Product Design Lab - II
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Refreshable Braille Display
Team K

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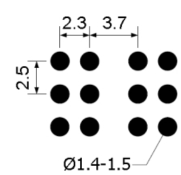
1 Problem Statement

The project aims to develop a cost-effective Refreshable Braille Display for the visually challenged with the following functions:

- Recognize characters in an input e-book or image
- Accordingly actuate the corresponding pins of the display representing the characters in Braille

2 Introduction

Braille has long been the language of reading for the visually challenged. It was created by *Louis Braille*, a visually challenged Frenchman, in 1824. The characters consist of small rectangular blocks called "cells", and small bumps called "dots". Each character is represented by a distinct combination of raised dots in a cell.
The Braille cell has specific dimensions and form to be followed, along with spacing specifications between two adjacent cells. The dimensions (in mm) are as shown in the figure below:



[1]

Figure 1: Braille Cell Dimensions

Each of the dots are raised by 1mm above the display in their actuated state.
The figure shown is that of a 6-dot Braille cell. There exists another convention of 8-dot Braille cell too. In this project, a refreshable display of 6-dot cell has been done.

2.1 Motivation

Braille has traditionally been read using the Braille Printer which embosses the characters on an emboss paper specially made for this purpose. In more recent times, there have been computer/mobile applications which use the speech to text and vice-versa technology to assist the visually challenged, diminishing the concept of Braille. However, after interaction with a visually challenged school teacher at his place it was found that using such technology had been resulting in poor vocabulary of many of the students as they were never really reading the words themselves. Also it was emphasized very clearly that the concept of reading Braille should never be neglected as it has been a long tradition.

While there have been a lot of refreshable displays around, almost all of them are unaffordable to the common man, especially in India. A study of the existing refreshable displays is as follows:

Figure 2: Focus 40 Blue
[2]

- Display Capacity: 40 cells
- Keyboard: 8 - dot Braille cell
- Cost: $ 2795

Figure 3: Smart Beetle
[3]

- Display Capacity: 14 cells
- Keyboard: 6 - dot Braille cell
- Cost: $ 1345

These are the most widely used Refreshable displays, and cost more than $ 1000 , in addition to the fact that they are not available in India and have to be imported.
This has been the largest motivator for the development of a cost-effective Refreshable Braille Display.

3 Target Customers and Product Specifications

The product has a specific user base: Visually challenged people.

Interaction with a group of visually challenged people was done, and the following features were expected out of the product:

- Low cost
- Small size so that it can be easily held in the hands
- Easy to access controls

The design parameters identified after the interaction were :

- Cost
- Dimensions
- Actuation or Display Speed
- Number of buttons for user interface

Based on these parameters and the basic requirements, the following specifications were decided for the product :

- *Number of cells* : Considering that an A4 paper consists of an average of 13-14 words per line and an average word is of 5 characters, the number of cells required per line of the display should be around 70-80.
- *Display Speed* : On an average a visually challenged person is able to read around 150 - 200 characters in a Braille page. Hence the display speed of the product would also match the same.
- *Dimensions and Weight* : Existing Braille printers in India, are very bulky and weigh around 20-35 kg, making them very difficult to be carried around. However, any product designed to assist the visually challenged should be portable so that it can be carried by them everywhere. Hence the dimmensions should be such that it is easy to hold in the hands and should weigh as less as possible. Dimensions decided for the final product are 600 x 100 x 100 mm and weight under 5 kgs
- *Number of user interface buttons* : As present in the existing displays, the product would consist of a button which would be responsible to refresh the display.

4 Challenges

The small dimensions of the Braille cells restricts the use of alot of mechanical/ electronic actuators for the movement of the pins as a result of which there are not many products. Products which do overcome these difficulties are very expensive and not easy available in many countries.

