LexAid

November 9, 2015

Andrew H. Rawicz
School of Engineering Science
Simon Fraser University
V5A 1S6

Re: ENSC440W Design Specification - Flipp: A Page Turning Device

Dear Dr. Rawicz,

In accordance with the requirements for ENSC305W and ENSC440W, enclosed with this letter are Lex-Aid's design specifications for Flipp: A Page Turning Device. The goal of this project is to design a device capable of turning the pages of a book in order to facilitate the process of flipping pages for the physically challenged.

The document contains a detailed explanation of the intended design of our device. In particular, this document will only outline the design specifications for the proof-of-concept of our device and will not describe the design of the final commercial product. This is done intentionally so that lessons learned during the construction of the proof-of-concept device can be incorporated into the final product.

The Lex-Aid team is comprised of 4 fourth year engineering students: Daniel Miess, Rajdeep Singh, Kamal Ezz and Hesam Bagheri Azghadi. If you have any questions or concerns about the contents of this technical specification please do not hesitate to contact us by e-mail at dmiess@sfu.ca or by phone at (778) 877-2836.

Sincerely,

D. Miess

Daniel Miess

Chief Executive Officer

Lex-Aid

Design Specifications for

Flipp: A Page Turning Device

Project Team:	Daniel Miess Rajdeep Singh Kamal Ezz Hesam Bagheri Azghadi
Contact Person:	Daniel Miess dmiess@sfu.ca
Submitted to:	Dr. Andrew Rawicz – ENSC 440W Steve Whitmore – ENSC 305W School of Engineering Science Simon Fraser University

Issue Date:	November 9th 2015
Revision:	1.5

Executive Summary

The design specification for Flipp outlines a detailed plan for the design and implementation of the page turning device. Within this document are specifications specifically targeted to the design of the proof-of-concept model. This document will seek to explain how the Lex-Aid team intends to realise the functional specifications outlined in Functional Specifications for Flipp: A Page Turning Device [1]. However, only the specifications labeled with I or III will be considered as these are the only technical specifications pertaining to the implementation of the proof-of-concept design.

This document will cover the design of all the subsystems of the device as well as the integration of the entire device itself. It will clarify the specifications for each of the mechanical arms and will go into implementation details such as materials and motors that will be used to drive them. The specific microcontroller that will be used to coordinate the functions of the device will be selected and justified. The document will also go into the details of the electrical setup for the entire system, from power to the microcontroller's digital pin wiring. Overall the document will seek to provide as much information as possible about the design of the device while still leaving some room for small changes that may occur during the development process.

As well, included within the document is a system test plan that will be used throughout the design to judge the effectiveness of the device. In this way the quality of the device produced can be measured against a set of objective goals.

Table of Contents

List of Figures

List of Tables

Glossary

AC – Alternating Current: Electrical current in which the direction of the flow of charge oscillates with a regular interval

DC – Direct Current: Electrical current in which the direction of the flow of charge is fixed

LED – Light Emitting Diode: A lighting device based on a semiconductor diode

NEMA – National Electrical Manufacturers Association

RPM – Rotations per minute

PCB – Printed Circuit Board: A board that supports and electrically connects the components of an electric circuit

1. Introduction

The Lex-Aid Flipp is a device that automates the turning of pages of a book, bringing the printed word back to those for whom physical disabilities have removed easy access. For many people the manual dexterity required to turn the pages of a book is simply too great of a challenge. By reducing the effort required to turn the page of a book to a mere button press or voice command these people will once again be able to enjoy their favorite books. The device will be capable of turning the pages of books that fall within the most common book sizes available. Lex-Aid seeks to provide this reading solution in such a way as to be minimally distracting to the user by covering as little of the book as possible when not turning the page. This document lays out the design specifications of Flipp, describing the requirements of our design and development procedures for our proof-of-concept model. The information contained within should provide a substantial basis on which to construct the device.

1.1 Scope

This document is intended to describe how the design of the Flipp device will satisfy the technical specifications laid out in Functional Specifications for Flipp: A Page Turning Device [1]. The design specifications within this document will set out to satisfy all specifications labeled with I and III. These specifications are respectively required for the prototype only and required for both the prototype and the final consumer product.

1.2 Intended Audience

This document is intended to be used by the design and test engineers of Lex-Aid. While designing and constructing Flipp it is intended that this document will be used by team members alongside Functional Specifications for Flipp: A Page Turning Device [1] to realise the goals for this device.

2. System Specifications

The Flipp device will allow the user to flip the pages of a book with the mere press of a button. The user will power on the device by plugging in the provided power adapter into a standard wall outlet. The user will then place a book onto the device's main platform and press a button on the main body of the device to signal that it is safe to begin operation. Upon pressing one of the buttons on the control unit or issuing a voice command the device's arms and flaps will engage, mechanically lifting up the page of the book and flipping it over to the other side. When not in operation the arms will move into neutral positions that will minimize their obstruction of the reader's view. Pictured below in Figure 1 is an artist's rendering of the device.

