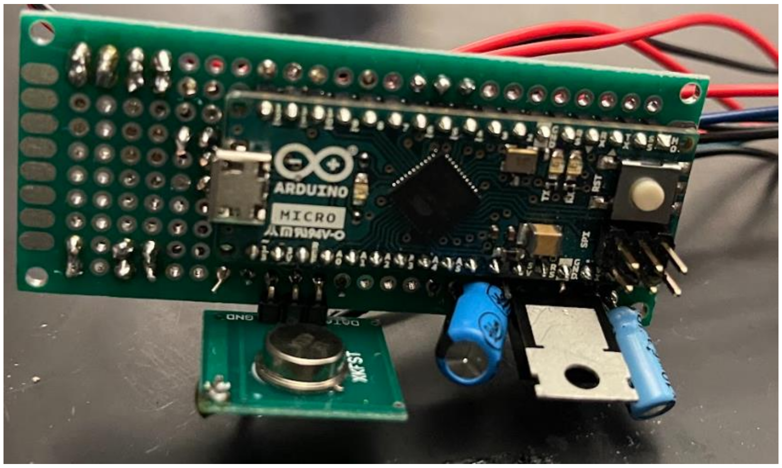


**Figure 10. Remote controller electronics**

In addition to selecting buttons which were easy to press to satisfy the user force requirement, we designed the remote controller housing to be as comfortable and intuitive as possible. The final shape, size, color, and layout of the remote controller housing were based on input from volunteers in our target audience. We took four prototypes to an assisted living facility and gathered feedback from three participants. After deliberation with the project sponsor, the vertical design shown in Figure 8 was chosen as the option that best fit our use cases. We printed the housing on an Ultimaker S5 with standard PLA filament and processed the print through sanding, priming, and painting. The matte black color was selected to improve the texture of the 3D housing and improve the contrast with the grey pieces of the buttons.

# Design Evaluation

### 3.1 Adjustability of holder angle

This test evaluated whether it is simple and feasible for the user to adjust the tablet position once the device is set up.

**Associated Test: Adjustability Test**

The B.A.T.T. tested the adjustment difficulty of the holder angle.

**Objectives**

This test evaluated the ease of adjusting the device for users' operation aiming to not have their applied pushing two-hand force exceed 20 pounds of force. Their maximum applied pinching force should not exceed 4.5 pounds. This test consisted of adjusting the angle of the holder, manipulating the height of the stand, and moving the device around using the mount. The design team expects that someone with strength and dexterity issues would be able to perform all the adjustments on their own. Along with the required force, this test evaluated the difficulty associated with carrying out each of these adjustments.

**Feature(s) Evaluated**

The features evaluated by the adjustment test included the mount movement, the stand height adjustment, and the holder angle adjustment.

**Test Scope**

The adjustment test required a completed device since it must be confirmed that the subsystems are integrated together successfully. This is because this test is contingent on the setup of the prototype already being completed.

**Test Plan**

The required resources to complete the adjustment test included a spring force gauge and a member of the B.A.T.T. We used the force gauge to take measurements of the forces required to adjust the height, angle, and location of the device. To test the force required to adjust the height and angle, we measured the user force applied as they adjust each degree of freedom through its full range of motion. This was done by fastening a loop of string tightly around the ideal location and using the spring force gauge in a perpendicular orientation. The team also measured the force required for the device to be moved by adjusting the device with the force gauge and recording the corresponding values. The ideal locations for the application of force were as follows. For the height adjustment test this location was at the end of the stand, near the holder-stand connector. For the angle adjustment this was at the end of the holder-stand connector, near the holder. These force measurements were repeated at least ten times to get an average value of the force necessary to conduct the adjustment. Additionally, the force applied was measured from an ideal position for the adjustment where the user would have to apply the least possible force to adjust this portion device. To test the simplicity of the adjustment, all four B.A.T.T. members went through each adjustment with their non-dominant hand except for the height adjustment as this requires two hands. The members then graded the adjustment simplicity using a 5-point Likert scale.

**Acceptance Criteria**

For the adjustment test to be considered successful, it must be verified that maximum user force required to adjust the angle of the holder does not exceed 5 pounds, to adjust the height of the device does not exceed 10 pounds, and to adjust the position using the mount with unlocked wheels does not exceed 20 pounds. The average adjustment simplicity rating for each feature should be greater than 4 plus or minus one standard deviation.

**Test Results**

The three adjustments were successfully able to accommodate the force requirements. For the height adjustment test the average force was 7.5 pounds, an ideal measurement for the goal of 10 pounds. The angle adjustment test resulted in an average force of 4.2 pounds, which is below the 5-pound requirement. It should be noted that this force is highly dependent on the tightness of the locking mechanism, and therefore can be higher or lower depending on how much the user is willing to release the knob. Finally, the movement test resulted in an average of 3.5 pounds, a value that is well below the requirement of 20 pounds. These results are seen in Table 1 below while a complete list of data recorded can be found in Section 5.3 of the appendix.

**Table 1: Average Adjustment Force Measurements**

| Adjustment Measurement | Average Force (lbs.) |
|---|---|
| Height | 7.5 |
| Angle | 4.2 |
| Location | 3.5 |

The simplicity portion of the testing was conducted by each of the four members of the B.A.T.T. The members individually performed adjustments from an ideal location on the height, angle, and location of the prototype. A 5-point Likert scale was then implemented ranging from strongly disagree to strongly agree for the statement "The device was simple to adjust". Each team member rated the adjustment process according to their own experience and made any notes or observations they may have encountered during the test. This data can be seen in Table 2.

**Table 2: Likert Scale Ratings**

| Member # | Rating (1-5) |
|---|---|
| 1 | 4.5 |
| 2 | 4.5 |
| 3 | 4.5 |
| 4 | 4.5 |
| **Average** | **4.5** |

### Evaluation

Using the data from the adjustability force testing it is evident that the test met the requirements laid out successfully. Both the height and movement tests passed with an average force well below the requirement, while the angle adjustment test passed by a margin that is narrower. However, as noted in the previous section, this average is subject to change as the user loosens the angle adjuster. This is a benefit to the project due to its ability to create a range of friction values to provide the user with a balance between loose adjustability and tighter support of the device.

## 3.2 Adjustability of stand height

This test evaluated whether it is simple and feasible for the user to adjust the tablet position once the device is set up.

### Associated Test: Adjustability Test

The B.A.T.T. tested the adjustment difficulty of the stand height.

**Evaluation**

The adjustability test completed in section 3.1 was used to evaluate this portion of the adjustability requirements. The average height adjustment force was 7.5 pounds, which is below the 10-pound requirement, meaning this requirement was met by the prototype.

### 3.3 Adjustability of device location

This test evaluated whether it is simple and feasible for the user to adjust the tablet position once the device is set up.

**Associated Test: Adjustability Test**

The B.A.T.T. tested the adjustment difficulty of the device location.

**Evaluation**

The adjustability test completed in section 3.1 was used to evaluate this portion of the adjustability requirements. The average location adjustment force was 3.5 pounds, which is well below the 20-pound requirement, meaning this requirement was met by the prototype.

### 3.4 Simplicity of Device Adjustability

This test evaluated whether it is simple and feasible for the user to complete each possible user adjustment on the device.

**Associated Test: Adjustability Test**

The B.A.T.T. tested the simplicity of adjustments for the device.

**Evaluation**

The simplicity portion of the adjustability test was evaluated in section 3.1. Using the data gathered it can be said that the device was simple to adjust, as the average score was above the required rating of 4. The team was able to increase the adjustability score for the device by addressing the two main concerns seen in previous testing. The first of these was creating chamfered edges on both the pin itself and each of the surfaces the pin passes through to allow for smoother pin insertion. The second was to strengthen the material used to connect the holder to the stand, by doing so the friction required to keep the holder in place was much easier to adjust. These adjustments allowed the system to pass the simplicity portion of the adjustability test with an average Likert score of 4.5. The team felt like many of the adjustments were "very easy" (5), with just the pin adjustment creating slight difficulty. Because of this, the team decided to score the simplicity of the set up between a 4 and 5.

### 3.5 Weight of the mount

This requirement stated that the mount should not be excessively heavy by staying below a maximum weight of 50 lbs.

**Associated Test: Mount Test**

This test evaluated whether the mount subsystem of the prototype was excessively heavy, allowed the device to be moved out the way as needed, and had functional locking wheels.

### Objectives

The goals of the mount test centered on ensuring that this subsystem of the device is performing correctly as a portion of the completed prototype. The mount must not be excessively heavy, must allow the device to be moved out of the way as needed, and must have functional locking wheels.

### Feature(s) Evaluated

The features evaluated by the mount test include the mount subsystem of the device.

### Test Scope

Portions of the mount test have been completed on a prototype of the mount subsystem alone, such as ensuring that it has functional locking wheels and that the subsystem itself is not excessively heavy. However, portions of the mount test required a holistic evaluation of the completed prototype due to the interdependency of the subsystems, such as ensuring that the device can be moved out of the way as needed. The design team conducted the mount test.

### Test Plan

The instruments required to complete the mount test included a mechanical scale, and a spring scale. First, a B.A.T.T. member measured the weight of the mount three times using the mechanical scale.

To test the effectiveness of the mount's wheel locks, a B.A.T.T. member locked all of the wheels and pulled on the side of the mount with a horizontal two-hand push force of 20 pounds. The spring scale was attached to the mount and a person on the other end pulled the scale making sure a force of 20 pounds was being applied.