5 Design Concepts

Based on the previously mentioned design parameters and challenged the following concepts were thought of :

- *Use of Piezo-elecctric Actuators* : Piezo-electric actuators are extensively used in the existing Braille displays due to their very accurate and precise nature. These actuators are capable of easily displacing the pins by the required amount. However these actuators are really expensive, beating the purpose of the design , hence this concept was rejected right away.
- *Solenoid Mechanism* : This mechanism would consist a solenoid to actuate the Braille pins. The default state of the pins would be on top, and upon actuation, pins would be actuated down, thereby displaying the characters by the appropriate actuation of the pins as required.
- Shape Memory Alloy Mechanism: The mechanism here would contain Shape memory alloy coiled as springs. These alloys would be actuated by passing current, thus allowing the phase transformation to actuate the dots. The original state would be brought by a user refresh.

The latter two mechanisms looked promising. Hence, the concept selection was done based on general product specifications- Dimension feasibility of the mechanism, amount of heat generated and actuation speed. The results were as follows:

- The diameter of the smallest solenoid available was 2.5 cm which was very big compared to the size of the cell hole diameter. A micro-mechanical solenoid would be used, however it is very costly, thus defeating the whole purpose of the end product.
- Each solenoid upon actuation of a pin would dissipate around 30 joules of energy at a current of 2 A, which when considered for the entire system of cells would result in a very large amount of heat generated. [4]

Considering the above defects of the Solenoid actuators the other option of Shape memory alloy actuation was considered:

- The use of SMA acutation was not hindered by the small dimension of the cell holes as SMA wires as thin as 0.5 mm in diameter were available.
- Upon calculating it was found that each SMA wire would generate only 5 joules of energy, which is very low compared to that of the solenoid.

Thus , the SMA actuation was considered superior and the properties of the wire were as follows :

Wire Diameter	0.5 mm
Length of wire needed per pin	20 mm
Temperature of transformation	55-70 ^{0} C
Heat Generated	5J per pin
Actuation time	2 sec
Current Required	2 A

The design aspects with using SMA were as follows :

- Repair and replacement of actuators
- Prevention of reverse motion due to force applied by the user
- Reducing the actuation time of SMA
- Having a common ground for the set of actuators

5.1 Iteration-1

To address the problems in the mechanism, the first iteration of design resulted in the following:

- A smaller diameter wire would be used, which would reduce the current requirement and also the time required for cooling.
- The main purpose of the alloy is to bring the pins down. Doing so with a wire of any dimension is feasible, as the load of the pin does not come on the wire, but on a restoring mount.
- Potential problem would be the actuation of the refresh stroke. This should be actuated at the appropriate time, else the dot would come up before a given line is read.
- A restoring mount, which was initially hypothesized to be a spring, has almost been discarded, keeping in mind the dimensions of the pins. An alternate mechanism, which would consist of web like elastic material is being thought about.

- Bi-stable actuation mechanism for motion of the pins.
- Using lateral space for placing the actuator/mechanism.

Some more calculations were done, values obtained, and the following results were arrived at:

- Minimum force required to be held by SMA : 0.15 N [5]
- If error in user's motion is 0.01 mm, minimum spring constant of the cooled SMA= 15 kN/m
- The calculations give n=3 turns for the spring SMA.

Three designs were developed on based on the ideation done:

- *Design 1* : Shape memory alloys are used to pull the pins down and then the restoring force of the spring pulls the pins back up. The main problem with such kind of a mechanism is that there needs to be a locking mechanism for the platform so that it does not move when the current through the SMA is stopped.(refer to attached figure 6)
- *Design 2* : The locking problem has been overcome in this mechanism. The SMA actuate the pins, and the refresh button provides the restoring force for the pins to go into their base positions. The SMA pulls the pins down, and the refresh button should be pulled up for refresh. A better option would be to use a lever mechanism, so that the user only pushes the button. (refer to attached figure 7)
- *Design 3* : The problem in the previous design- of the SMA not being able to hold the force might be overcome in this, since the SMA is in compressed state, and has much higher spring constant than in the cold state. This would technically enable it to hold much larger force. Here, the spring would be below the middle plate, and would enable any stray force applied by the user to be held by the plate. (refer to attached figure 8)