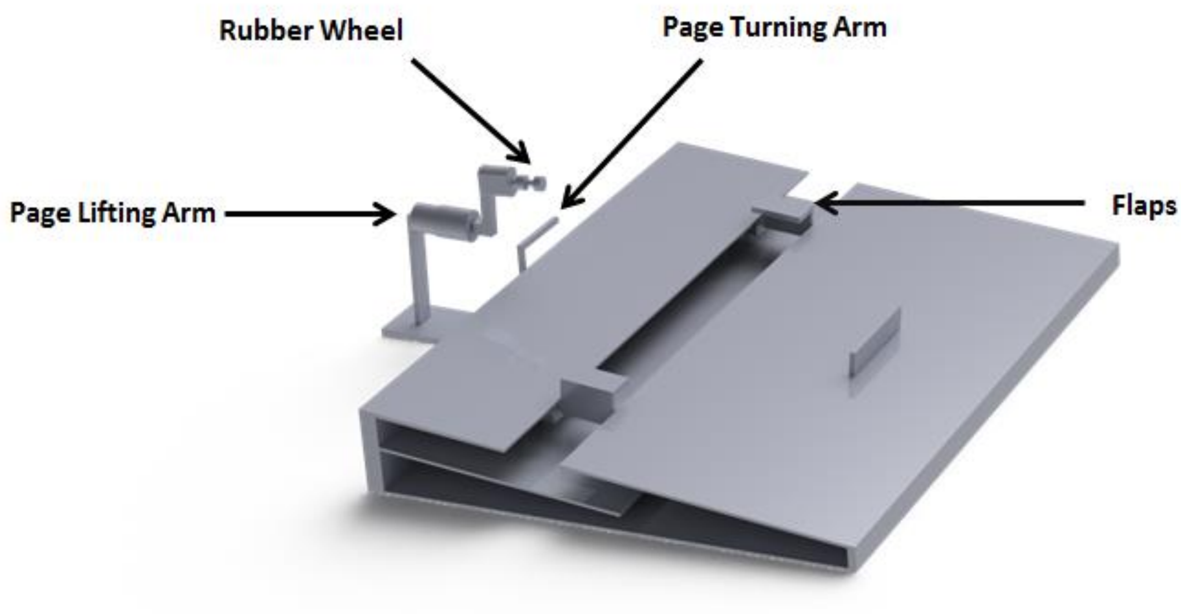

Figure 1: Rendering of whole device

When the user signals the device to begin a page flipping operation a complex series of mechanical movements takes place. The list below outlines the actions that will take place when the user instigates a forward page flip:

1. Page lifting arm moves from neutral position to the right side of the book.
2. Page lifting arm lands on page and presses down.
3. The rubber wheel spins clockwise flipping single page on top of the wheel
4. Page lifting arm lifts slightly off the page with the page to be turned resting on top of it.

5. Page turning arm rotates clockwise hooking the page and pushing it to the left-hand side of the book.
6. Page lifting arm rotates to the left side of the book and presses down holding the pages in place.
7. Left flap releases and page falls under the flap.
8. Left flap engages holding the new page in place.
9. Page lifting arm returns to a neutral position.

The main body of the device will be constructed from a custom designed piece of aluminium and will be roughly 60cm by 60cm in size. The main platform upon which the user places the book they want to read will measure roughly 45cm by 60cm and will be mostly hollow inside, providing a location for the electrical and mechanical components to be stored.

3. Electrical Design

The Flipp makes use of a number of different electrical subsystems with differing required voltages and power draws. The following section outlines the voltage levels that are required and describes how the electrical systems will be integrated. All of the schematics listed below in this section and the microcontroller section will be implemented on a surface mount PCB board.

3.1 Power Supply

The Flipp will receive all of its power from a standard North American wall outlet. In order to simplify the process of obtaining safety certification an existing wall power adapter will be used that is external to the main body of the device. The specifications for this power adapter will be as follows:

- Input: 110V – 120V AC at 60Hz
- Input Connection: NEMA 5-15 Socket
- Output: 12V DC
- Output Current: 3A

The power adapter will supply the main 12V power to the device. From this voltage the two lower voltage levels required will be derived: 5V and 3.3V. Between these three voltage levels all of the systems of the device will receive power. Pictured below in Figure 2 is a schematic rendering of the power regulation system within the device.

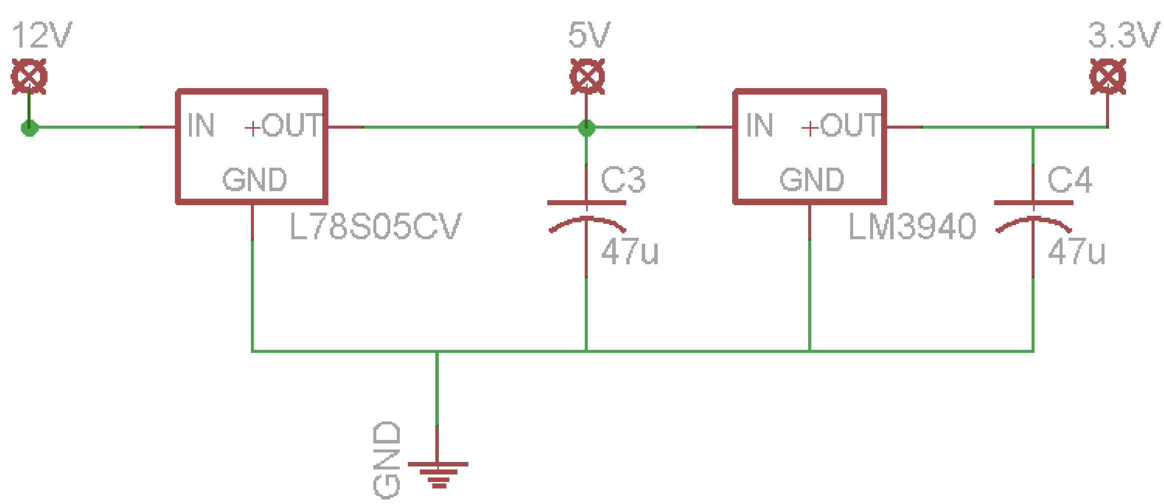

Figure 2: Power regulation schematic

Laid out below in Figure 3 is the organization of the different voltage levels and the sub-systems of the device that they will power.

