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EGTactile
Braille Display Device

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Abstract

The Braille alphabet is an important tool that allows visually impaired people to live as comfortably as those with normal vision. As a result, new applications based on the Braille alphabet are being created.

In this study, a new Refreshable Braille Display was developed to help visually impaired individuals learn the Braille alphabet easier and take notes. By mechanically moving pins to form the tactile dots of Braille, text, and voice, the output was capable of representing each letter of the alphabet in Braille.

Piezoelectric braille cells, electromagnetic mechanisms, push-pull solenoids, gear mechanisms, brushless DC motors, Geneva wheel mechanisms, shape memory alloys, and CD-ROM stepper motors were among the technologies studied and tested for usage.

Each had pros and cons, which the case required examination. The interface pins were controlled by a Raspberry-pi based microcontroller with shift registers.

In addition to serving as a Braille learning tool, the developed Refreshable Braille Display also functions as a notetaker software system. The system enables visually impaired individuals to take notes in Braille and save them in electronic format.

The notetaker software system was designed to be user-friendly and easy to use. It features a Braille keypad for inputting text, and users can navigate through menus and options using simple commands. The system is also equipped with a text-to-speech feature that can read out the notes to the user.

Additionally, notes can be organized into folders and accessed later for review or editing. Basic input features like next and previous had

to be added for the Braille learning device to function as a teaching tool and interact with the other parts.

Acknowledgement

We would like to thank our supervisors for making a significant effort to assist us, for their ongoing assistance, and for everything they provided us during this process.

First and foremost, we would like to thank **Dr. Randa Mohammed** for the opportunity to work with her; she is always supportive and present if we require assistance with the project; she provided us with helpful notes; and she is concerned about how we represent something beneficial; we hope to have made her proud.

We'd also want to thank our **TA. Ahmed Darwish**, for his remarks and encouragement.

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We would like to offer our heartfelt gratitude to **ODC** "Orange Digital Centre" for their constant support and direction throughout our project; their expertise, knowledge, and useful insights have been critical to our project's success, and we are sincerely grateful for their efforts. We appreciate their efforts in providing us with the materials and assistance we require to complete our business properly. We would like to thank **Dr. Randa** and the **ODC** for their tremendous assistance and contributions to our project.

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Chapter 1
Introduction

1.1 Problem Definition

Blind and visually impaired individuals face significant challenges when it comes to accessing digital information, which can severely impact their quality of life and independence. While various technologies exist to help overcome these challenges, they are often expensive and not accessible to a large portion of the visually impaired population.

The high cost of Braille display devices is one such barrier. Braille displays are devices that allow blind individuals to read digital text by translating it into Braille characters. While these devices are effective, they can cost thousands of dollars, making them unaffordable for many people. This lack of affordability limits the ability of visually impaired individuals to access and interact with digital information, which can impede their education, employment, and overall quality of life.

Therefore, the problem addressed by this project is the lack of an affordable Braille display device that provides visually impaired individuals with a reliable and effective means of accessing digital information. By developing a low-cost Braille display device, this project aims to break down the financial barriers to access to this technology and improve the quality of life and independence of visually impaired individuals.

1.2 Motivation

A low-cost Braille display device can have a significant impact on the lives of individuals who are visually impaired. Braille is a crucial tool for communication, education, and employment for people who are blind or have low vision. However, traditional Braille display devices can be prohibitively expensive, with prices ranging from several hundred to thousands of dollars.

The development of a low-cost Braille display device has the potential to significantly increase access to Braille for those who may not have been able to afford it in the past. This could lead to improved literacy rates, better job opportunities, and an increased ability to fully participate in society.

In addition, a low-cost Braille display device would also benefit organizations that serve individuals who are visually impaired, as they would be able to purchase more devices and provide them to a larger number of people. This could help bridge the digital divide and reduce the disparities in access to technology between individuals with disabilities and their non-disabled peers.
Overall, the development of a low-cost Braille display device has the potential to greatly improve the quality of life and opportunities for individuals who are blind or have low vision.

1.3 Objective

The objective of this project is to design and develop a low-cost Braille display device that enables blind and visually impaired individuals to access digital information with ease. The device will be portable, lightweight, and easy to use, with a reasonable level of accuracy and reliability. The device will also be affordable to ensure accessibility to a larger number of visually impaired individuals. The device will have the following features:

- User-friendly interface and controls for easy navigation and customization.
- Ability to provide feedback to the user through haptic or auditory means that allow visually impaired users to receive feedback on their interactions with the device, enhancing their user experience.
- Reading from USB: **EG**Tactile has the ability to read data from a USB drive, providing a cost-effective way for users to access digital content on the device.
- Taking notes with braille and save it as txt file.
- Reading braille from braille cells: The device features Braille cells that can be mechanically moved to form tactile dots, allowing visually impaired users to read Braille characters in a cost-effective manner.

To achieve our objective, we will focus on:

- Developing a cost-effective design that utilizes readily available components and materials.
- Ensuring the device is easy to use.
- Conducting thorough testing and user feedback sessions to ensure the final product meets the needs of the target audience.

Overall, the objective of this project is to improve the quality of life and independence of visually impaired individuals by providing them with a low-cost solution for accessing digital text, this is the first generation of this project and others will be manufactured from it in the future.

1.3 Document Organization

- **Chapter 2: Background**
  This chapter includes an introduction to braille display devices, shows a review of some existing braille display devices, the way they work and a brief contrast of the advantages and drawbacks each one has.
- **Chapter 3: Analysis and design**
  This chapter includes the diagrams that declare an overview of the entire system at which how it works and how it is organized along with system architecture and system users.
- **Chapter 4: Experimental results**
  This chapter presents and analyses the experimental results obtained during the research study.
- **Chapter 5: User manual**
  This chapter gives a brief description to the user of how the system works, guidance to the user and the installed applications.
- **Chapter 6: Conclusions and future work**
  This chapter includes the conclusion and the result of the system, problems that had been faced throughout the project and the future to work on improving this system.

Chapter 2
Background

2.1 Previous studies

2.1.1 Braille reading methods

- **Braille paper books**

  Traditional Braille books are printed on paper and have raised dots that can be read with the fingertips.

  One of their ***advantages*** is their simplicity and accessibility. They don’t require any special technology or devices and can be read anywhere and at any time. They are also durable and do not require batteries or electricity.

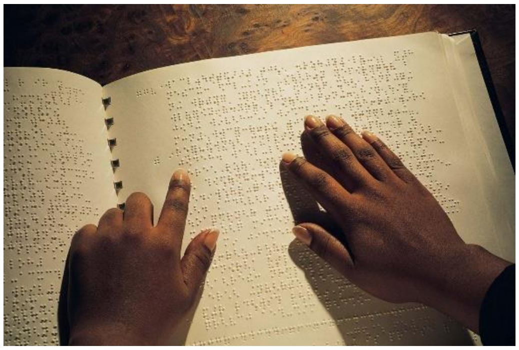


Figure 1_ Braille paper

  However, Braille paper books can be bulky and heavy, particularly for longer texts. They may also be more difficult to produce and distribute than digital formats, which can limit their availability and accessibility.

- **Braille label makers**

  Braille label makers are devices that enable individuals to create Braille labels for various items. They offer ***advantages*** such as accessibility, portability, and efficiency. However, there are also some ***disadvantages***, including high cost, a steep learning curve, maintenance requirements, and limited availability in some areas. Overall, Braille label makers are a useful tool for individuals with visual impairments, but their use may be limited by accessibility and cost considerations.

Figure 2_ Braille label maker

- **Refreshable Braille displays**
  allows blind or visually impaired individuals to read digital text by rendering it into Braille characters that can be felt with the fingertips. The device typically consists of a row of Braille cells, each of which contains a series of pins that can be raised or lowered to form Braille characters.
  They offer ***benefits*** such as portability, versatility, and the ability to display a wide range of languages and character sets. ***However***, they can be expensive and may require some technical expertise to set up and use effectively.

Figure 3_ Braille display device

2.1.2 Braille writing methods

- **Perkins Braille**
  mechanical device used for writing Braille. It was invented by David Abraham Perkins in the early 1950s and has since become one of the most widely used tools for producing Braille. The Perkins Brailler consists of a keyboard with six keys, each of which represents one of the six dots in a Braille cell. When a key is pressed, a metal stylus punches the corresponding dot onto the paper. The paper is fed through the machine, and the user can read the Braille cells by feeling the raised dots with their fingertips. They offer **advantages** such as it produces high-quality Braille that is easy to read and durable. It is also relatively simple and inexpensive compared to electronic Braille writing devices. ***However***, the Perkins Brailler can be loud and bulky, which can make it difficult to use in certain situations. It also requires a certain amount of physical strength, and motor coordination to operate effectively.

Figure 4_Perkins Braille

1. **Perkins SMART Brailler**
   The upgraded version has a video screen and audio feedback that displays and speaks letters and words in real-time as they are brailled, making it easier for people who are unfamiliar with braille to learn. In addition, sighted teachers and parents may see and follow along with what their students and children are brailling.

Figure 5_Perkins SMART Brailler

2. **Next generation Perkins Brailler**
   It is intended to be a more modern and user-friendly replacement for traditional Perkins Braillers. It is based on a standard brailler, so it performs the same functions but is smaller and lighter. This makes it easier for brailler users to carry and use. There're some ***disadvantages*** to consider, such as the higher cost, learning curve, and risk of electronic component damage.

Figure 6_Next Generation Perkins Brailler

- **Slate and stylus**
  Handheld device used for manually writing Braille. It is a low-tech alternative to mechanical or electronic Braille writers and is often used in situations where other devices are not available or practical. The Slate and stylus consist of two parts: a slate and a stylus. The slate is a flat metal plate with rectangular openings that hold the paper in place, while the stylus is a pointed tool that is used to press dots into the paper through the openings in the slate. The user places the paper on the slate, inserts the stylus into the openings, and presses down to create the dots that form Braille letters and words. One of its ***advantages*** is that it is lightweight, portable, and requires no electricity or batteries to

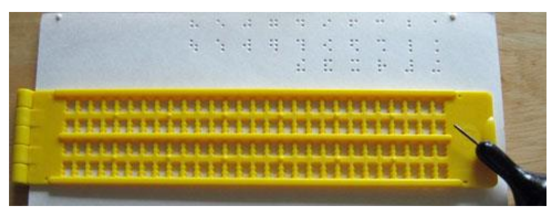


Figure 7_Slate and stylus

operate. It is also relatively inexpensive compared to other Braille writing devices and can be easily replaced if lost or damaged.

However, it can be slow and may require a high degree of accuracy and precision to produce readable Braille.

- **Braille notetaker**

Figure 8_Braille notetaker

portable electronic device that allows blind or visually impaired individuals to take notes, write documents, and access digital content using Braille. The device usually contains a Braille keyboard for input, as well as a refreshable Braille display for output. It may also have additional features such as a speech synthesizer for audio output, a microphone for recording voice notes, and a variety of connectivity options such as USB, Bluetooth, and Wi-Fi. Some of its ***benefits*** of Braille notetakers include their portability, ease of use, and ability to provide access to digital content in Braille. They can also be used to take notes in Braille during meetings or lectures, which can be later translated to text or speech for others to understand. **However**, Braille notetakers can be expensive and may require some technical expertise to set up and use effectively.

2.2 Related H/W used for Braille cell mechanism

how to build a braille cell There are too many mechanisms to build it, so the following sections examine discuss implementations.

1. **Piezoelectric braille cell**

   Figure 41 & **Figure 42** depict a "**piezo braille cell**" that will enable us to develop an efficient device like the Chameleon 20. This braille cell costs "**128.00 euros per piece**".

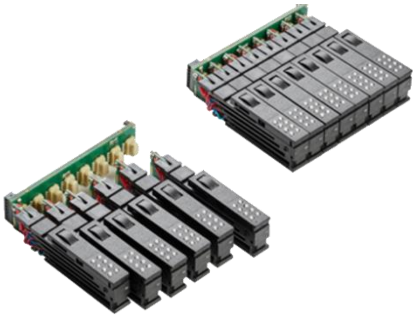


Figure 9_ piezo braille cell with "multi characters preview"

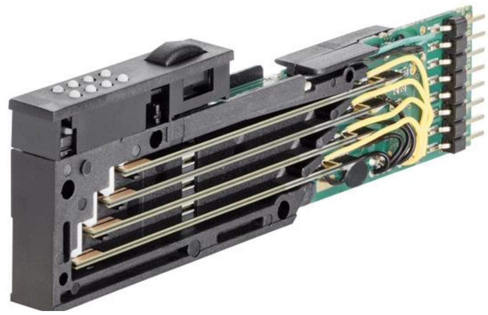


Figure 10_ piezo braille cell

2. **Electromagnetic mechanism(coil)**

   3D printed rod with metallic/magnetic inside, copper coil wrapped around it to generate magnetic field into the center of it, magnetic field formed inside the coil impacts the rod, forcing it to move up when there is a current.

   Advantages:

   - Simulate piezoelectric braille cell mechanism.

   Disadvantages:

   - The magnetic field can cause the coil rod to heat up.
   - Magnetic fields can interfere.
   - Increase the cost dependent on the number of practical experiments conducted.

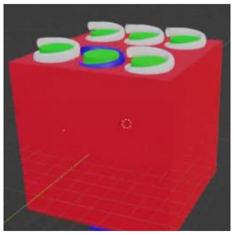


Figure 11_3D View of braille cell (Electromagnetic mechanism)

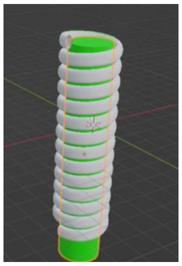


Figure 13_rod without current

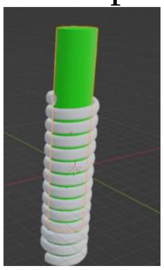


Figure 12__rod with current

3. **Push-pull solenoid**

converts electrical energy into mechanical motion

Advantages:

- High efficiency (ex. Response time)
- Simple design

Figure 14_Push-pull solenoid

Disadvantages:

- Cost (225 EGP/piece)
- High power consumption (4.5v, 600 mA)
- Small size isn't available.

Cost increase according to (size, Force / Stroke)

4. **Gear**

Simple mechanism by rotating.

Advantages:

- Reduce complexity.
- Reduce the cost of the device.