Given the dimensional tolerances, the parts, especially the Braille pins, were 3D printed (refer to attached figure 9). But, these parts had inherent problems themselves:

- Surface features of the pin were missing, due to inaccuracy in the manufacturing process.
- Accurate manufacturing of pin resulted in the pin being very fragile, hence, the Shape memory alloy couldn't be secured to the pin.
- The solution ideated involved turning a brass pin, and using it as the Braille pin.

5.2 Iteration-2

The new design, with **brass pins** was done (refer to attached figure 10) .The model followed was Design: 3. Two Braille pins were actuated simultaneously. But, it had its own set of problems:

- Brass is conducting. This caused the current to flow through the pin, rather than flow through the Shape memory alloy.
- The Shape memory alloy, in the shape of a spring, couldn't be secured rigidly to the pin. Securing would require hole to be drilled through the pin, or any other process in which the alloy would come in direct contact with the pin. This would cause the conduction problem.
- No other operation could be done on the brass pins, as their dimensions were too small for any operation to be done.

These problems were solved by revisiting one of our earlier ideas- using lateral space for actuation.

5.3 Iteration-3

The final design was done by having toothpicks as the primary actuator to which the Shape memory alloys were attached. Hole drilling and insulation were taken care off in this case, and the Braille pins were minimized by just using strands of wire as the Braille pins. The pins were attached to the primary actuators by wire, and were isolated from the Shape memory alloy. The final product presented had the following features:

- A single Braille cell was successfully actuated.
- The third design of system was used, and a guide was made for the refresh spring at the bottom.
- The Shape memory alloy was wound around the primary actuator (Toothpick, here) and the primary actuator was coupled to the Braille pin.
- The Shape memory alloy and the Braille pin are effectively isolated, and no current can flow through the pin.
- A current of 2 Amperes was used for actuation.
- A relay circuit was designed for the control of actuation of pins.
- The control of pins was done using the Arduino microcontroller.

6 Future work and Scope

The product, with all of its functionality, faces quite a few problems, and many improvements can be done:

- *Modularity* : The product is not modular at all. One fault and it would be difficult to rectify it.
- The copper wires used in place of the Braille pin might interfere. This must be removed, and suitale changes to be done to the system.
- *PCB design* : As of now, the circuit (refer to attached figure 11) has been done using a GCB, but making a PCB and shield out of the circuit would greatly reduce the complexity of the setup.
- *Cap Design* : The uppermost form of the Braille pin is specific, and that is to be implemented in the current product.
- *Display Speed* : While the actuation speed is nominal, it can be increased.
- *Complete Display* : A single cell has been actuated, but the same is to be done for an entire display.

The final product looked like:

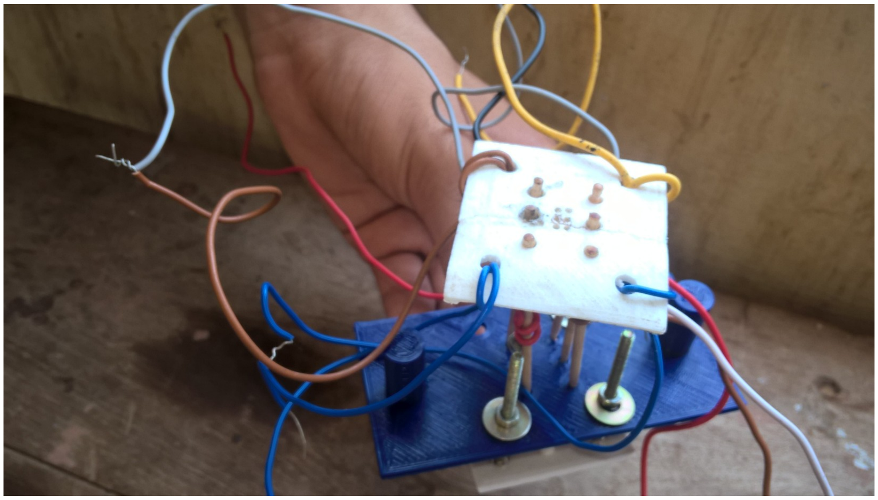


Figure 4: Final Product

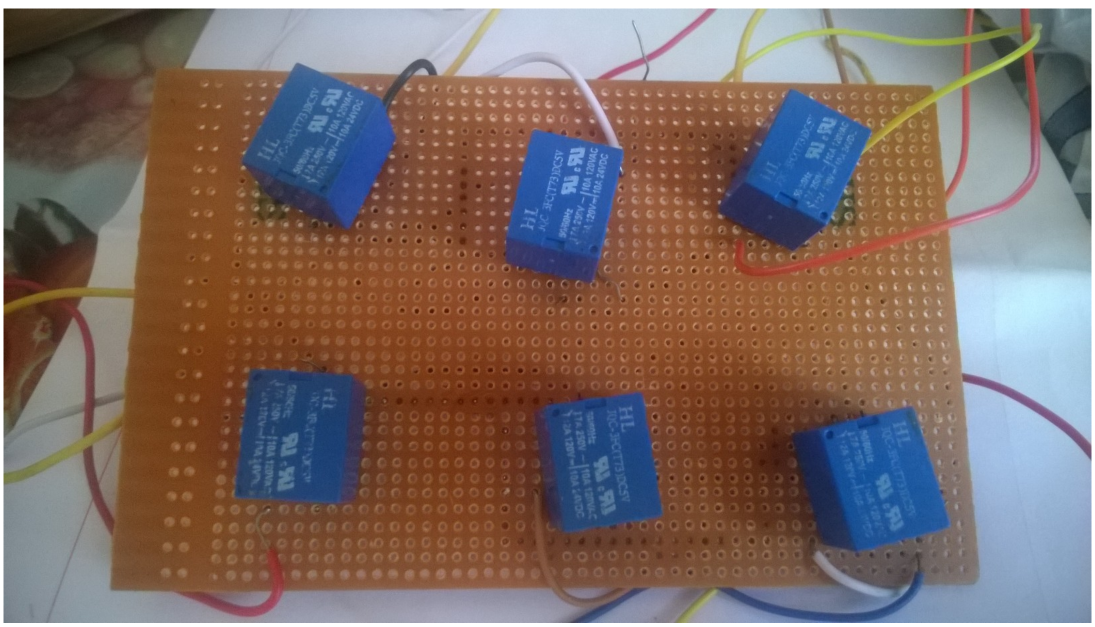


Figure 5: Final Circuit

7 Appendix

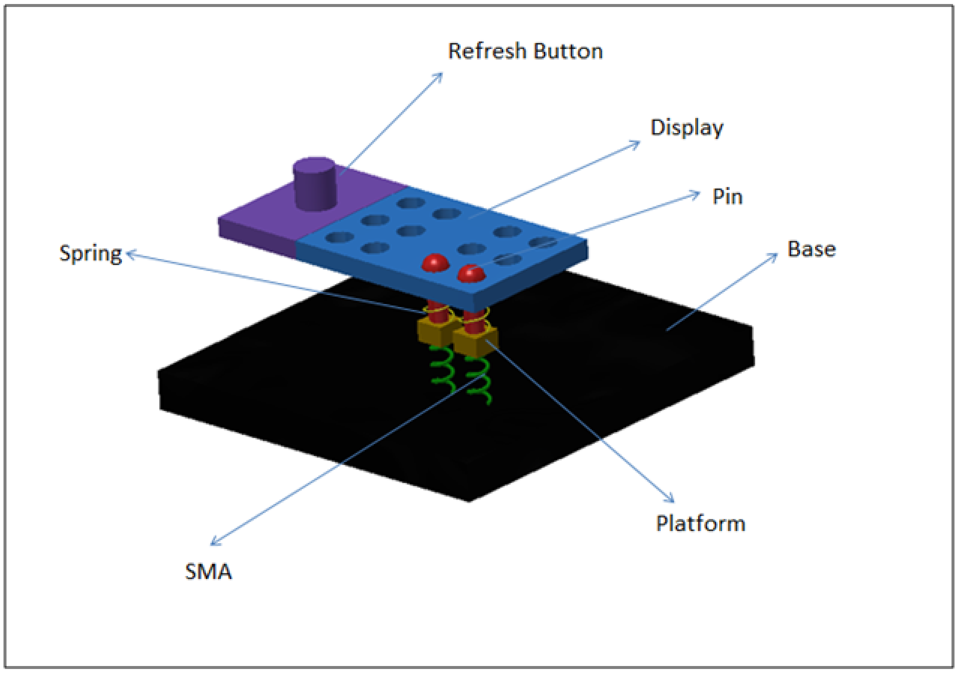


Figure 6: Design 1

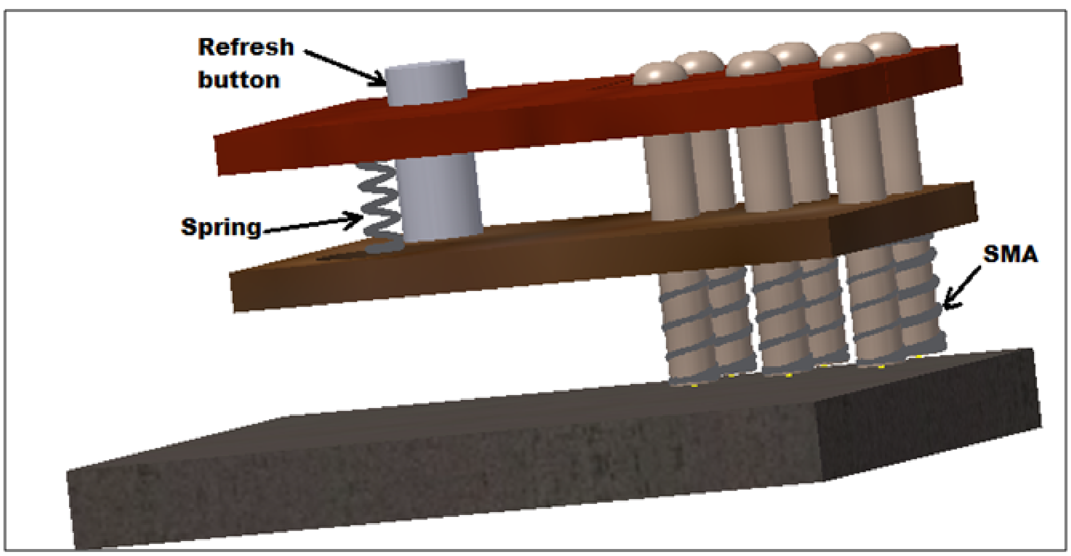


Figure 7: Design: 2

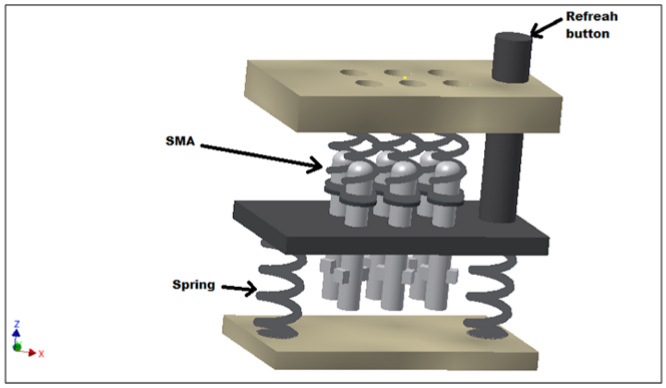


Figure 8: Design: 3