Allowing the device to be moved out of the way as needed means that when the wheels are not locked the assistants and/or end users are able to roll it out of the way. We had each of our team members try to move the mount when the wheels are both locked and unlocked with a 20-pound force. The team tested the mobility of the device by pulling the mount from the middle. The force required to move the device three feet horizontally, so it is out of the way was measured in five separate trials.

### Acceptance Criteria

For the mount to meet the working criteria of the design it had to be of a certain weight, lock correctly, and move out of the way with minimum effort. The average weight of the mount should be less than 50 pounds plus one standard deviation and the scale uncertainty. To make sure that the locks are in place the mount should stay in place when a force of 20 pounds is applied. Finally, the mount should be moved out of the way with a 20-pound force 5 times successfully.

**Test Results**

As shown in Table 3, the mount was weighed three separate times using the scale in the makerspace to determine that the average weight does not exceed 50 pounds. The first acceptance criteria were weighing the mount and ensuring it did not exceed a weight of 50 pounds. Since this acceptance criteria were met, the mobility of the mount was evaluated next. In all five trials, the force needed to move the mount out of the way did not exceed 20 pounds, so the acceptance criteria were met. The final criteria for the mount test were the mount being able to withstand a force of 20 pounds with the wheels locked and not moving. The mount slid once a force of 21 pounds was applied, therefore it did meet the acceptance criteria for this portion of the mount test.

**Table 3: Mount Weight**

| Trial # | Weight (lbs.) |
|---|---|
| 1 | 27 |
| 2 | 27.5 |
| 3 | 27 |

**Evaluation**

The acceptance criteria for the weight of the mount were satisfied. Weighing the mount in three separate trials confirmed that the weight did increase from the previous prototype, but still does not exceed the maximum as dictated by the requirement.

### 3.6 Mobility of the mount

This requirement stated that the mount should allow the device to be moved out of the way as needed. With the wheels unlocked, the force required to move the mount should not exceed 20 pounds.

**Associated Test: Mount Test**

**Evaluation**

This requirement was evaluated using results from the previous test in Section 3.5 as it ensured that the mount was mobile and allowed the device to be moved out of the way as needed. Despite increasing the weight of the mount from the previous prototype, the mount was still easily moved with a force not exceeding 20 pounds. The acceptance criteria regarding the mobility of the mount were satisfied, therefore the requirement was met.

### 3.7 Functional locking wheels of the mount

This requirement is meant to ensure that the device can stay in a fixed position as needed. With the wheels of the mount locked, it should be able to withstand a force of up to 20 pounds without moving.

**Associated Test: Mount Test**

**Evaluation**

The evaluation of this requirement was done using the results from the mount test in Section 3.5 as well. This requirement was not satisfied using the previous prototype of the mount, however by increasing the weight of the mount in the new prototype it was satisfied. The force required to move the mount with locked wheels increased from 13 to 21 pounds with the prototype revision. This established that the locking wheels of the mount function as desired and the requirement was satisfied.

## 3.8 Height adjustment of the stand

The stand should support the tablet from a height of 30 inches to 60 inches off of the ground.

**Associated Test: Stand Test**

This test evaluated the stand portion of the device to ensure that it may be adjusted to the minimum and maximum values of the desired height range. Additionally, the stand must be able to allow the tablet to be rotated in a range of motion sufficient for the user to view it from different angles in the horizontal and vertical directions.

**Objectives**

The goals of the stand test included ensuring that the stand may be adjusted in height from 30-60 inches off the ground and allow the tablet to be rotated up to 120 degrees in both the horizontal and vertical directions.

**Feature(s) Evaluated**

The features that this test evaluated are the height and angle adjustment of the stand subsystem of the device.

**Test Scope**

This test required a complete prototype to test the stand with the entire device. This is because the evaluation of the height will be measured from the tablet secured in the holder to the floor, and the combination of the added holder and mount will contribute to the height. Additionally, measuring the angle change of the tablet required the holder to be attached to the stand already.

**Test Plan**

The materials necessary for the completion of the stand test included a meter stick and a protractor. We used these instruments to take measurements of distance and angle relevant to the functioning of the stand. Five measurements of the distance and angle were taken in order to determine an average and ensure the stand is performing as intended.

The primary assumption in the stand test is that it was evaluated once it was a portion of the completed prototype, since this is critical to verify it functions as intended while being a portion of the entire device. The data and information that came from the stand test were mainly

quantitative. The quantitative measurements include distance and angle as mentioned previously and were repeated multiple times to verify repeatability. The distance that was measured is the height of the stand from the ground and the angle was the angle of view the stand provides the user of the tablet while they read.

### Acceptance Criteria

For the stand design to satisfy the working criteria, the height measurements of the stand must be able to accommodate a range from 30-60 inches off the ground. The protractor measurements of the angle the stand allows the tablet to move within must have a range of 120 degrees in both the horizontal and vertical directions. For each set of measurements, the average plus or minus one standard deviation must be met to be considered satisfactory.

### Test Results

The first portion of the stand test is measuring the height of the device from the ground to the holder where the tablet will be situated. Table 4 shows the results of these measurements, and it did ensure that the acceptance criteria for the height adjustment of the stand test was met. The second portion of the stand test is measuring the range of angle adjustment the stand allows the tablet to move within. Table 5 shows the results of those measurements and indicates that it did satisfy the acceptance criteria of this portion of the stand test.

**Table 4: Stand Height Measurements**

| Value | Minimum Height (in.) | Maximum Height (in.) |
|---|---|---|
| Average | 3 | 68.3 |
| Standard Deviation | 0 | 0.48 |

**Table 5: Angle Adjustment Measurements**

| Value | Horizontal Range (deg.) | Vertical Range (deg.) |
|---|---|---|
| Average | 360 | 180 |
| Standard Deviation | 0 | 0 |

### Evaluation

The acceptance criteria for the adjustment of the height of the stand were satisfied. The stand allowed the height of the tablet to be adjusted within the range of 30 to 60 inches off the ground. The previous prototype of the stand allowed for a height adjustment ranging from 28.1 to 66 inches, while the current prototype of the stand allows for a height adjustment ranging from 3 to 68.3 inches. Therefore, the height adjustment requirement for the stand was met and improved upon through prototype revisions.

### 3.9 Angle adjustment of the stand

The stand must allow the angle of the tablet to be adjusted in a minimum range of 120 degrees in both the horizontal and vertical directions.

**Associated Test: Stand Test**

**Evaluation**

The evaluation of this requirement was done utilizing the results of the previous test in Section 3.8. The piece that allows for the angle adjustment of the tablet is two ball joints interfaced together, so it provides a very good range of motion for angular adjustment. As shown in Table 5, the angle adjustment range in both the horizontal and vertical directions exceed 120 degrees. Therefore, the acceptance criteria for the angle adjustment of the stand was satisfied and the requirement was met.

### 3.10 Set-up of the device

The device is simple to set up for an average, non-technical individual.

**Associated Test: Set-up Test**

This test evaluated whether the tablet holder device is simple for an able-bodied person assisting an end user to set-up once they have received the device.

**Objectives**

The goal of the set-up test was to ensure that the device is simple for an able-bodied individual without a technical background to set up (i.e., someone who is assisting the end users in setting up their stand). This included them setting up each individual subsystem feature for the entire device. They must be able to set up the mount, stand, holder, controller, and page turner for use without significant strain. Setting the device up included assembling each of the subsystems and combining them to form a finalized device.

**Feature(s) Evaluated**

The setup test evaluated features from each of the five subsystems, including the mount, the stand, the holder, the remote control, and the page turner. However, it should be noted that the set-up test primarily focuses on the mount, the stand, and the holder as these are the features that are the most difficult to set-up.

**Test Scope**

The initial portion of the set-up test was completed using an incomplete prototype of each feature of the design. This is primarily because ensuring that the feature is easy to set-up can be completed using that individual section of the device. Finishing the set-up of the device involved assembling each of the subsystems into a final working device.

**Test Plan**

The required resources to complete the set-up test were able-bodied, non-technical individuals who can evaluate the device to ensure that the target audience was able to set up each feature of

the prototype and adjust features of the device. This included confirming that each feature of the device is simple for them to set up. The test was executed by having individuals without manual dexterity issues or a technical background set-up each feature of the device and combine them to form the completed device. The individuals then completed a survey using a 5-point Likert scale to determine the simplicity of the set up. Our target end users are individuals with manual dexterity issues; however, we are assuming the assistance of able-bodied individuals when determining that the device can be set up by most users.

### Acceptance Criteria

For the set-up test to be considered successful, it must be qualitatively verified that each feature of the device is simple to set-up for the majority of users. The majority of users are defined as seventy percent or greater. The set up is deemed simple if it is intuitive and does not require the use of excessive strain. This was measured by implementing a 5-point Likert scale into a brief survey completed by the individuals who evaluated the set-up of the device.

### Test Results

Four individuals with non-technical backgrounds attempted to set up the device and ranked the difficulty of the set-up using a 5-point Likert scale. The scale evaluated the difficulty of setting the device up by presenting the individuals with the statement "The device was very simple to set-up" and having them respond according to the Likert scale. The scale ranged from 1 (strongly disagree), to a maximum of 5 (strongly agree). Satisfying the acceptance criteria meant a minimum of seventy percent or greater of the individuals in the test believed the set-up was simple, corresponding to a four or higher on the Likert scale. From the four individuals who completed the set-up test, their scores were 5, 5, 4, and 4, which meant one hundred percent of the individuals believed the device was simple to set-up.

