Braille Study Aid

ECE 445 Design Document - Spring 2021

Team 36:

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1 Introduction

1.1) Problem and Solution Overview

Braille is a tactile written language used by people with visual impairments [1]. Unfortunately, only 10% of blind children learn to read Braille due to a lack of access [2]. Many students are taught through a seeing teacher. The current issue with that process is that most seeing teachers are not familiar with Braille and they are not always available. We want to provide an easier way for a student to learn independently. The study aid will allow for a quick succession of practice at the user's own pace while providing audio confirmation on each word. The aid will cycle between a hundred introductory words, displaying Braille and auditory representation.

There are currently expensive Braille e-readers on the market, but they are targeted more to extended reading and not teaching the language [3]. Our design improves on competing braille teaching methods by offering more flexibility than purely mechanical blocks and books. Though there are more complex Braille readers, they are expensive and specialized for leisure reading, not studying. Our solution offers a flexible learning opportunity without requiring a seeing or Braille familiar tutor.

1.2) Visual Aid

'Figure 1' represents how our Braille Study Aid is intended to be used. A user will run a finger across the character display, reading the embossing. After realizing the word, the user can hit the second button to confirm the word with the speaker. The speaker will output the given word to the user. When the user is ready, they can click the upper button to progress to the next word in the sequence. The protective cover will lower and shield the user from the recalibrating gears. Once the gears configure to their new positions, the cover will rise and the user can repeat the process with a new word.

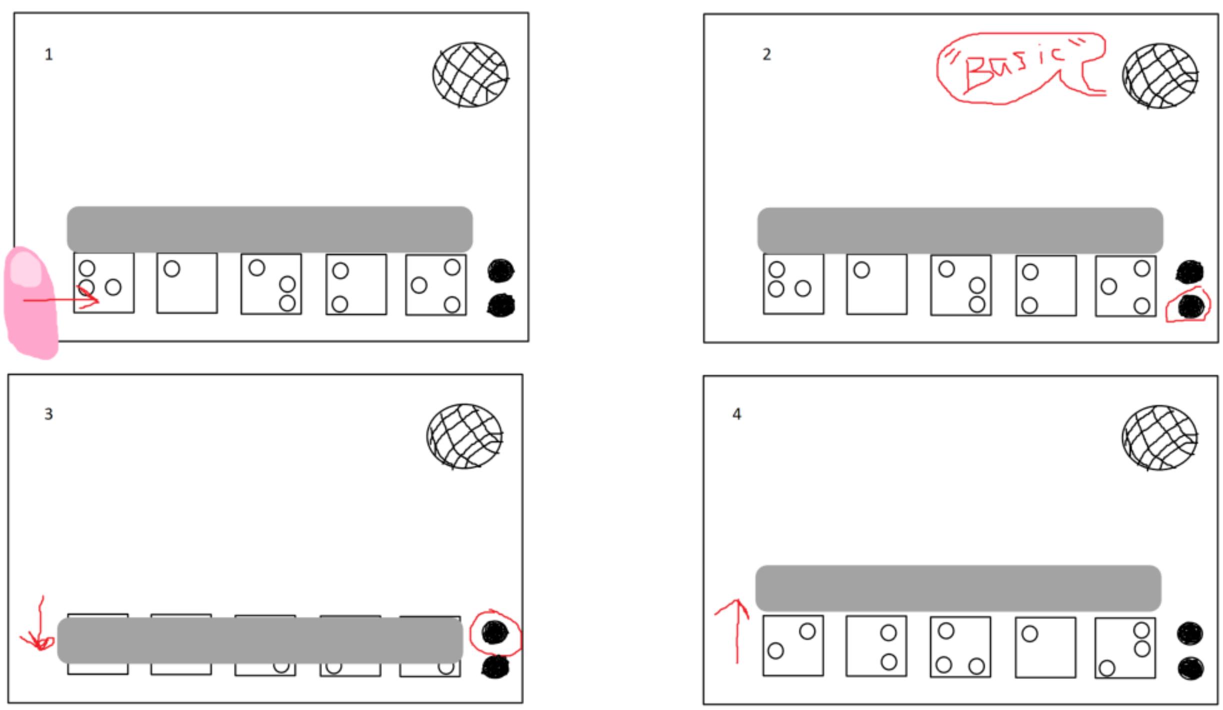

Figure 1: A Visual Representation of how a User will Interact with the Aid

1.3) High-level requirements list

1.3.1: The study aid must display five braille characters.
1.3.2: The study aid must provide audio for the word being displayed upon button push.
1.3.3: The study aid must allow the user to switch to the next word within 10 seconds.