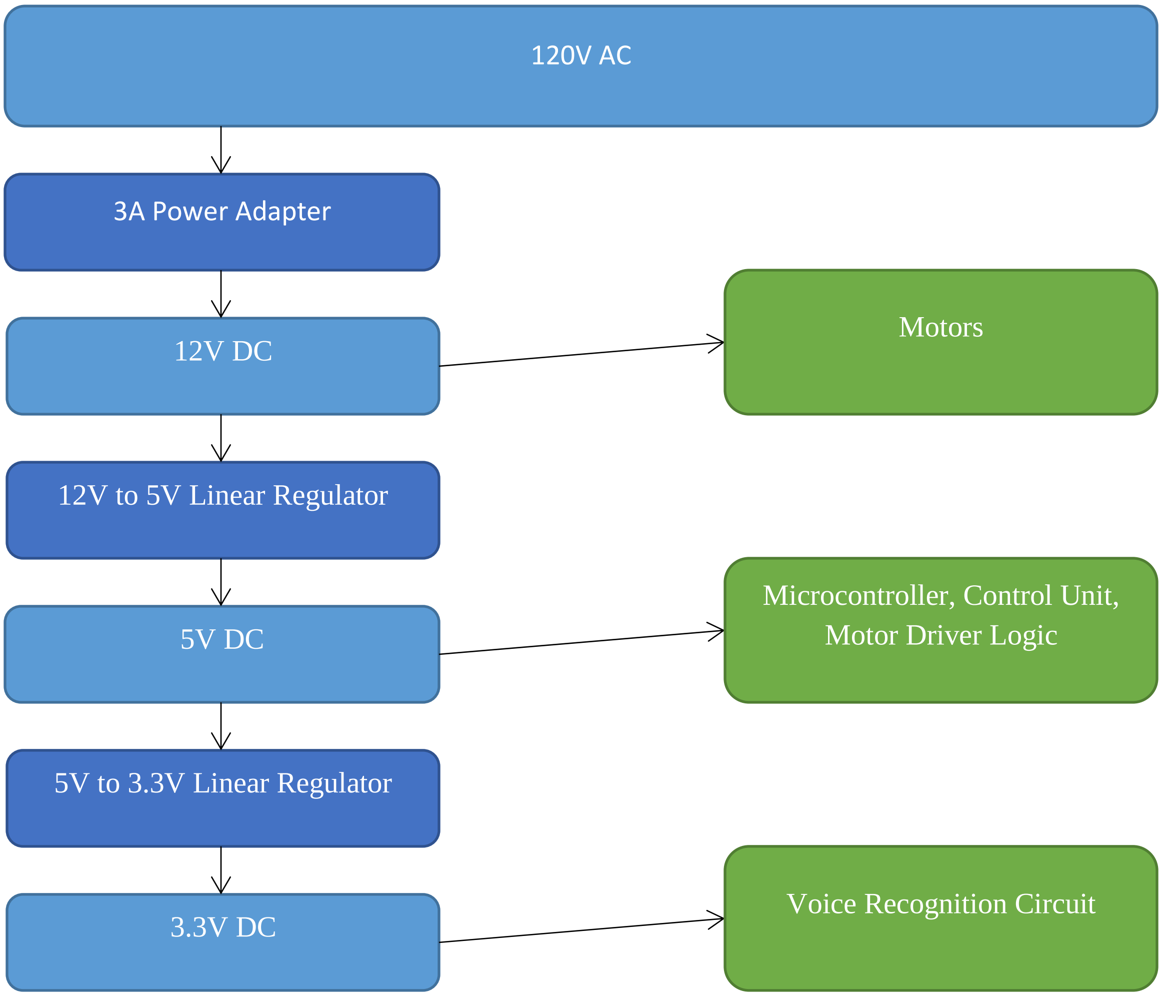

Figure 3: Subsystem voltage levels

3.2 DC Motors

The device will have a total of 5 DC motors that drive the arms, flaps and wheels of the device. The device will utilize 3 different types of motors. These types are outlined below in Table 1.

Table 1: Motors utilized in the design of Flipp

Product #	Weight	Shaft Diameter	Voltage	Rated Load Current	Torque
PAN14EE12AA1[2]	39g	1.5mm	12V	792mA	34.5mNm
FP050-FN [3]	22g	3mm	12V	43mA	19.6mNm
RS-545PH [4]	156g	6mm	12V	460mA	17.4mNm

All of the motors in the device are required to be capable of operating in both directions. In order to achieve this bidirectional rotation the design will make use of H-bridge drivers to power the motors. In the circuit diagram below in Figure 4 is the layout for a single H-bridge driver chip. The chips that will be used contain two drivers so the circuit pictured will need to be repeated three times.