### Evaluation

Previously, the set-up test failed as the four prior participants rated the ease of setting up the device a 2, 3, 4, and 5. However, modifications were made to the design to make it easier for individuals to set-up, such as increasing the size of the hole in the brackets that the screws connecting the stand to the mount must run through. These modifications paired with more explicit instructions on how to set up the device resulted in the four participants rating the ease of setting up the device a 5, 5, 4, and 4. All four of the participants either agreed or strongly agreed that the device was very simple to set up, therefore the majority of users agreed, and the acceptance criteria was met.

## 3.11 Page turner successful swipe

The page turner is able to successfully complete a swipe upon receiving a signal.

### Associated Test: Page Turner and Remote Control Test

### Test Overview

This test evaluated the page turning subsystem of the device to ensure that it functions properly, including its connection to the remote-control subsystem and the tablet holder subsystem.

## Objectives

The goal of the test for the page turning subsystem was to accurately assess its ability to swipe in all four cardinal directions quickly and effectively, and reliably. Since the page turner must also receive commands from the remote controller to successfully swipe pages, the reliability of the of the RF link between the two systems was also assessed. The requirements to achieve these objectives are the following: the device shall operate without error 98% of the time, while also being able to turn a page within 2 seconds of receiving the command from the remote-control device.

## Feature(s) Evaluated

This test examined the device's ability to consistently swipe in all four cardinal directions at the correct speed requirement and the RF link between the remote controller and page turner.

## Test Scope

The key test conditions for the page turner analysis were two-fold. The first of these was to determine a percentage for the successful page turns with respect to the total number of pages turns attempted. The required percentage for this success rate is 98%, therefore the physical page turning and RF signal transmission must both be at least 99% successful to yield a combined 98% success rate. The second key test condition was the time it takes to turn the page once the page turning device has received the input from the remote controller. For this test condition to be met successfully this time must be two seconds or less.

## Test Plan

The set-up for the page turner test was straightforward, with only the prototype, a video recording device for measuring the time, and an excel sheet for data collection necessary. The mathematics involved with this test consisted of percentage calculations and averages, both of which were completed through the excel documentation. This data was also used to perform standard deviation calculations on the time to turn the pages, which help determine the consistency of the page turning motion. The key requirement for the success of this subsystem test was the assumption that the remote controller device would be able to consistently send a command to the page turning device. This allowed for consistent testing, but did not interfere with the time requirements, as those will be taken after the signal has been received by the device. This prototype test included 400 test runs consisting of 100 swipes in each of the cardinal directions After these 400 tests, 10 samples from each direction were randomly selected from the video recording to analyze the time taken to complete the task frame-by-frame. Finally, this prototype testing plan was constructed under the assumption that the tablets tested are representative of the full range of devices users may want to use with the design.

For the remote control test, the remote controller and page turner microcontrollers were connected to a set of LED lights to display whether signals were sent and received (red for left page turns, green for right page turns). Successful signal transmission was determined by observing whether both the remote controller and page turner LEDs lit up. Trials were run an

equal number of times for both left and right page turns until 100 overall successful signal transmissions were documented. Then the communication success rate can be calculated as the ratio of inputs received to inputs sent.

**Acceptance Criteria**

The acceptance criteria for the quickness, effectiveness, and directional capabilities of the page turning subsystem are as follows:

- The success rate of the swiping method in all four cardinal directions will be 99% or greater.
- The time it takes for the device to successfully complete a single swiping motion for all four cardinal directions will be 2 seconds or less.
- The success rate of the RF signal transmission between the remote controller and page turner will be 99% or greater

For the page turner test measurements, the average plus or minus one standard deviation must be met to be considered satisfactory.

**Test Results**

The page turner testing was adjusted from last semester by including performance on two different tablet models, an Apple iPad tablet, and a Kindle, and testing four directions as opposed to the two conducted previously. For the prototype itself, the tip used to contact the tablet screen was modified from a frayed wire to a conductive foam tip to protect the tablet face. To examine the impact of the modifications on the prototype the previous semester's data is included in Table 6. The results will be compared to that of this semester's prototype testing.

**Table 6: Fall 2022 Page Turner Performance - Apple iPad**

| **Orientation** | Horizontal | Vertical |
|---|---|---|
| **Swipe Direction** | N/A | N/A |
| **Reliability** | 100% | 95% |

The main purpose of this semester's testing was to refine the page turner to be more consistent in conjunction with the holder subsystem. The results from the Fall seen in Table 6 are slightly skewed due to the test being set up in way that promoted consistency by eliminating variables that would interfere with the system. This was done to show proof of concept. For the final prototype, the design was tested while mounted to the holder. The results seen in Tables 7 and 8 indicate that the page turner was able to meet the consistency requirement of 99% outside of the ideal testing set up. For this test, the average of the 8 individual tests were taken, so although one score came in just below the required percentage, the average was still higher than the required value. It can also be seen in Table 9 that the remote controller also successfully met the 99% requirement for consistency.

**Table 7: Spring 2023 Page Turner Performance - Apple iPad**

| **Orientation** | Vertical | Vertical | Horizontal | Horizontal |
|---|---|---|---|---|
| **Swipe Direction** | Up | Down | Left | Right |
| **Success Rate** | 99% | 100% | 100% | 97% |

**Table 8: Spring 2023 Page Turner Performance - Kindle**

| **Orientation** | Vertical | Vertical | Horizontal | Horizontal |
|---|---|---|---|---|
| **Swipe Direction** | Up | Down | Left | Right |
| **Success Rate** | 100% | 100% | 98% | 99% |

**Table 9: Remote Controller Signal Consistency**

| **Type of Signal Transmission** | Turn Page Left | Turn Page Right | **Combined** |
|---|---|---|---|
| **Success Rate** | 100% | 98.04% | **99.1%** |

The second portion of the page turner subsystem testing was a measurement of the time required to perform a single page swipe. Once again, this test will be compared to the data collected last semester as seen in Table 10. The data collected this semester remains consistent with last semester's observations and successfully completed the requirement of 2 seconds or less.

**Table 10: Average Page Turner Swipe Time**

| **Semester** | Fall 2022 | Spring 2023 |
|---|---|---|
| **Average Duration (s)** | 0.699 | 0.834 |

## Evaluation

Since both the page turner and RF signal transmission were at least 99% successful, the page turning system met the consistency requirement of a 98% successful swipe rate. By implementing form fit screw holes and a conductive foam tip the page turner device proved to be more consistent, even when implemented outside of the ideal testing set up used in the previous semester. The page turner design could be improved further by implementing a more permanent connection between the two servos. Although the 3D printed servo mounts are adequate for this version of this final prototype, creating a more unified system would further reduce

inconsistencies. The page turner electronics were also laid out on a breadboard for the prototype testing and will need to be transferred to a soldered project board and mounted to the holder for the final iteration of the prototype. Both the RF receiver and transmitter antennas were wound more tightly and had a longer effective length compared to the prototype test report iterations, which made a big enough difference to satisfy the reliability requirements.

### 3.12 Page turner swipe speed

The page turner is able to complete a swipe within the required time allotment.

**Associated Test: Page Turner Test**

**Evaluation**

As the page turner test covered both the successful swipe rate and swipe speed, the data from section 3.11 was used to complete this evaluation section. The data in Table 9 indicates that not only was the average swipe speed well below our requirement of 2 seconds, but that each individual data point was also below the requirement. Therefore, the acceptance criterion for the page turner's swipe speed was satisfied and the requirement was met. The increase in average swipe time for the Spring semester is due solely to adjustments made when tuning the servos. By increasing the swipe distance across the screen, attempts were made to make the page turner more consistent, increasing the average swipe time. This did not affect the success of the test in any way and can be adjusted as needed.

### 3.13 Tablet size accommodation

The holder could **accommodate a tablet that ranges from a size of 6" x 4" x 0.1" to 14" x 10" x 0.5" (width, height, thickness).**

This test evaluated the holder to ensure that it could accommodate a tablet that ranges from a size of 6" x 4" x 0.1" to 14" x 10" x 0.5" (width, height, thickness) and a weight of up to 5 pounds.

**Objectives**

The objective of this test was to ensure that the tablet holder accommodated a tablet that ranged from a size of 6" x 4" x 0.1" to 14" x 10" x 0.5" (width, height, thickness) and a weight of up to 5 pounds.

**Feature(s) Evaluated**

The subsystem that was evaluated in this design was the holder. Within the holder, the vertical and thickness adjusters were evaluated to see if they could adjust to a different range of tablet sizes.

**Test Scope**

The test can be completed with the holder prototype alone.

**Test Plan**

To make sure the tablet holder fits different tablets replicas of the smallest and largest tablet sizes were constructed and evaluated if the tablet holder could accommodate the tablets. 5lbs were added to the holder to see if the holder would stay intact.

**Acceptance Criteria**

The holder must demonstrate the ability to support tablets ranging from 6" x 4" to 14" x 10" (width, height) and weighing up to 5 pounds.

**Test Results**

The tablet holder accommodates tablets with widths from 6 to 14 in, heights from 4 to 10 in, and thicknesses from 0 to 0.5 inches. The tablet holder was able to support a max weight of 5lbs.

**Evaluation**

The tablet holder is adjustable to all tablets within this range.

### 3.14 Tablet rigidity

Tablets of all sizes stay rigid when put on the holder.

**Associated Test: Holder test**

**Test Overview**

This test will evaluate if tablets with all range of sizes will stay rigid when secured in the holder.

**Objectives**

The objective of this test is to make sure the tablet stays in place while the user is adjusting the holder.

**Feature(s) Evaluated**

The subsystem that was evaluated in this design is the holder. Within the holder the vertical and thickness adjusters were evaluated to see if they can keep the tablet in a rigid position.