2 Design

2.1) Block Diagram:

In order to implement our Braille teacher to the specifications described, we require four main modules: power, control, audio, and Braille output. The power module will convert AC wall power to the DC power specifications of both the controller and motors. The control module will convert user input into instructions for the motors and speaker, positioning the motors appropriately and activating the speaker at the user's request. The audio module is responsible for reading out the word being tested. Finally, the Braille output module accomplishes the goal of displaying the tested word in Braille using the gear mechanism. It includes a protective cover to prevent confusion or interference as the gears move between turns. The interactions between modules are described in 'Figure 2'.

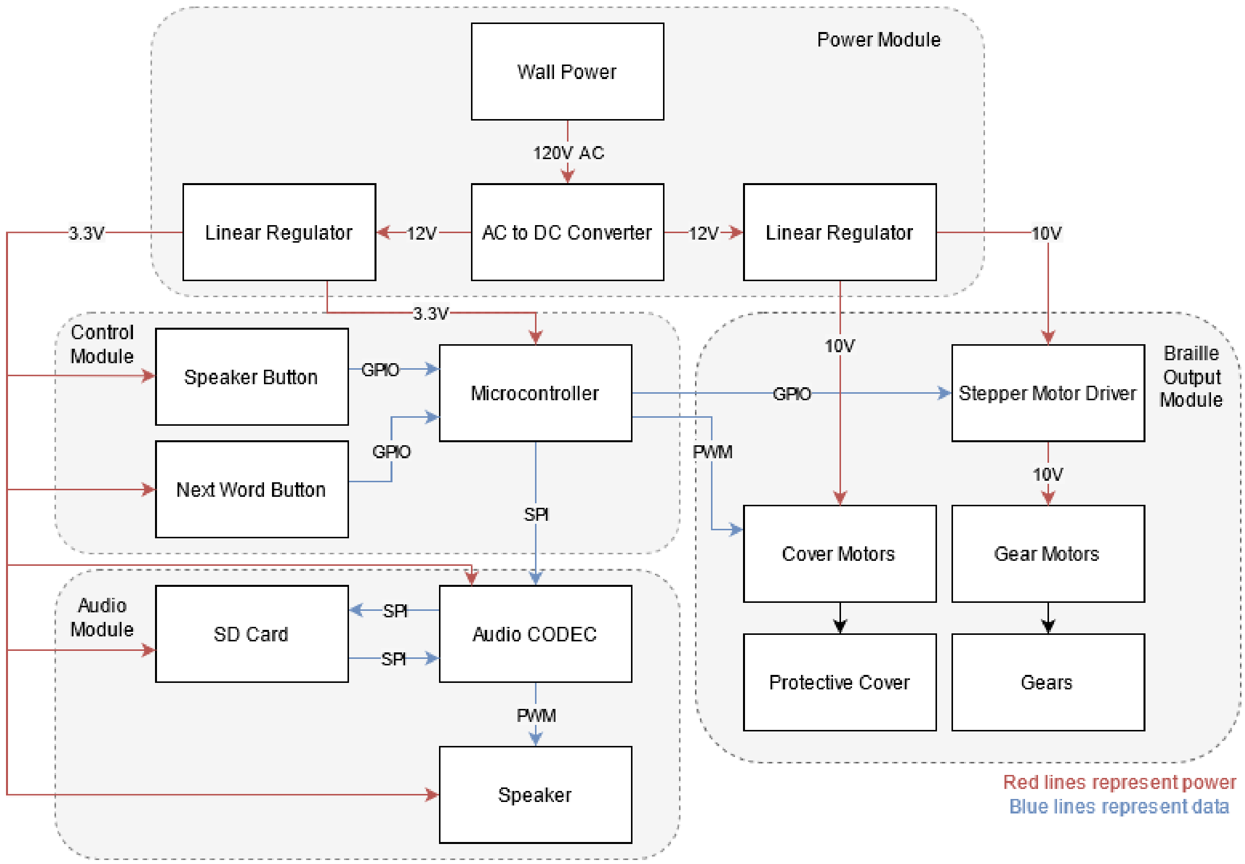

Figure 2: Braille Study Aid block diagram

2.2) Physical Design:

The following figures are a physical representation of our design. We intend to include 5 slots for Braille characters to be shifted out to the user. Our gears will have 28 sides, to encompass the 26 Braille characters, a numeric symbol, and a blank tile [1]. They will rotate through a section of bristles to help separate the user from the moving parts and to include distinction between the character that should be displayed and its neighbors. Our design also includes a speaker to output an audible representation of the currently displayed word. The two buttons will cycle between new words and queue the speaker to provide audio feedback. All moving parts and wiring will be contained in a casing. In the casing, A PCB will contain the majority of our parts, with wires connecting all parts and motors. The external user view of the study aid is displayed in ‘Figure 3’. A simplified version of our interior is seen in ‘Figure 4’. A closeup of our design for our Braille Gears is represented by ‘Figure 5’. Each gear will be 89.3mm in diameter and each tooth that a Braille character will rest on will be 10mm long.

