Penta Solutions

Penta Solutions Ltd.
SFU Engineering Science
8888 University Drive,
Burnaby, BC V5A 1S6
Email: ashpak@sfu.ca

13th March 2022

Dr. Mike Hegedus
School of Engineering Science
Simon Fraser University
8888 University Drive,
Burnaby, BC V5A 1S6

Re: ENSC 405/440 Capstone Project: Braillingo Design Specification

Dear Dr. Hegedus,

On behalf of Penta Solutions Ltd, I am pleased to submit the Design Specification document for our ENSC 405W/440 capstone project Braillingo. The aim of this document is to give an overview in terms of software and hardware design specifications for this project. Braillingo as a product is meant to be an assisting tool for the visually impaired to comprehend today's text based world.

Braillingo's main aim is to use an optical device to capture text, use a single-board computer to perform character recognition and provide the user with the information extracted in the form of a Braille cell. Feedback will be provided to the user using an audio output device for better performance and notification to the client. The Design Specification document will help better describe the constraints and the complexities associated with the project. References to the Requirement Specification document of Braillingo will be made to better justify the choices made in regards to components and parts chosen for the project.

On behalf of Penta Solution Ltd., I would like to thank you for your time reviewing our Design Specification document. Please feel free to email me with any questions regarding the document
or the project.

Sincerely,

Anastasiia Shpak

Penta Solutions

Design Specification: Braillingo

Submitted to: Dr. Mike Hegedus

Submission Date: 13th March 2022

Company #5

Anastasiia Shpak	Chief Communication Officer
Angelique Caballa	Chief Administrative Officer
Chloe Dai	Chief Financial Officer
Korcan Uyanik	Chief Product Officer
Kunal Gossain	Chief Executive Officer

Abstract

Today at least 252,000 people in British Columbia have sight loss [1]. There are many devices that can output digital Braille text for blind people. Many of them require digital text as their input. Penta Solutions' aim is to manufacture a device, Braillingo, that can convert images of physical text to digital text and output as physical Braille cells.

This document defines the design specifications for a portable device that converts image text to Braille as part of an 8 month Capstone Project, Braillingo. It presents various design choices made to meet functional and nonfunctional requirements that were outlined in the requirements specification document. Design Specification consists of 2 main components: the Software Design and Hardware Design. In each part, it specifies sets of specifications that are imposed during design and verification of the product namely Proof-of-Concept Phase, Engineering Prototype Phase, and Product Validation Phase. This document will conclude with three appendices containing information regarding Design Alternatives, Test Plans, and User Interface.

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Glossary

Term	**Definition**
Braille	Braille is a system of raised dots that can be read with the fingers by people who are blind or who have low vision.
Actuator	A mechanical part responsible for movement by converting energy
Single-board computer	A complete computer built on a single circuit board, with microprocessor(s), memory, input/output (I/O) and other features required of a functional computer.
Matrix	Rectangular array with entities in the rows and columns. Typically is described as an mxn where m is the number of rows and n is the number of columns.

Table 1 - Glossary

Version History

Revision	Description	Date
0	Initial creation of document.	13-Mar-2022

Table 2 - Version History

Approvals

Approval	Description	Date
1	Initial creation of the document was approved by Penta Solutions.	13-Mar-2022

Table 3 - Approvals

1. Introduction

Braillingo device aims to improve the lives of visually impaired people by introducing a way of converting visual text into Braille. It would mimic the ability of a visual person to independently get information from the outside world using an image to Braille conversion system. Input text is received from the built-in camera and then outputted in the refreshable display that the user can read by touching it. Using the Requirements Specification document as a basis, Penta Solutions are developing a detailed description of the future device and starting building a prototype. Current progress is divided into hardware and software parts. Both parts are developed in parallel and will be integrated after the two are completed.

- **Hardware**
  Main challenge for the hardware part is implementation of braille cells. The team has received feedback from the teaching staff and is now considering multiple options. The best option will be chosen after careful analysis of all potential solutions. Another problem to solve for the hardware team is a battery. Braillingo is designed to be portable and therefore needs a battery that can last for a long time and have enough power to sustain the device. Penta Solutions are analyzing similar products to choose the best battery option.

- **Software**
  Software team is working on improving the text recognition program. The main aim of the team is to achieve a perfect translation from image to digital text without any errors. In order to reach the desired performance level, similar programs are being researched and studied.

1.1 Scope

This document describes the design specifications of Braillingo. Specifications are divided into software and hardware categories. The document shows the core design decisions that were made by the team and forms the basis for the future development of the project.

1.2 Intended Audience

This document is created for the members of Penta Solutions Ltd, professor Michael Hegedus, teaching assistants and potential clients.

1.3 Design Classification

Des {Section}.{Subsection}.{Requirement Number} {Project Stage}

Project Stages
A = Proof-of-Concept
B = Engineering Prototype
C = Product Validation

1.4 System Overview

The Braillingo hardware components include an optical sensor, a processing unit, 6 linear actuators, user input switches, and audio output. The user input switches will allow the user to take or retake photos and navigate through text the bi-directionally. The optical sensor is acquiring the images containing texts that exist in different reading environments with appropriate resolution, regardless of the lighting condition. The audio output lets the user know if a photo is taken and whether the processing unit can detect text in the image taken. As for the processing unit, it is supposed to detect text in the image, translate the text into Braille characters, and output the digital signals corresponding to different characters. Aftering receiving those digital signals, actuators perform small rising mechanical movements to create Braille cells for users to feel. In addition, the hardware allows for the device to be either powered while plugged in at all times or consume its battery charge, allows for external storage such as USB-A flash drives to be inputted for text files to be read in Braille, allows for user to navigate the file system of the external storage, allows for the user to input earphones to quietly listen to audio feedback, allows for the user to pair Bluetooth earphones with the device should they not have wired earphones, and allows adjusting of audio output volume.

1.4.1 Block Diagram

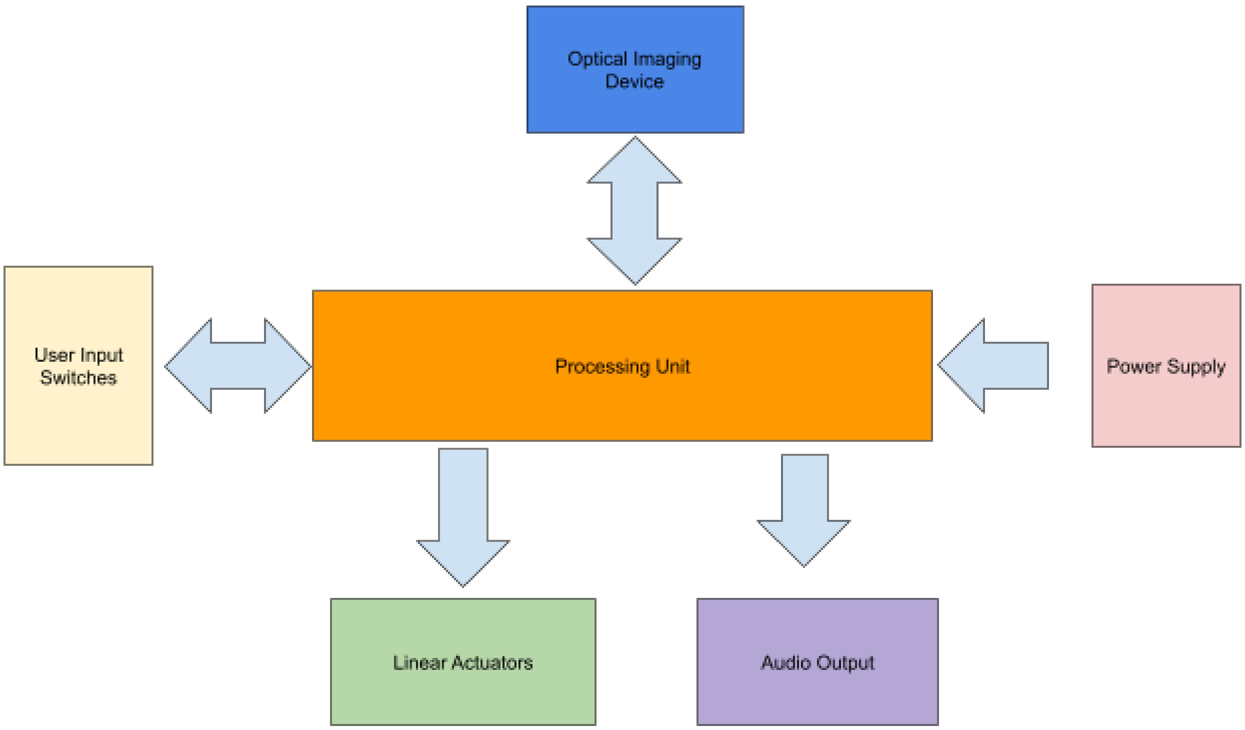

Figure 1 - System Overview

2. Software Design

Software is an important aspect of the project that has a big impact on the overall quality of the device. First of all, Braillingo uses text recognition to convert images of text into digital text. Then, it translates English into Braille and creates output sets of 8 Braille symbols that can be outputted one by one. Another feature of the device is system audio response, that guides users along every step. Change of audio volume and display of battery percentage are also regulated by system software.

The upcoming pseudocode and flowchart will outline the algorithm in meeting the following requirements:

- Req 3.2.3 A The device should correctly extract text inside the image captured.
- Req 3.2.4 A The device should map detected text to corresponding Braille characters.
- Req 3.2.6 A The device should allow the user to navigate through detected text bi-directionally.
- Req 4.1.5 A The software should alert the user when the beginning of the text or end of the text is reached.

2.1 Libraries

The following libraries will be used to achieve the aforementioned

- **Tesseract**: Python-tesseract is an optical character recognition (OCR) tool for python. That is, it will recognize and “read” the text embedded in images.

- **BlueZ API**: Provides support for the core Bluetooth layers and protocols. It is flexible, efficient and uses a modular implementation.