**Test Scope**

This test can be completed with the holder prototype alone.

**Test Plan**

Replica tablets of varied sizes were put on the holder, moved in various positions, and then evaluated that they were secured in the holder.

**Acceptance Criteria**

Tablets of varied sizes must be secured in the holder at various positions.

**Test Results**

Tablets that had a height of 4-6 inches did not stay rigid on the holder. Tablets from heights 6-10 inches stayed in a rigid position.

**Evaluation**

As the tablets got bigger the tablets were more secure. The tablet with the smallest height of 4 inches did not stay rigid. This is because the springs on the vertical adjuster started to create tension at a height of 6 inches. At a height of less than 6 inches the springs would bounce up and down causing the replica tablets to be unstable. The thickness adjuster alone did not secure it. A short-term solution for this problem is to flip the smallest size tablet where the width is the height. A long-term solution is to either to find a spring that creates tension on all heights or to find a way prevent the springs from bouncing up and down.

**3.15 Visibility of tablet screen**

The eBook can be read with clear visibility.

**Associated Test: Holder test**

**Test Overview**

This test evaluated if the eBook can be seen clearly with the holder and the page turner in the design.

**Objectives**

This test's objective is to ensure that the holder and page turner do not block the screen.

**Feature(s) Evaluated**

The subsystem that was evaluated in this design is the holder and page turner. Within the holder the vertical and thickness adjusters were envaulted to see if they could adjust to a different range of tablet sizes. We must also ensure that the page turner does not block the screen when integrated with the thickness adjuster.

**Test Scope**

This test was performed with a completed prototype of the holder and the page turner.

**Test Plan**

The tablet will be placed on the holder and evaluated by the team if the eBook is visible.

**Acceptance Criteria**

The team must agree that the eBook must is visible to read with the holder and the page turner

**Test Results**

Our team evaluated that the eBook was visible to read with the holder and page turner. An image of the tablet and the page turner can be seen in Figure A.7.

**Evaluation**

The eBook was visible and did not block the screen according to the team. The holder did not block the eBook at all, but the page turner arm blocked a small portion of the eBook. Since the page turner can move the small portion that the page turner arms blocks can be seen.

**3.**16 Tablet Damage
The tablet is not damaged when placed on the tablet holder.

**Associated Test: Holder test**

**Test Overview**

This test evaluated if the tabled was damaged when placed on the holder.

**Feature(s) Evaluated**

The subsystem that was evaluated in this design is the holder. Within the holder the vertical and thickness adjusters were envaulted to see if they do not damage the tablet.

**Test Scope**

This test was performed on the protype of the holder alone.

**Test Plan**

A replica of a tablet was constructed with a weak material and was then put on the holder to see if then it was evaluated if the tablet was damaged.

**Acceptance Criteria**

The tablet holder must not damage the replica tablets while they are being used.

**Test Results**

The tablet holder did not damage the replica tablets.

**Evaluation**

The tablet was not damaged even when it was tested with a clay model that was very brittle. Since tablets are usually made with stronger materials in comparison to clay, they will not be damaged when used by the tablet holder.

**3.**17 User Input Force
The force from a user needed to register an input is adequately small.
**Associated Test: User Force Test**

**Test Overview**

This test evaluated the user force acting on the remote controller input mechanisms.

**Objectives**

Verify that the force required to turn pages is less than 2.5 pounds (11.13 Newtons).

**Feature(s) Evaluated**

This test examined the force required to depress the user inputs on the remote controller.

**Test Scope**

The test consisted of measuring the force threshold of the input mechanisms on the remote controller, and was conducted by members of the B.A.T.T.

**Test Plan**

This test used a weight scale and a force gauge to measure the force required to operate the remote controller. For all the inputs except the on/off switch the input was placed on the scale and zeroed before the button or switch was pressed down and the force value was recorded. For the on/off switch we tied a string on one end and on the other end the force gauge. The force gauge was pulled gently, and the value was recorded. We conducted this test for 10 trials, averaging the recorded forces to minimize the effect of measurement deviations.

**Acceptance Criteria**

The user force test will be validated if the average force required for the remote controller to register an input is under 2.5 pounds plus one standard deviation.

**Test Results**

The user force test was used to evaluate various remote controller input mechanisms. All the remote controller input mechanisms met the criteria of having to use a force of under 2.5 pounds. Table 11 shows the results for the user force applied in the different remote controller input mechanisms. Both the input mechanisms used in the remote controller design met the user force requirement of 2.5 pounds.

**Table 11: User force applied in different remote controller input mechanisms**

| Button/Switch Type | Average Force [lbs.] | Standard Deviation [lbs.] | Average plus standard deviation [lbs.] |
|---|---|---|---|
| Buttons | 0.777 | 0.054 | 0.831 |
| Power Switch | 0.594 | 0.034 | 0.628 |

**Evaluation**

The two button choices selected for the final remote controller design were tested after implementation into the device itself. These results did not differ from the testing done in the previous iterations of this test. Consequently, both buttons successfully met the requirement of needing less than 2.5 pounds of force to complete a single depression.

### 3.18 Tablet Safety Catch

The tablet is safely secured so that it will not injure a user in the case of a disconnection and fall.

**Associated Test: User Safety Test**

**Test Overview**

This test qualitatively evaluated the safety of the completed design system.

**Objectives**

Verify that the device will not injure the user through falling components, extreme force requirements, or sharp edges.

**Feature(s) Evaluated**

This test examined the implementation of preventative safety features.

**Test Scope**

The test consisted of qualitatively examining the safety features implemented across the completed design.

**Test Plan**

This test included the examination of the two safety catches for possible component failure in the holder and stand subsystems. Each component that required user interaction to function was assessed for potential pinch risks and sharp edges that could harm the target audience.

**Acceptance Criteria**

The user safety test will be validated if each of the three qualitative safety assessments indicates minimal potential safety risk.

**Test Results**

The safety catches for the holder and stand subsystems acted as intended and successfully held the weight of the components in question while also using a low length to minimize fall distance. Similarly, the wrist strap attachment for the remote controller provides a safe way to keep the remote controller close to the user. Therefore this portion of the test requirements were met successfully. The pinch risk was analyzed for four main subsystems: Mount, stand, holder, and remote controller. Each of these subsystems contains a component that the user may interact with. For the mount, the locking of the wheels posed very little pinch risk as they are recessed slightly under the base and the locking will be completed with the user's foot. The pin system for the stand posed the greatest potential pinch risk initially. This risk was addressed by chamfering the edges of both the pin and its associated holes. Although some pinch risk is unavoidable, it was decided by the B.A.T.T. that the design features implemented greatly reduced this risk, allowing the stand to meet the requirements. For the holder, low-force springs on the height and thickness adjusters made the pinch force negligible. The use of a tightening knob, as opposed to a nut and bolt, on the holder angle adjuster also helped eliminate any potential pinch risk. Finally, the selection of plunger style buttons for the remote control helped reduce pinch risk. To address the sharp edges requirement all possible edges on the device were either chamfered or sanded down appropriately. This included the wooden base, aluminum stand frame, and 3D printed components of the holder. A large focus was placed on the components that users would

be interacting with the most, such as the pin system and holder angle adjustment, as these systems posed the greatest risk to pinching. After thoroughly examining the system in a subsystem-by-subsystem manner, the B.A.T.T. determined that there were no remaining sharp edges on the device.

**Table 12: Potential Safety Risk Analysis**

| Safety Feature | Pass/Fail |
|---|---|
| Fall Catches | Pass |
| Pinch Risk | Pass |
| Sharp Edges | Pass |

**Evaluation**

The safety catches were the easiest safety requirement to assess. The chains used are needed to meet two sub-requirements, being to successfully hold the weight of the component and include a short enough length to minimize fall distance. Both features were met successfully for the stand and holder subsystems.

**3.19 Pinching Hazards**
The system reduces pinch risk for components that are user interactive.
**Associated Test: User Safety Test**

**Evaluation**

Although completely negating all potential pinch risks is not realistic, the team was able to successfully minimize the number of possible pinch regions. Similarly, those regions that are necessary to the design were implemented so that the potential forces involved were minimized.

**3.20 Sharp Corners**
The system does not include sharp edges that may harm the target audience.

**Associated Test: User Safety Test**

**Evaluation**

The portion of the user safety test relating to sharp edges was completed by doing a check of the entire design to ensure that no potentially dangerous edges were missed upon subsystem construction. All potential edges were successfully chamfered and sanded allowing this requirement to be met. One design improvement that could more greatly negate this risk would be selecting a different material for the mount base. However, due to there being little to no user

interaction, it was determined that sanding the edges to be smooth was an adequate solution given the design budget.

## Conclusions

Altogether, the prototype does perform the promised tasks in the most recent project plan. It can support a multitude of tablets in a variety of positions that users can read from without using their hands. Once the device has been completely set-up and adjusted to the ideal position the user simply must input commands into the remote controller to turn the pages of their tablet. Of the 18 requirements that the project sought to satisfy, only 1 of them was not met. The only requirement that was not met was that the holder should be able to hold the tablet in a rigid position. This requirement is important for the overall function of the design as it must be able to secure the tablet in a rigid position, however the requirement was only not met because the smallest tablet size was too small for the springs of the height adjuster to secure in a rigid position. Smaller springs could be implemented to accommodate the smallest tablet size, but it makes the height adjuster too difficult to raise high enough to secure the largest tablet size. Therefore, the design team decided to implement the larger springs on the height adjuster of the holder to accommodate a larger range of tablets even though it cannot accommodate all of them.