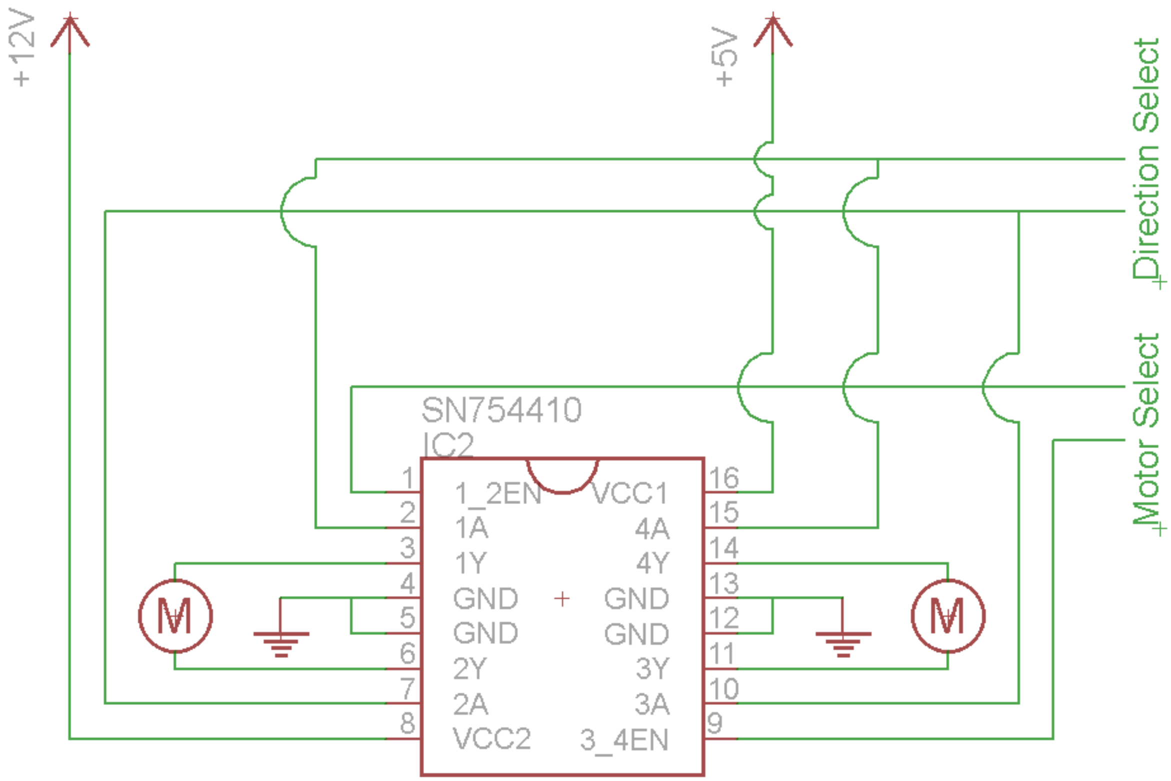

Figure 4: H-Bridge driver schematic

Due to the nature of an H-bridge circuit this will dramatically increase the number of outputs that will need to be controlled. If each motor were to be independently operated in both directions this would require 15 digital output pins on our microcontroller which is far greater than what can be achieved. In order to reduce this number the design will take advantage of the fact that no more than a single motor needs to be in operation at any given time. This means that all of the H-Bridge drivers can share the same direction selection lines. Table 2 below shows how forward and reverse operation of the motors can be achieved through the direction selection lines attached to the microcontroller.

Table 2: Motor Direction Selection Using H-Bridge Driver

Digital 5	Digital 6	Motor Select	Direction Selection
High	Low	High	Counter Clockwise
Low	High	High	Clockwise
High	High	X	No Motion
X	X	Low	No Motion

In order to further reduce the number of microcontroller output pins required to drive the motors the design will make use of a 3:8 demultiplexer to select the motor that should be used. Shown below in Table 3 is how three output pins on the microcontroller can be used to select one of the five motors to operate.

Table 3: Motor Selection Layout Using 3:8 Demultiplexer

Digital 7	Digital 8	Digital 9	Motor Selection
0	0	0	Main Arm Rotation
0	0	1	Page Flip Motor
0	1	0	Page Rotate
0	1	1	Left Flap
1	0	0	Right Flap
1	0	1	None
1	1	0	None
1	1	1	None

3.3 Voice Recognition

The device will make use of voice recognition technology as one of the two available input methods. This will be especially useful for users for whom even the relatively simple motion of pressing a button is too cumbersome. Voice recognition functionality will be included in the device through an external voice recognition PCB board sourced from MikroElektronika. After researching options for implementing voice recognition it was decided that in order to provide a reliable solution within the timespan of this project an external board would have to be used. In the final product this functionality will be provided on the main microcontroller.

While the device is powered on and the button on the main body of the device indicating that it is safe to begin operation has been depressed, the microphone will process received audio, keeping watch for input commands. When an input command is received it will function in an identical way to a button press on the control unit and the appropriate action will be taken. While the device is in the process of flipping a page the microcontroller will not process any received voice commands. The particular voice commands that will be used are the words “forward” and “backward”.

4. Page Lifting Arm

The purpose of the page lifting arm is to lift the page that is to be flipped up from the rest of the book. It will be composed of a strong arm attached to the rear base of the device and secured to a motor. Mounted at the end of the arm is a rectangular 'S' shaped piece that connects the arm to another smaller motor. This motor has attached to it a rubber wheel. This rubber wheel when rotated will lift the top page up from the rest of the book. Below in Figure 5 is a computer rendering of the page lifting arm highlighted in red.

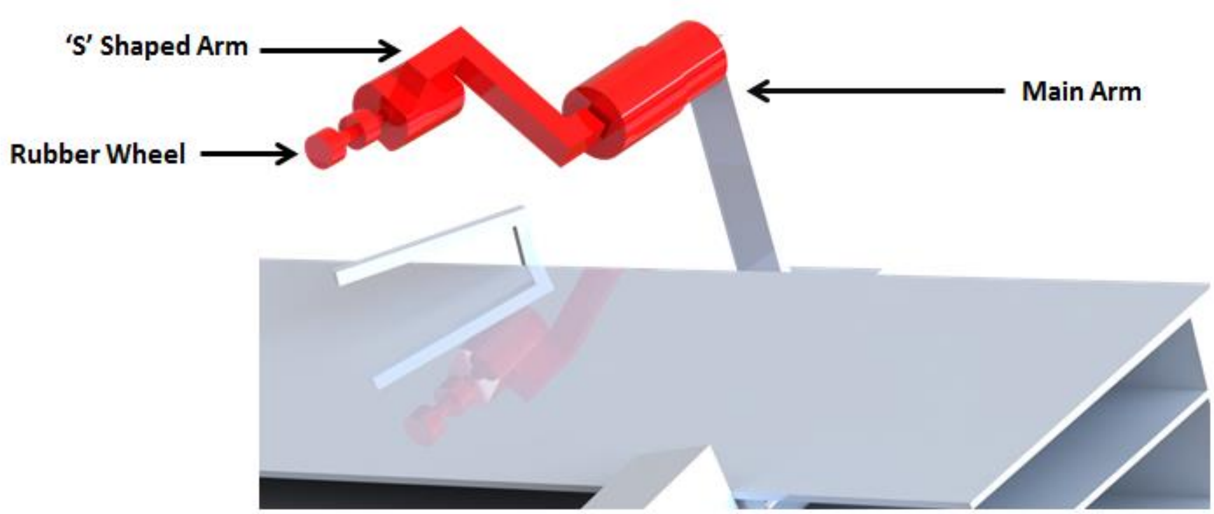

Figure 5: Rendering of page lifting arm

The main arm will attach to a motor at the rear of the device. The motor that the arm will connect to is the RS-545PH. This motor was selected because when combined with a gear box it offers a high torque capable of turning all of the weight attached to the arm. The arm itself will be constructed of aluminium of sufficient thickness to hold the weight placed upon it without bending. This arm will be capable of turning in both directions to allow for flipping the page of a book both forward and backward.