- **raspistill:** raspistill is the command line tool for capturing still photographs with a Raspberry Pi camera module.

- **gTTS**: Python library and CLI tool to interface with Google Translate's text-to-speech API. Write spoken mp3 data to a file, a file-like object (bytestring) for further audio manipulation, or stdout.

Design ID	Design Specification Requirement.
Des 2.1.1 A	The software should use Tesseract to recognize and read the text embedded in images.
Des 2.1.2 B	The software should use BlueZ AP to allow the Raspberry Pi to use its Bluetooth capabilities.
Des 2.1.3 A	The software should use raspistill for the Raspberry Pi camera to capture images.
Des 2.1.4 B	The software should use the Python library and CLI tool to interface with Google Translate's Text-To-Speech API to achieve Text to Speech Capabilities.
Des 2.1.5 A	The software should store a Braille encoding scheme for each English letter, number, and symbol.

Table 4 - Software Design Specifications

2.2 Flowchart/State Machine

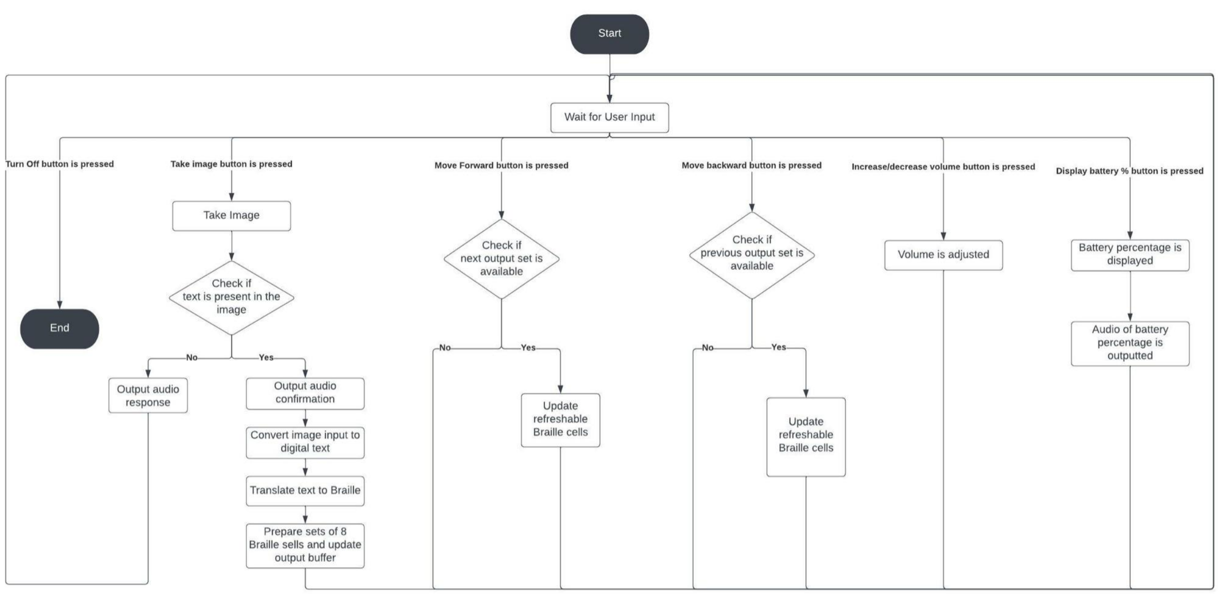

Figure 2 - Software Flowchart / State Machine

2.3 Pseudo Code

```
Initialize values and load model into memory
Send speaker the speech: "Braillingo has powered on!"

Loop
   If (camera button triggered)
      Camera mode on

   If (camera mode on)
      If(shutter button triggered)
         Call camera API, store image
         Load image into machine learning model
         Run the model
         Store returned string
         Parse the string and store

         If(string not empty)
            Update output stream with first "n" characters
            Camera mode off
         Else
            Ping the user

   If (cancel button triggered)
      Restore previous state

   If (pause/play button triggered)
      If(pause)
         Send the speaker the speech: "Paused!"
         Save current state and set default values for braille cells
      Else
         Send the speaker the speech: "Play!"
         Restore saved state

   If (next or previous button triggered)
      Update output stream with braille string array index shifted by "n"

   If (power is low)
      Send speaker a sound and signal all braille cells for "x" seconds
      Restore previous braille condition
```

```
If (audio volume button triggered)
   Set speaker volume
   Send speaker a "click" sound

If (help button triggered)
   Send speaker information about previously triggered button

If (bluetooth button triggered)
   If(bluetooth mode off)
      Send speaker the speech: "Bluetooth Mode"
      Call bluetooth API to connect audio output to a available device
   Else
      bluetooth mode off

If (battery button triggered)
   If(braille mode)
      Signal braille cells power left for "x" seconds
      Restore previous braille condition
   Else
      Send speaker the remaining battery value as speech

If (braille mode)
   Signal braille cells the output stream
Else
   Signal braille cells default values
   Send speaker output stream as speech

If (USB button triggered)
   Signal braille cells directory name
   Wait for a selection or cancel button
   Signal braille cells filename name
   Wait for a selection or cancel button
   If(selected)
      Store returned string
      Parse the string and store
      Update output stream with first "n" characters

Update battery power percentage per "x" seconds
...
```

3. Hardware Design

3.1 Processing Unit

The main processing unit for Braillingo will be Raspberry Pi 4B.It houses the latest Raspberry Pi features, it runs at 1.5 GHz and has 2GB, 4GB or 8GB SDRAM and Broadcom BCM2711 Quad Core Cortex-A72 (ARM v8 64-bit SoC). The decision to choose Raspberry Pi came from its reputation and characteristic of being able to easily communicate with hardware and perform complex functions. The Raspberry Pi 4B comes with 40 GPIO pins which operate at maximum voltage of 3.3 V and draw a current of 16 mA. The Raspberry Pi operation voltage is 5.1 V at 3 A with minimum power of 15.3 W. The Raspberry Pi 4B comes with a CSI camera connector port, where the camera module can be connected for operation. The image below shows the Raspberry Pi 4B layout.

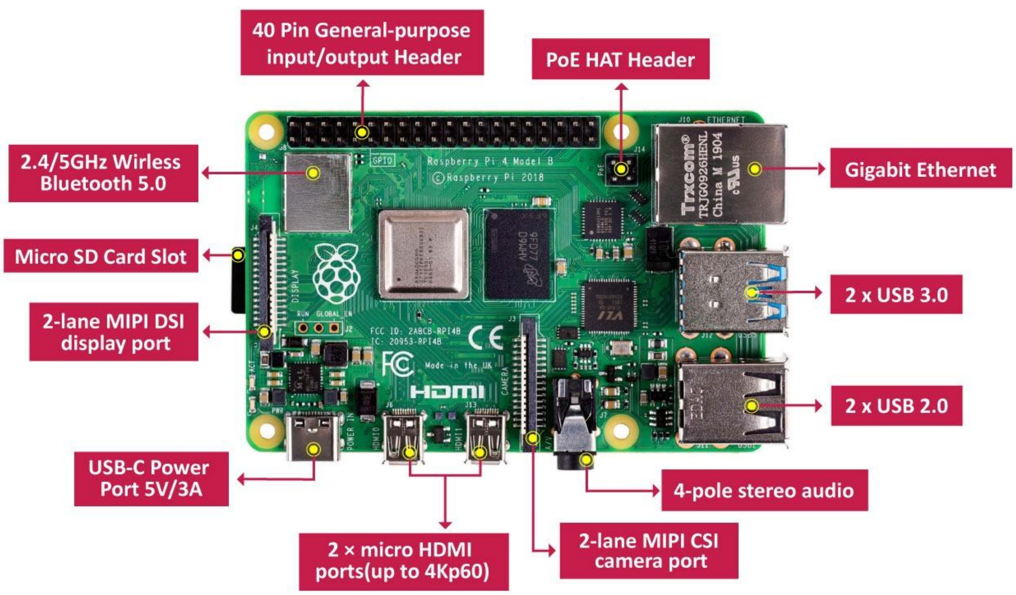

Figure 3 - RaspberryPi layout [2].

Design ID	Design Specification requirement
Des 3.1.1 A	Include Camera Connector interface
Des 3.1.2 A	Include enough GPIO for audio feedback, control buttons and motor driver board.
Des 3.1.3 B	The Raspberry Pi 4B should fit the design case and meet required weight for portability
Des 3.1.4 A	The processor capability includes the ability to work with image analyzing software and perform complex image processing tasks.

Table 5 - Processing Unit Design Specifications

3.2 Optical Imaging Device - Camera module

The camera chosen for this design was the Waveshare RPi camera, which supports all versions of Raspberry Pi devices. It comes with a 5 megapixel OV5647 sensor to perform an adjustable-focus function, with CCD size to be ¼ inches and best resolution being 1080p.

Design ID	Design Specification Requirement
Des 3.2.1 A	Interface with Raspberry Pi Model B
Des 3.2.2 A	Adjustable focus module
Des 3.2.3 A	High resolution

Table 6 - Camera Module Design Specifications

Figure 4 - Pi Camera module [3]

3.3 Audio Feedback device - Speakers

The speaker module for Braillingo will be used for feedback purposes to let the user know simple tasks are performed by the device, for example, on pressing the button “PLAY” it will let the user know that the button was pressed, and the task will be performed. There are two possible ways of wiring the speaker to the Raspberry Pi for feedback.
The second way to implement audio feedback would be to use the AUX port and Raspberry Pi GPIO pins to give the feedback to the user. This is the expected implementation for Braillingo. To accomplish this, a Y-audio splitter cable can be used, where one of the audio jack contains the speaker output and the other audio jack allows the user to plug in their own headphones. The figure below shows the Y-audio splitter.

Figure 5 - Y-type audio splitter. [4]

The speaker will use the jack port on the Y-splitter and will also use the GPIO pins to function. The image below shows the speakers in connection to the Raspberry Pi followed by the schematic of the amplified speaker provided by the manufacturer of the speaker.