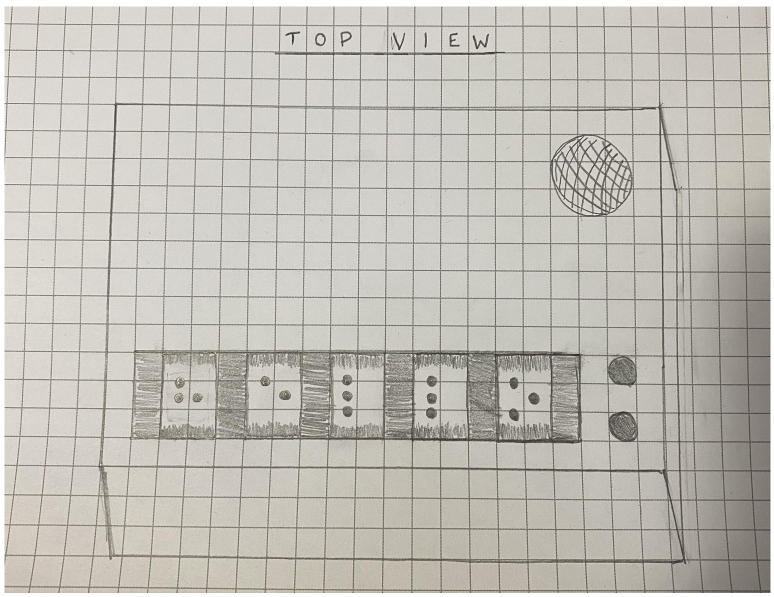

Figure 3: Anticipated exterior design of the Braille Study Aid

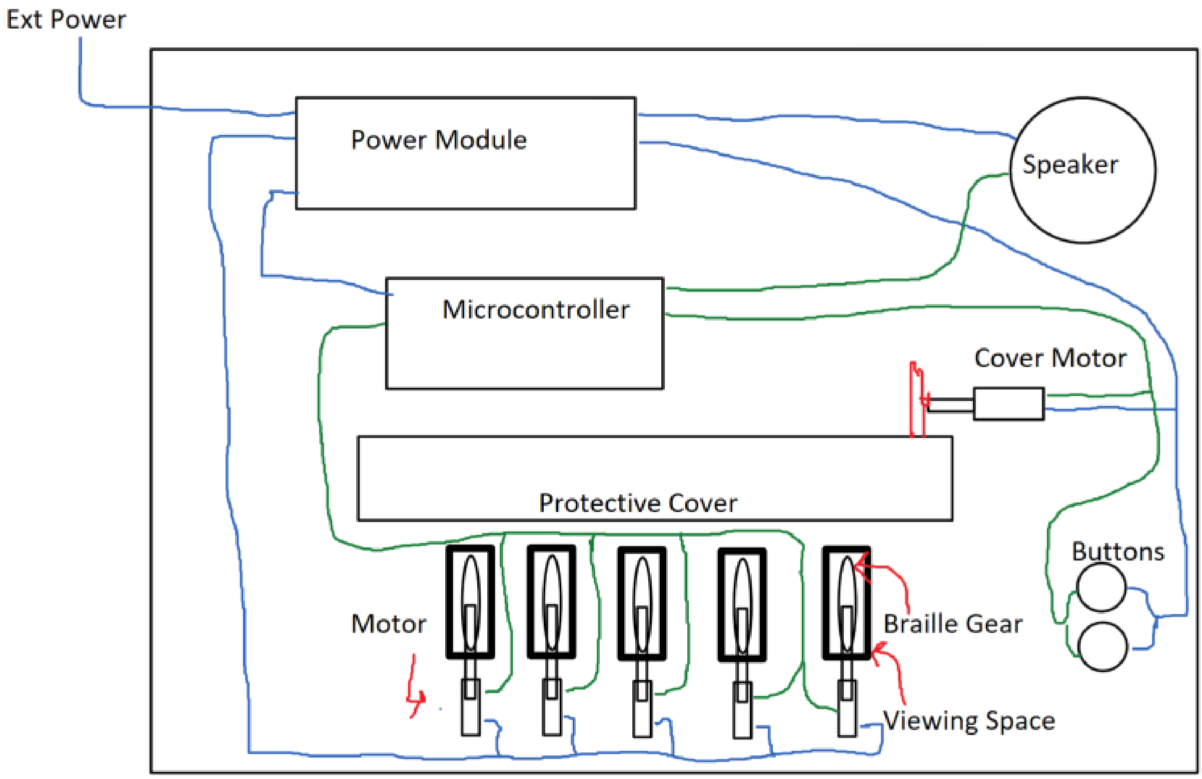

Figure 4: Anticipated interior design of the Braille Study Aid. Parts will be much cleaner with the implementation of the PCB Board.

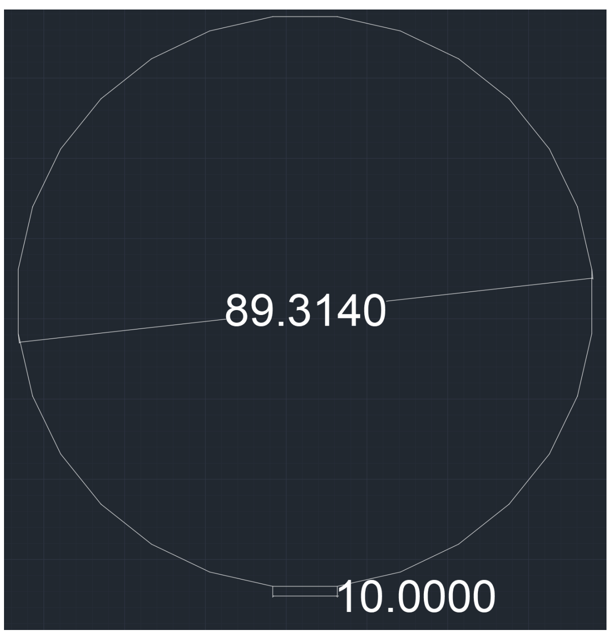

Figure 5: CAD Representation of 28 Sided Character Gear (measurements in mm)

2.3) Subsystem Descriptions, Requirements and Verification

2.3a) Power Module - Take in 120V AC from the wall socket and utilize an AC-DC converter to bring this down to a usable DC voltage that will supply power to microcontroller, motors, and speaker. This must deliver 5V with a small ripple continuously to the PCB which will be stepped down to 3.3V to supply the microcontroller. The power module must supply each gear motor and cover motor with 4.8-6V at 550-650mA. Finally the power module must supply the speaker module with 5V at 600mA.

2.3a.1)Power Supply AC-DC Converter:

Requirements	Verification
The power supply must step down 120V AC from wall socket to 11.5-12.5V DC up to 8.5A.	1) Test open circuit output voltage with voltmeter to ensure output voltage within 11.5-12.5V. 2) Apply high power resistive load of 1.5Ω to measure current at 8.5A.

2.3a.2) 3.3 and 10V Linear Regulators:

Requirements	Verification
Ensure linear regulators output desired voltage at required load.	1) Test open circuit output voltage with voltmeter to ensure output voltages are 3.3V and 10V for each regulator. a) Probe output and GND pins to measure voltage 2) Apply high voltage resistive loads to measure current output at varying loads.

2.3b) Control Module - Microcontroller is responsible for communicating servo orientations necessary to form a Braille word when the next word button is pressed. It also sends the audio CODEC a signal for the current word when the speaker button is pressed. This must be able to simultaneously output signals for 5 stepper motor drivers at once. The control module must also communicate with the speaker through the CODEC to play 8kHz audio [4]. The microcontroller must start communication when respective “play word” and “next word” buttons are pressed.

2.3b.1) Microcontroller: Microcontroller is responsible for communicating stepper motor orientations necessary to form a Braille word. It receives input from buttons, determines the orientation of each gear in the next word, computes transitions between the current and next state, and transmits signals to gears. Additionally, it controls the cover motor and determines its orientation during transition and display. Finally, it is responsible for transmitting 8kHz audio to the speaker matching the displayed word.