The 'S' shaped connector will likely be an existing component that will be purchased and integrated into the design of the device. Like the main arm it will also be constructed of aluminium. Because it has to be supported by the main arm, weight will be of very high concern when selecting the part and a lighter component will be strongly favoured.

The motor that drives the rubber wheel is FP050-FN. This motor has already been purchased and was favoured because it came with a gearbox that reduced its speed of rotation to 30 RPM. This will allow for the fine control that is required for this application. If the wheel were to spin too many rotations it may start to lift up more than one page. The rubber wheel itself is salvaged from a consumer printer. This was decided to be a logical choice since the printer applies the rubber wheel for an almost identical application. The main difference however is that the wheel in the printer only moves the page laterally and does not have one side of the paper fixed as is the case with the spine of a book.

5. Page Turning Arm

The purpose of the page turning arm is to hook onto a page that has been lifted up from the main body of the book and carry it to the other side of the book. It has an "L" shape that allows it to be operated by a motor mounted on the rear of the device. Pictured below in Figure 6 is a rendering of the page turning arm highlighted in red.

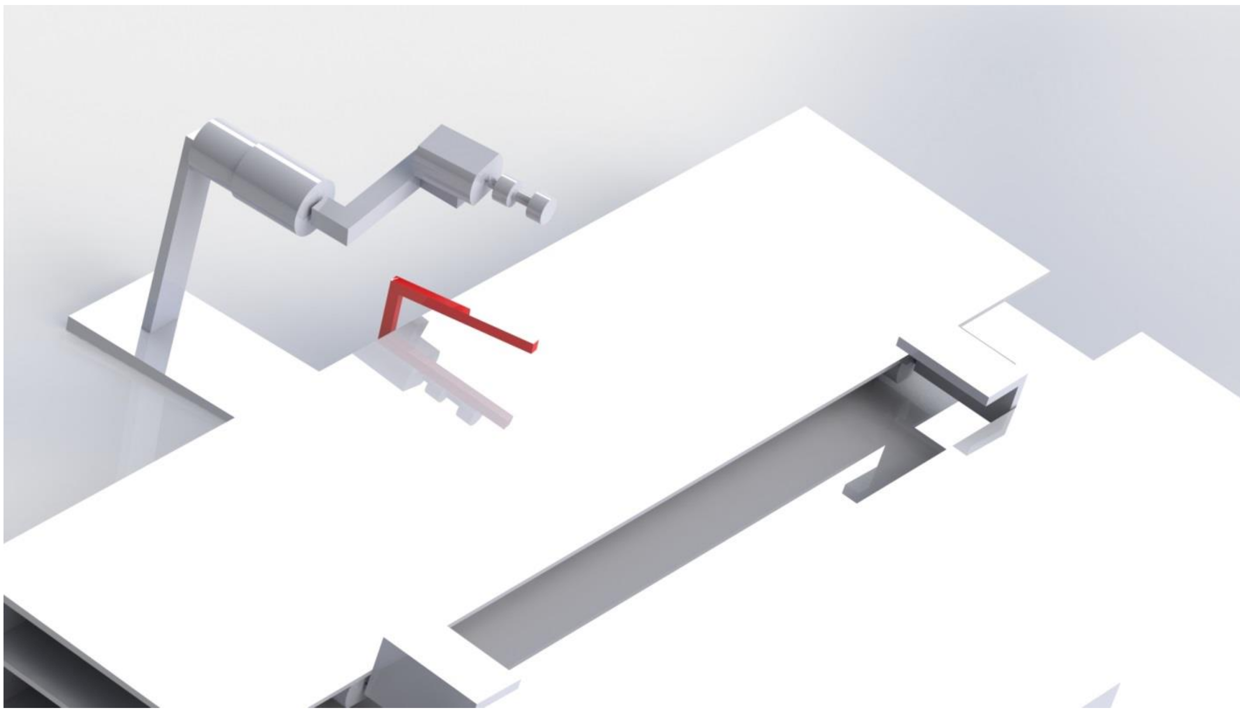

Figure 6: Rendering of page turning arm

The page turning arm will be driven by a motor mounted to the rear side of the device. The motor that will be used is PAN14EE12AA1. This is a low cost motor that has sufficient strength to move the arm. The arm itself will be a custom made aluminium piece. It will be ground down so as to remove any sharp edges and prevent it from ripping the pages of the book being flipped.

6. Flaps

The Lex-Aid Flipp will contain 2 mechanical flaps powered by DC motors located on the sides of the device. The purpose of these flaps is to press down on the sides of the book, keeping the book wide open and preventing it from closing.

The flaps will be made of L-shaped aluminium pieces and they will be controlled by 2 independent motors that will apply sufficient pressure to keep the book open. The motors that will control the flaps are the FP050-FN. These motors were chosen because the team was able to find a variant of this motor for sale with an attached gearbox. This gearbox prevents the motor from being able to be rotated when current isn't applied so that the book's pages will continue to be held down while other motors are in use. Pictured below in Figure 7 is an artist's rendering of the flaps highlighted in red.

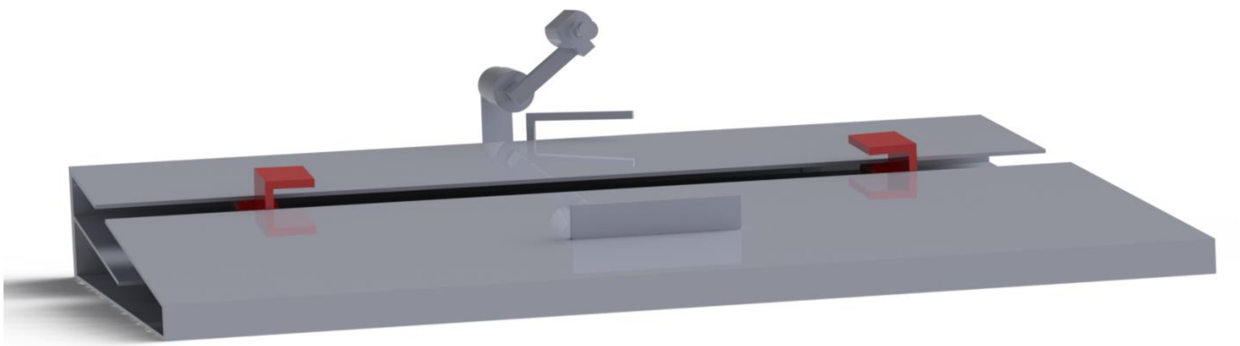

Figure 7: Rendering of the flaps

In order to accommodate books of different sizes, the flaps will be mounted on sliders that allow them to be moved in and out so that they line up with the edge of the book. The sliders will make use of geared and toothed tracks that it can slide within. This design is inspired by a design that the team found within a commercially available printer and is pictured below in Figure 8.