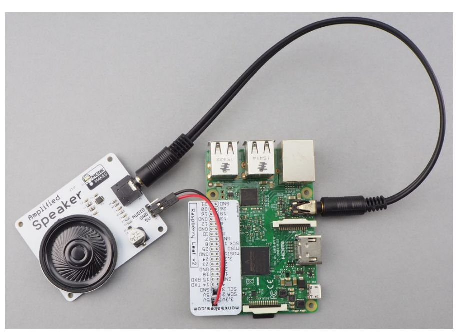

Figure 6 - Amplified speaker layout with Raspberry Pi. [5]

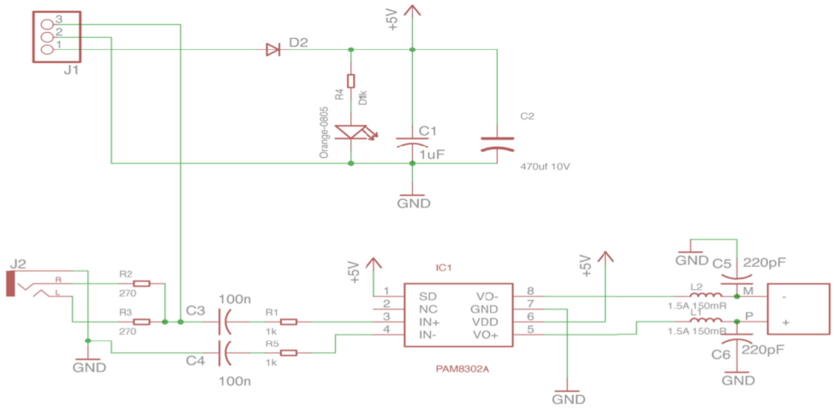

Figure 7 - Speaker schematic from Monk make. [5]

From the schematic above, it can be noted that J1 pins connect to the GPIO pins on the Raspberry Pi 4B and J2 is connected to one of the Y-audio splitter jacks.

Design ID	Design Specification Requirement.
Des 3.3.1 B	Adjustable volume to the audio signal
Des 3.3.2 B	Provide clear and amplified audio feedback to users.
Des 3.3.3 B	Resources a limited amount of current from the Raspberry Pi.

Table 7 - Speaker Module design specifications

3.4 User Input Buttons and Switches

The input buttons module for Braillingo will be used for the user control panel to provide users the capability of adjusting the reading procedure and changing the basic settings for the device. Two types of switches are used to construct the button, with slide switch for power button and push buttons for other control signals.

Design ID	Design Specification Requirement
Des 3.4.1 A	Should be connected to Raspberry Pi circuit board
Des 3.4.2 A	Should perform associated task with the pressed button

Table 8 - Button module design specification

Figure 8: Switches for Braillingo [6].

3.5 Power Supply and Battery

Due to the portability feature of Braillingo, a power reserve must be used in situations when the person isn't connected to the outlet using Braillingo. For the device to run upto 4-6 hours on use the following formula was used.

$$Battery\ Capacity\ (in\ mAh)/Rated\ Current(mA)\ =\ time$$

Since the raspberry operational current is 1250mA , the expected battery capacity is 5000mAh -7500mAh.Penta Solution plans to use an Uninterruptible Power Supply (UPS) Hat for Raspberry Pi with a stable output of 5V for Raspberry Pi.The attractive part of this power supply is that it can be functional (gives out power) while being charged hence providing uninterrupted power.It comes with with backup battery holder that holds 18650 Li battery (2300mAh-3500mAh) each and also provides multi circuit protection such as overcurrent protection , short circuit protection and overcharge protection.The USB output voltage from the UPS hat is 5V hence matches the operational voltage of the Raspberry Pi.The image below shows the UPS hat, followed by the schematic provided by the manufactured.

Figure 9: UPS hat with 18650 Li battery [7].

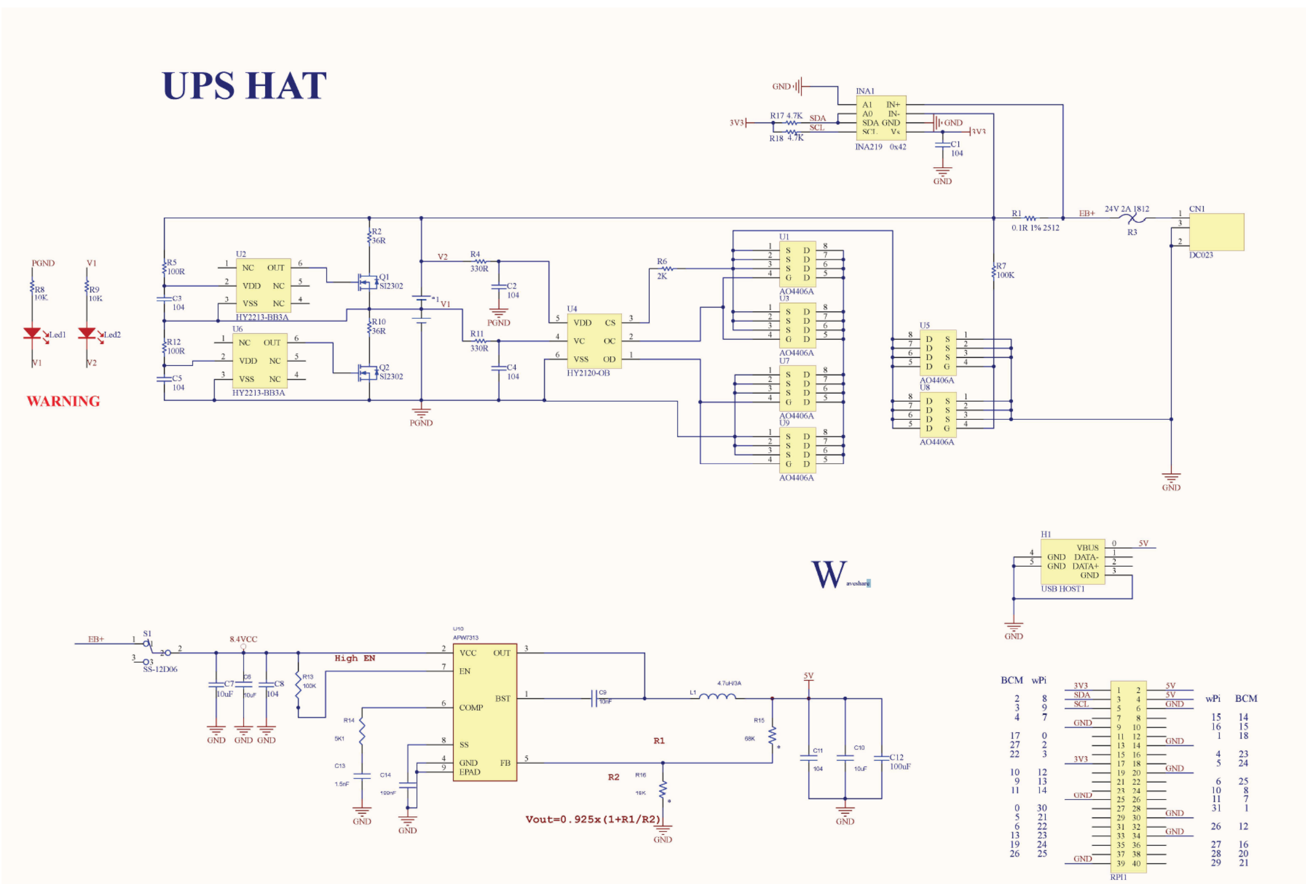

Figure 10: UPS Hat schematic [8].

Design ID	Design Specification Requirement
Des 3.5.1 B	The battery should be rechargeable
Des 3.5.2 B	The battery should be last for a reasonable amount of time
Des 3.5.3 B	Should be able to provide constant DC voltage of 5 V.

Table 9: Power Supply Design Specifications

3.6 Braille Actuators

The Braille actuators described in this section aims to meet Req 3.2.5 A, in which “The device should output the Braille character”.

In addition, as per Req 5.4.9 C, the spacing of actuator pins from each other and other cells should adhere to Braille Authority of North America’s Standards for Braille Signage as closely as possible. The dimensions are shown below:

Dot Base Diameter	1.5mm to 1.6mm
Distance between two dots in the same cell	2.3mm to 2.5mm
Distance between corresponding dots in adjacent cells	6.1mm to 7.6mm
Dot height	0.6 mm to 0.9 mm
Distance between corresponding dots from one cell directly below	10.0 mm to 10.2 mm

Table 10 - Braille Authority of North American Standards for Braille signage

English is the only language so far to be implemented into Braillingo, meaning only 6 dots are required for each letter in a 3x2 matrix as per Req 5.1.2 B where the actuators should form a 3x2 matrix for each Braille cell. For other languages though, up to 8 dots can be used i.e. a 4x2 matrix for each Braille cell.

For Braillingo’s Proof of Concept, Linear Solenoid Actuators will be used. Piezoelectric bending actuators were considered to be used for the Proof of Concept initially; however due to time constraints, piezoelectric actuators will not be used until the Engineering Prototype phase. Linear Actuators as they are much easier to purchase and more commonly available in electronic component stores.

Linear actuators come in continuous, intermittent, or pulse configurations. To simulate the final product's functionality as much as possible, the linear actuators should be able to remain raised for an indefinite amount of time, thus continuous actuators were chosen.

Linear actuators also come in two types options, push and pull. For PoC, we will demonstrate the raising dots functionality. It was determined that as long as the actuators raise and retract when outputting certain letters, the PoC of the functionality will be successful regardless of whether the Braille dots are raised when off. Pull linear actuators were chosen as they were less expensive than push actuators.

To meet the aforementioned conditions for the PoC Braille actuators, Johnson Electrics Continuous Pull-type Solenoid actuators were chosen for Braillingo's Proof-of-Concept as shown below in Figure 11:

Figure 11: Box Frame Pull-type Continuous Latching Solenoid Actuator by Johnson Electric, B17-L-154-B-3 [9].