Disadvantages:

- Large size

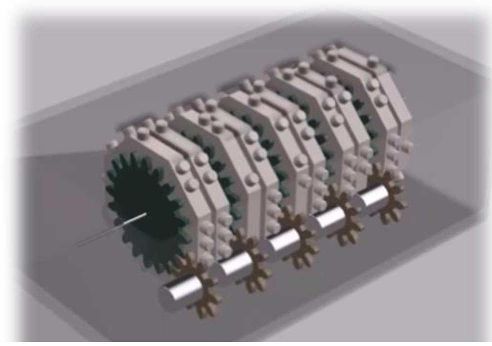


Figure 15_Gear mechanism

5. **Geneva wheel**

It'll be attached with 3D part containing braille dots.

Advantages:

- Smooth motion
- The least expensive of all intermittent motion mechanisms.
- Less power consumption

Figure 16_Geneva wheel mechanism

Disadvantages:

- Need more time to study motion mechanism and test it.
- Mistake in choosing size of gears may make it has large size.
- No feedback from DC motor, so we can't judge accuracy.

6. **Flexinol muscle wire**

   Metal wire that shortens in length when electrically powered.

   Advantages:

   1. Smaller size than motors.
   2. Light weight
   3. Low power
   4. Direct linear action.

   Disadvantages:

   Misuse may cause overheating, reducing lifetime or damaging the wire.

Figure 17_Flexinol muscle wire

Chapter 3
Analysis and design

3.1 System Requirements

3.1.1 Functional requirements

- Writing mode
  - Take notes with braille buttons from user, convert it to text with its algorithm and save it as characters in txt file.
  - Edit text files during writing using (backspace, space), there's audio feedback that help the user knew what he writes.
- Reading mode
  - Read from USB, choose which PDF you need to read to parsing it to txt file and finally convert text to braille.
  - Read braille from braille cells which will display text converted from the step before.
  - Read text files with "Text to speech."
- Simple implemented file system that can:
  1. Rename files or directories in device memory.
  2. Add a new txt file.
  3. Remove file / folder.
  4. Search for specific file/folder
- Learning mode

  Every character you enter in braille will be heard.

3.1.2 Non-functional requirements

1. *Usability*: easy to use and navigate, with clear and intuitive controls and feedback mechanisms.
2. *Portability*: It's lightweight and portable.
3. *Performance*: It's able to display Braille characters accurately with minimal latency or errors.

3.2 System Architecture

The system architecture designed for this device is shown in **figure 17.**

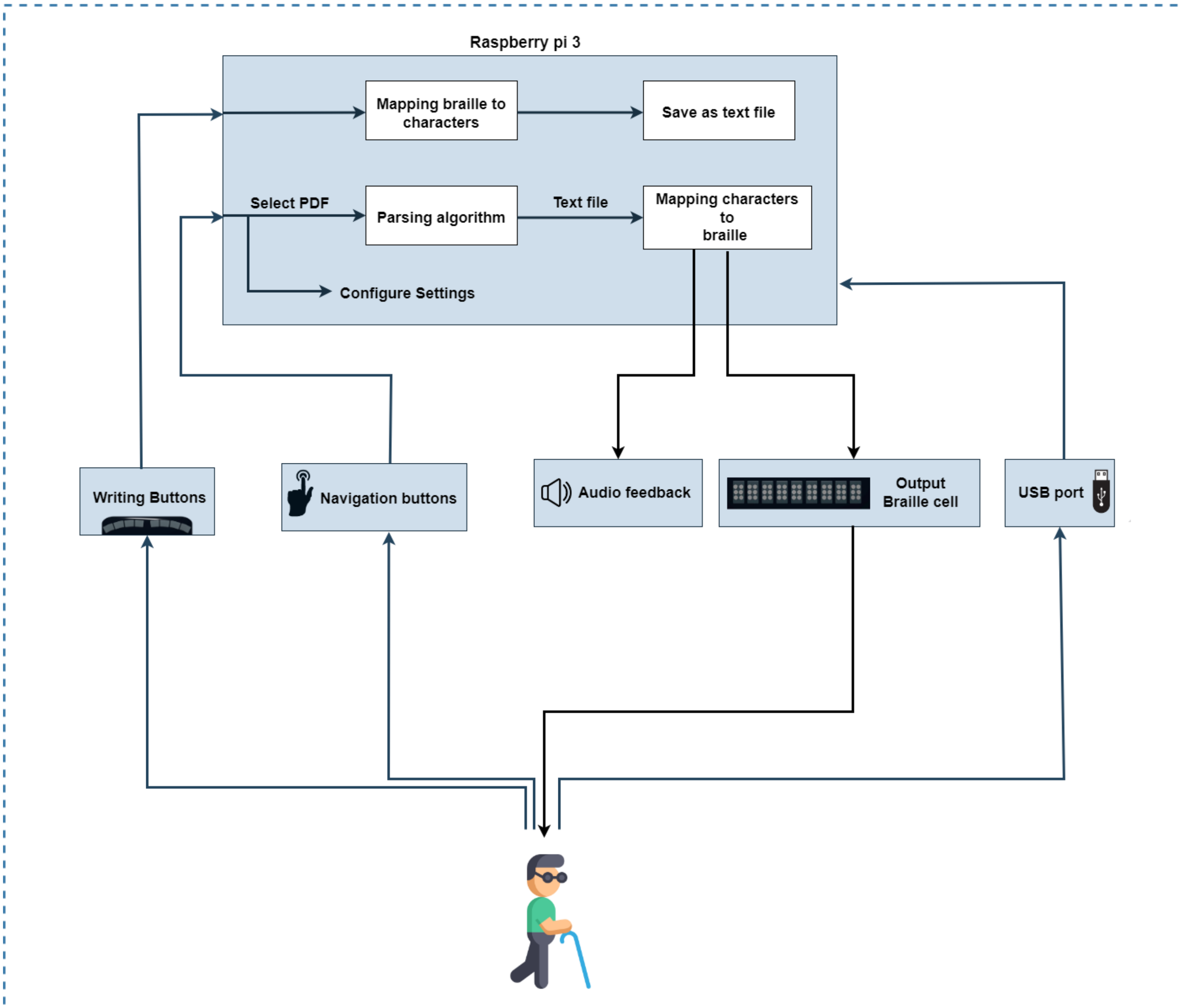


Figure 18_System architecture

3.3 Hardware Components

- **Raspberry Pi 3 model b+**

It boasts a 64-bit quad core processor running at 1.4GHz, 5GHz wireless LAN, Bluetooth 4.2/BLE, and faster Ethernet.

Raspberry Pi 4 Specs needed in this project:

Figure 19_ Raspberry Pi 3 model b+

Processor	Broadcom BCM2837B0, Cortex-A53 64-bit SoC 1.4GHz
Memory	4GB
Connectivity	1. 2.4GHz and 5GHz IEEE 802.11.b/g/n/ac wireless LAN, Bluetooth 4.2, BLE 2. Gigabit Ethernet over USB 2.0 (maximum throughput 300Mbps) 3. 4 × USB 2.0 ports
Access	Extended 40-pin GPIO header
Video& sound	1 × full size HDMI
SD card support	Micro SD format for loading operating system and data storage
Input power	1. 5V/2.5A DC via micro-USB connector 2. 5V DC via GPIO header
Environment	Operating temperature, 0–50°C

Overall, the Raspberry Pi 3 Model B+ is a robust platform for developing and building a Braille display device, with a variety of connections and I/O choices that make it simple to combine with other devices and networks.

This project's first version does not require all of these specifications; but, for future work, you will require them.

▪ CD-ROM stepper motor

Figure 20_CD-ROM stepper motor

A CD-ROM stepper motor (from laptops) can be used in a Braille display device project for several reasons:

1. ***Precise Control:***
   provide precise control over the movement of the motor shaft, allowing for accurate positioning of the Braille pins in the display.
2. ***Low Cost:***
   They are low-cost, making them a cost-effective solution.
3. ***Compact Size:***
   They are small and lightweight, making them easy to integrate into a compact Braille display device.
4. ***Low Power Consumption:***
   Stepper motors consume very little power, which is important for portable devices like Braille displays that need to operate on battery power.
5. ***Easy to Control:***
   Stepper motors are easy to control using microcontrollers or other embedded systems.

Overall, a CD-ROM stepper motor can provide an efficient and cost-effective solution for driving the Braille pins in a Braille display device, while providing precise control and low power consumption.

- **Inverter SN74HC04D**
  To reduce the number of pins needed in half.

Figure 21_Inverter SN74HC04D

- **L293D Motor Driver**
  1. ***Motor Control***
  2. ***Bi-Directional Control***
  3. ***Low Cost***

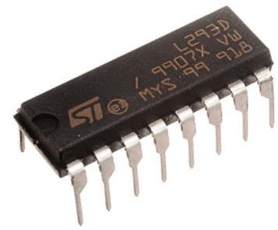


Figure 22_L293D Motor Driver

- **Buttons**
  - Navigation buttons
  - Control buttons
  - Writing buttons

Figure 23_Buttons

- **Resistors (10k Ω) & Capacitors (100 nF)**

- **Heat sink**
  Electronic devices generate heat during operation, and excessive heat can cause damage to the device or even permanent failure. The heat sink helps to remove this heat by providing a larger surface area for the heat to transfer to the surrounding environment.

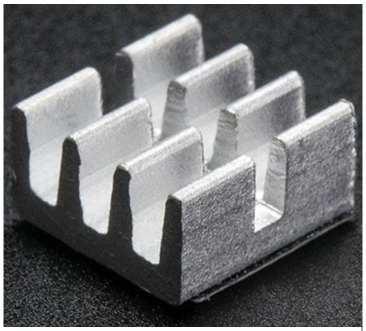


Figure 24_Heat sink

Chapter 4
Experimental results

4.1 Reading Process

4.1.1 Choose braille cell mechanism.

1. **Micro Brushless Dc Motor**

Every dot has 1 motor.

Advantages:

- Small size (7mm X 20mm)
- High speed (18000 Rpm)

Figure 25_Micro Brushless Dc Motor

Disadvantages:

- Its small size makes it hard to implement 3D printing part.

With increasing the number of dots

- Approving scalability will be hard.
- Cost increase

Figure 26_ 3D design for braille dot with DC brushless motors

2. **Flexinol muscle wire**

Many 3D designs for braille cells were designed and evaluated.

1) **Lever system**

In a lever system using flexinol muscle wire, the wire is attached to a lever that is connected to a pin or dot in the braille cell. When an electrical current is applied to the wire, it undergoes a change in shape, causing the lever to move and the pin or dot to be raised or lowered. When the current is re moved, the wire returns to its original shape, causing the pin or dot to return to its original position.

Advantages:

1) ***Low power consumption:*** Flexinol muscle wire requires very low power consumption which makes it ideal for portable and battery-powered devices.

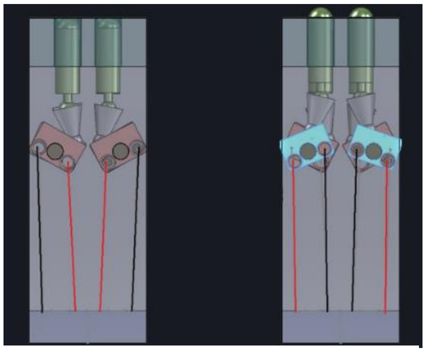


Figure 27_Lever system 3D design

2) ***Lightweight***

Limitations:

1) Limited force
2) The complexity of the 3D design to implement (as we are new to 3D design)

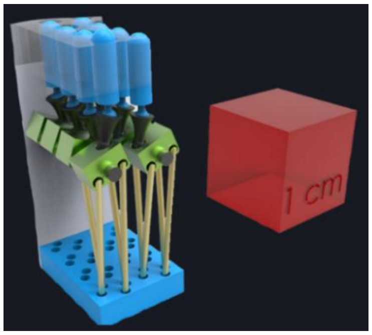


Figure 28_Lever system 3D design expected size.

3. **Click pen mechanism.**

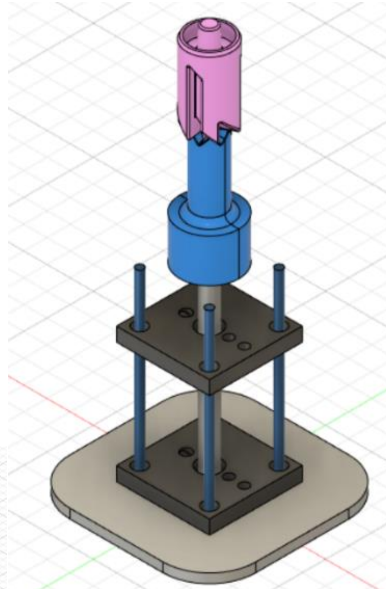


Figure 29_click pen mechanism 3D design version 1.

Advantages:

1) Small size
2) Lightweight

Limitations:

1) extremely weak and easily broken.
2) Very small size (hard to implement)

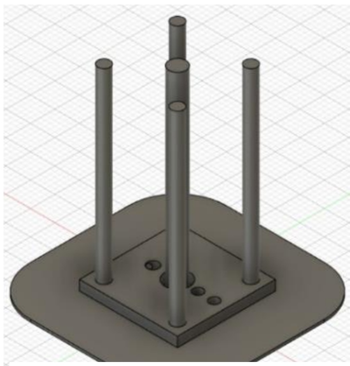


Figure 30_4 poles for click pen mechanism.

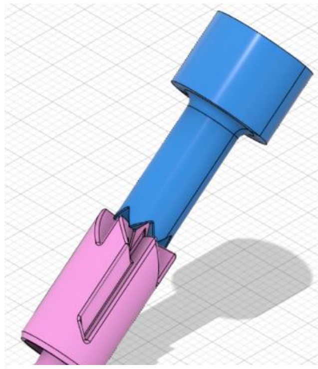


Figure 31_click pen mechanism.

We try another support, the circle shown in figure 57, because the four poles are weak and easily broken.

Limitations:

Flexinol muscle wire melted the 3D printing material when energized by 1150 mA.

It might work with other materials that resist heat without melting.

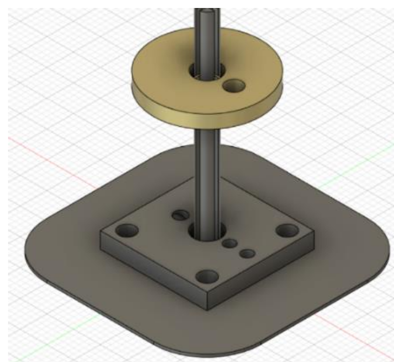


Figure 32_click pen mechanism 3D design version 2.

Due to the limits of Flexinol muscle wire and 3D printing materials, we are seeking for wire alternatives.

Despite the drawbacks of motors, we wish to reduce their constraints, which leads to the selection of "**CD-ROM stepper motors**", first we test motors from PCs as shown in figure from laptops shown in **figure19** in order to reduce the size of the braille cell as much as possible.
In this implementation every character'll need only 2 motors.