Requirements	Verification
Microcontroller must transmit six separate PWM signals to the gears and cover. Microcontroller must transmit audio signal to speaker. Microcontroller must be able to play same audio sample multiple times. Microcontroller must change between words. Microcontroller with SD card must store 1 MB of memory. Microcontroller must have a maximum latency of 0.1 sec.	1. Probe the power input and verify a 3.3V input to the microcontroller. 2. Hit the "Speaker" button and verify audio is processed from the microcontroller to the audio module. 3. Hit the "Speaker" button twice in a row to ensure the same output is produced. 4. Hit the "Next Word" button to trigger a state change, activating cover, gears, and current audio sample. 5. Probe each connection between modules during the off state to ensure proper connections.

2.3b.2) Buttons: Two buttons allow users to interface with the device. The "Next Word" button informs the microcontroller to change words. The "Speaker" button informs the microcontroller to play the audio sample associated with the word.

Requirements	Verification
Buttons will press without restraint and return to upright position once the signal is sent.	1. Verify the button's signals are received at each component through response and probing at destination.

2.3c) Audio Module - Take signal from microcontroller to output what is currently displayed on the gear display audibly. The speaker will be controlled by an audio CODEC that receives messages from the microcontroller for when to output audio that is stored on an external SD card. This must output audio at least 8kHz to encompass the frequency content of human voice [4]. This subsystem will be powered from the 3.3V rail.

2.3c.1) Audio CODEC

Requirements	Verification
The Audio CODEC must receive a message from a microcontroller and access the corresponding audio file from the SD card. The CODEC must then decompress the audio file and output the audio through the speaker.	1) Transmit and receive audio files to SD card via the microcontroller. 2) Output single frequency pure tone audio through speaker.

2.3c.2) Speaker

Requirement	Verification
Speaker can output characters and words audibilly to the user at around 50 dB.	1) Send speaker messages from microcontroller/arduino to ensure the speaker outputs audible speech. 2) Drive speaker output with verified CODEC above and ensure audible speech is heard.

2.3d) Braille Output Module - Motors take signal from microcontroller through stepper motor driver detailing what position each gear needs to be to display the next word. Upon a new word button press the protective cover motor will move out to prevent the user from accessing the spinning gears and the cover will retract once new word is in position. Stepper motors must be capable of rotating 360 degrees and stop at 28 equally spaced points along this rotation. Stepper motors will be powered with 10V at 550-650mA by the power module [5]. Character gears must be able to accommodate 28 braille cells along their circumference. Given the dimension of a single Braille cell, the circumference of the gear must be approximately 8.9cm.

2.3d.1) Gear Motors: The 5 gear motors (exact product) will receive signals from the microcontroller and turn the gears an appropriate amount to display the correct Braille symbol. The motors will also receive power via the AC/DC power converters from the Power Module. The motors will need to operate under relatively precise constraints, given the 28 characters and small radius of gears. Motor will be able to rotate in two directions in order to minimize possible errors.

Requirements	Verification
Cycle between each Braille character, stopping precisely at an expected orientation.	1. Send a signal to the motor to turn the wheel to each of the 28 positions. 2. Press the “Next Word” button to move the wheel motors.

2.3d.2) Gears: The 5 gears will be manufactured to have 28 teeth with unique Braille characters representing all letters of the alphabet, a numeric indicator, and a blank space. The gears will be of uniform size and rotate smoothly in their harness. Additionally, the gears should rotate freely among the brushes at the display level. According to standards [6], each Braille character, or cell, is 7.7mm high, which we will round up to a 10mm side length to accommodate some space above and below the dots.

Requirements	Verification
Gear should only allow one Braille character to be shown at a time.	1) Press the “Next Word” button to bring up a word. 2) Confirm that the only characters accessible are the expected characters for the given word.

2.3d.3) Cover Motor: The cover motor will be similar to the stepper motors, but will serve to move the protective cover over the Braille characters during the orientation of the gears. The motor will receive power from an AC/DC power converter in the Power Module. The motor will need to orient the cover in two specific locations (covering all Braille characters, and fully open).

Requirements	Verification
Cover motor will rotate the Protective Cover from the open to close positions in under 2 seconds.	1. Push the “Next Word” button to send a signal to the motor. 2. Start a stop watch once the motor begins to spin 3. Stop the stop watch once the motor stops and verify that the run time was under 2 seconds.

2.3d.4) Protective Cover: The protective cover will slide over the interactive Braille character space to separate the user from the moving gears. The cover will have two unique positions, covering all Braille spaces and a fully open position. The cover will be mechanized by the cover motor.

Requirements	Verification
Protective cover will fully separate the user from the spinning gears	1. Press the “Next Word” button to lower the Protective Cover. 2. In the closed position, inspect the cover to make sure the spinning gears are not accessible.