Voltage (Rated)	12 VDC
Type	Pull
Duty Cycle	Continuous
Size	28.45mm x 13.01mm x 15.09mm
Diameter of Pin	4.83 mm
Stroke Length	4.57 mm
Power	1.6W

Table 11 - B17-L-154-B-3's features and characteristics [9].

Though Linear actuators will be used for PoC, they were deemed inefficient for achieving scalability. The linear actuators were deemed inefficient for scalability due to their size and high power consumption. With size, it would be difficult to adhere to the aforementioned Standards of Braille Signage, in particular, the spacing between dots and characters. Larger space between dots also means higher space consumption, meaning a larger casing will be needed for the electronics.

As mentioned earlier in this section, piezoelectric actuators were considered for the Engineering Prototype. With small-width piezoelectric actuators, less space will be needed between dots and more dots will be able to be available on Braillingo. In addition, most Braille devices use piezoelectric actuators for their refreshable Braille displays, so Braillingo will be as competitive in the market by using piezoelectric actuators.

Johnson Matthey (JM) manufactures Braille modules as shown in Figure 12 below. The dot spacings are 2.4 mm dot heights are 0.75mm, which adhere to Req 5.4.9 C, which requires that the device's Braille pin spacing should be within the tolerance of North American Standards of Braille signage. As per its characteristics, the module's pins are able to withstand Tactile Force of upto 170mN. Because the 32-pin Braille Module was manufactured and tailored to Braille devices, it can be said that 170mN meets Req 5.3.2 A, that the Braille actuator pins should be able to handle pressure from the user without retracting.

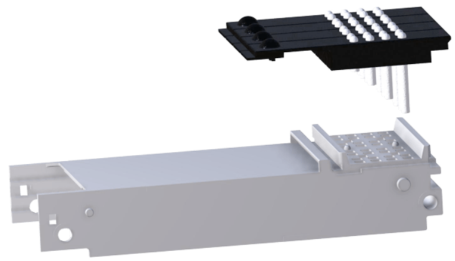

Figure 12 - 32-pin Braille Module by JM [10].

Dot Spacing	2.40 mm
Tactile Pin Diameter	1.3 mm
Tactile Pin Stroke	0.75 mm
Character Spacing	4.00 mm
Tactile Force	≥ 0.17 N
Logic Supply	3.3 to 5V DC
High Voltage Supply	200V DC
Assembly Size	13.7 mm x 62.7 mm x 25.57 mm

Table 12- Electrical Characteristics for 32-pin Braille Module by JM [10].

The 32-pin Braille Module also has a special set of pins as shown in Figure 13:

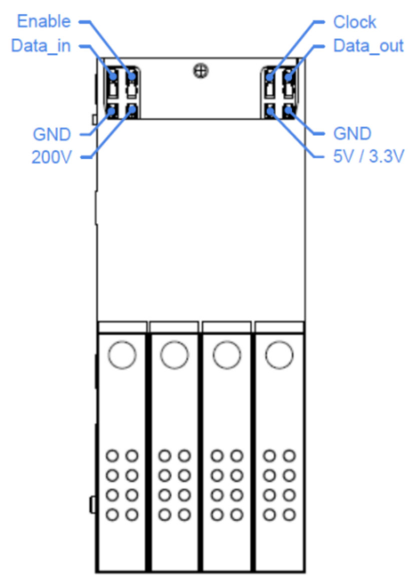

Figure 13 : Pin mapping for JM's 32-Pin Braille Module [10].

The module requires 200V as the High Voltage Supply to bend the actuators. To achieve this, a Step Up Converter will be required and will be outlined in the next section. The 5V/3.3V Logic Supply, Enable, Data_in, Data_out, Clock, and GND will be connected to the Raspberry Pi.

Design ID	Design Specification Requirement
Des 3.6.1 A	The Braille actuators should form at least a 3x2 matrix for English Braille.
Des 3.6.2 B	The Braille actuators should be spaced according to North American's Standard for Braille Signage.

Table 13 - Braille Actuators Design

3.7 Step Up Converter

To achieve 200V for the High Voltage input of the 32-Pin Braille module, a Step Up Converter will be used. Since the system will be powered by 5V, a 5V to 200V DC DC converter was selected, namely XP Power's A02P-5 as shown in Figure 13:

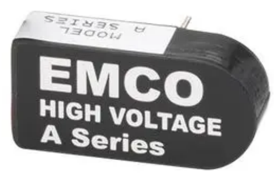

Figure 14 - XP Power's 5V to 200V DC DC Converter [11].

3.8 Braille Logic Controller

To control the linear actuators used for the proof-of-concept phase, several Motor Drivers will be used, namely SparkFun Electronics's Motor Driver, TB6612FNG. This was chosen as the driver is compact and allows for two inputs and two outputs, lessening the purchase for multiple motor drivers. As shown in Figure 15:

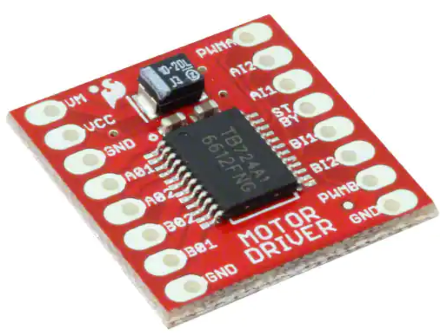

Figure 15 - SparkFun Electronics's Motor Driver, TB6612FNG [13].

3.9 Housing/Casing

The housing is a significant part of the User Interface and is shown in Figure 3.9.1. In particular, the housing has abbreviated Braille indicators for the user input to follow Req 5.4.5 B, where the housing should have its inputs labeled in Braille and tactile text for ease of use. Further details on the UI can be found in Appendix C: User Interface, including the test plan in regards to the User Interface.

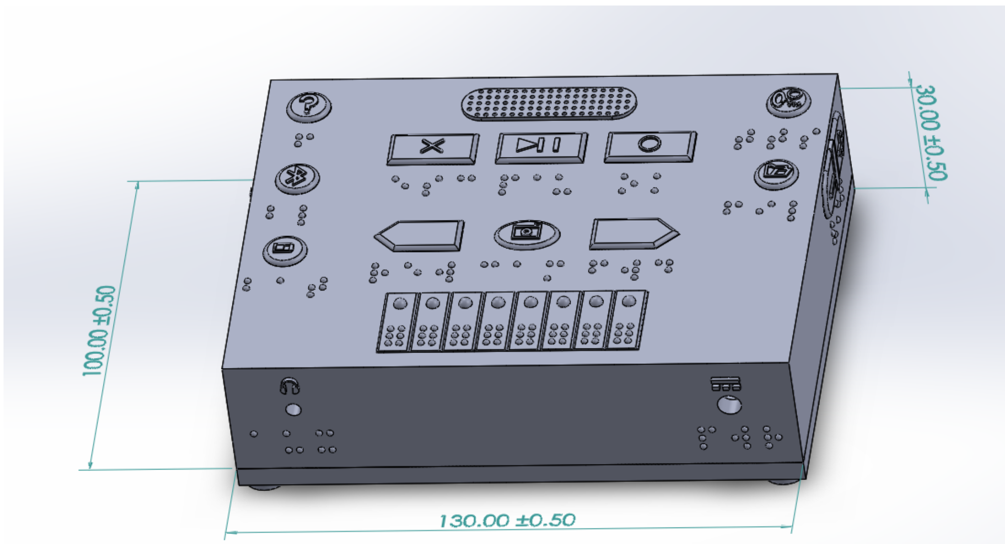

Figure 16 - CAD drawing of Braillingo Housing with dimensions in mm.

The housing will be 3D printed with PLA material due to its recyclable capabilities. In addition, 3D printing will allow the device to get higher precision in dimensions of its housing. This can easily achieve the following requirements:

- Req 5.4.1 A -The top of the Braille actuator pins when retracted should be leveled or below with surface.
- Req 5.4.2 A - The top of the Braille actuator pins when raised should be above the surface of the lid by at least 0.5 mm
- Req 5.4.3 B - The housing should fit all electrical components associated with the Braille cell system.
- Req 5.4.4 B - The housing should have appropriately sized holes for the Braille cell actuators and user input switches.

3D printing the device will meet the following requirements:

- Req 5.4.3 B requires that electronics are to be fit inside the housing. This can be easily met by 3D printing the housing as adjusting the size will be easy by simply changing the 3D model.

- Req 5.4.5 B requires the buttons to be labeled in Braille, and Req 5.4.9 C requires Braille dimensions to follow the North American Braille signage Standard. These two can be easily achieved by adding Braille into the model's surface with the appropriate dimensions.

4. Conclusion

Penta Solution is a portable braille reading device that performs text extraction from physical books and converts them into easily readable braille for the visually impared.The device will be designed with some of the readily available parts like Raspberry Pi ,Pi Camera and Amplified Speaker.

The Braillingo system comprises of two main subsystems that make it functional as product
- Software system: Text detection from text,image processing and signal processing

- Hardware design:Capture image, CPU controls peripherals and process and extract text and send signal to braille cells with audio feedback. Also have portability features.

This document serves as a guide in terms of design for braillingo during the proof of concept stage,prototyping stage and engineering phase.

5. References

[1] "Blindness in Canada". [Accessed: 13-Feb-2022] https://cnib.ca/en/sight-loss-info/blindness/blindness-canada?region=bc

[2] Nitin, "Getting started with Raspberry Pi + Installation Guide for tensorflow 2.3.1 and opencv 4.5.1," *Medium*, 18-Feb-2021. [Online]. Available: https://nitin9809.medium.com/getting-started-with-raspberry-pi-installation-guide-for-tensorflow-2-3-1-and-opencv-4-5-1-3a5bd0b6de2d. [Accessed: 13-Mar-2022].