<u>3D designs for using these motors to implement a braille cell:</u>

<u>Limitations:</u>

1. Size
2. Difficulty of cutoff the motors' rod

Shown in **figure59** & **figure60**

Figure 33_CD-ROM motor from PCs

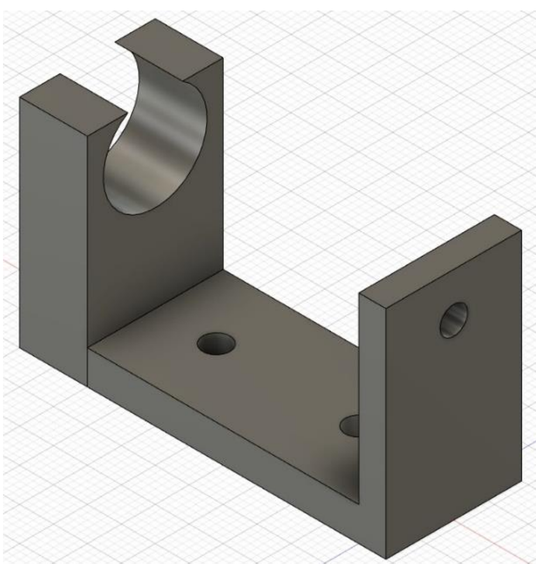


Figure 34_1st 3D design mechanism with CD-ROM motor

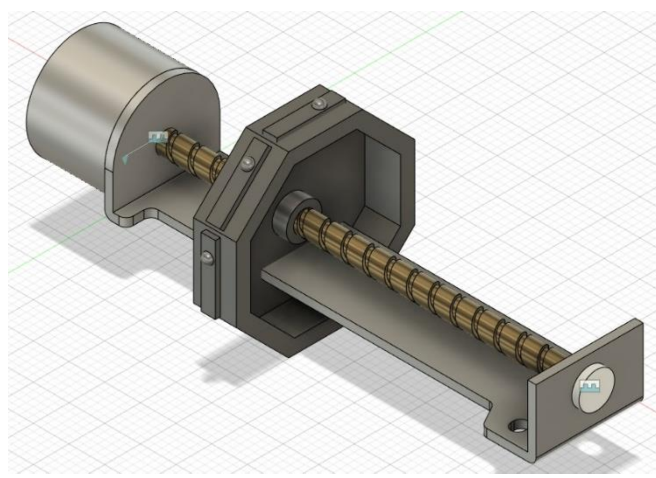


Figure 35_Holder of CD-ROM motors 1st design

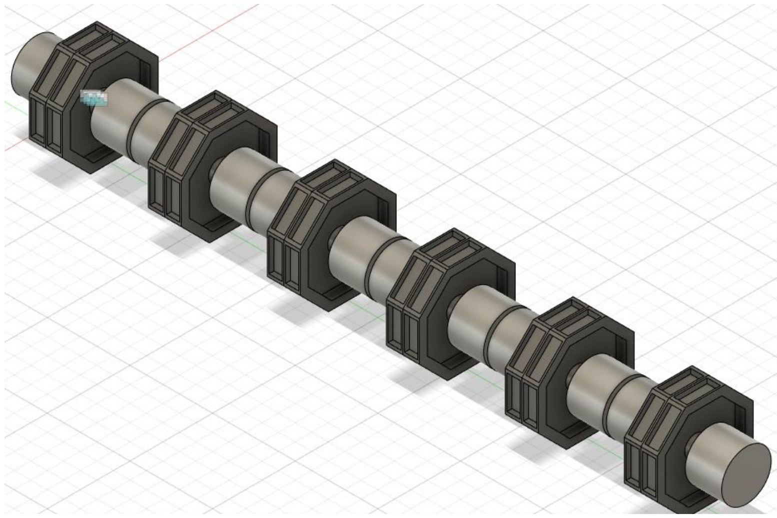


Figure 36_3D view of CD-ROM motors mechanism

Because of these limitations we decide to work with **CD-ROM motors** from Laptops as shown in **figure11**.
Using same mechanism using gears as shown in **Figure62**& **Figure63**& **Figure64**

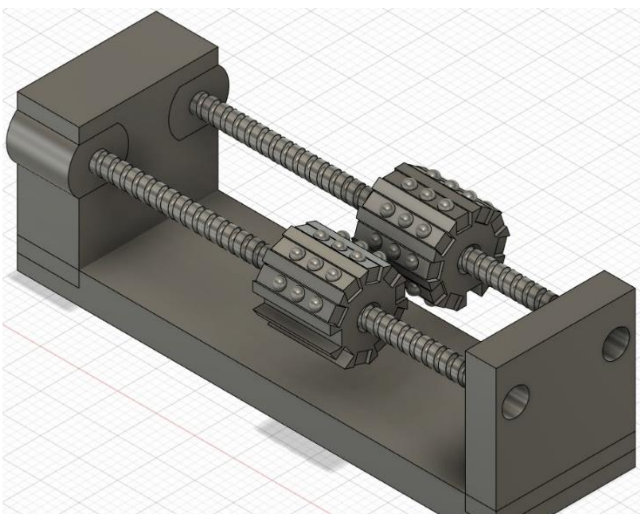


Figure 37_3D mechanism for CD-ROM motors from laptops

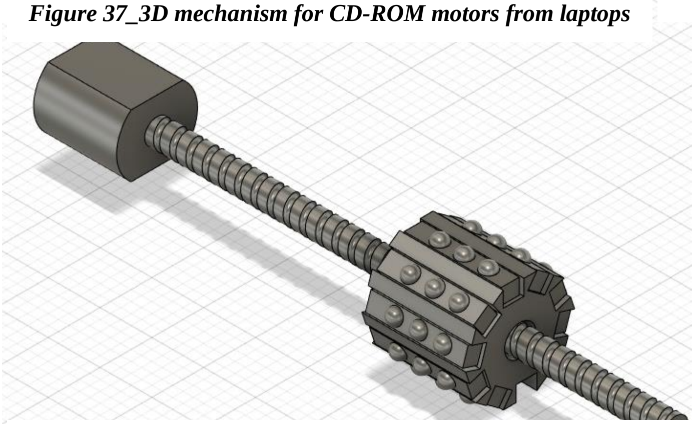


Figure 39_3D mechanism for CD-ROM motors "half character"

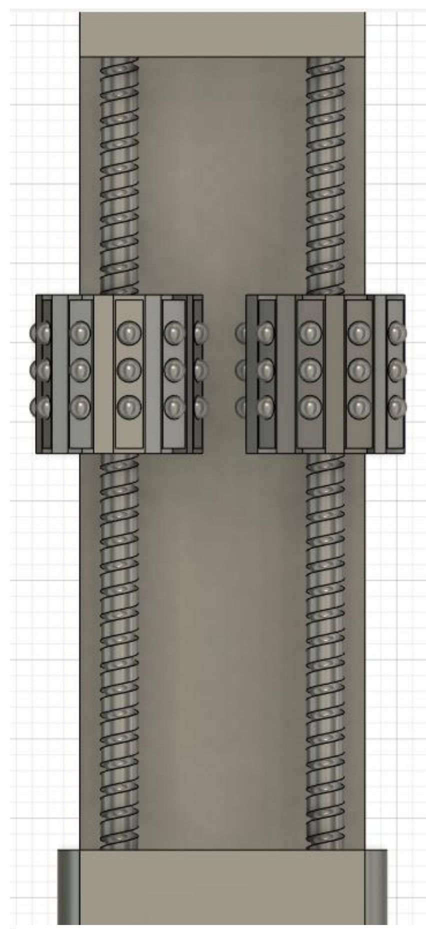


Figure 38_3D mechanism for CD-ROM motors from laptops "front view"

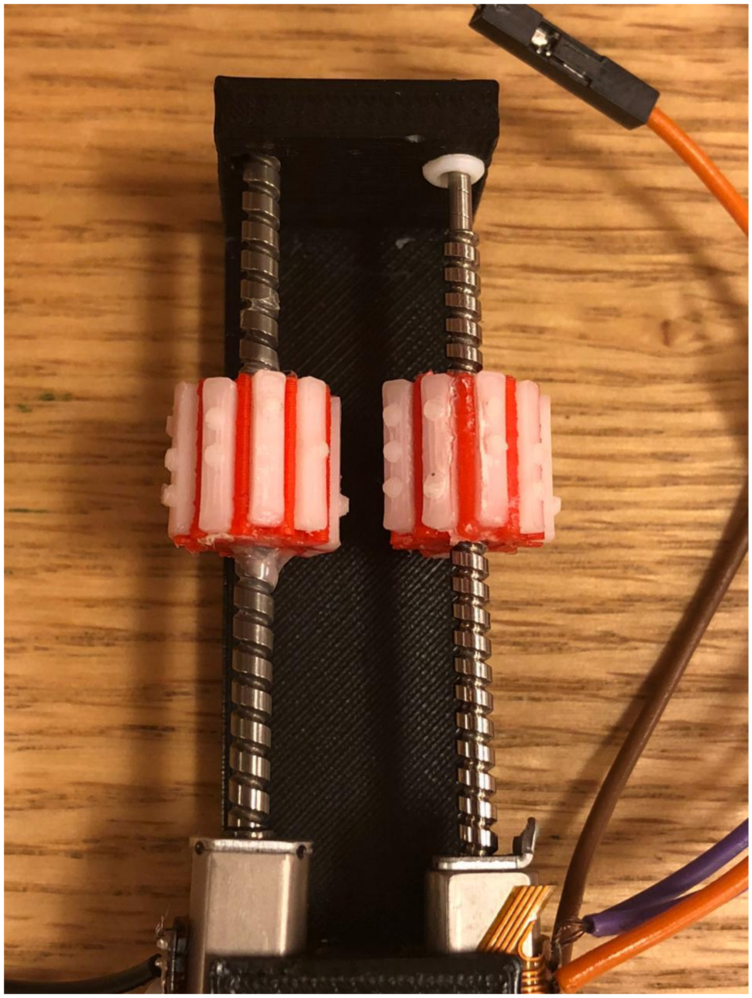


Figure 40_Actual view of 3D design mechanism with CD-ROM motors

size between 2 columns of the character shown in **Figure 66.**

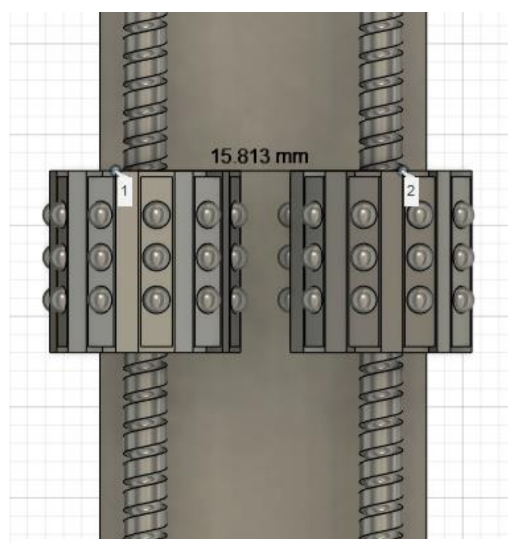


Figure 41_Distance between 2 dots in 2 columns

4.1.2 Braille display software system

Software part:

1. Parsing PDF to txt files using PyPDF2 library. PDF may be from USB or from memory of the device.
2. Read txt files and convert each character to corresponding character in braille.
    - Map for all characters: 2 value pair, key is the character we need to map, value is a tuple, 1st $\longrightarrow$ number of characters in 10 faces octagonal of braille cell, 2nd $\longrightarrow$ index of this face.
    - Map every character with characters in this map, if it exists return the tuple, if **NOT** return 0,0
3. Determine how many steps the motors should move after conversion using the tuple created before. One character is shaped by two motors.

4.1.4 Test reading features with LEDs

In this stage, we connect components as shown in **figure57** & **figure58** & **figure59,** the system was consisting of six LEDs as an output, that represent one braille cell. This stage was made to check the logic of the reading of the software system, which presents one braille character on six LEDs.