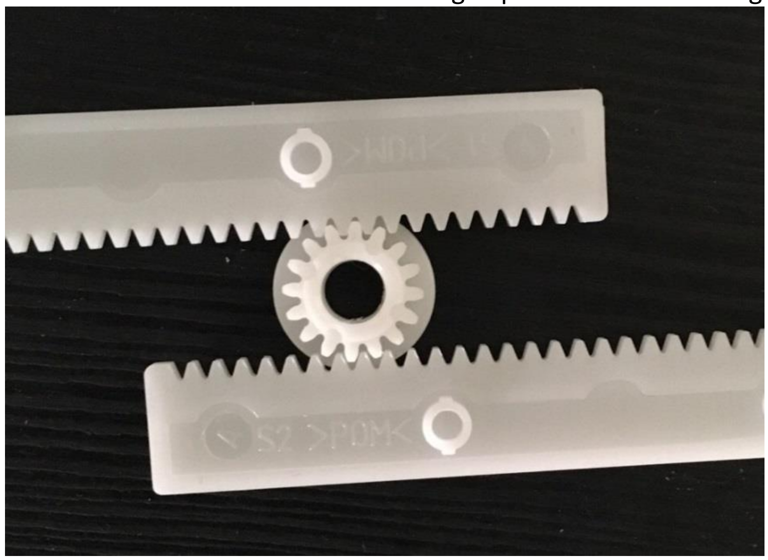

Figure 8: Slider mechanism for flaps

6.1 Alternate Design

During the course of the design of Flipp an alternate implementation for the flaps was considered. Originally the design of the flaps called for the use of a linear actuator for each flap. This design was considered superior as the force would be spread more evenly over the flap since the shaft of the actuator would be mounted at the center of the flap. After conducting research into linear actuators this idea was abandoned because the cost of the actuators fell too far outside the range of the proposed budget. The final commercial product should however be designed using linear actuators and a bulk purchase of this component will bring the price down considerably.

7. Control Unit

The control unit is one of the components of Flipp that allows the user to interact with the device. By pressing down on one of the buttons located on the control unit, the user issues a command to turn the page either forward or backward, depending on the button pressed. The overall design of the control unit is intentionally kept simple so as to enable other designers to construct additional control units that serve the need of users with particular disabilities. Shown below in Figure 9 is an artistic rendering of the control unit.

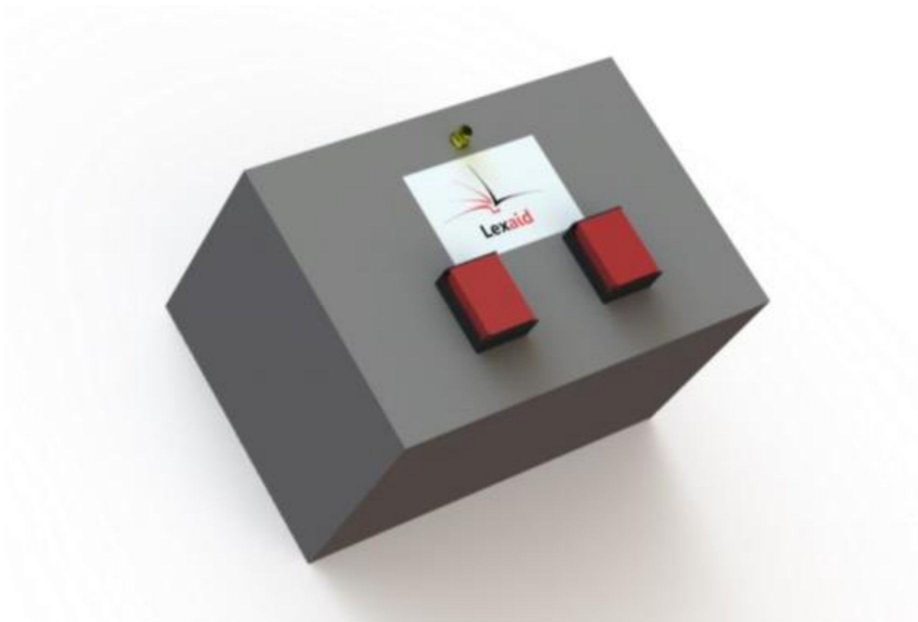

Figure 9: Rendering of control unit

The control unit consists of a box containing two buttons and a status LED. The two buttons will be clearly labeled and will allow the user to signal the unit to turn the page of the book either forward or backward. The status LED will simply alert the user as to whether or not the device is currently receiving power and is ready for operation. The circuit diagram below in Figure 10 shows the schematic representation of the contents of the control unit.