[3]."Waveshare RPI camera (b), adjustable-focus," *PiShop.ca*. [Online]. Available: https://www.pishop.ca/product/rpi-camera-b-adjustable-focus/. [Accessed: 13-Mar-2022].

[4]."Weastlinks 2PCS 3.5mm 1 in 2 couples audio line earbud headset headphone earphone splitter for pad phone Android mobile MP3 MP4 - Newegg.com," *Newegg.ca - Computer Parts, Laptops, Electronics, HDTVs, Digital Cameras and More!* [Online]. Available: https://www.newegg.ca/p/1BJ-00AR-00003?Description=headphone+splitter&cm_re=headphone_splitter-_-9SIAYT9FGC9004-_-Product. [Accessed: 13-Mar-2022].

[5].“Datasheet amp speaker - monkmakes.com.” [Online]. Available: https://www.monkmakes.com/downloads/datasheet_amp_speaker.pdf. [Accessed: 14-Mar-2022].

[6]. “5Pcs on/off boat rocker switch 5Pcs 2 pin position snap 12V 110V 250V QTEATAK : Amazon.ca: Industrial & Scientific,” *5Pcs On/Off Boat Rocker Switch 5Pcs 2 Pin Position Snap 12V 110V 250V QTEATAK : Amazon.ca: Industrial & Scientific*. [Online]. Available: https://www.amazon.ca/5Pcs-Rocker-Switch-Position-QTEATAK/dp/B07Y1GDRQG/ref=sr_1_20?crid=16641U7EEP5WA&keywords=micro%2Bswitches&qid=1647145299&sprefix=micro%2Bswitches%2Caps%2C199&sr=8-20. [Accessed: 13-Mar-2022].

[7].“Uninterruptible Power Supply Ups hat for Raspberry Pi, stable 5V power output,” *Waveshare*. [Online]. Available: https://www.waveshare.com/ups-hat.htm. [Accessed: 13-Mar-2022].

[8].“Ups hat,” *UPS HAT - Waveshare Wiki*. [Online]. Available: https://www.waveshare.com/wiki/UPS_HAT. [Accessed: 13-Mar-2022].

[9] Ledex Dormeyer Saia, a Division of Johnson Electric, “Ledex® Magnetic Latching Box Frame Size B17-L”, *B17-L-154-B-3.* [Online]. Available: https://media.digikey.com/pdf/Data%20Sheets/Emerson%20PDFs/B17-L-yyy-B-3_2-27-15.pdf. [Accessed: 13-Mar-2022].

[10] “Cost-efficient solutions for Braille displays,” Johnson Matthey Piezo Products GmbH - Customized electromechanical Piezo modules, Piezo actuators and Piezoelectric ceramics. [Online]. Available: https://www.piezoproducts.com/32-pin-braille-cell-manufacturer/#. [Accessed: 13-Mar-2022].

[11] XP Power, “DC-HVDC CONVERTER”, A02P-5. [Online]. Available: https://www.xppower.com/portals/0/pdfs/SF_A_Series.pdf [Accessed: 13-Mar-2022]

[12] SparkFun Electronics, “Motor Driver”, *TB6612FNG*. [Online]. Available: https://media.digikey.com/pdf/Data%20Sheets/Sparkfun%20PDFs/ROB-14451_Web.pdf [Accessed: 13-March-2022]

[13] P. Smithmaitrie, Analysis and Design of Piezoelectric Braille Display, 2009. [Online]. Available: https://cdn.intechopen.com/pdfs/9307/InTech-Analysis_and_design_of_piezoelectric_braille_display.pdf. [Accessed: 13-Mar-2022].

[14] “Piezoceramic Bender,” *Johnson Matthey Piezo Products GmbH - Customized electromechanical Piezo modules, Piezo actuators and Piezoelectric ceramics*. [Online]. Available: https://www.piezoproducts.com/products-solutions/bending-actuators/. [Accessed: 13-Mar-2022].

[15] Sinocera, “Piezo Actuators”, *QDA3–2.1–0.7*. Available: https://www.alibaba.com/product-detail/piezo-actuator-used-in-braille-devices_60524787915.html?spm=a2700.details.0.0.34a43b6aSRpTPF. [Accessed: 13-Mar-2022].

[16] L. F. Knox, “Navigating Your Child’s Braille Journey”, *FamilyConnect: A Parent's Voice*, 13-May-2022. [Online] Available: https://familyconnect.org/blog/familyconnect-a-parents-voice/navigating-your-childs-braille-journey/. [Accessed: 04-Mar-2022].

[17] "Size and Spacing of Braille Characters", *Brailleauthority.org*, 2022. [Online]. Available: http://www.brailleauthority.org/sizespacingofbraille/. [Accessed: 13-Feb-2022].

[18] "IEEE Standard for Software Maintenance". [Online] Available: https://standards.ieee.org/ieee/1219/1842/. [Accessed: 04-Mar-2022].

[19] "ANSI C18.2M: Portable Rechargeable Batteries Specifications", [Online] Available: https://blog.ansi.org/2020/06/ansi-c182m-portable-rechargeable-cell-batteries/ . [Accessed: 04-Mar-2022].

[20] "IEEE Standard for Software Test Documentation" [Online] Available: https://ieeexplore.ieee.org/document/573169 . [Accessed: 04-Mar-2022].

[21] "Functional safety of electrical/electronic/programmable electronic safety-related systems". [Online] Available: https://webstore.iec.ch/publication/5515 . [Accessed: 04-Mar-2022].

[22] "Systems and software engineering — System life cycle processes". [Online] Available: https://www.iso.org/standard/63711.html . [Accessed: 04-Mar-2022].

[23] “ISO 9241-210:2010,” *ISO*, 04-Jul-2019. [Online]. Available: https://www.iso.org/standard/52075.html. [Accessed: 04-Mar-2022].

[24] “IEEE Standard for Software User Documentation,” *SA Main Site*. [Online]. Available: https://standards.ieee.org/ieee/1063/1554/. [Accessed: 04-Mar-2022].

[25] “Ease of operation of everyday products” *ISO*, 09-Dec-2020. [Online]. Available: https://www.iso.org/standard/34122.html. [Accessed: 04-Mar-2022].

[26] “ISO/IEC JTC 1/SC 35,” *IEC*. [Online]. Available: https://www.iec.ch/dyn/www/f?p=103%3A7%3A%3A%3A%3A%3AFSP_ORG_ID%3A3409. [Accessed: 04-Mar-2022].

[27] “Electrical Aids for Physically Disabled Persons,” *Standards Council of Canada - Conseil canadien des normes*. [Online]. Available: https://www.scc.ca/en/standardsdb/standards/2743. [Accessed: 04-Mar-2022].

Appendix A: Design Alternatives

A.1 Hardware

A.1.1 Actuator Alternatives

Although the JM 32-Pin Braille Module has the benefit of being already assembled, it may come with some software challenges. An alternative to this is to assemble one's own piezoelectric braille cell actuator and create the circuit to control the actuators. This however came with much more challenges such as creating a mechanical jig and pins for each Braille cell. A sample assembly and behavior of piezoelectric bending actuators can be seen on Figure 17 and Figure 18 respectively below:

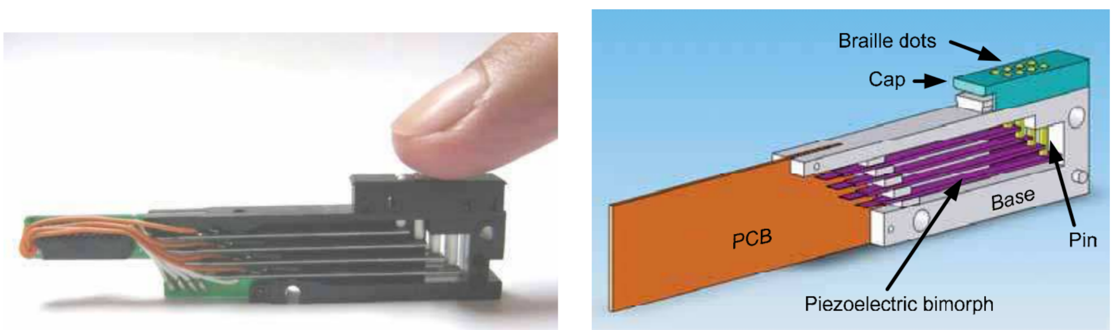

Figure 17 - Example (Left) and Assembly (Right) of a Piezoelectric Braille Cell [13].

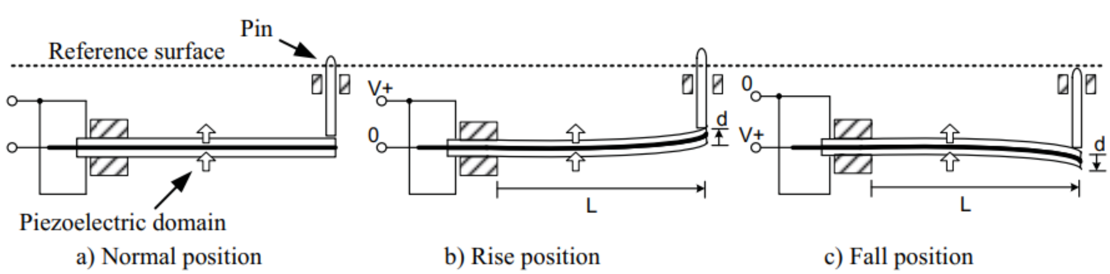

Figure 18 - Piezoelectric actuation mechanism typically used in Braille cells [13].