Despite not meeting all the requirements, the device is still a working prototype. It can still be utilized to secure a tablet in a variety of positions and turn the pages on the E-book without having to touch or support the tablet. The only major issue with the device is that it cannot accommodate the full range of tablets the team originally sought to, however it is still functional with a large variety of tablets except a few on the smaller end of the size spectrum. Tablets on the smaller end of the spectrum can still be held by the holder, it is just not rigid due to the springs being too large. Adding a spring stopper to the height adjuster so that it does not bounce off when securing the smallest tablet size is a solution that may enable the holder to hold the full range of tablet sizes in a rigid position. Additionally, the springs create enough tension to hold the tablet in a rigid position when the height adjuster is raised 6 inches, so flipping the smallest tablet size to a vertical position does enable the holder to secure it in a rigid position. Although the prototype is currently working, this design flaw may be addressed by modifying the holder as mentioned above and then redoing the holder test to ensure that it meets all the requirements the design team sought to satisfy. Although not a design issue, the page turner electronics must also be transferred to a soldered project board and attached to the holder to clean up the design aesthetic and fully capture the spirit of the project.

# Appendices

## 5.1 B.A.T.T. Standard Operating Procedure (SOP)

### Tablet Holder Set-Up/Operating Manual

**1. Purpose**

This operating manual provides detailed instructions on how to set up and operate the tablet holder as intended by the design team.

**2. Scope**

This protocol has been developed for the sole purpose of setting up and then operating the tablet holder. The procedure has been created by the design team who created the device and is intended to provide clear instructions on how the user interacts with the device. The safety of the user is the top priority in this manual, as the end users are potentially vulnerable given the age demographics of the target audience for the device.

**3. Responsibilities**

It has been assumed that an able-bodied, non-technical individual can assist the end user in setting up their tablet holder device. There are portions of the device that may be adjusted by the user as they see fit, however, portions of the device may require the assistance of an able-bodied individual to adjust. As such, precautions must be taken by the user to only adjust portions of the device that they are capable of and seek assistance from an able-bodied individual, as necessary.

**4. Specific Set-Up Procedure**

4.1 The materials required to set up the device are limited to a Phillips head screwdriver and the assistance of an able-bodied individual

4.2 The device comes with three core components that must be assembled, the mount, the stand, and the holder

4.3 The stand is attached to the mount by inserting the stand into the brackets on the top face of the mount, the orientation of which direction the stand should be inserted into the mount is confirmed by the hole system on the side of the stand and the brackets. One hole in the bracket aligns with one hole in the stand, as shown in Figure A1

4.4 Once the stand has been inserted into the brackets and is oriented correctly, the eight screws in the assembly box must have one washer applied over the threaded section of each of the screws

4.5 Now, the screws must be inserted into the aligned holes in the brackets to attach the stand to the mount using the Phillips head screwdriver. There are two screws per bracket so all eight of screws should be utilized

4.6 The completed mount and stand have been configured with one another, so attaching the holder will require inserting the ball joint into the interfacing piece on the top end of

the stand and using the handle to tighten the piece and secure the holder into place as shown in Figure A2

4.7 Attach the safety catch on the stand to the back of the holder using the carabiner clip as shown in Figure A3. This serves to catch the holder and the tablet if it were to fall in the case of user error or failure of the joint connecting the stand and holder

4.8 The page turner comes attached to the holder and only requires that the power supply be plugged into a wall outlet and connected via the barrel connector

4.9 The remote controller requires the bottom of the housing to be removed to insert AA batteries into the battery pack as shown in Figure A4

4.10 If the red and black wires attached to the battery pack are not connected to the top part of the remote controller, attach the two leads by matching the red and black wires

4.11 All of the subsystems of the device have now been configured and are ready for operation

## 5. Specific Operating Procedure

5.1 Adjust the height of the device to the desired height for operation by removing the pin in the ring system on the side of the stand and moving the swing arm to the desired position. Once the swing arm has been adjusted to the desired position, insert the pin through the ring system and the swing arm to lock the height of the device in place as shown in Figure A5

5.2 Move the device to the ideal location for the user in the room by wheeling it into position using the wheels of the mount. Once the device is in the desired location, use your foot to lock the wheels of the mount and secure the location of the device as shown in Figure A6

5.3 Adjust the angle that the tablet will face the user by turning the handle counterclockwise of the joint interfacing the stand and the holder to loosen it and then repositioning the ball joints. Once the angle of the holder/ tablet is as desired using the ball joints, turn the handle of the interfacing joint clockwise to lock the angle in place as shown in Figure A2

5.4 Now that the height, position, and angle of the device are set as desired, insert the tablet into the holder. The tablet can be secured in the holder by pulling up the height adjuster and pulling out the thickness adjuster, then sliding the tablet into place and allowing the springs of the two adjusters to secure the tablet in place as shown in Figure A7

5.5 The device is now securely holding the tablet in the desired position, so the page turner can now be turned on using the power switch on the back of the holder. The remote controller can also be turned on at this stage using the power switch

5.6 The simply press the corresponding buttons on the remote controller to turn the pages of the E-book as pictured in Figure A10 and enjoy the reading experience

5.7 When operating the device, there are three primary safety concerns to consider. Firstly, the wheels of the mount can pose a minor tripping hazard since they are on the ground. Additionally, the pivot joint that the stand swings can pose a pinching hazard if an individual sticks their fingers in the joint. Lastly, it is important that the safety catch for the holder be utilized to prevent the tablet from falling on the user in the case of failure or user error.