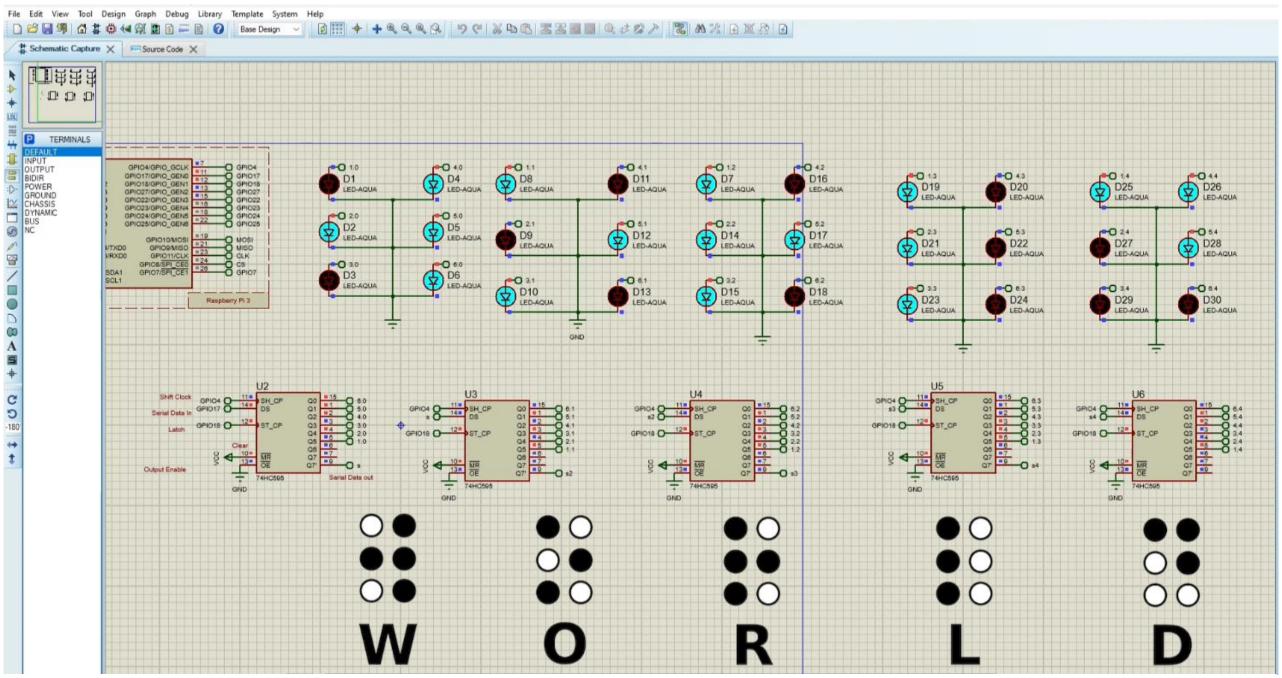


Figure 43_text to braille with LEDs circuit in Proteus

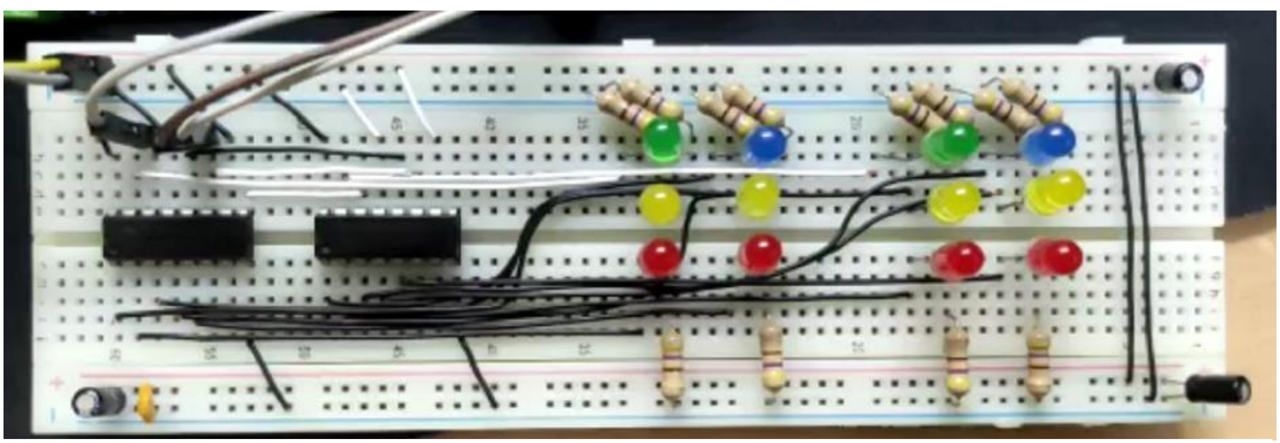


Figure 42_text to braille with LEDs circuit

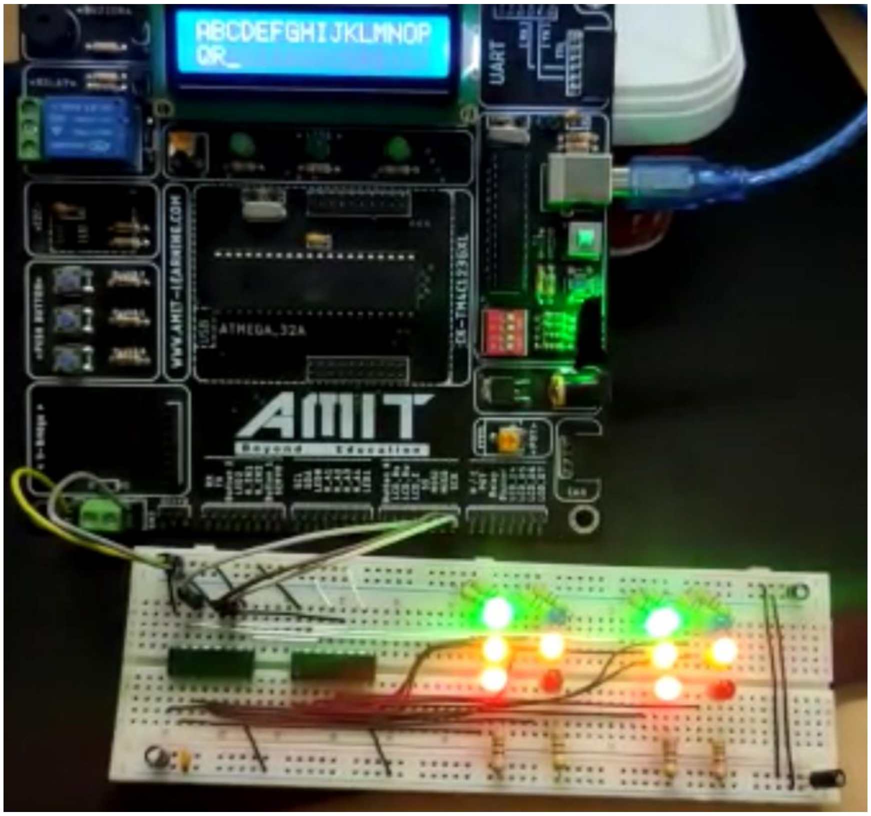


Figure 44_text to braille with LEDs results

4.1.3 PCB design

In this stage, we implement and test PCBs for motor drivers.

- **Motor driver PCB (**Double layer**)**

  Double layer PCBs advantages:

  1. Provide higher density and smaller size.
  2. provide better electrical performance due to reduced noise and interference between traces.

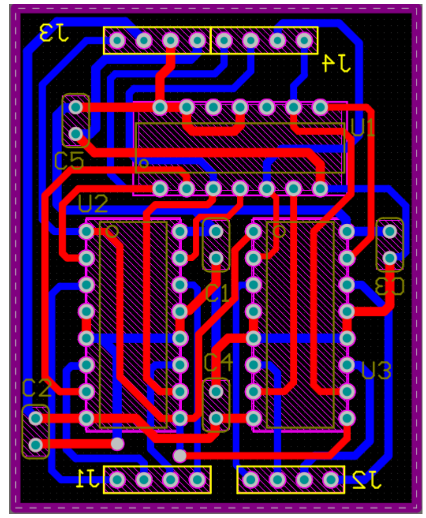
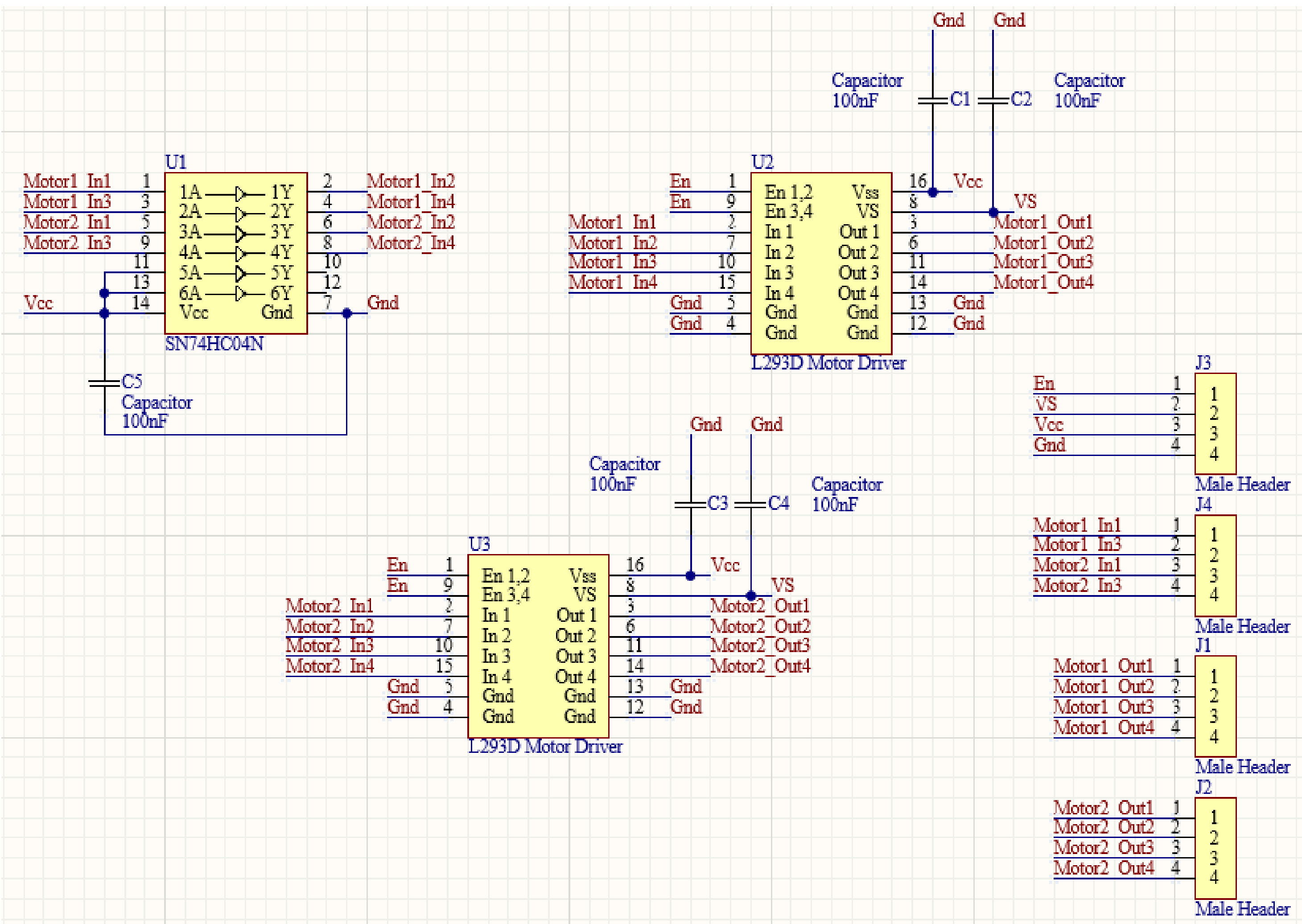


Figure 45_Motor Driver Dip footprint



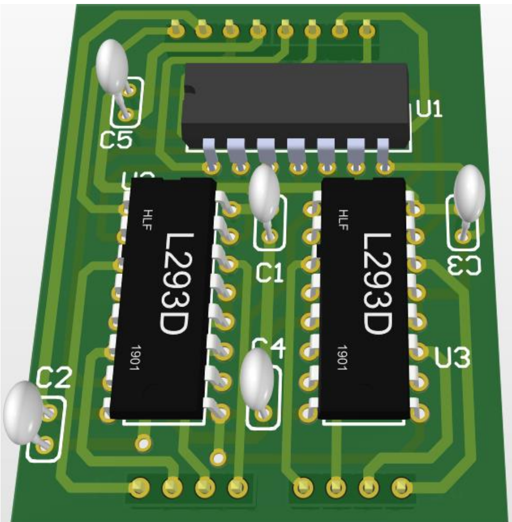


Figure 48_Motor Driver 3D View (Top)

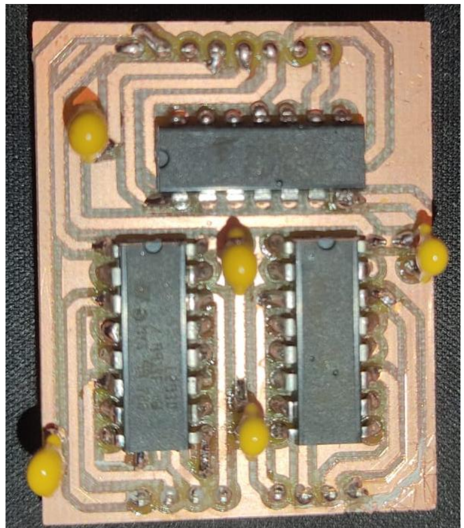


Figure 49_Motor Driver Actual view (Top)

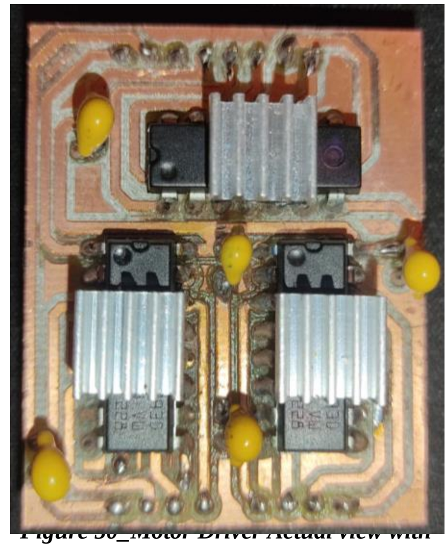


Figure 50_Motor Driver Actual view with heat sink (Top)

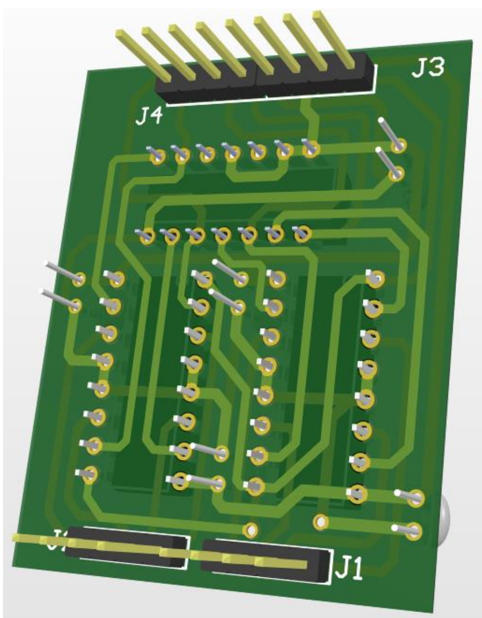


Figure 52_Motor Driver 3D View (Bottom)

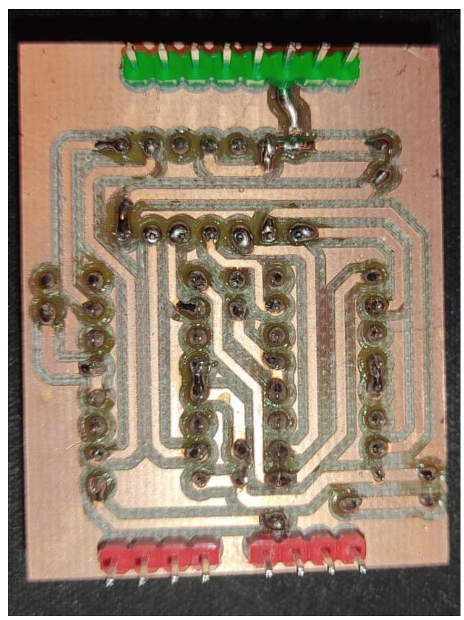


Figure 51_Motor Driver Actual view (Bottom)

- **Motor driver SMD PCB (**Double layer**)**
  SMD components are mounted directly onto the surface of the PCB, without the need for holes or insertion into the board.

  SMD components are typically smaller than DIP components and are available in a wide range of sizes and shapes. They are widely used in modern electronics due to their ***small size***, ***high density***, and ***ease of manufacturing*** using automated assembly processes.