All piezoelectric devices need high driving voltage, for example, 200V, so a Step Up Converter will be used. To control the piezoelectric actuators, a sample circuit was created and can be seen below in Figure 19:

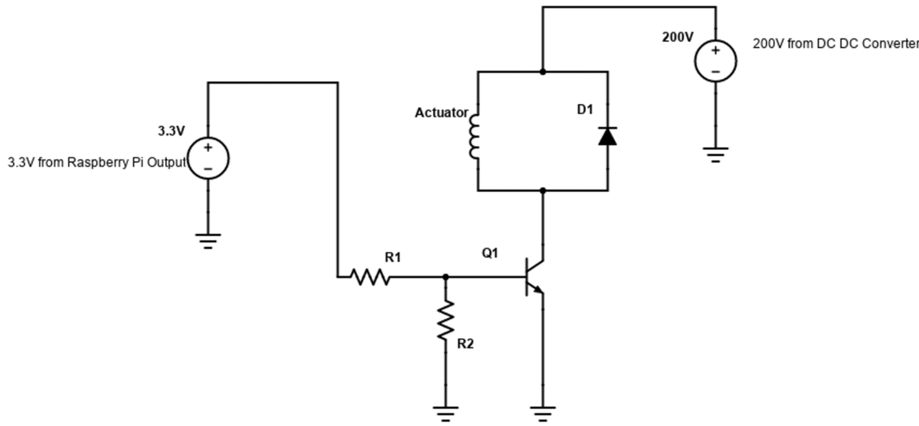

Figure 19 - Logic Circuit for Piezoelectric Actuator.

The values associated with the circuit above is specified as follows:

- R1 = 0 Ω
- R2 = 206.25Ω
    - Raspberry Pi outputs at most 16mA from each GPIO pin and 3.3V, so a voltage drop of 3.3 can be achieved with 206.25Ω.
- D1 is the Snubber Diode that prevents the actuator's 200V from damaging the rest of the circuit. The Diode's Reverse voltage was chosen to be at least greater than 200V.
- Q1 is an NPN BJT transistor that acts as a switch with at minimum a Vce of 200V.

The actuator pins themselves can be purchased from either JM or Sinocera. Both bending actuators were chosen for their bending Force as well as with of ~2.1mm to allow about 2.3 mm to 2.5 mm of space between each dot:

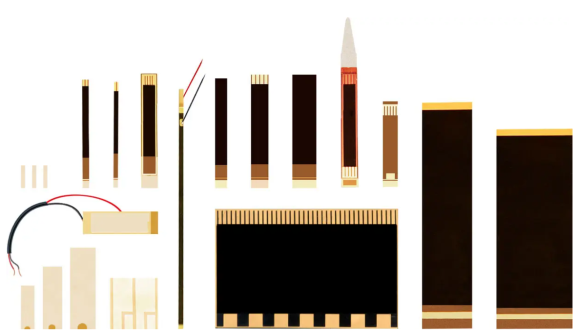

Figure 20 - Bending Actuator strips by JM [14].

Blocking Force on each Side	500mN
Size	49 mm x 2.1 mm x 0.90 mm
Total Displacement	2.0mm
Driving Voltage	230V DC

Table 14 - Electrical Characteristics for Piezoceramic Bender #2 by JM [14].

Figure 21 - Bending Actuator strips by Sinocera [15].

Force	≥ 140 mN
Size	36 mm x 2.1 mm x 0.7 mm
Deflection	≥ 1.1 mm
Voltage	200 DC

Table 15 - Electrical Characteristics for *QDA36–2.1–0.7* by Sinocera [15].

A.1.2 Audio Feedback Alternatives

The alternative to implement a speaker on Raspberry Pi would be to use a mini external USB stereo speaker which would easily plug into the Raspberry Pi's 2.0 USB. The dimensions of such speaker in terms of volume are 84 mm X43 mm X 32 mm and weighs 73.6g and requires 5V for operation

.
Figure 22 - Mini External USB speaker

Alternative design plan for power supply
An alternative way to provide power to the Raspberry Pi to make it portable would be to use lithium ion batteries with a boost converter to step up the voltage from the Lithium ion battery as they provide 3.7 V and Raspberry Pi gets powered by 5 V. The diagram below shows the possible way to power the circuit.

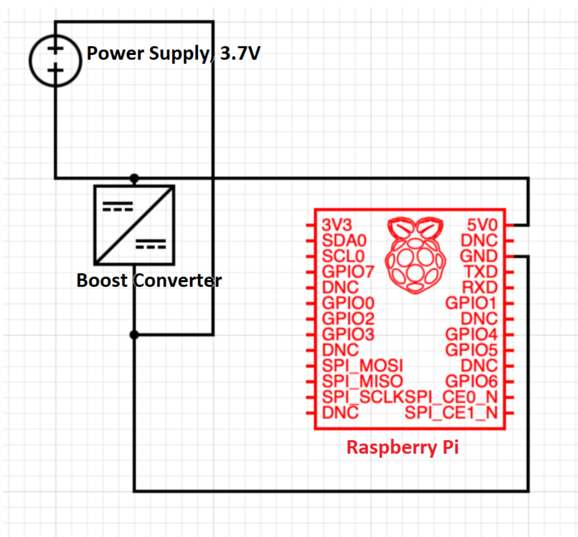

Figure 23 : Schematic for power supply

Appendix B: Test Plan

B.1 Software

Software Component	Test Plan	Pass (P) / Fail (F)	Comments
Image acquisition	Can it capture images? Are they clear?		
Image recognition(Angle)	Text in the image has an angle. Can it be recognized correctly?		
Image recognition(Distance)	Text is far away or too close. Can it be recognized correctly? What are the limits?		
Next/Previous command	Can the program fetch next/previous “n” characters? Go back and forth. Go till the beginning and end.		
Play/Pause	Send pause then play commands. Check the internal state. It should be preserved.		
Audio	Check if the text can be correctly transformed into speech.		
Help	Press a random button, call the help function and check if the information is correct.		
Bluetooth	Send audio data to a bluetooth speaker.		
Battery	Read battery life with software algorithms and compare it with physical testing equipment.		
Braille mode/Speaker mode	Turn braille mode on and check if the output is in braille. Switch between speaker and braille mode.		

USB read	Connect a USB. Check directory and file names. Choose a filename, check contents by directing it to stdout.		
Image recognition(Boundary)	Image has boundaries, can it be segmented correctly?		

Table 16 - Test Plan for Software

B.2 Hardware

Hardware Component	**Test Plan**	**Pass (P) / Fail (F)**	**Comments**
Processing Unit	Do control signals of the circuit board can be sent/received correctly by input/output devices?		
Optical Image Device	Does the camera adjust focus length when acquiring an image? Is the image quantity appropriate for further processing?		
Audio Feedback Device	Is the sound quality from the speaker audible?		
User input buttons	Do the outputs from the speaker reflect the press of buttons?		
Power Supply and Battery	Is the capacity enough to power all components?		
Braille Actuators	Do actuators stay at a reasonable temperature?		
Braille Actuators	Do actuators return or stay at their original position (raised or flat) when tactile pressure is applied to them?		

Braille Actuators	Do the Braille dots raise when the 32-Pin Braille Module is powered up with appropriate inputs such as DATA_IN, DATA_OUT, CLOCK, ENABLE?		
Braille Actuators (Backup Prototype)	Do actuators raise when wired in parallel?		
Step up Converter	Does the Converter properly output 200V?		
Braille Logic Controller	Does the circuit or motor controller output the appropriate when it is TRUE and none when it is FALSE?		
Housing/Casing	Does the housing fit electronics?		
Housing/Casing	Is the Braille pin raised 6.1mm to 7.6mm above the surface of the housing?		
Housing/Casing	Is the Braille pin leveled or below the housing when retracted?		

Table 17 - Test Plan for Hardware

Appendix C: User Interface

C.1 Introduction

The development team for Braillingo strives to accomplish a product that offers a simple ,user friendly and less complicated user interface so as to be operated with minimum effort and basic understanding of the product.On our priorities list for interaction between the user and the product is to ensure user safety, comfort and user accessibility. Braillingo is mainly designed to be operated and used by a visually impared person and will be designed accordingly.

C.1.1 Purpose

The purpose of this document is to provide the description and purpose of Braillingo at all theoretical levels.This document will provide reasoning for the critical design elements that will be taken into consideration that will enable Brailling to become as user friendly and as efficient as possible.

C.1.2 Scope

The scope of this document will cover the 5 important topics of UI design process

- User Analysis
  This section will describe the basic knowledge the user will be required to have and their prior experience with similar devices or systems.

- Technical Analysis
  This aspect of the document will describe how the design process takes the important seven elements of User Interaction into account for Braillingo.

- Engineering Standard
  Here the document will describe the various engineering standards that will be taken into account in relevance to the user, the device and overall system.

- Analytical Usability Testing.
  The analytical usability testing section will detail the series of testing Braillingo will undergo to enhance and correct any possible bugs, issues or inconvenience from an analytical perspective.

- Empirical usability Testing
  This part of the document will address safe and reliable use of the device by eliminating or minimizing errors and possible risk associated with the device.It will also describe further testing on future implementations.

C.2 User Analysis

Penta Solutions is making Braillingo with user convenience in mind. The device does not require any prior experience as it is designed to be intuitive and accessible for all potential users. As the customers of the device are visually impaired people, each function of Braillingo can be understood through tactile indicators such as braille subscriptions under every button. The user manual for Braillingo will be done on Braille paper and go together with the device.

Required Knowledge

Being a translation device, Braillingo works with languages and writing systems. It uses Braille as an output writing system as it is used worldwide and known by a big percentage of visually impaired people. English is used as an input language. Therefore, users are required to know both English and Braille to use the device.

Physical abilities

- Braillingo is a fragile device that, when used, is held in hands. Users should be able to ensure its safety by having a strong enough grip and avoid dropping.

- The device has an option of voiceover of the captured text. In order to use this feature, users need to have a good hearing condition. However, hearing is not required to use the Braille output feature or text capture.

- The device is designed to be used by visually impaired people without any help. Therefore, good eye sight is not a requirement to use Braillingo.

Experience with similar products

Our team considered user experience with similar products such as refreshable braille display for e-books. This product is safe and very easy to use, therefore there are very few restrictions on potential users. Braille displays are widely used to teach young children to use Braille even during preschool years. Children before the age of 9 should be supervised by adults [16].