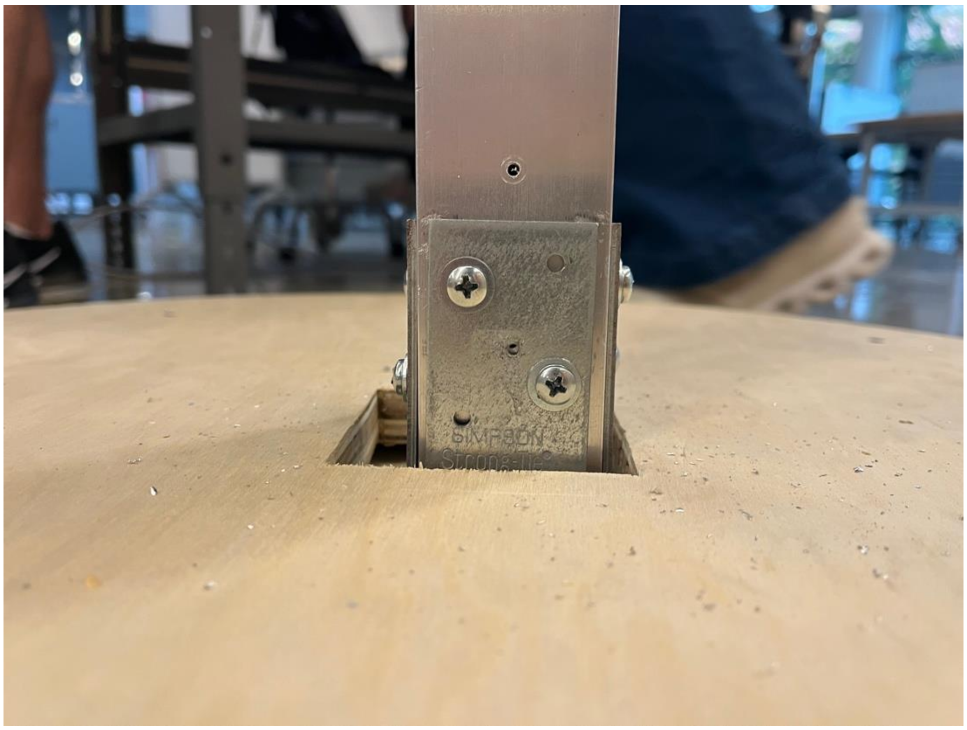

**Figure A1. Hole alignment of the stand and mount bracket**

**Figure A2. Ball joint connection between the stand and holder**

**Figure A3. Carabiner clip safety catch attaching to the back of the holder**

**Figure A4. Remote controller housing with the removable battery cover outlined in blue**

**Figure A5. Pin and ring system securing the height of the stand**

**Figure A6. Engaging the lock on the wheels of the mount to secure its position**

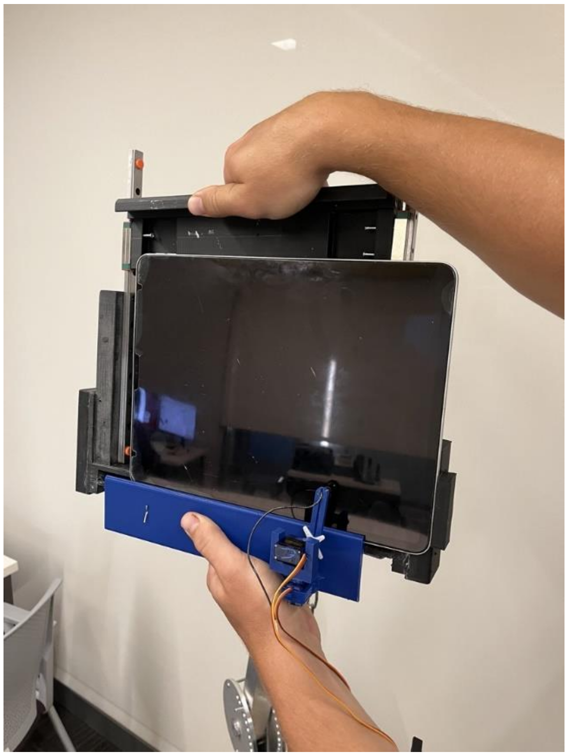

**Figure A7. Adjusting the height and thickness adjuster of the holder to secure the tablet**

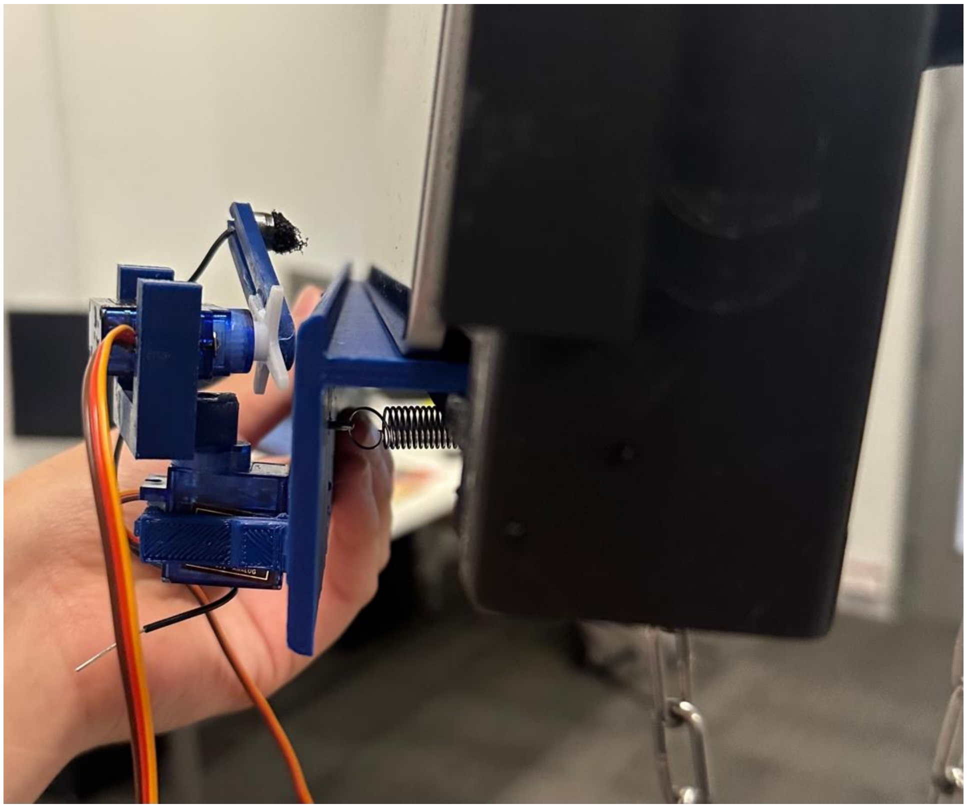

**Figure A8. A closeup of adjusting the thickness adjuster**

**Figure A9.A side view of the tablet holder.**

**Figure A10. Remote controller buttons to actuate the page turner**

### 5.2 Tipping Calculations

%Variables
W_base = 27; %mount weight in pounds
W_counter = 0; %Counterbalance weight in pounds
W_holder = 2; %holder weight in pounds
W_tablet = 5; %Tablet weight in pounds
W_tandh = W_tablet + W_holder;
W_AB = 2.5; %Weight of stand section AB in pounds
W_BC = 2.5; %Weight of stand section BC in pounds
syms F_pull_horizontal; %Pull force on the stand in pounds
syms F_push_horizontal; %Push force on the stand in pounds
syms F_pull_vertical; %Pull force on the stand in pounds
syms F_push_vertical; %Push force on the stand in pounds
r_mount = 12; %mount radius in inches
r_wheel = r_mount; %radial distance from the center of the mount to the center of a wheel (in tipping position)
syms r_counter; %radial distance from the center of the base to the counter weight in the opposite direction of the wheel radius

```
L_AB = 28; %Length of stand section AB in inches
L_BC = 30; %Length of stand section BC in inches
L_pull = L_BC; %Distance from the mount to the pull location in inches
theta_stand_horizontal = 90; %Angle measured between stand segments AB & BC in degrees
theta_stand_vertical = 180; %Angle measured between stand segments AB & BC in degrees
%Equations
%Moment about tipping point (4 wheel model with wheel as tipping point)
% F_pull = double(solve(r_mount*W_mount+r_mount*W_BC-(0.5*L_AB-r_mount)*W_AB-
(L_AB-r_mount)*(W_holder+W_tablet)-L_pull*F_pull == 0,F_pull))
%Moment about tipping axis between wheels (5 wheel model)
L_wheel = sqrt(r_wheel^2+r_wheel^2 - 2 * r_wheel^2*cosd(72)) %Distance between two wheel
mounting points
r_tip = sqrt(r_wheel^2-(0.5*L_wheel)^2) %Radius from the center of mount to the tipping axis
of rotation
%Assuming Member AB is horizontal
F_push_horizontal = -(W_tandh*(L_AB-r_wheel)+W_AB*(L_AB/2-r_wheel)-r_wheel*W_BC-
r_wheel*W_base-W_counter*(r_wheel+r_counter))/L_pull;
F_pull_horizontal =
(W_tandh*(L_AB+r_tip)+W_AB*(L_AB/2+r_tip)+r_tip*W_BC+r_tip*W_base-
W_counter*(r_counter-r_tip))/L_pull;
%Assuming Member AB is vertical
F_push_vertical = -(-r_wheel*W_tandh-r_wheel*W_AB-r_wheel*W_BC-r_wheel*W_base-
W_counter*(r_wheel*r_counter))/L_pull;
F_pull_vertical =
(r_tip*W_tandh+r_tip*W_AB+r_tip*W_BC+r_tip*W_base+W_counter*(r_counter-
r_tip))/L_pull
%Output
%Graphs, tables, etc
%Assuming Member AB is horizontal
figure
fplot(F_pull_horizontal, [-12 12], 'blue')
hold on
fplot(F_push_horizontal, [-12 12], 'red')
%Assuming Member AB is vertical
fplot(F_pull_vertical, [-12 12], 'green')
fplot(F_push_vertical, [-12 12])
legend('Horiz. Pulling force','Horiz. Pushing force', 'Vert. Pulling force','Vert. Pushing force')
title('Tipping Force Visualization')
xlabel('Counterweight location [in from stand base]')
ylabel('Tipping force [lbf]')
xlim([-r_mount r_mount])
ylim([-10 30])
line([-100 100],[20 20], 'Color', 'black', 'LineStyle', '--');
xintercept = 5.5;
line([xintercept xintercept],[-10 30], 'Color', 'black', 'LineStyle', '--');
grid on
```

hold off

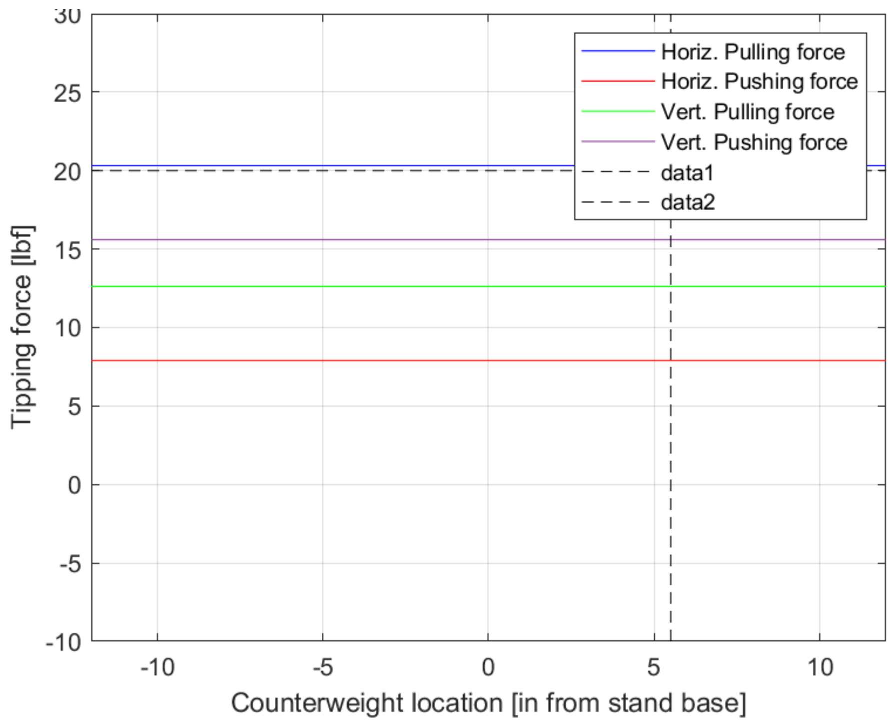


**Figure A9. Tipping force analysis of the device**

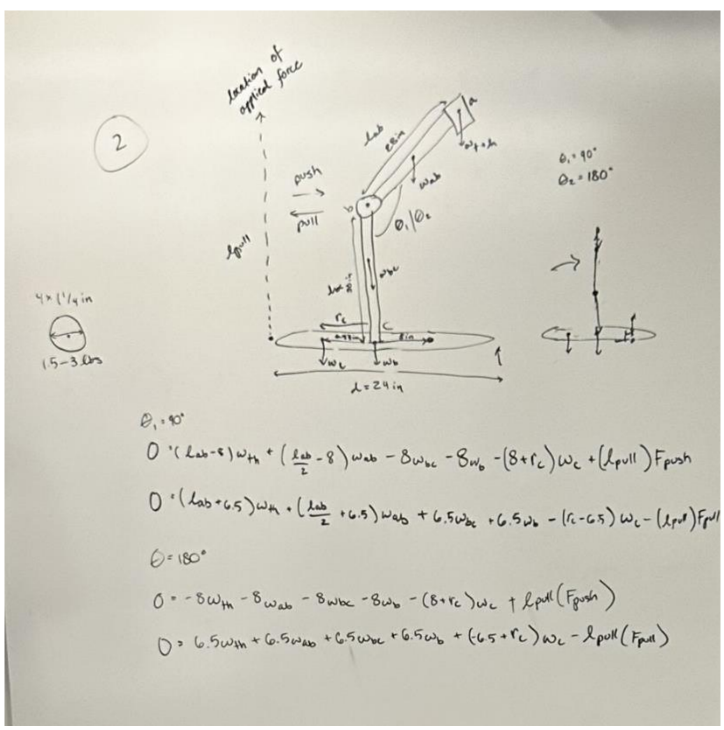

**Figure A10. Free body diagram of mount tipping analysis**

### 5.3 Complete Data from Prototype Testing

**Table A1. Height Adjustment Force Measurement**

| Trial | Measured Force (lbs) |
|---|---|
| 1 | 7.3 |
| 2 | 7.8 |
| 3 | 7.1 |
| 4 | 7.9 |
| 5 | 7.6 |
| 6 | 7.4 |
| 7 | 7.8 |
| 8 | 7.2 |
| 9 | 7.2 |
| 10 | 7.6 |
| **Average Force** | **7.5** |