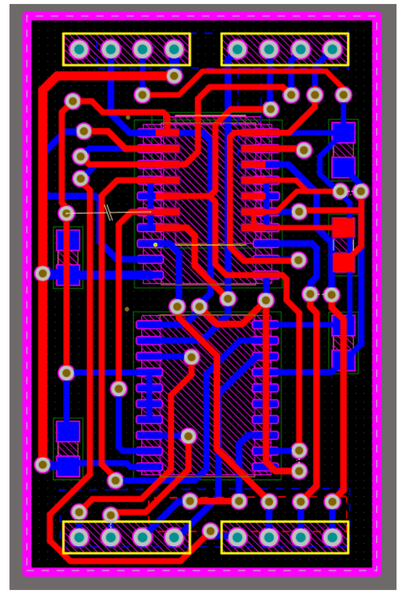


Figure 53_Motor Driver SMD FootPrint

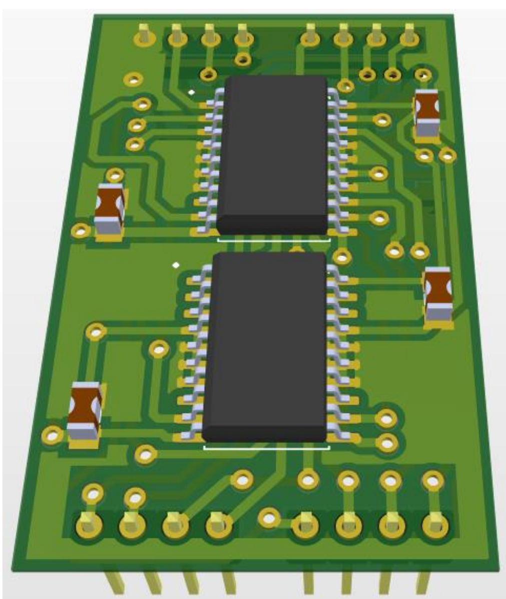


Figure 54_Motor Driver SMD 3D View (Top)

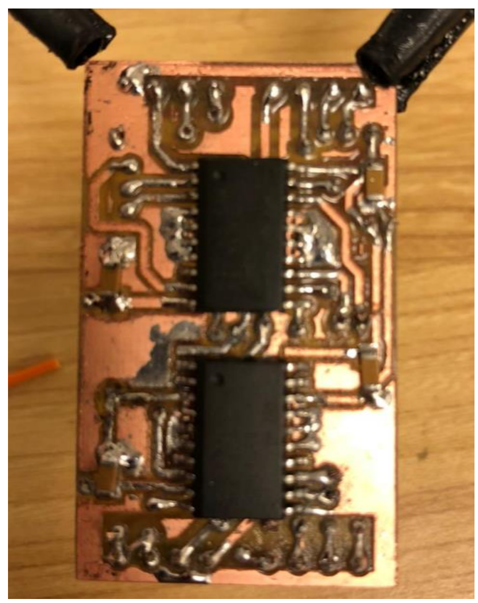


Figure 55_Motor Driver SMD actual view (Top)

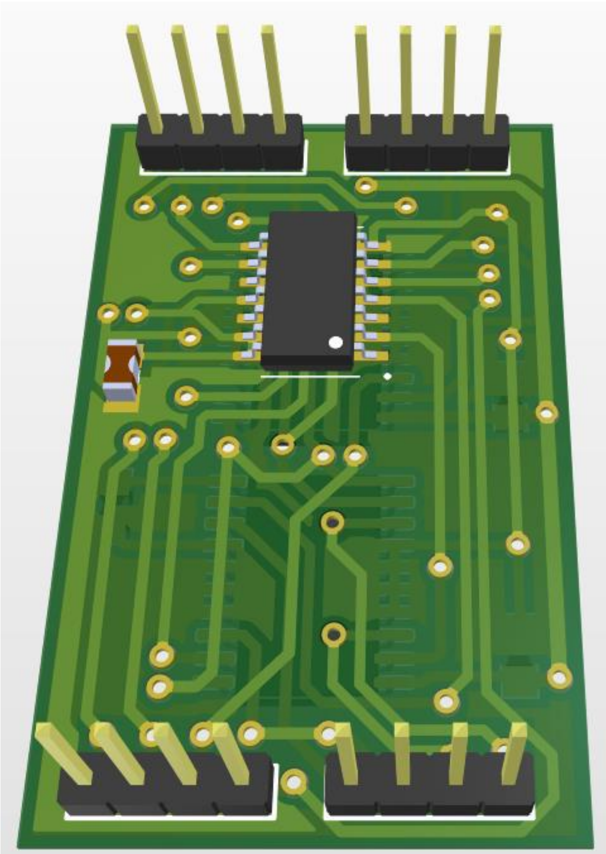


Figure 57_Motor Driver SMD 3D View (Bottom)

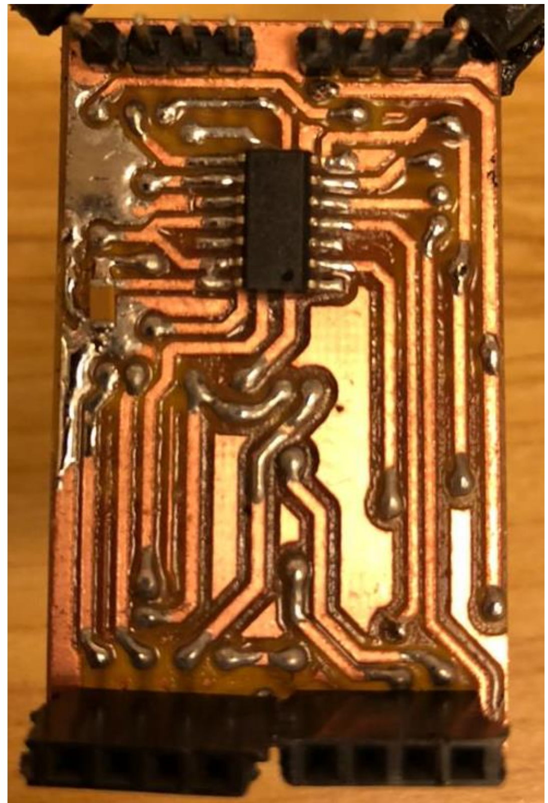


Figure 56_Motor Driver SMD actual View (Bottom)

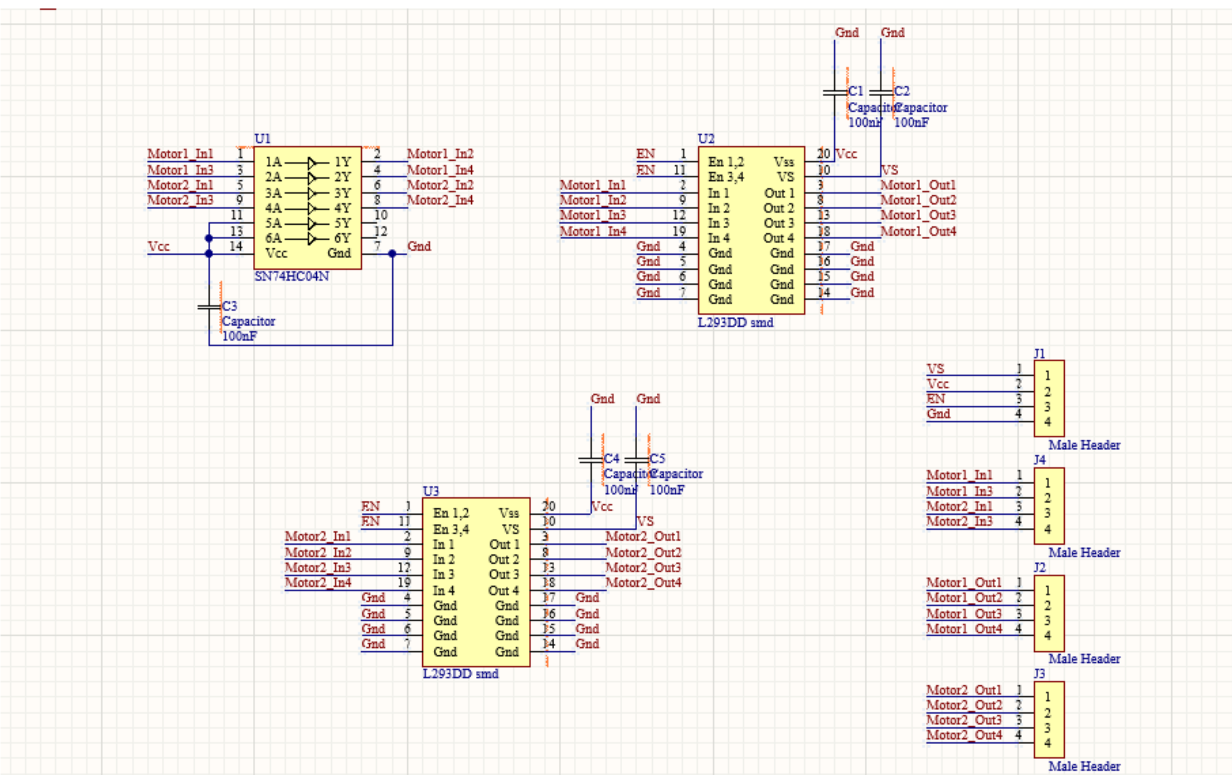


Figure 58_ Motor Driver SMD Schematics

4.2 Writing Process

4.2.1 Add writing feature.

In this stage, we connect components needed for testing the writing feature as shown in **figure 70** & **figure 71**.