Figure 9: 3D printed pins

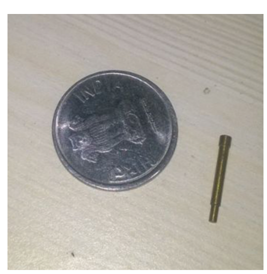


Figure 10: Brass pin

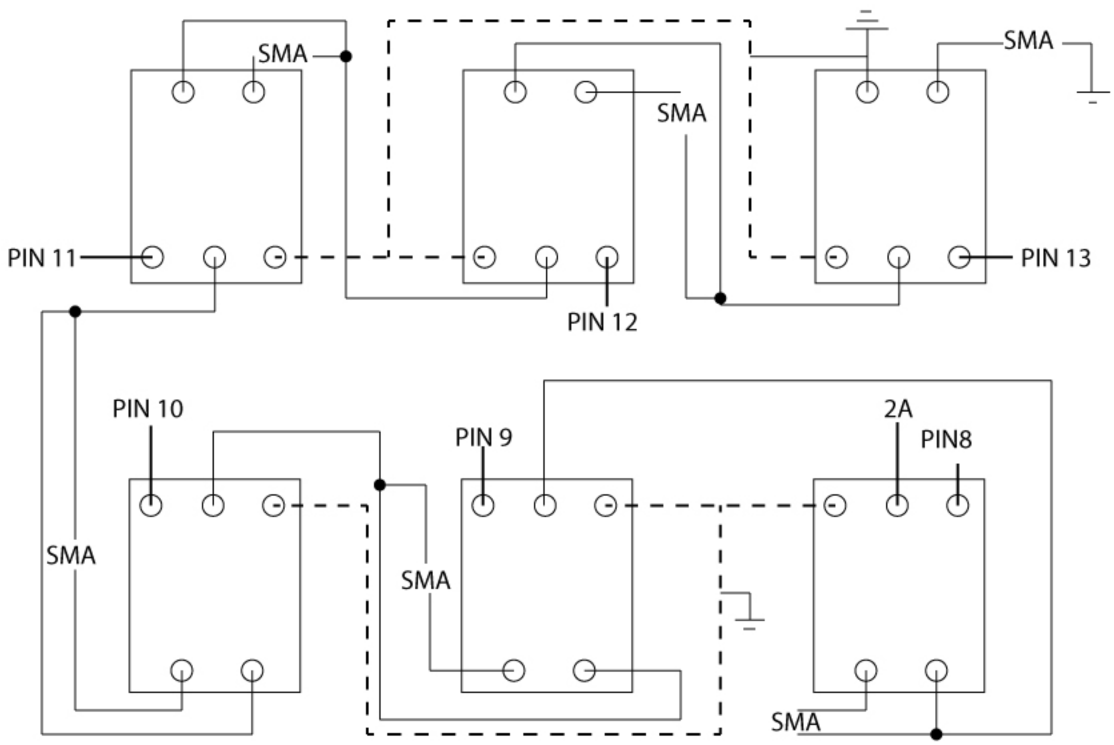


Figure 11: Circuit

8 Acknowledgements

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References

[1] *Braille Cell Dimensions : http://vlevesque.com/papers/Levesque-WHC07/fig4a.jpg.*

[2] *Focus 40 Blue : http://vlevesque.com/papers/Levesque-WHC07/fig4a.jpg.*

[3] *Smart Beetle : http://vlevesque.com/papers/Levesque-WHC07/fig4a.jpg.*

[4] *Solenoid Calculations : http://www.sparkfun.com/products/11015.*

[5] IIT Delhi Pulkit Sapra et.al. *A COMPLIANT MECHANISM DESIGN FOR REFRESHABLE BRAILLE DISPLAY USING SHAPE MEMORY ALLOY.*