C.2.1 Technical Analysis

C.2.1.1 Graphical Presentation of UI

Braillingo consists of a mostly physical user interface tailored to the visually impaired. The Solidworks CAD models were created to better visualize the UI and can be viewed in the upcoming sections. N=8 Braille cells were assumed for the Solidworks model.

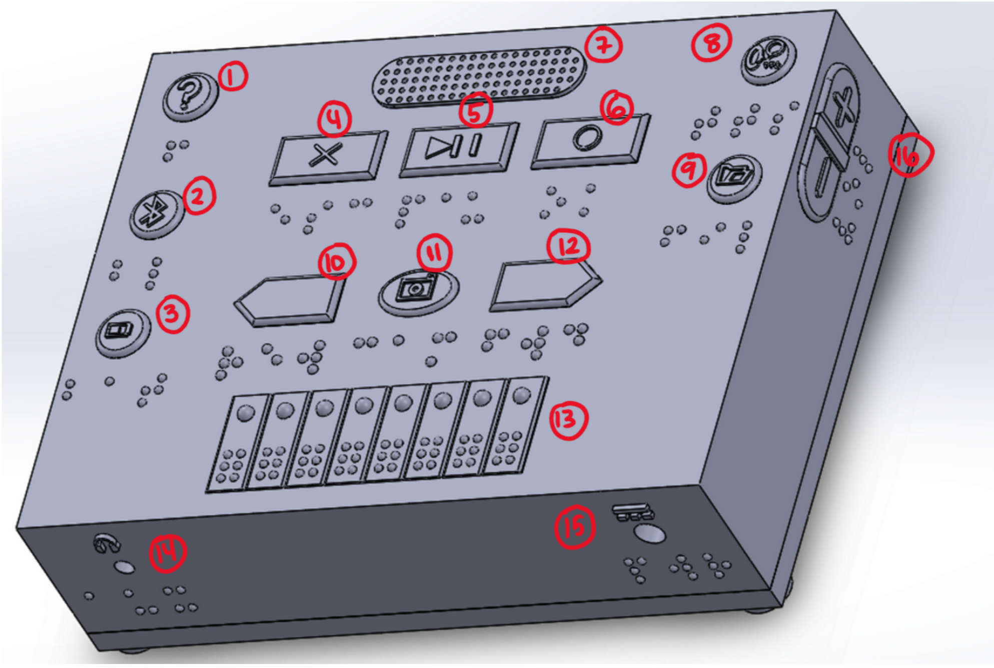

Figure 24 - Braillingo Top, Front, and Right view with numbering.

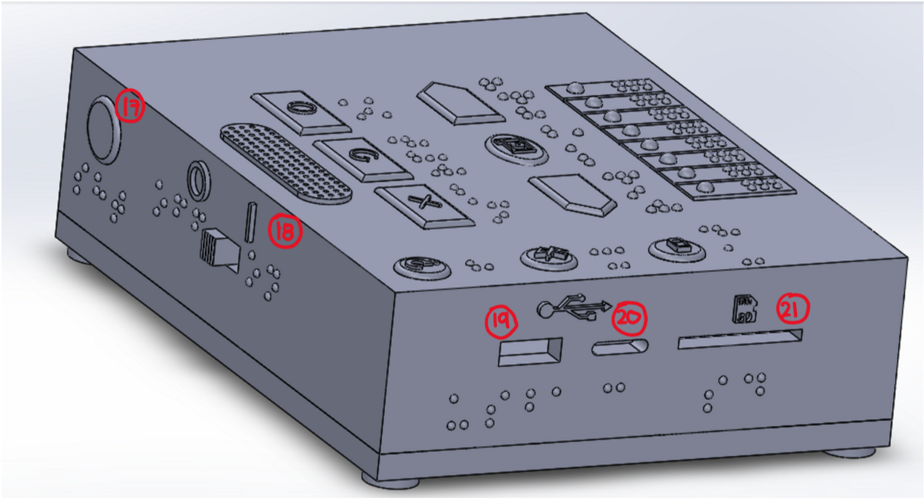

Figure 25 - Braillingo Top, Back, and Left view with numbering.

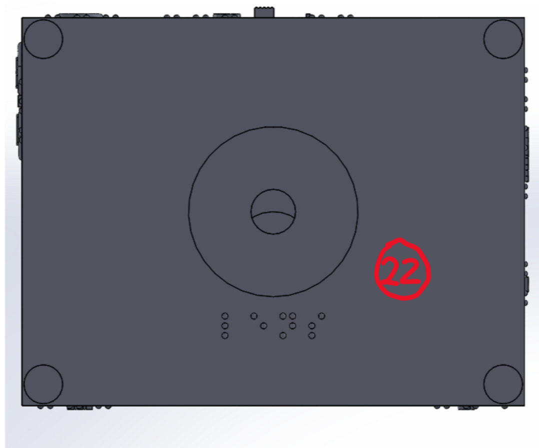

Figure 26- Braillingo Bottom with numbering.

Cad Model Numbering Legend for Figure 24, 25, and 26

1) Help Button (**?** ⠦)
2) Bluetooth Button (**BL** ⠃⠇)
3) Battery Button (**BAT** ⠃⠁⠞)
4) Cancel/Escape Button (**ESC** ⠑⠎⠉)
5) Pause/Play Button (**PAU** ⠏⠁⠥)
6) OK/Accept Button (**OK** ⠕⠅)
7) Speaker
8) Text to Speech Button (**TTS** ⠞⠞⠎)
9) Read File Button (**FIL** ⠋⠊⠇)
10) Rewind/Left Button (**REW** ⠗⠑⠺)
11) Camera Button (**CAM** ⠉⠁⠍)
12) Forward/Right Button (**FWD** ⠋⠺⠙)
13) N number of Braille cells
14) Auxiliary Port (**AUX** ⠁⠥⠭)
15) DC Power Port (**PWR** ⠏⠺⠗)
16) Volume (**VOL** ⠧⠕⠇)
    a) Volume Up Button (**+**)
    b) Volume Down Button (**-**)
17) Shutter/Capture Button (**SHT** ⠎⠓⠞)
18) Off/On Switch (**OFF** ⠕⠋⠋ and **ON** ⠕⠝)
19) USB-A Port (**USBA** ⠥⠎⠃⠁)
20) USB-C Port (**C** ⠉)
21) SD Card Ports (**SD** ⠎⠙)
22) Camera Lens (**LENS** ⠇⠑⠝⠎)

C.2.1.2 Seven Elements of UI Interaction

C.2.1.2.1 Discoverability

Discoverability focuses on allowing the user to determine what actions are possible and the current state of the device. Braillingo's current state of the device will be notified to the user through audio output through it speakers (Figure 24, #7) and Braille messages on the Braille cells (Figure 24, #13).

When powering the device on, the Braille pins will all go up and down to indicate to the user that it has successfully powered on and is accompanied by an audio message indicating that the device turned on.

When the device arrives at a state, it indicates its current state and possible actions to be performed with an audio message in the following form:

"(Description of current state). (Actions that can be performed)."

For example, "Awaiting user input. Scan new text with CAM or load a file with FIL". Should the user miss the audio above audio output, the user can press the Help button (Figure 24, #1) and follow instructions to repeat the most recent audio messages related to the device's state.

C.2.1.2.2 Feedback

Feedback aims to have the user have full and continuous information and results of the current state of the device and actions. In addition, the user should be able to easily determine the resulting new state after actions are performed by either the user or device. After the user presses buttons to input the next action, audio output and Braille messages will tell the user the action that was just performed, and the result of the action, which is then continued by informing the user of the actions that can be performed. Similar to Discovery, the most recent audio messages can be repeated using the Help button (Figure 24, #1) and will output the message in the following form:

"(Action performed). (Description of current state). (Actions that can be performed)"

For example, if the user pressed the Forward button (Figure 24, #12) when the end of the text is reached, the message will be "Forward Pressed. End of Line on current text scanned. Scan the next page with CAM or load a file with FIL"

C.2.1.2.3 Conceptual Models

The conceptual model of the device is related to the user's feelings of control with the device and also relates to Discoverability. For ease of use, Braillingo's UI follows some familiar conventions in terms of placement of a few user input buttons. In addition, the placement of other inputs were assigned at particular locations with the convenience of the user in mind.

Braillingo's UI was inspired from a smartphone placed on a surface with its screen face up. The main control panel of Braillingo, which has most of the input buttons, was placed on top of the device, similar to the screen of a phone. Just like a lot of smartphones, which is familiar to a lot of people, the auxiliary/audio jack (Figure 24, #15) and the charging/power port (Figure 24, #14) is perpendicular to the main control panel, facing the user. It was also chosen to be at the front so that the user can still easily grip the device to take photos when charging the device. In addition, in a lot of smartphones, the volume buttons (Figure 24, #16) are placed on sides perpendicular to the main control panel. This convention was also followed on Braillingo where the button to decrease the volume was located closer to the side with auxiliary and power ports and the button to increase the button was located further.

Because the camera is on the bottom of the device, (Figure 26, #22) the user has to lift the device in order for the device to capture a picture. The device can be held like a typical photographic camera on its left and right side with the user’s hands. Just like a typical photographic camera, the user can use their right index finger to capture the photo with the shutter/capture button on the back of the device (Figure 25, #17).

The external storage inputs were placed on the left side of the device. When both USBs are plugged in, USB-A (Figure 25, #19) and USB-C (Figure 25, #20), the user will not be able to hold that area as easily compared to when none are connected. It was decided that if the user chooses to read inputted text files, they are likely not to take pictures of physical text and have the device laid down on the surface at normal orientation, so holding the camera would likely not be an issue.

C.2.1.2.4 Affordances

Affordance is the device’s ability to make desired actions possible. The affordance of Braillingo is provided by various input buttons, various input ports, slider switch for power, and Braille cells as displayed on Figures 24, 24, and 25. All provided affordances are labeled with appropriate signifiers.

