DESIGN AND DEVELOPMENT OF SOLENOID-BASED REFRESHABLE BRAILLE CELL

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ABSTRACT

Vision is one of the senses given by god which is an important aspect in human life. With this sense, humans are able to see the beauty of the god's creations. However, some of them are unfortunate because they do not have this one sense, which will give them some problems doing the daily chores as a normal person does. The problem becomes worse when they are unfamiliar with the place. The primary aids available for navigation presently include walking canes, guide dogs, and personal human assistance. While individuals can achieve a degree of independence using walking canes and guide dogs, they cannot discern the safest and most suitable routes for those with visual impairments. Hence, to minimize their difficulties, a concept has been thought to help Visually Impaired people to understand things and their surroundings. Thus, this report discusses designing and developing a solenoid-based refreshable Braille cell by controlling push-type solenoids by using an Arduino microcontroller. This research found that solenoid-based Braille cells commonly operate at low voltage, facilitating diverse Braille character displays. Each cell's design, featuring a 3x2 array of six dots per Braille character, responds to user input signals, causing the corresponding dot to rise. Notably, the programming language for the Arduino microcontroller used in this system is CCS C. It is anticipated that employing this device will boost the confidence of visually impaired individuals, empowering them to navigate independently.

Keywords: *Accessibility Technology, Braille Display, Solenoid-based Refreshable Braille Cell, Visually-Impaired*

1.0 INTRODUCTION

Vision is an important aspect of completing any task. Visually impaired is a very big obstacle especially when travelling to an unfamiliar place. In a survey of 39 countries, it is reported by the World Health Organization (WHO) found that there were 285 million visually impaired people in the world, which is the majority of them over the age of 50 years [1]. This is such a big proportion of the number of people in the world, which is constantly increasing over the years, that it cannot be ignored. For individuals who are blind or have visual impairments, the Braille system serves as a critical tactile method for reading and writing. It provides essential access to written information, facilitating independence in education, employment, and daily life activities.

Recent advancements in Braille technology have brought forth various innovations. One such innovation is the Refreshable Braille cell [2], a unit capable of displaying and refreshing any Braille character based on command inputs. Another notable development is the Device Braille System Note, designed for converting words into Braille writing [3]. Additionally, the Jot-A-Dot Portable Brailler [4], while offering portability, has encountered limitations due to an unfavorable blocking mechanism, leading to fatigue during extended writing sessions.

This project, Solenoid-based Refreshable Braille Cell main purpose to help the visually impaired person to handle their surroundings more naturally everywhere using a device. It is designed to focus more on how the implementation of a solenoid Braille actuator functions in terms of the Braille specifications, including Braille dot dimensions, spacing, displacement, lifting force, and response time requirements. It is significant to the use of visually impaired persons to touch the e-Braille word very well and easily.

2.0 METHODOLOGY

In this section, we analyze how the Solenoid-based Refreshable Braille Cell integrated with the mechanical and electrical system. Firstly, the design of the device is created to be low-cost and portable and can be implemented in devices. The design of the dot formation also needs to be taken into account, as the visually impaired person solely depends on the sense of touch. Figure 1 shows the flowchart of the methodology conducted in this research.

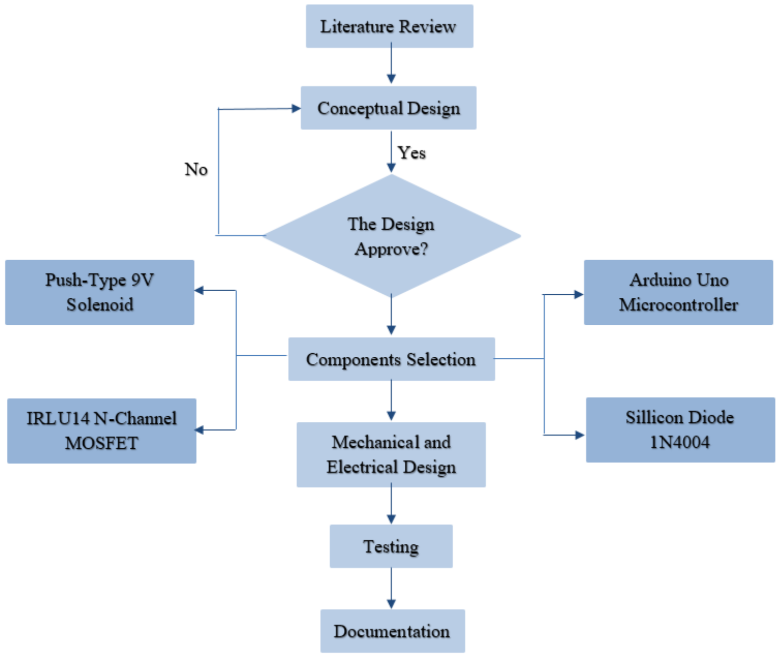

Figure 1: Flowchart of the Research Methodology

2.1 Conceptual Design

The design must have 6 Braille pins, as shown in Figure 2, which will indicate a single character in Braille language. The Braille pins will move upward when there is an input signal from the input source. The Braille pin must withstand a certain amount of force from the touch of the fingertips of the visually impaired person and be comfortable to touch.