2.4) Tolerance Analysis:

One of the most crucial aspects of our design is the alignment of our gears. With 28 sides, there is a limited range for which the Braille display will be comfortably readable. Small errors will cause annoyance for the user by misaligning subsequent cells. On top of this, small errors can accumulate over frequent use and will make the word altogether unreadable by displaying the wrong characters. One way to counteract an accumulation of small errors is to reverse each rotation after a spin, essentially returning back to the origin between movements. This tactic would aim to remove any offset from one movement by moving an equidistant backwards.

We require 360° rotation in order to display each face of the gears, which we will accomplish by using stepper motors. Our selected motor has a step angle of 1.8°, and can be adjusted in increments of quarter steps (0.45°), meaning we can stop at 800 equally spaced points to complete one full rotation [5]. Because 800/28 is not an integer, the alignment of different faces will be slightly different, and the following calculations support why this is a tolerable range.

To move from one centered gear face to the adjacent one, the gear should ideally move 12.86°. This corresponds to 28.58 0.45° quarter steps, which will be rounded to the nearest integer, 29, leaving an offset defined by 'Eq 1'. We are interested in the worst possible case for the purposes of tolerance analysis. This occurs at the cell 15 faces from the initial point, which would be offset of 0.19°.

Since the angle between face centers is 12.86°, maximum displacement of a face, where the edge between two faces is centered on the display, occurs when the offset angle is 6.43°. The worst possible offset of 0.19°, will not be enough to expose the next face, preventing the largest concern.