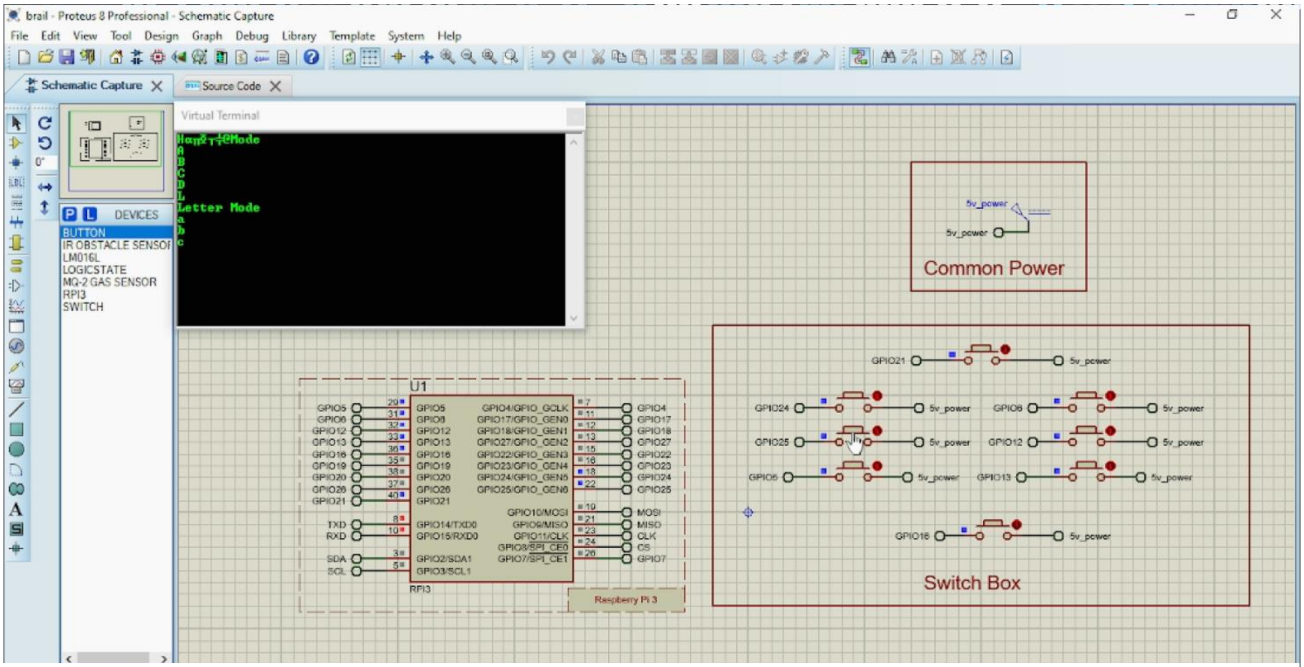


Figure 59_writing circuit in Proteus

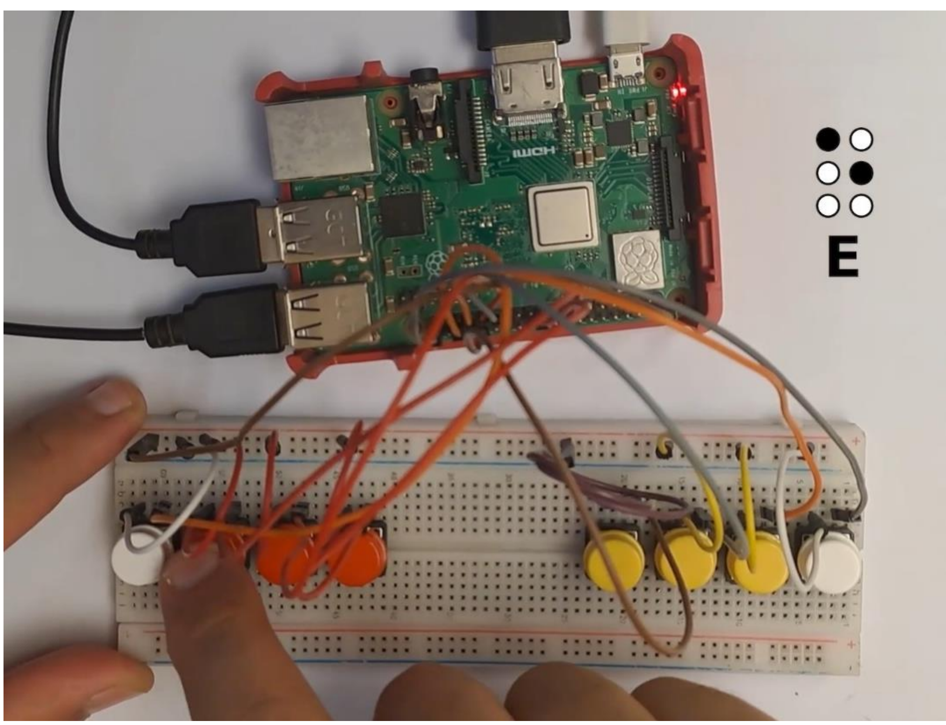


Figure 60_test writing code circuit

4.2.2 Notetaking software system

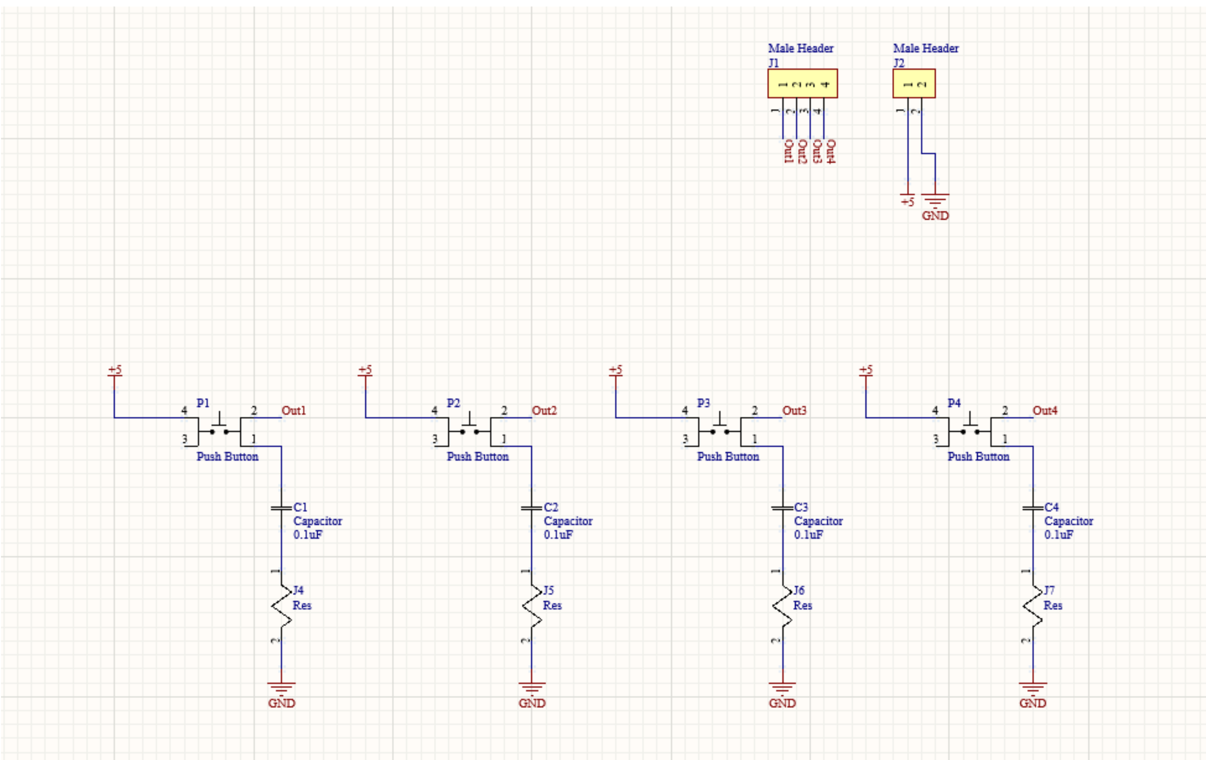
Software part:

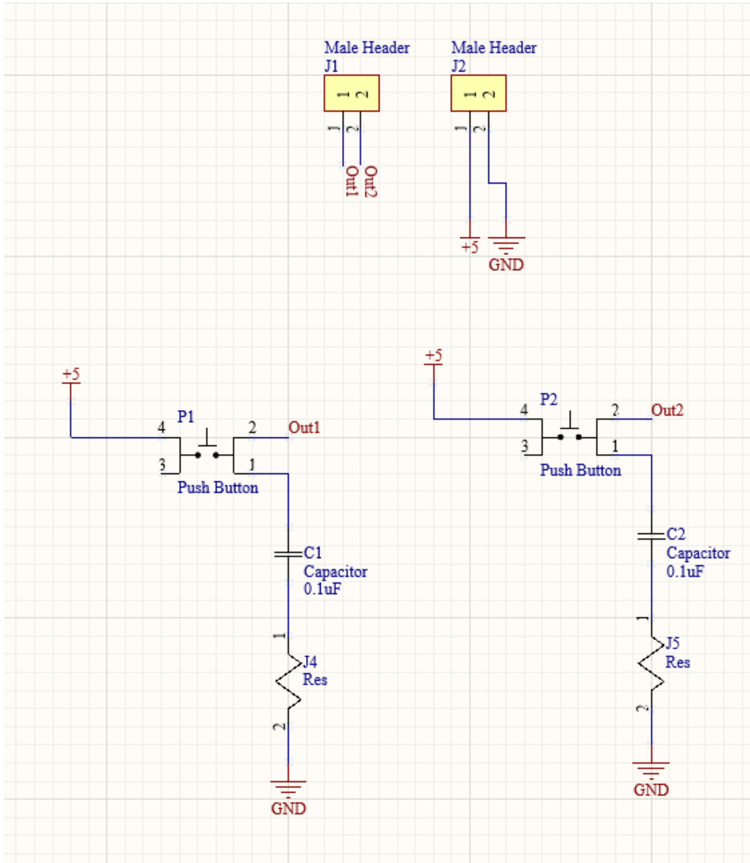
1. Dictionary that contains all characters
2. Key = weight of the character, value = the character
3. Every button has weight, when the user presses buttons that he wants, the algorithm adds all weights and maps it to its character using this weight.

4.2.3 PCB design

Implement and test writing PCBs shown in **figure29**: **figure36.**

- **Writing PCBs (**single layer**)**





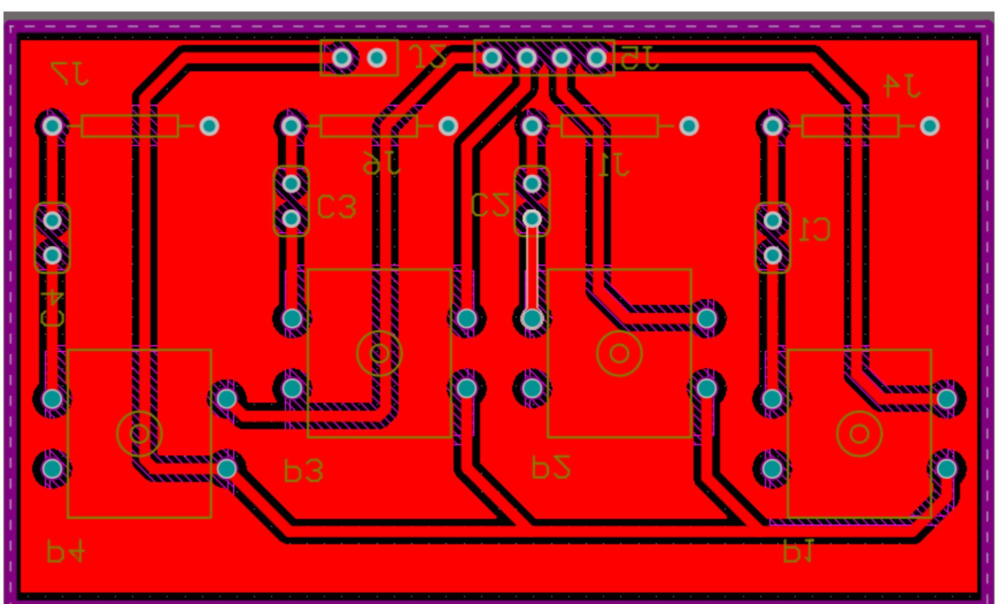


Figure 63_4 Buttons footprint

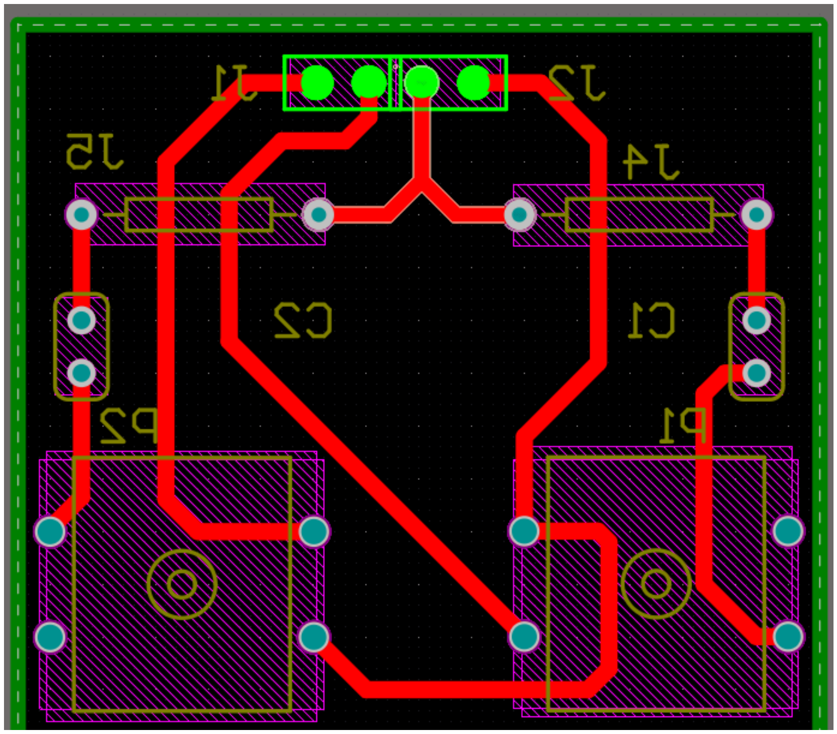
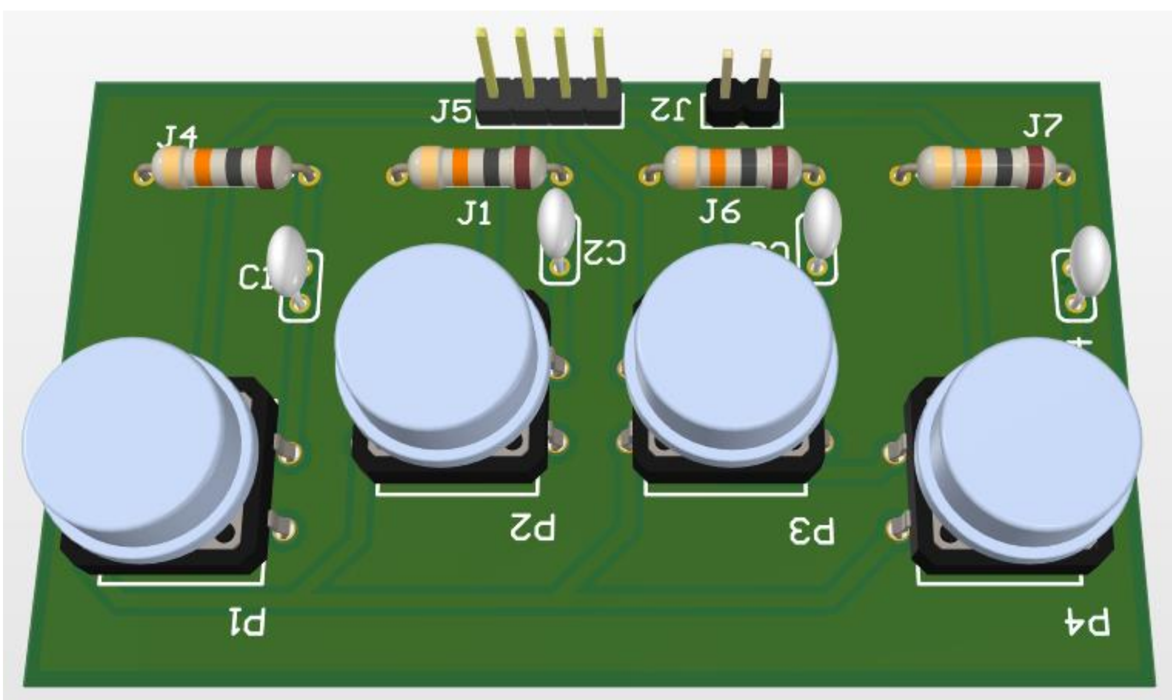


Figure 64_2 Buttons footprint



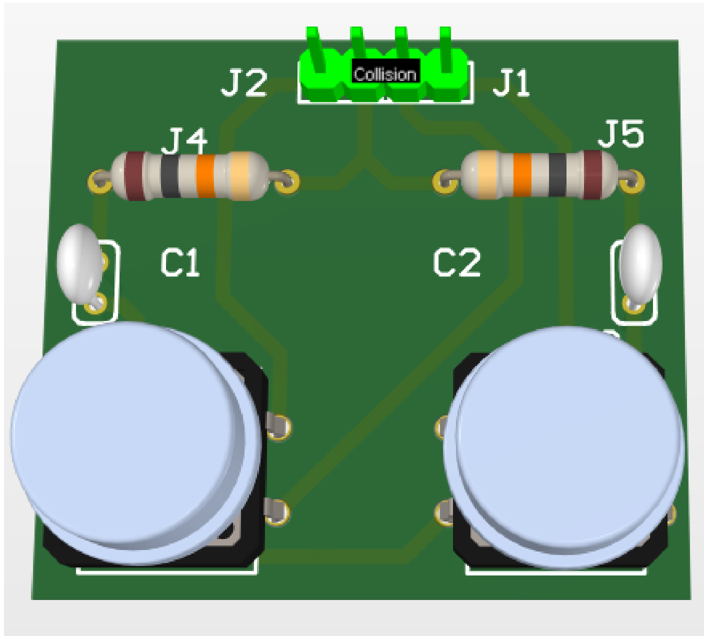


Figure 67_Buttons PCB

4.2.4 Add file system features.

Add features related to writing and provide input to the device, such as:

1) Navigation
2) Learn braille “Write characters with audio feedback.”
3) Write in text files and save it.
4) The ability to open previously stored files and edit them.
5) Look for a specific file or directory.
6) The ability to create, delete and rename.
7) The ability to listen to previously saved files again via audio feedback.

4.3 Packaging and prototype

4.3.1 Integration code

In this stage we integrate writing code with reading in one system and test it.

Test and measure percentage of accuracy for writing and reading.