**Table A2. Angle Adjustment Force Measurement**

| Trial | Measured Force (lbs) |
|---|---|
| 1 | 4.1 |
| 2 | 4.3 |
| 3 | 4.3 |
| 4 | 4.2 |
| 5 | 4.0 |
| 6 | 4.4 |
| 7 | 4.1 |
| 8 | 4.5 |
| 9 | 4.3 |
| 10 | 4.2 |
| **Average Force** | **4.2** |

**Table A3. Location Adjustment Force Measurement**

| Trial | Measured Force (lbs) |
|---|---|
| 1 | 3.4 |
| 2 | 3.6 |
| 3 | 3.4 |
| 4 | 3.4 |
| 5 | 3.5 |
| 6 | 3.8 |
| 7 | 3.6 |
| 8 | 3.4 |
| 9 | 3.6 |
| 10 | 3.3 |
| **Average Force** | **3.5** |

### 5.4 Microcontroller Code

The following sections contain the main code run by the page turner, servo driver, and remote controller Arduino microcontrollers. All the programs utilize external libraries and header files which were redacted from this report for clarity but can be found in the B.A.T.T. GitHub repository: https://github.com/adeerin1/BATT.git.

### 5.4.1 Page Turner Software

```
//receive_RF.ino
//Program to control swipe and tilt servos using RF communication with the remote controller for the B.A.T.T. page
turning subsystem
//Written by: Andrew Deering
//Trinity University, Engineering Science, Spring 2023

//Libraries
#include "VirtualWire.h"     //from: http://www.airspayce.com/mikem/arduino/VirtualWire/

//      Variables
//RGB LED PWM pins on the Arduino UNO
const int ledRED = 11;
const int ledGREEN = 10;
const int ledBLUE = 9;
```

```
const int swipeLeftPin = 3; //Digital pin connected to the arduino nano driving the servos
const int swipeRightPin = 2; //Digital pin connected to the arduino nano driving the servos
const int datain = 14;  //Data input pin connected to the RF receiver

void setColor(int redValue, int greenValue, int blueValue) {
  analogWrite(ledRED, redValue);
  analogWrite(ledGREEN, greenValue);
  analogWrite(ledBLUE, blueValue);
}

void swipeLeft() {
  digitalWrite(swipeLeftPin, HIGH);
  digitalWrite(swipeRightPin, LOW);
  delay(50);
  digitalWrite(swipeLeftPin, LOW);
  delay(1000);
}

void swipeRight() {
  digitalWrite(swipeLeftPin, LOW);
  digitalWrite(swipeRightPin, HIGH);
  delay(50);
  digitalWrite(swipeRightPin, LOW);
  delay(1000);
}

void runTests() {  //Automatically runs the page turner prototype testing
  delay(2000);
  for (int i = 0; i < 20; ++i) {
    setColor(0,0,255);
    swipeLeft();
    setColor(0,0,0);
    delay(500);
  }
  delay(1000);
  setColor(0,0,255);
  delay(200);
  setColor(0,0,0);
  delay(200);
  setColor(0,0,255);
  delay(200);
  setColor(0,0,0);
  delay(200);
  setColor(0,0,255);
  delay(200);
  setColor(0,0,0);
  delay(1000);
```

```
  for (int i = 0; i < 20; ++i) {
    setColor(0,0,255);
    swipeRight();
    setColor(0,0,0);
    delay(500);
  }
  int i = 0;
  while (i == 0) {
    setColor(0,0,255);
  }
}

void setup() {
  Serial.begin(9600);  //starting serial communication, use for debugging

  //configuring LED pins as output and turning it off
  pinMode(ledRED, OUTPUT);
  pinMode(ledGREEN, OUTPUT);
  pinMode(ledBLUE, OUTPUT);
  pinMode(swipeLeftPin, OUTPUT);
  pinMode(swipeRightPin, OUTPUT);

   //LED color testing
  setColor(255, 0, 0); //red
  delay(500);
  swipeRight();
  setColor(0, 255, 0); //green
  delay(500);
  swipeLeft();
  setColor(0, 0, 255); //blue
  delay(500);
  setColor(0,0,0);

  //RF Communication setup
  vw_set_ptt_inverted(true);
  vw_set_rx_pin(datain);
  vw_setup(2000);
  vw_rx_start();
}

void loop() {
  //**FOR PAGE TURNER TESTING: UNCOMMENT THE NEXT LINE AND COMMENT OUT EVERYTHING ELSE
IN THE LOOP**
  //runTests();

  //**FOR SERIAL BASED PAGE TURNER TESTING: UNCOMMENT THE NEXT LINE AND COMMENT OUT
EVERYTHING ELSE IN THE LOOP**
```

```
  //serialMovement();

  //parsing RF message

  uint8_t buf[VW_MAX_MESSAGE_LEN];      //Buffer containing the RF message
  uint8_t buflen = VW_MAX_MESSAGE_LEN;  //Message buffer length

  if (vw_get_message(buf, &buflen)) {
    //Serial.println(buf[0]);  //prints first buffer character to serial monitor, useful for debugging
    if (buf[0] == '0') {   // Number 1 means turn page forward
      //Serial.println("forward");  //prints first buffer character to serial monitor, useful for debugging
      setColor(0,255,0);
      swipeRight();        //turn page forward
    }
    if (buf[0] == '1') {  //Number 2 means turn page backward
      //Serial.println("backward");  //prints first buffer character to serial monitor, useful for debugging
      setColor(255,0,0);
      swipeLeft();        //turn page backward
    }
    if (buf[0] == '2') {  //Number 0 means no page turning
      setColor(0, 0, 0);  //turn off led
    }
  }
}
```

### 5.4.2 Servo Driver Software

```
//page_turner.ino
//Program to control swipe and tilt servos for the B.A.T.T. page turning subsystem
//Written by: Andrew Deering
//Trinity University, Engineering Science

//Libraries
#include <Servo.h>  //default arduino servo library

#include "turnPage.h"        //header file containing page turning logic
#include "serialMovement.h"  //header file containing logic for adjusting both servo angles with serial monitor input

//Variables
//contained in serialMovement.h
//int swipePos; //variable to store the swipe servo angle in degrees
//int tiltPos; //variable to store the tilt servo angle in degrees

//contained in turnPage.h
//Servo tilt; //create servo object to control tilt servo
//Servo swipe;  // create servo object to control swiping servo
//const int swipeLeftPin = 11;
```

```
//const int swipeRightPin = 12;

void setup() {
  tilt.attach(5);      // attaches the servo on pin 5 to the tilt servo object
  swipe.attach(3);     //attaches the servo on pin 4 to the swipe servo object
  Serial.begin(9600);  //setup serial communication for input

  pinMode(swipeLeftPin, INPUT);  //Digital input from sw1 and sw2
  pinMode(swipeRightPin, INPUT);

  //test section to verify servos are working
  tiltPos = 90;
  swipePos = 90;
  writePos();  //contained in turn page, writes tiltPos and swipePos to the servos
}

void loop() {  //Three operating modes for this program
  //runRF();
  runTests();
  //serialMovement();
}
```