$$0.42 * 0.45° = 0.19° \quad \text{Eq. 1}$$

2.5) Circuit Schematics

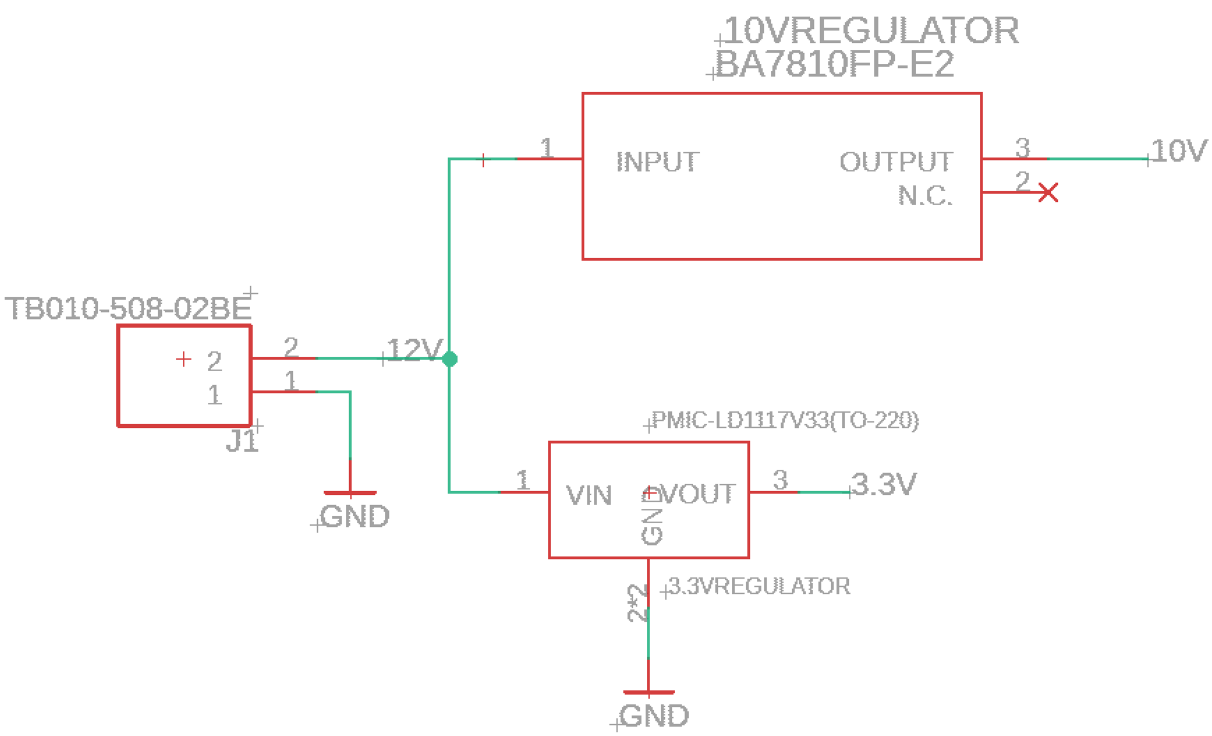

Figure 6: Power Module Schematic

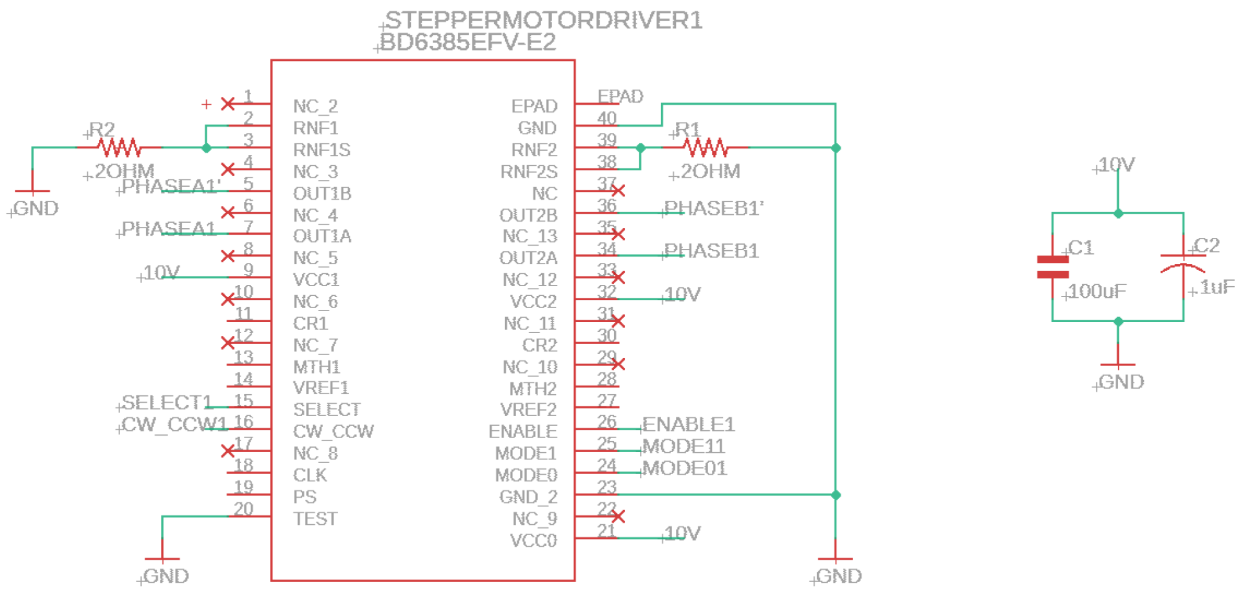

Figure 7: 1 of the 5 Stepper Motor Driver Circuits

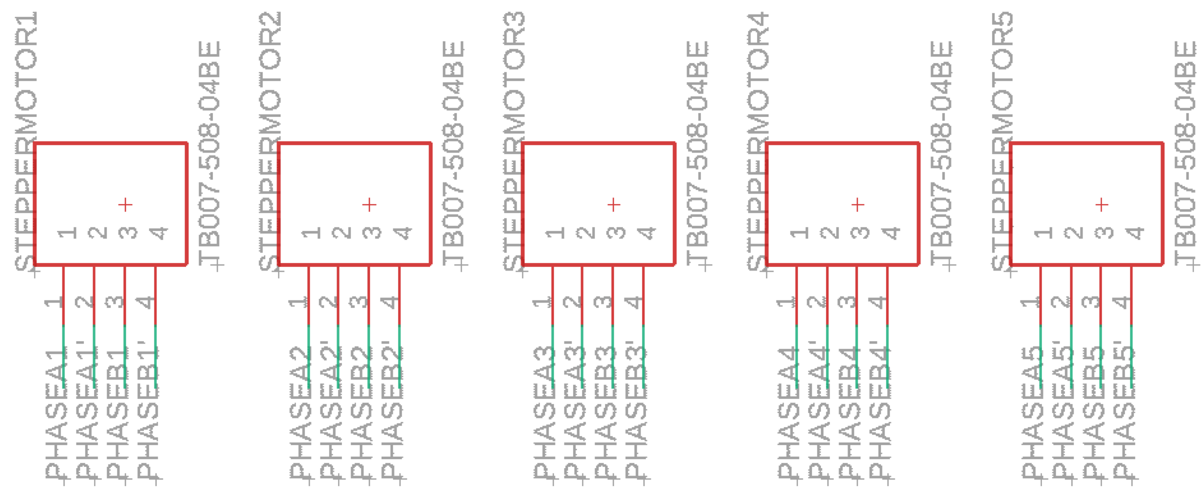

Figure 8: Stepper Motor Connections

3 Cost and Schedule

3.1) Cost Analysis

Going by industry standards, our fixed development costs will be set at $33.65, 10 hours/week, for an estimated 8 work weeks, for three people. This will work out to a labor sum cost of $20,190. Our part costs can be seen in ‘Table 1’, resulting in $137.37. The total cost will come out to $20,327.73