4.3.2 PCB for holding motor drivers.

- Motor driver PCB holder (single layer**)**

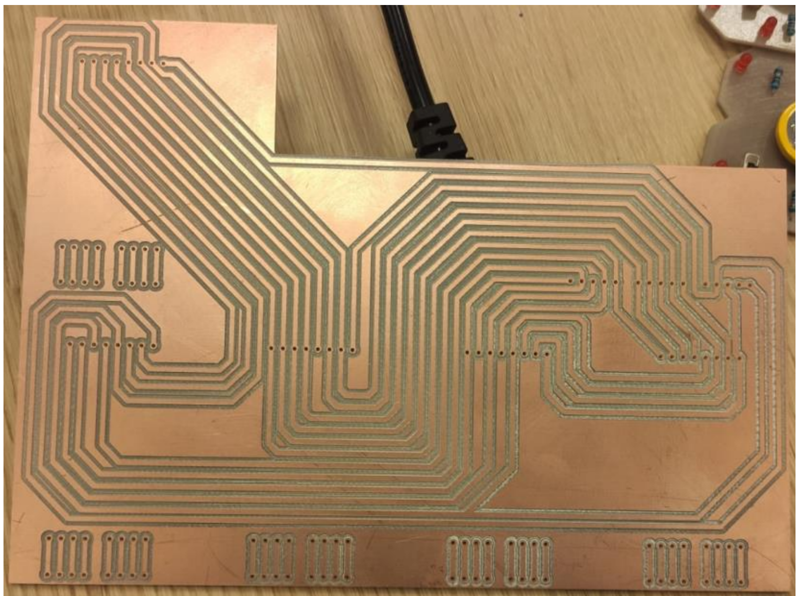


Figure 68_Motor driver PCB holder actual view

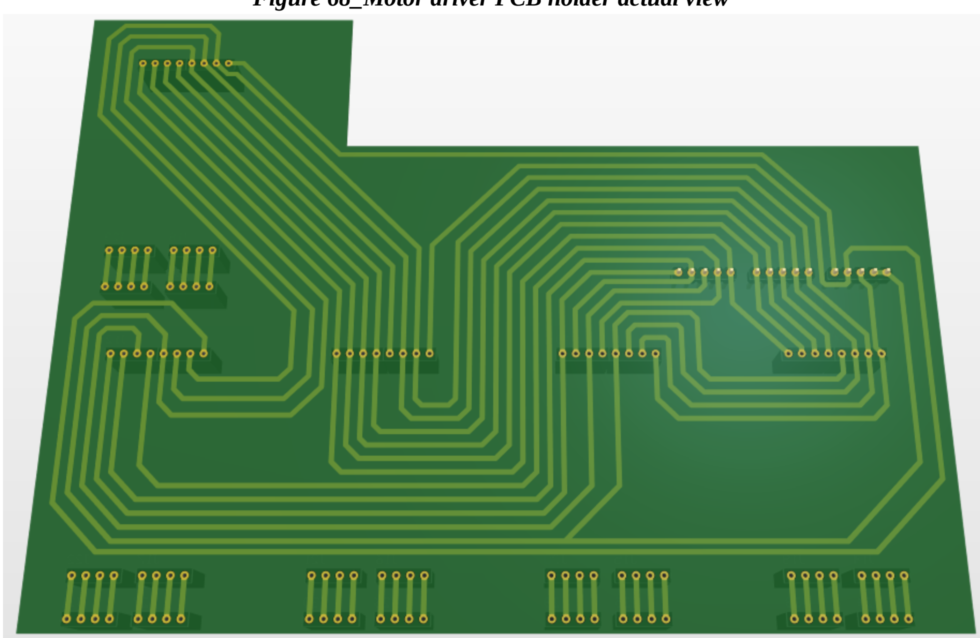
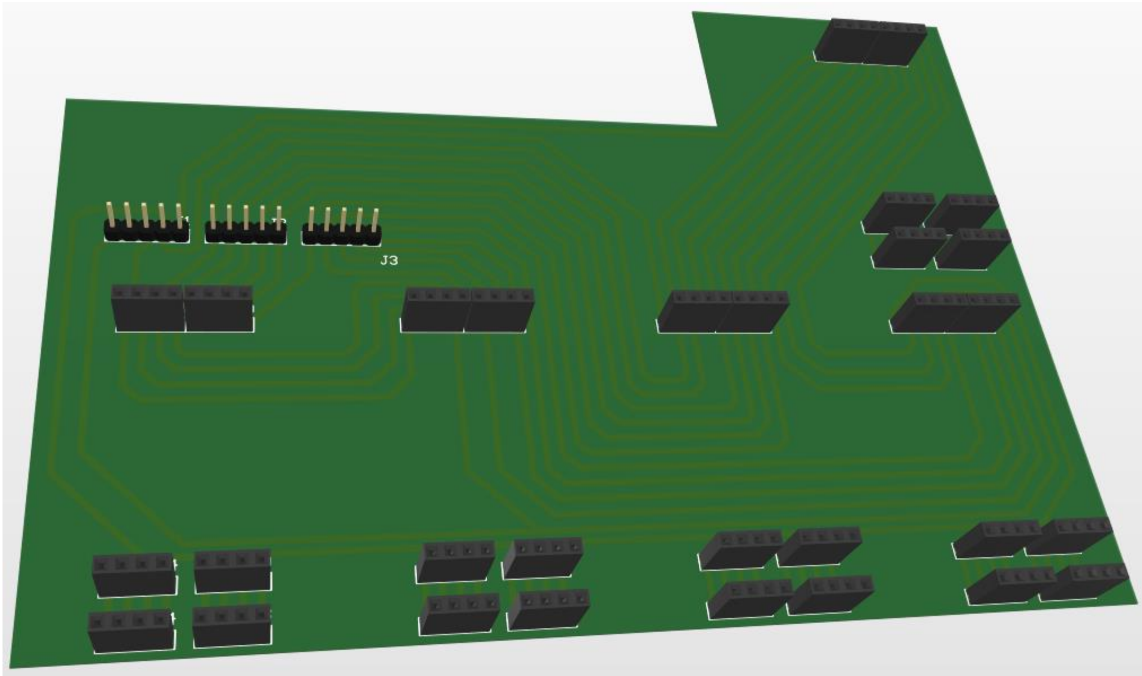


Figure 69_Motor driver PCB holder 3D view 1



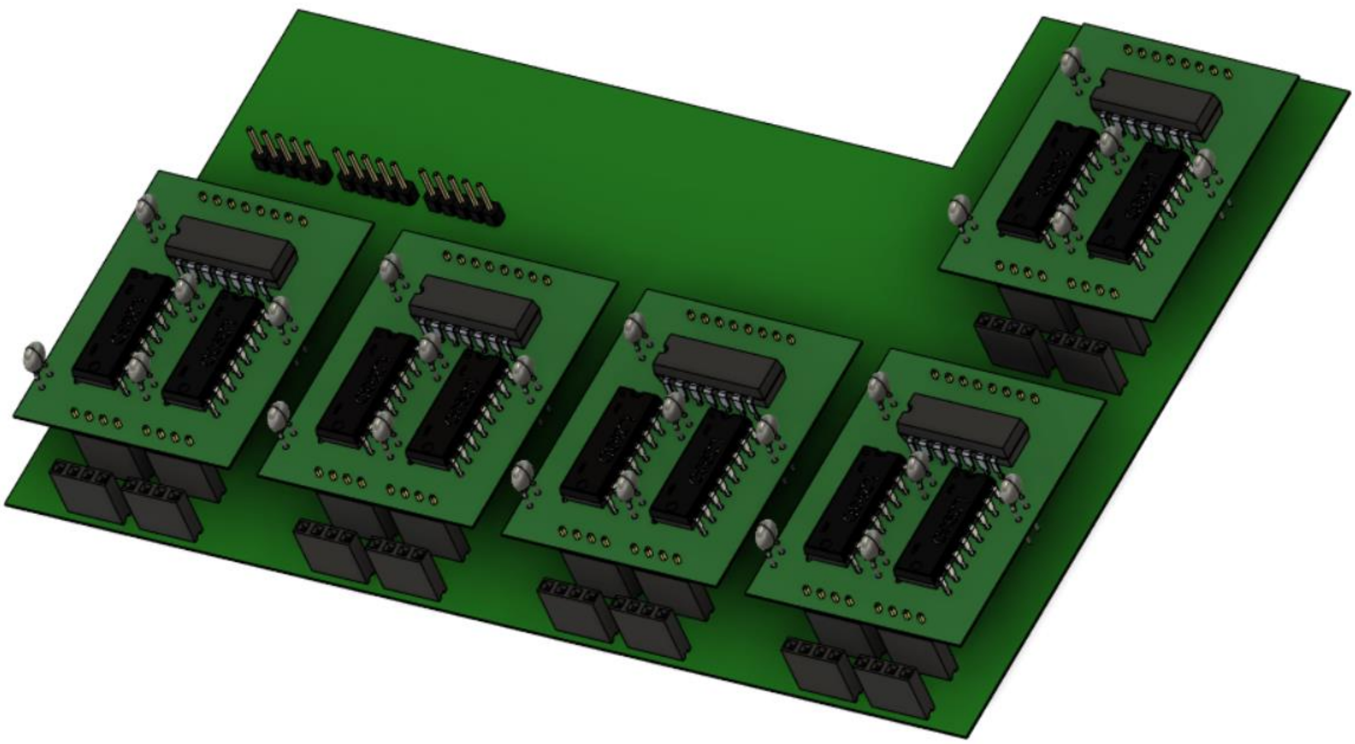


Figure 71_3D model of a motor driver PCB holder

4.3.3 Body 3D design

At this stage, design the final design for the device's body, as shown in **Figure 73: Figure 75**.