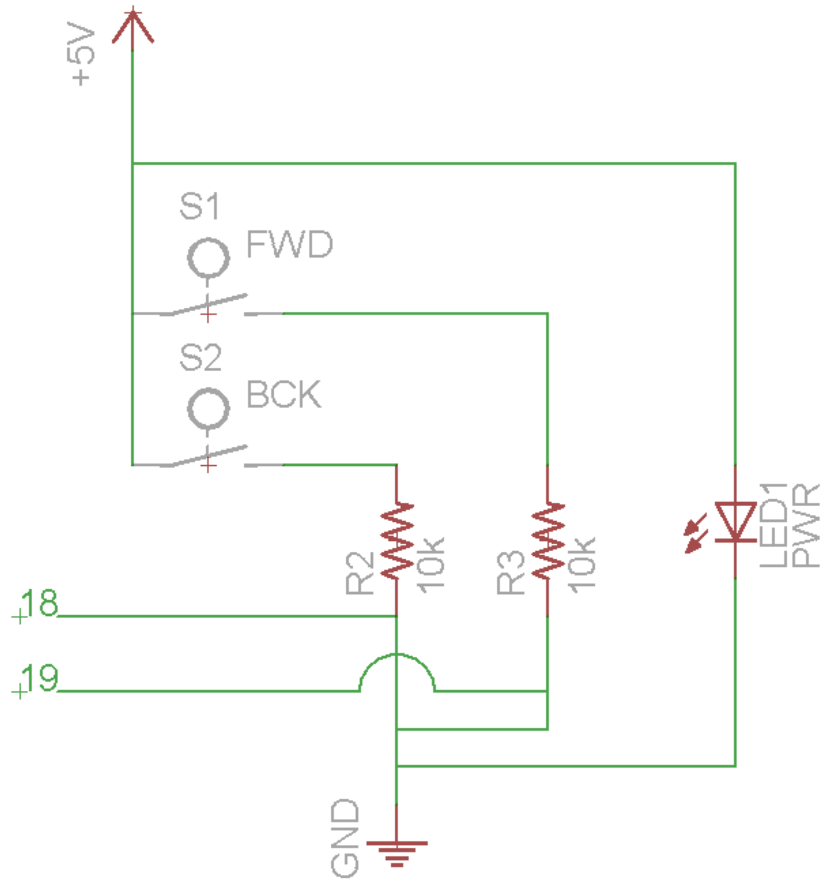

Figure 10: Control unit schematic

The control unit will connect to the main body of the device through a cable. This cable can be detached from the main device by releasing it from the attached socket. Within this cable will be four wires which will carry power, ground and a signal line for each of the two buttons. These wires will not carry any signal until the user has specified that the device is ready for operation.

Each of the push buttons in the control unit will be illuminated to assist the user with finding the buttons in the dark. These buttons will also be easy to depress so as to be useful to as wide a range of users as possible. The buttons that will be used are momentary push buttons to ensure that the button does not remain in the activated state after it has been depressed. Below in Figure 11 is an image of the type of button that will be used in the design.

Figure 11: Momentary Button [5]

The housing for the control unit will be constructed by repurposing the packaging of an existing commercial electronic device. By reusing this box it can be certain that the control unit housing will be made primarily from post-consumer recycled content [6]. The image below in Figure 12 shows the working constructed design for the control unit.

Figure 12: Box for control unit

8. Microcontroller

The Flipp device by nature of its design has to receive several inputs and generate a number of corresponding outputs. In order to facilitate this process the device makes use of a microcontroller to perform computational tasks. The logical control of the device will be controlled by an Atmel ATmega328 microcontroller. The various inputs and outputs to the device are outlined in the Table 4 below.

Table 4: Microcontroller Digital Output Pin Configuration

Microcontroller Digital I/O Pin	Input? / Output?	Function
1	X	Unused
2	X	Unused
3	X	Unused
4	X	Unused
5	Output	Direction Selection
6	Output	Direction Selection
7	Output	Motor Selection
8	Output	Motor Selection
9	Output	Motor Selection
10	Input	Forward Page Turn Voice Command
11	Input	Reverse Page Turn Voice Command
12	Input	Forward Page Turn Button
13	Input	Backwards Page Turn Button

The 16MHz clock speed should be more than sufficient to respond to inputs with a low enough latency to ensure the quality of the user experience. This chip also features 32KB of flash memory which will provide adequate storage space for our control algorithms [7]. While other choices in microcontroller were considered the ATmega328 was chosen for the primary reason that it is used within the Arduino Uno [8]. The members of the Lex-Aid team have had previous experience writing programs for the Arduino Uno and by using this microcontroller they will not have to learn a new and unfamiliar development workflow.

The circuit design for the microcontroller is relatively simple. Besides the microcontroller itself, the design will also include a crystal oscillator to achieve the 16 MHz clock speed. While it is possible to run the ATmega328 off an internal timing circuit at 8 MHz research indicates that the timing isn't very reliable and adding in an external oscillator is relatively simple. Besides power and ground connections, the only other notable feature of the microcontroller circuit is the reset pin connection. The ATmega328 has a reset pin that is normally kept high and a low signal triggers a reset. Because of this, the reset pin is connected to power through a 10kΩ. The reset pin only needs to be triggered when uploading code to the chip so a reset button or a switch is not required in this design. Figure 13 below shows a schematic representation of the microcontroller circuit.