### 5.4.3 Remote Controller Software

```
//RF_transmitter.ino
//Program to send page turning commands as RF signals to the page turning subsystem based on user input from the pushbuttons
//Written by: Andrew Deering
//Trinity University, Engineering Science, Spring 2023

//Libraries
#include "VirtualWire.h"

//Variables
const int SWLeft = 10;        //pin for the left switch (forward)
const int SWRight = 12;       //pin for the right switch (backward)
const int dataOut = 8;        //pin to send information to the RF transmitter
const int interruptPin = 11;  //pin used to wake the device from low power mode
//RGB LED pins
const int ledBLUE = 4;
const int ledGREEN = 5;
const int ledRED = 6;
const int delayTime = 1000;  //Required duration in ms to hold inputs before sending signals
//Variables to store the switch input values
int left = 0;
int right = 0;
```

```
char *data;  //variable to store the message sent to the RF receiver. 2 = no page turn; 0 = turn page forward; 1 = turn page backward

//Function to set the color of the RGB LED
void setColor(int red, int green, int blue) {
  analogWrite(ledRED, red);
  analogWrite(ledBLUE, blue);
  analogWrite(ledGREEN, green);
}

void setup() {
  //configuring the LED pins as outputs
  pinMode(ledRED, OUTPUT);
  pinMode(ledGREEN, OUTPUT);
  pinMode(ledBLUE, OUTPUT);

  //Input switches operating in active low
  pinMode(SWLeft, INPUT_PULLUP);
  pinMode(SWRight, INPUT_PULLUP);

  //LED color testing
  setColor(255, 0, 0);  //red
  delay(500);
  setColor(0, 255, 0);  //green
  delay(500);
  setColor(0, 0, 255);  //blue
  delay(500);
  setColor(0, 0, 0);

  Serial.begin(9600);  //used to start serial communication, can use for debugging

  //RF communication setup
  vw_set_ptt_inverted(true);
  vw_set_tx_pin(dataOut);
  vw_setup(2000);
}

void loop() {
  //Reading the input switches
  left = digitalRead(SWLeft);
  right = digitalRead(SWRight);
  if (left == LOW && right == HIGH) {  //Page forward input received
    delay(delayTime);
    left = digitalRead(SWLeft);
    right = digitalRead(SWRight);
    if (left == LOW && right == HIGH) {  //Checking to see if input was held for the full duration
      data = "0";
      Serial.println(data);
```

```
    vw_send((uint8_t *)data, strlen(data));
    vw_wait_tx();
    setColor(0, 255, 0);  //set LED green
    delay(1000);
    setColor(0, 0, 0);
    delay(3000);
  }
} else if (left == HIGH && right == LOW) {  //Page backward input received
  delay(delayTime);
  left = digitalRead(SWLeft);
  right = digitalRead(SWRight);
  if (left == HIGH && right == LOW) {  //Checking to see if input was held for the full duration
    data = "1";
    Serial.println(data);
    vw_send((uint8_t *)data, strlen(data));
    vw_wait_tx();
    setColor(255, 0, 0);  //set LED red
    delay(1000);
    setColor(0, 0, 0);
    delay(3000);
  }
} else {  //do not turn page
  data = "2";
  vw_send((uint8_t *)data, strlen(data));
  vw_wait_tx();
}
setColor(0, 0, 0);  //turn LED off
}
```

## 5.5 Electronic Schematics

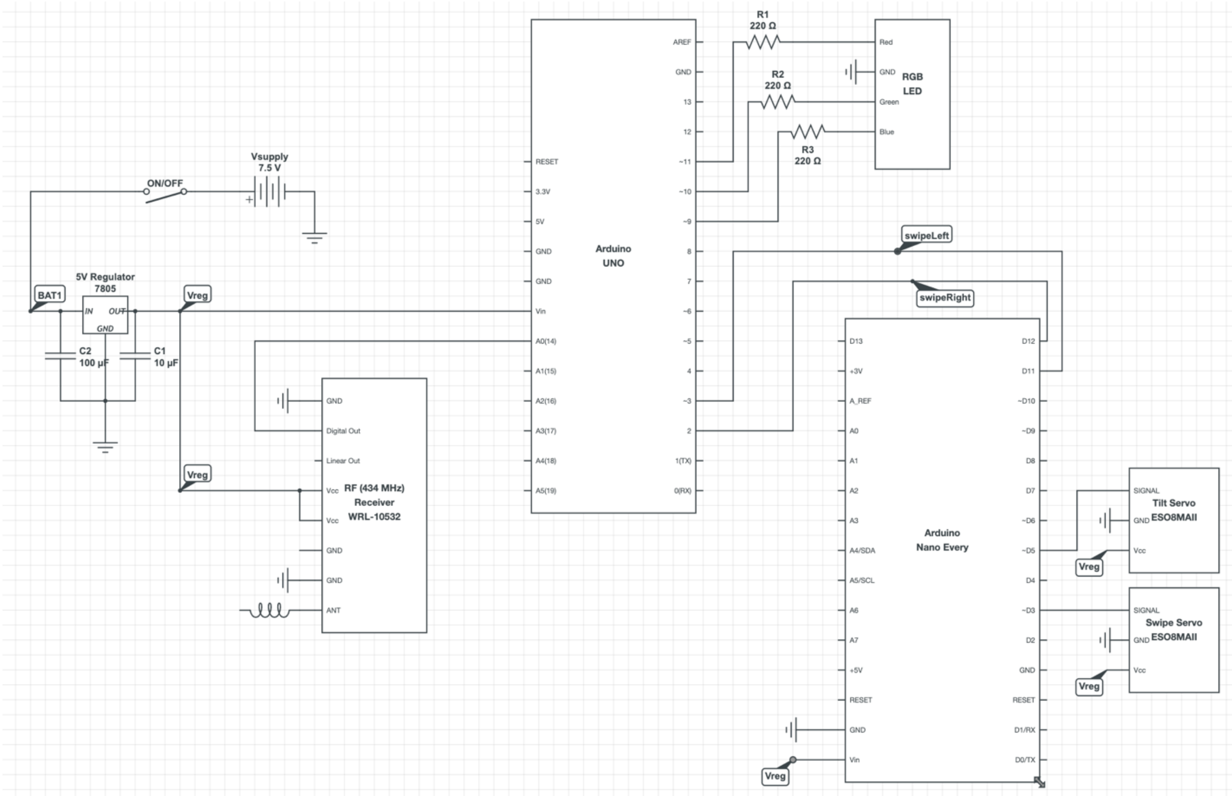


**Figure A11. Complete electronic schematic for the page turner subsystem**

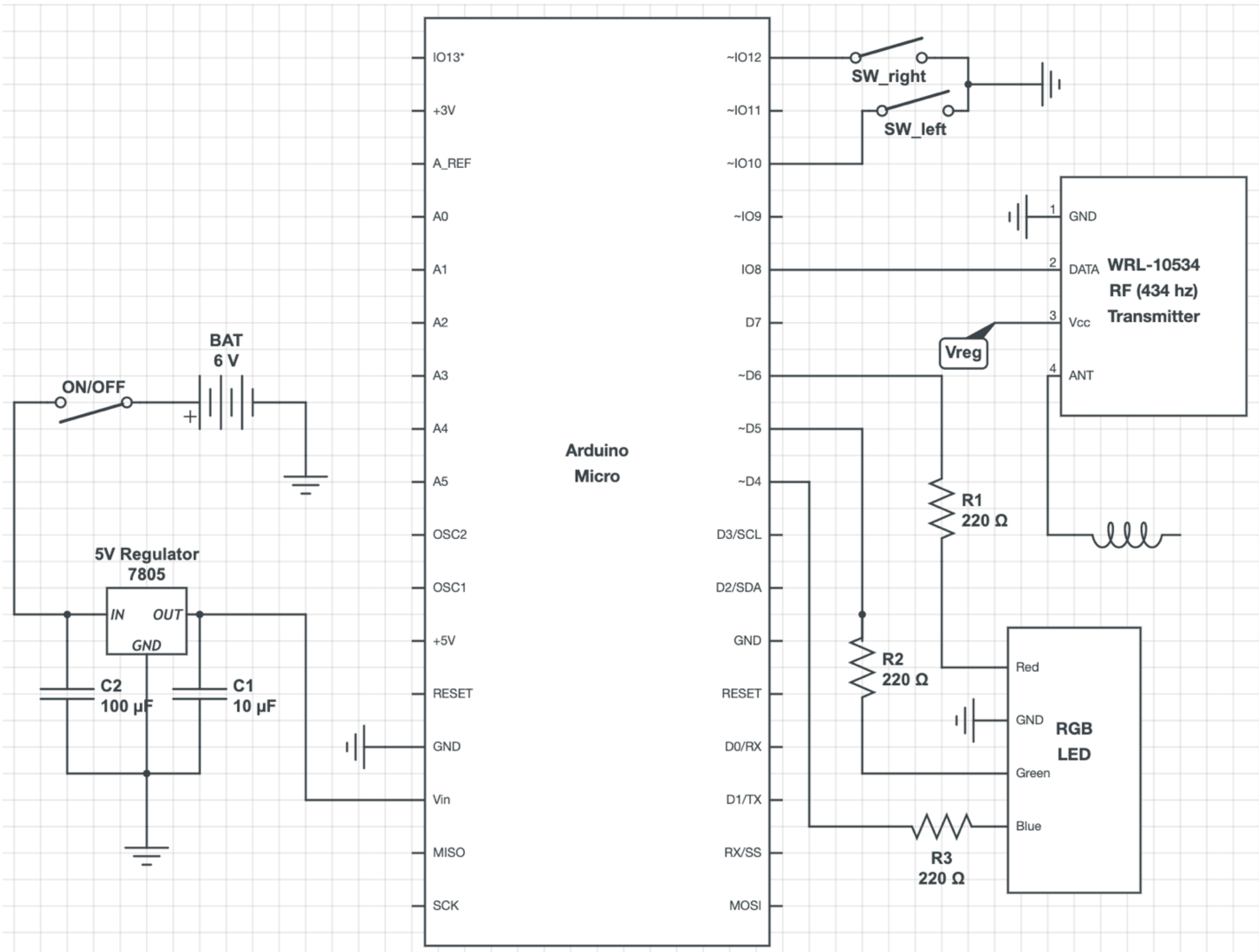


**Figure A12. Complete electronic schematic for the remote controller subsystem**

# Bibliography (APA)


Ergoweb LLC.(2013, Sept 8). *Force Guidelines.* Retrieved October 25, 2022,from https://ergoweb.com/force-guidelines/.

National Disability Authority. (2020). *Irish national IT Accessibility Guidelines*. Centre for Excellence in Universal Design. Retrieved April 25, 2023, from https://universaldesign.ie/technology-ict/archive-irish-national-it-accessibility-guidelines/