Figure 72_3D design for braille display device view1

Figure 74_3D design for braille display device view2

Figure 73_3D design for braille display device view3

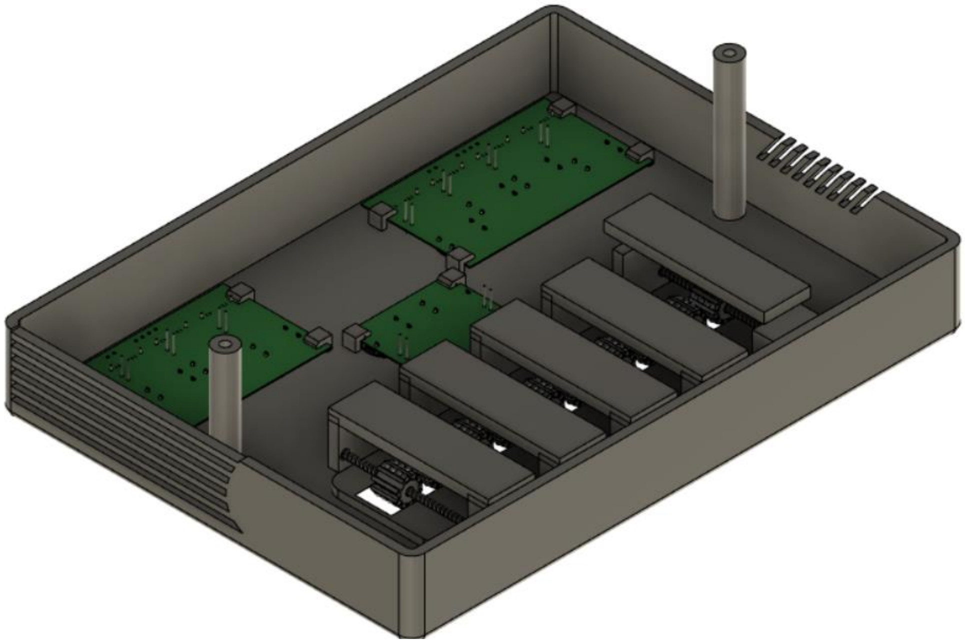


Figure 75_inner 3D design for braille display device from the bottom

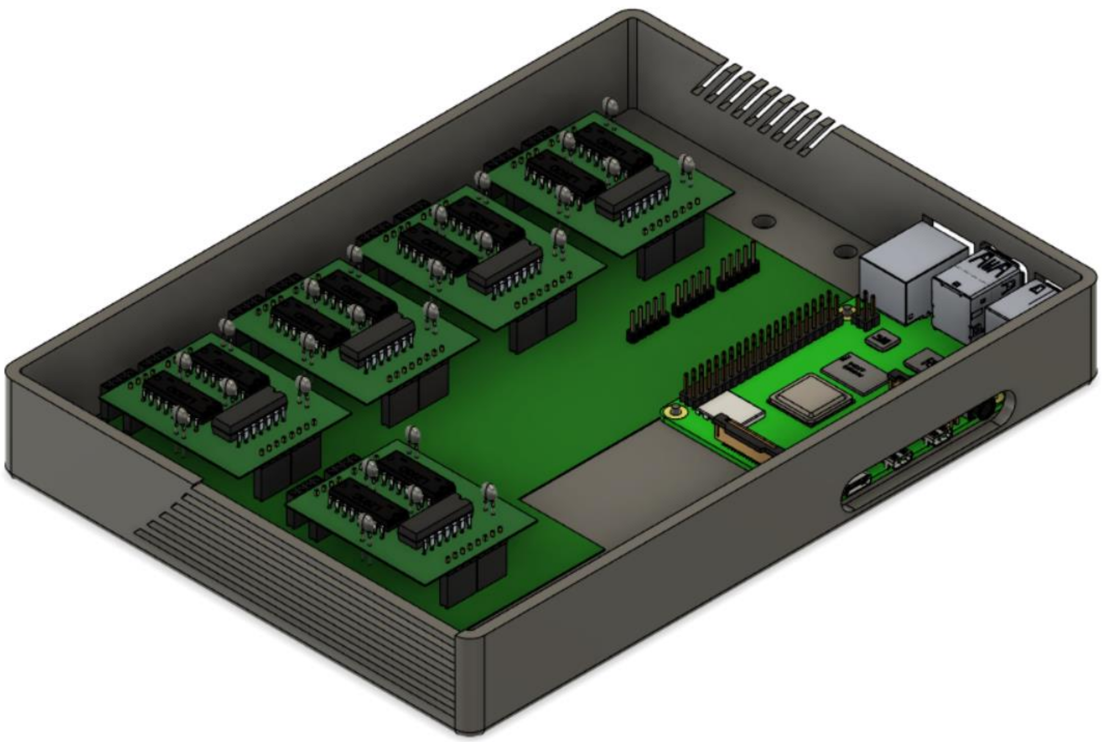


Figure 76_inner 3D design for braille display device from the top

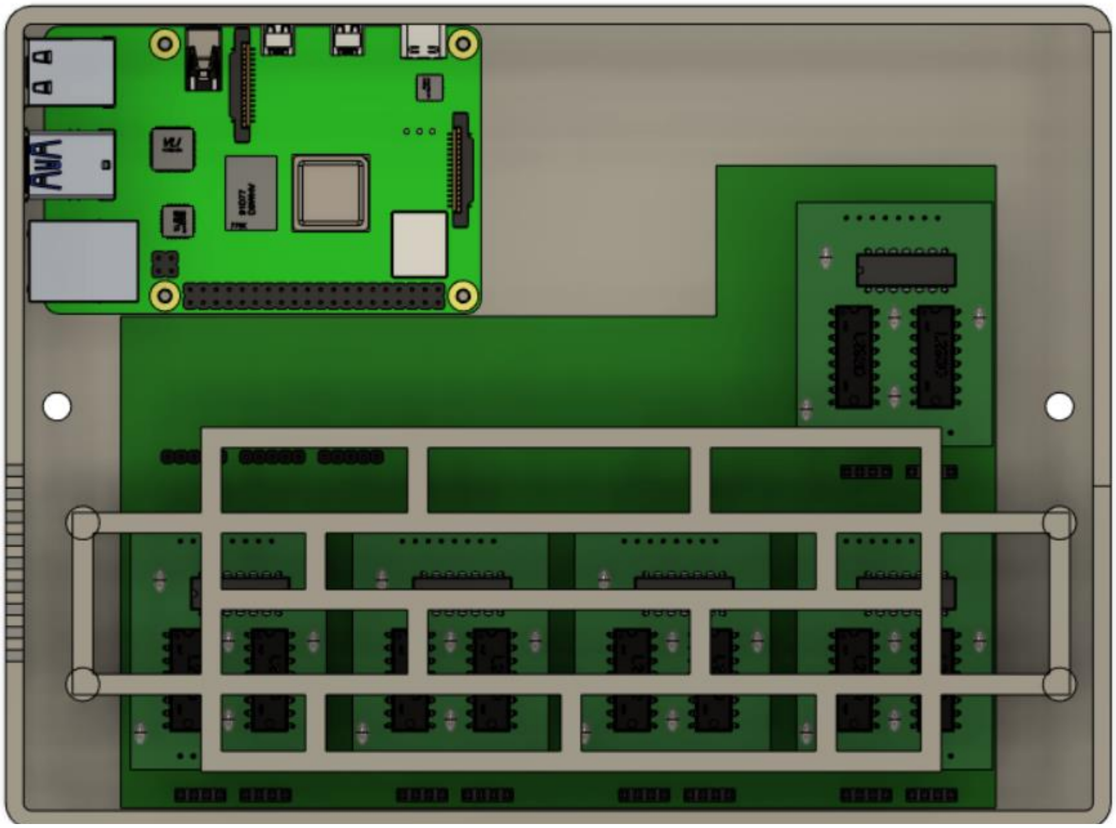


Figure 78_3D design for motors holder

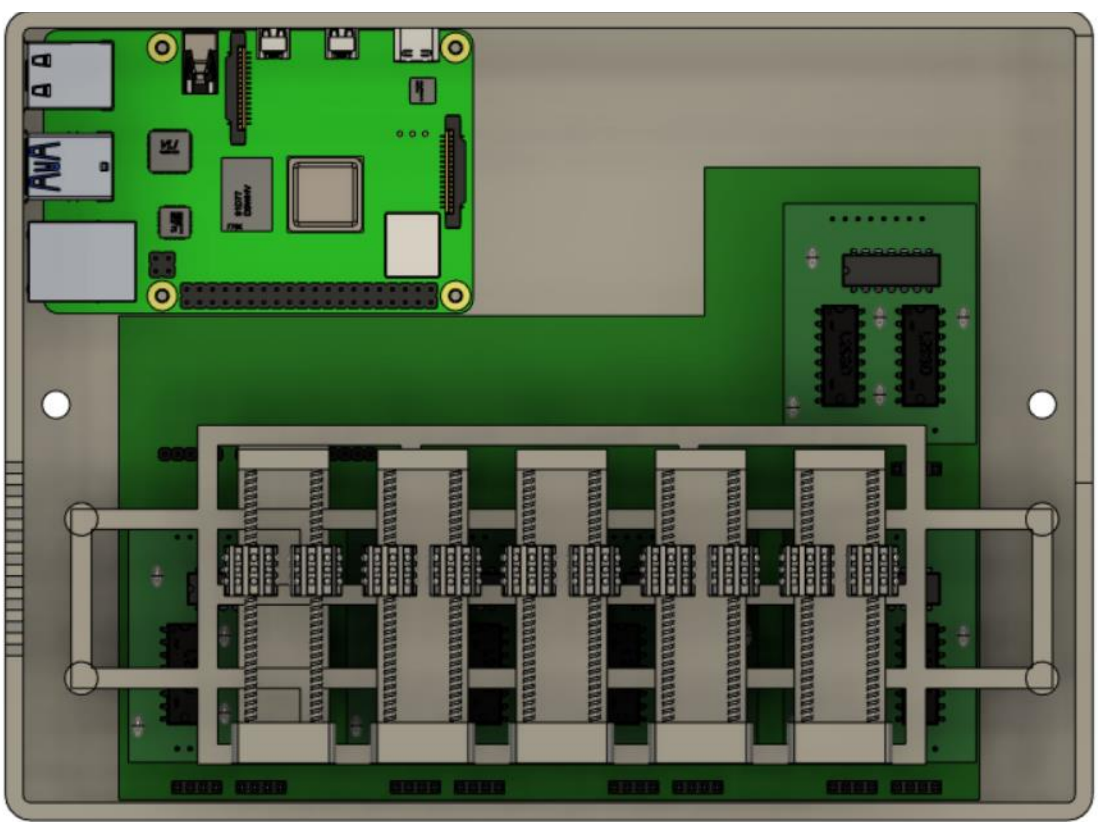


Figure 77_3D design for motors holder with motors

3D design for Internal arrangement of components inside the device is shown in **figure70**.

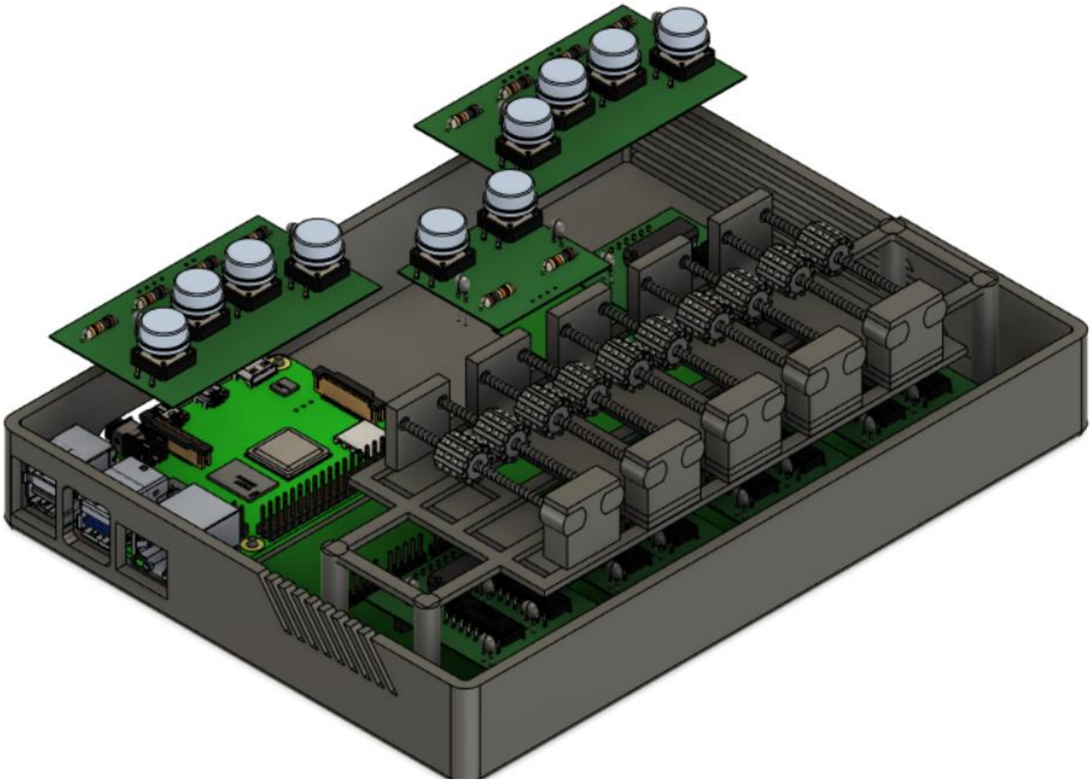


Figure 79_internal 3D design for braille display device view 1

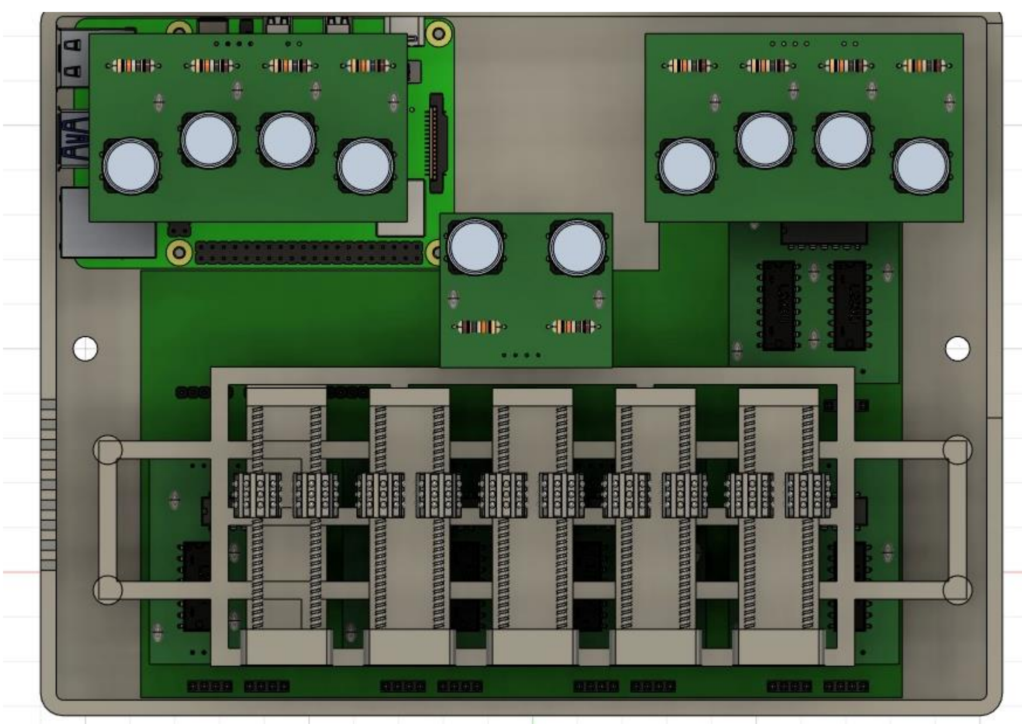


Figure 80_internal 3D design for braille sdisplay device view 2

H/W metrices for braille display device:

Number of braille cells	**5**
Refresh rate	**100ms** for every motor for refresh all braille cells
Connectivity	USB
Power consumption	Two power sources: 1. One for Raspberry pi =2 ampere & 5 Volt 2. One for motors (max 3 ampere & 3.3 Volt) Can be 1 ampere & 5 volt but it'll take more time to display characters. **Total (MAX when all motors run)** **=** **5 ampere & 5 Volt**
Size and weight	Lightweight ~ 650 gm
Noise level	No noise

Table 1 _ H/W metrices

	Cost	Energy	Latency
EGTactile	~$90	Internal⟶5 Volt **LOW** External⟶5 Volt **LOW**	**LOW** **(~100 ms)**
Chameleon20	$1,715.00	Internal⟶3600 Volt **HIGH** External⟶**LOW**	**LOW**

Table 2 _Comparison

Accuracy measures for EGTactile will refer to the ability of the device to correctly translate and display digital content into braille, as well as the accuracy of the device's note-taking features as shown in **table 3**:

*These values are based on **20** trials of testing at various times.*

	Notetaker	Braille display
Character accuracy	98%	97%
Word accuracy	98%	96%
Note-taking accuracy	98%	-
Translation accuracy	98%	97%

Table 3_Accuracy measures

s

Chapter 5
Conclusions and future work

5.1 Conclusion

As shown in the previous chapters, the output of our project is simple and easy to use by any blind person, who simply turns on the device and selects what he wants from the gadget's settings.
The device has proven to be safe, comfortable, and appropriate for blind people; they can use it to read any text file in English, write in English, or edit files using the file system that has been developed.

In conclusion, the low-cost braille display project is a promising initiative that seeks to address the issue of accessibility for visually impaired individuals. The project aims to develop an affordable and easy-to-use braille display device that can be widely accessible to the visually impaired community.
By leveraging low-cost materials, the project has the potential to significantly reduce the cost of braille display devices, making them more accessible to individuals and organizations with limited resources.
While there are challenges and limitations associated with the project, such as the need for ongoing development and refinement, the potential benefits are significant. Ultimately, the low-cost braille display project has the potential to make a meaningful difference in the lives of visually impaired individuals by improving their accessibility to information and communication.

5.2 future work

The following tasks are suggested as future works:

1. **Wireless connectivity:** The braille display can be further developed to enable wireless connectivity, such as Bluetooth or Wi-Fi, to provide greater flexibility and convenience for users.
2. **Integration with voice assistants**: The braille display can be enhanced to integrate with voice assistants such as Siri or Alexa to provide a more comprehensive solution for visually impaired individuals.
3. **Support for multiple languages**: The braille display can be further developed to support multiple languages such as Arabic, enabling users to read and write in their native language.
4. **Replace power supplies with removable batteries**.
5. **Advanced navigation features:** The braille display can be further developed to incorporate advanced navigation features such as ***search***, ***bookmarks***, and ***annotations***, enabling users to more easily navigate and interact with digital content.

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[3] Ayse Eldem, Fatih Basciftci, "Electronic and Computer-Assisted Refreshable Braille Display Developed for Visually Impaired Individuals", in World Academy of Science, Engineering and Technology, International Journal of Medical, Health, Biomedical, Bioengineering and Pharmaceutical Engineering, Vol: 9, No.:1, 2015

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[5] **Stepper motor** https://en.wikipedia.org/wiki/Stepper_motor

[6] Premkumar, T. (2017). "*Braille display by rotating multi-octagonal segment*".

[7] Dynalloy Inc., Technical Characteristics of Flexinol Actuator Wire. *Dynalloy Inc*. [Online] Oct 10, 2009. [Cited: Oct 10, 2009.] http://www.dynalloy.com/pdfs/TCF1140RevD.pdf.

[8] —. Flexinol Muscle Wire Properties. [Online] Oct 10, 2009. [Cited: Oct 10, 2009.] http://www.dynalloy.com/pdfs/MWPBv4.00_FlexSpecs.pdf.