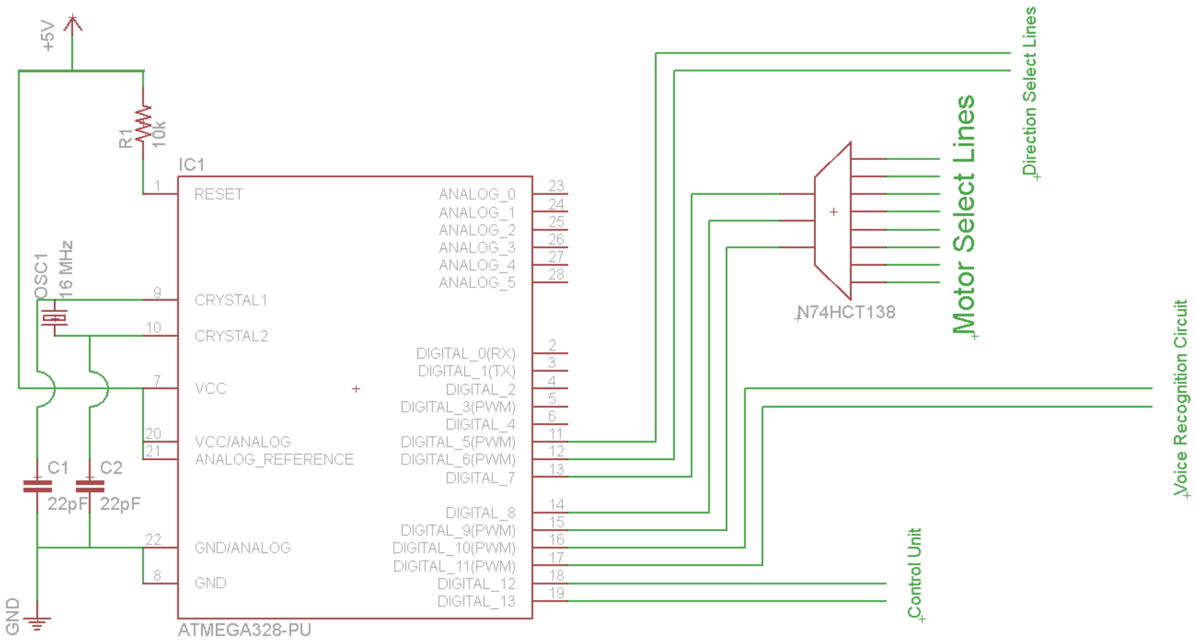

Figure 13: Microcontroller Schematic

9. System Test Plan

The Lex-Aid Flipp will undergo intense testing procedures in order to guarantee the user a safe and reliable experience. Before the device is considered to have passed system testing, the Lex-Aid team will test each of the individual subsystems separately. The device will be designed in such a way that the designers will be able to manually trigger each of the individual subsystems. Once all subsystems pass their respective tests, then an integration test will be performed on the complete device.

9.1 Subsystem Tests

9.1.1 Page Lifting Arm

The page lifting arm consists of 2 main parts that are responsible for the page lifting mechanism, which will be tested individually. First is the arm that moves from one side of the book to the other, and the other is the rubber page turning wheel. Testing the page lifting arm will include the following:

- The page lifting arm will rotate to each side of the platform.
- The rubber wheel will make contact with the platform.
- The rubber wheel will rotate in both directions.

9.1.2 Page Turning Arm

The page turning arm flips the page over to the other side of the book. Testing the page turning arm will include the following:

- The page turning arm will rotate in both directions.

9.1.3 Flaps

The flaps are responsible for keeping the book open on the main platform. Testing the flaps will include the following:

- The flaps when engaged descend to at least the level of the platform.
- The flaps will be able to disengage.
- The flaps will not be able to be moved by manual force when engaged.
- The flaps will be able to slide horizontally along the surface of the platform.

9.1.4 Control Unit

The control unit is responsible for the user interaction portion of the device. Testing the control unit will include the following:

- The status LED will turn on when power is supplied to the unit and the device is ready for operation.
- Both the forward and backward button presses are recognized by the microcontroller.
- A button held down will only register as a single button press.

9.1.5 Voice Recognition

Voice recognition will allow the user to control the operation of the device through the use of voice commands. Testing the voice recognition will include the following:

- Speaking the word "forward" into the microphone is registered as a forward page flip command
- Speaking the word "backward" into the microphone is registered as a backward page flip command

9.2 Integrated Tests

One of the selected testing books is placed open on the platform and the flaps will be adjusted to fit the book. The testing books will cover a range of book sizes, paper thicknesses and cover types. The tester will then use the control unit to turn a page forward and turn another page backward. The tester then speaks the voice command "forward" and following a successful page flip speaks the voice command "backward". If all four of these page flipping operations are successful for all testing books then the integration test is considered to be successful.

10. Conclusion

Using the design specifications outlined in this document the Lex-Aid team intends to both design and implement Flipp. A detailed description was provided for the design of the main body of the device, all of the arms and flaps as well as the electrical systems including the microcontroller. During the design and construction of this device a concerted effort will be made to adhere to the solutions contained within this document. However, if it becomes apparent during the implementation of the device that following these specifications will be contrary to producing a functioning device then that section of the design specifications will be reconsidered.

References

[1] Lex-Aid, “Functional Specifications for Flipp: A Page Turning Device”, Simon Fraser University, Burnaby, BC, Canada. October, 2015.

[2] NMB Technologies Corporation. “PAN14” [Online] Available: http://www.digikey.ca/product-detail/en/PAN14EE12AA1/P14346-ND/2417070 [Accessed: 08 – Nov – 2015]

[3] Standard Motor. (2013). “FP050-FN Motor Reference Guide” [Online] Available: http://www.standardmotor.net/sc_webcat/ecat/product_view.php?lang=1&cat=204&id=169&page=1 [Accessed: 08 – Nov – 2015]

[4] Mabuchi Motor. “RS-545PH” [Online] Available: http://www.mabuchi-motor.co.jp/cgi-bin/catalog/e_catalog.cgi?CAT_ID=rs_545ph [Accessed: 08 – Nov – 2015]

[5] Amazon.com. (2012, July). “Arcade Game 24mm Yellow Illuminated Momentary Push Button SPDT Micro Switch” [Online] Available: http://www.amazon.com/Arcade-Yellow-Illuminated-Momentary-Button/dp/B008MU3PPM [Accessed: 08 – Nov – 2015]

[6] Apple Inc. (2012, Sept.). “iPhone 5 Environmental Report” [Online] Available: https://www.apple.com/environment/reports/docs/iPhone5_product_environmental_report_sept2012.pdf [Accessed: 08 – Nov – 2015]

[7] Atmel. (2014, Oct.). “Atmel 8-Bit Microcontroller with 4/8/16/32Kbytes In-System Programmable Flash Datasheet” [Online] Available: http://www.atmel.com/images/atmel-8271-8-bit-avr-microcontroller-atmega48a-48pa-88a-88pa-168a-168pa-328-328p_datasheet_complete.pdf [Accessed: 08 – Nov – 2015]

[8] Arduino. “Arduino UNO & Genuino UNO” [Online] Available: https://www.arduino.cc/en/Main/ArduinoBoardUno [Accessed: 08 – Nov – 2015]