C.2.1.2.5 Signifiers

Signifiers ensure discoverability and that feedback is well communicated and intelligible. For Braillingo, the input buttons have corresponding abbreviated labels in Braille and have raised graphical icons. The graphical icons are also indicators for sighted people who are assisting visually impaired people in using the device. All abbreviated labels use lower case Braille characters to save space as adding a capitalization indicator in braille is an extra braille character on its own. For example, the SD Card input (Figure 25, #21) has a raised SD card “graphical” icon above the port and “sd” (lower caps) in braille, ⠎⠙ beneath the port

C.2.1.2.6 Mappings

Mappings are the relationships between controls and their actions. For Braillingo, each button’s Braille abbreviation is very close to the button. All buttons and ports have their corresponding signifiers below them. The signifiers are below the buttons and ports because in the case of the user interacting with the top of the device to read the Braille output on Figure 24, the user’s hands are coming from the front of the device, the fingers would read the Braille signifier first with their fingers prior to feeling the button. The only exception is that The Off/On switch is a slider, as displayed on Figure 25 (18) and has the Off and On Braille on the next to corresponding sides of the switch.

C.2.1.2.7 Constraints

Constraints tailors the device's possible actions, capabilities, and appearance. Constraints can be physical, logical, semantic, and cultural. In the case of Braillingo, the user interface is physical, as opposed to software, as users are visually impaired. The device's size is constrained to our requirement to make the device portable. In addition, the size constrains the number of buttons available on each side of the device. The input buttons and Braille signifiers are laid out in a way such that the Braille dimensions (i.e. spacing of dots and cells from each other, size of dot, and dot height) are restricted to the North America's Standards for Braille Signage [17] and such that the Braille words are the are distanced appropriately from the other words for the buttons to be distinguishable.

C.2.2 Sustainability and Safety

Penta Solutions aims and tries to make sure safety and sustainability standards are met and maintained for Braillingo. We also plan to use material that can be easily recycled such as using PLA for 3D printing the case for the braille. The table below shows some of the safety and sustainability requirements Braillingo must meet

Requirement ID	Requirement description
Req S.1	The device casing should be solid, strong and not easy to damage or break.
Req S.2	The device must be waterproof and insulated, as all circuitry needs to be covered to prevent user electrocution.
Req S.3	The battery should be rechargeable to reduce battery waste.
Req S.4	The device should avoid improper component and wiring size, and overloading circuits that can smoke and fire.
Req S.5	The device case should be 3D printed using PLA so it can be recycled.
Req S.6	The device should shut down in case of overheating.
Req S.7	The device should meet the minimum operating temperature ranges for electronic devices.

C.3 Testing and Verification

C.3.1 Empirical Usability Testing

This section will describe the tests that will be performed by the intended user of this product. The tests are aimed at users with a certain level of knowledge and skill for reading braille. After performing the tests, the user will provide verbal feedback so as to provide crucial aspects of the design and comment on aspects that can be improved.

User Analysis 1: Assessing the user interface and physical design.

- Were there any sharp edges or corners that can be dangerous while feeling the product?
- Are the printed braille near the control buttons easy to interpret?
- Was the product too heavy to hold up while taking pictures?
- Was loading the electronic copy of the book/pdf easy or cumbersome?

User Analysis 2: Checking control buttons and the braille and turning the device on.

- Is the braille cell easy to identify and interpret?
- Is the braille unit able to withstand the pressure from your fingers?
- Was the power button easy to find on the product?
- On turning on the power was there feedback/ notification from the speaker letting you know that the device turned on?

User Analysis 3: Assessing the features of the product and performing

- Were the feature related buttons easy to identify and use from the product?
- On using the camera capture button, do you hear the notification from the speaker?
- When the picture isn’t in focus, does the product inform you about that?
- On using wired or wireless options for output such as bluetooth headphone or plug in earphones, can you hear the speech clearly ?
- Were you able to easily move forward and backwards along the text while having the correct output on the braille cell?

User Analysis 4: Assessing the location of the port and battery in the device.

- Do you feel that the device heats up ?
- Are the location of the charging cable and AUX port ideal?

C.3.2 Analytical Usability Testing

The main design goal for Penta Solutions is to make the device comfortable and intuitive in usage. As we are working with visually impaired users, it is important to make Braillingo easy to understand by touch. Our team is going to perform a series of tests to determine the best design option for Braillingo. We hope testing will help us to find potential flaws in our design and fix them in the early stage of development. The tests for software and hardware components are listed below.

C.3.2.1 Software

Software will output a response to user actions in the form of both voice and Braille to convey system messages.

1. Messages should be outputted at a correct time, without any interruptions.

2. Word choice for all messages should be very clear and easily understandable.
3. Voice messages should have a clear and pleasant sound.

C.3.2.2 Hardware

In this section, the hardware components and their usabilities will be demonstrated:

1. Control buttons are designed on 5 different surfaces of the device, and there are 12 buttons, with corresponding braille cells designed and printed in the adjacent area.
2. Once the help button is pressed, the speaker should produce a vocal sound “Help” to indicate the behavior.
3. Once the Bluetooth button is pressed, the speaker should produce a vocal sound “Bluetooth mode” to indicate the function is activated, and can be tested from bluetooth devices such wireless speakers or wireless headphone.
4. Once the battery button is pressed, a vocal output from the speaker should notify the user on the battery level.
5. Once the Cancel/Escape button is pressed, the speaker should produce a vocal sound “cancel” to abort the ongoing process.
6. Once the Pause/Play button is pressed, if it’s in the process of reading, the speaker should produce a vocal sound “Pause” and braille cells and readout of text will stop. Users can resume reading by pressing the “Play” button and the speaker will produce a vocal sound “Play” to indicate a resume of reading.
7. Once the OK/Accept button is pressed, the speaker should produce a vocal sound “Accept” to approve the request of ongoing behavior.
8. Once the Text to speech button is pressed, if the current mode is text mode, the speaker should produce a vocal sound “Speech mode is activated” and output text by sound. If the current mode is speech mode,the speaker should produce a vocal sound “Braille mode is activated” and output text by refreshable braille cells.
9. Once the Read File button is pressed, a previously loaded file in the device starts to be present in braille or speech depending on the mode chosen by the user.
10. Once the Rewind/Left button is pressed, the speaker should produce a vocal sound “rewind” and reset the reading on the previous word.
11. Once the Forward/Right button is pressed, the speaker should produce a vocal sound “forward” and push the reading on the next word.
12. Once the Volume control buttons are pressed, the speaking should produce a vocal beeping sound to indicate the current volume.
13. Once the camera button is pressed, the device should be ready in Camera mode ready to take the picture.
14. Once the shutter/capture button is pressed, the device should take the picture of the book in focus.

C.3.3 Engineering Standards

C.3.3.1 Device's Functions

Penta Solutions will adhere to the following key engineering standards that apply to Braillingo and that are well known industry wise.

1.**IEEE 1219-1998**
IEEE Standard for Software Maintenance
The process for managing and executing software maintenance activities is described. [18]

2. **ANSI C 18.2M 1991**
Portable Rechargeable Cells & Batteries
As prolific and reachable products, portable rechargeable cells and batteries benefit from the clear identification of standard specifications and guidance. [19]

3.**IEEE 829-1983**
IEEE Standard for Software Test Documentation
A document describing the scope, approach, resources, and schedule of intended testing activities. It identifies test items, the features to be tested, the testing tasks, who will do each task, and any risks requiring contingency planning. [20]

4.**IEC 61508**
Documentation that covers those aspects to be considered when electrical/electronic/programmable electronic (E/E/PE) systems are used to carry out safety functions. [21]

5.***ISO/IEC/IEEE* 15288:2015**
It defines a set of processes and associated terminology from an engineering viewpoint. These processes can be applied at any level in the hierarchy of a system's structure. Selected sets of these processes can be applied throughout the life cycle for managing and performing the stages of a system's life cycle. This is accomplished through the involvement of all stakeholders, with the ultimate goal of achieving customer satisfaction. [22]

C.3.3.2 User-Device Interaction

Penta Solutions will adhere to the following key engineering standards that apply to the user-device interaction.

1.**ISO 9241-210:2010**
Ergonomics of human-system interaction
Provides requirements and recommendations for human-centered design principles and activities throughout the life cycle of computer-based interactive systems. [23]

2. **IEEE 1063-2001**
IEEE Standard for Software User Documentation
Minimum requirements for the structure, information content, and format of user documentation, including both printed and electronic documents used in the work environment by users of systems containing software, are provided in this standard. [24]

3**. ISO 20282**
Provides requirements and recommendations for the design of easy-to-operate everyday products, where ease of operation addresses a subset of the concept of usability concerned with the user interface by taking account of the relevant user characteristics and the context of use. [25]

4.**ISO/IEC JTC 1/SC 35 Scope**
Standardization in the field of user-system interfaces in information and communication technology (ICT) environments and support for these interfaces to serve all users, including people having accessibility or other specific needs, with a priority of meeting the JTC 1 requirements for cultural and linguistic adaptability. [26]

5.**Z323.3.1-1982 (R2008)**
Electrical Aids for Physically Disabled Persons
This Standard applies to electrical aids intended to be used by physically disabled persons to facilitate their ability to communicate with others, alter the state of their environment, and to position themselves. [27]

C.4 Conclusion

The design of the user interface requires crucial information and input from the user to make the product as user friendly and safe for them to use. During the design and execution stage many times the micro details from the users perspective might be overlooked simply because of unequal knowledge or skills, hence making the operation of the product much more difficult. On this note, clear surveys have been sent out to the Center of Accessible Learning at Simon Fraser University to the predicted users of the product so as to understand their needs and level of comfortability with reading braille.While designing braillingo the users language, knowledge a dn skill regarding braille has to be taken into consideration. On completion of Braillingo, Penta solutions aims to provide a demo of the product to the user to get reliable feedback and make necessary changes accordingly. Penta Solutions plans to meet the user requirements and create an intuitive, simple, interactive and user friendly user interface.