Table 1: Parts Price List

Part Name	Description	Manufacturer	Part Number	Quantity	Cost
Power Supply	12V DC, 8.5A	MEAN WELL	LRS-100-12	1	$16.00
Stepper Motor	500mA, 200 step, 10V	Pololu Corporation	2183-1208-ND	5	x$13.81 ($69.05)
Servomotor	3-6V DC, 3 pin	Adafruit Industries LLC	1528-4326-ND	1	$5.95
Speaker	40mm, 4Ω, 3W	Adafruit	3968	1	$4.95
Microcontroller	32KB, 8 bit, 32 pins	Microchip Technology	ATMEGA328PB-AN-ND	1	$1.51
Linear Regulator	3.3V, 800mA	STMicroelectronics	LD1117V33	1	$0.59
Linear Regulator	10V, 300mA	Rohm Semiconductor	BDJ0GA3WNUX-TR	1	$0.72
Buttons	3A, Push Button	NTE Electronics Inc	2368-54-385A-ND	2	x$2.13 ($4.26)
Terminal Block	2 Position Wire to Board	CUI Devices	TB010-508-02BE	1	$0.80
Terminal Block	4 Position Wire to Board	CUI Devices	TB007-508-04BE	7	x$0.95 ($6.65)
Stepper Motor Driver	Full Bridge, 4.5-35V, 2.5A	Monolithic Power Systems Inc.	MP6601GU-Z	5	x$2.95(14.75)
Audio CODEC	MP3 Player and Recorder	Adafruit Industries LLC	1681	1	$12.50

3.2) Schedule:

Table 2: Project Timeline

Date	Luis	Emma	Aris
3/1	Draft a PCB Design	Finalize Machine Shop Design	Finalize Part Orders
3/8	Confirm PCB Design with Finalized Parts	Emboss Braille Characters into Gears	Start Code Inception for Motors and Buttons
3/15	Order PCB	Purchase Parts	Finalize Code for Motors and Buttons
3/22	Plan out Power Converters	Design Protective Cover	Draft Code for Speaker and Power Supply
3/29	Solder PCB with Parts	Ensure Microcontroller Communicates Correctly	Finalize Code for Speaker and Power Supply
4/5	Test Power Converters	Check Communication of Buttons with Parts	Test Motor Accuracy
4/12	Test Motor Power Constraints	Assemble Design	Prepare for Mock Demo and Debug
4/19	Debug	Debug	Debug
4/26	Prepare for Presentation	Prepare for Presentation	Prepare for Presentation

4 Discussion of Ethics and Safety

Our design is aimed at mitigating any potential safety concerns. Our mechanism for interchanging the Braille characters will involve a spinning gear, so in order to avoid the user from mistakenly halting the motor or jamming a finger, we intend to shift a cover over the characters to block the gears from the user while they reorient. This cover will ensure that the interaction between the user and a moving gear can be isolated.

Most of our manufacturing will happen in the senior design lab. We have identified possible risks that could be encountered, including soldering, using lab power supplies, as well as regular lab safety. Before we begin soldering, we can make sure to complete the soldering assignment so that we can be better prepared. We have all completed the laboratory safety courses and can safely use the equipment in the lab. In order to avoid any potential dangers regarding high voltage sources, a relevant safety document will ensure proper safety [7].

With a predetermined catalogue of words being imputed to our study aid, we are eliminating any potential ethical issues regarding inappropriate words, such as profanity or harassment, from being taught. This mitigation aligns with IEEE Code of Ethics, 7.8.II: “To treat all persons fairly…” [8].

Citations:

[1] afb.org, “What Is Braille?”, 2016. [Online]. Available: https://www.afb.org/blindness-and-low-vision/braille/what-braille. [Accessed: 3-26-21].

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[7] coloradostate.edu, “High Voltage Safety Manuel”. [Online]. Available: https://lasers.colostate.edu/wp-content/uploads/2019/04/High-Voltage-Safety-Manual.pdf. [Accessed 3-1-2021].

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