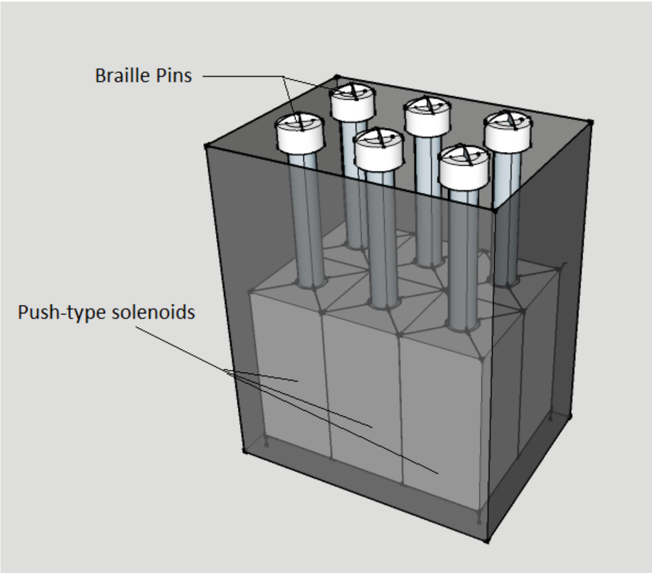

Figure 2: Conceptual Design of a single Braille character

There are many types of solenoids available in the market, such as push-type, pull-type, and both push and pull-type. It has been used in many device applications that require a push or pull motion as an effect. For a brailler, a minimum push movement is required to indicate the small movement of a Braille dot.

Besides the minimum movement, the solenoid must be a push-type one. It is because the brailler needs an upward push force to push the Braille dot upward. A portable device needs a DC supply voltage to activate it and all its functions. A DC supply of 3V to 12V is a suitable one as the battery for this type of voltage comes in handy and small. For this project, a small miniature push-type solenoid with a small stroke of less than 5mm, an operating range of 3V-12V, and a small dimension will be fit. Thus, it is an economic type, and it is small in size, which can resemble the Braille character.

2.2 Design Specification

2.2.1 Low Cost

The final prototype must be economical with existing Braille cells that are currently on the market today, which denotes the design of a prototype that is easily manufacturable. As the Piezoelectric Braille Cell nowadays is very expensive, there is significant room for improvement over the existing Braille cell. The cost of designing the prototype may be slightly higher than in Figure 2. However, mass production and manufacturing techniques will ensure the lowering of production costs. Once a final design of the prototype is selected, it will be subjected to economic and manufacturing.

2.2.2 Portability

The final prototype shall be small, readily available to be used by blind individuals, and to be implemented in a device later. This size requirement shall not impede the ability of the device, for each solenoid dimension size is given as 21mm x 11mm x 10mm, which will push upward for each Braille dot.

2.2.3 Dot Formation

The dot formation of each Braille cell must meet a certain requirement so that the dot is easy and comfortable to touch by the majority of people. A field study was conducted at Tammasakon School, a school of visually impaired people in Hat Yai, Songkhla, to acquire information for the design of Braille cells. Most of them prefer in round shape of the Braille dots and not to be too small.

2.2.4 Mechanical Design Specification

The mechanical design challenges of this project can be separated into three distinct components: Braille dimple formation, circuit design, and Arduino coding to make it push upwards by keypad input or ASCII keyboard.

2.3 Braille Pin Design

2.3.1 Braille Dot Specification

The Braille system was invented in 1825 by Louis Braille [5]. The design of the pin of the Braille cell is very important because the impaired person is sensitive to touch. When some of the dots are raised, it can change the word and alphabet of the word. So, the design of the Braille dot must follow the standard specification [6]. The specification is referred to the Table 1 below.

Table 1: Specification for Braille alphabet

Measurement Range	Minimum (Millimeter)	Maximum (Millimeter)
Dot base diameter	1.5	1.6
Distance between two dots in the same cell	2.3	2.5
Distance between corresponding dots in adjacent cells	6.1	7.6
Dot height	0.6	0.9
Distance between corresponding dots from one cell directly below	10.0	10.2

Based on this specification that given. The design of the Braille dots is designed like Figure 3 below. It consists of eight dots for each cell that has four rows and two columns. The diameter of each dot is 1.5 millimeters (mm); the distance between each dot in the same cell is 2.5 mm; the distance between corresponding dots in adjacent cells is 6.4 mm; and the dot height is 0.8 m. Nowadays, it is suitable to make eight dots instead of six dots because the technology has developed, and the other two dots have functions. Besides that, certain countries like Japan, Germany, and France use different languages and have their word.

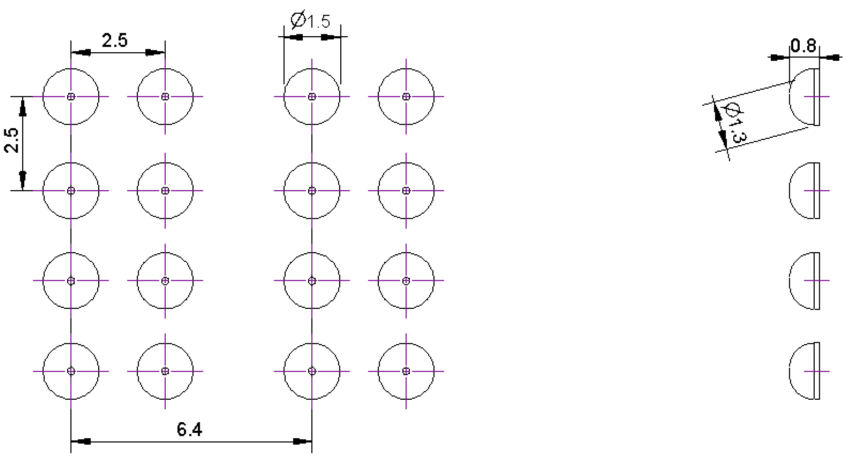

Figure 3: Braille Dot Design

2.3.2 Braille Alphabet

The Braille Alphabet is shown in Figure 4 below. The Braille alphabet normally has only six dots. Another two dots are usually used as an indicator and used in other countries like Japan and Germany.

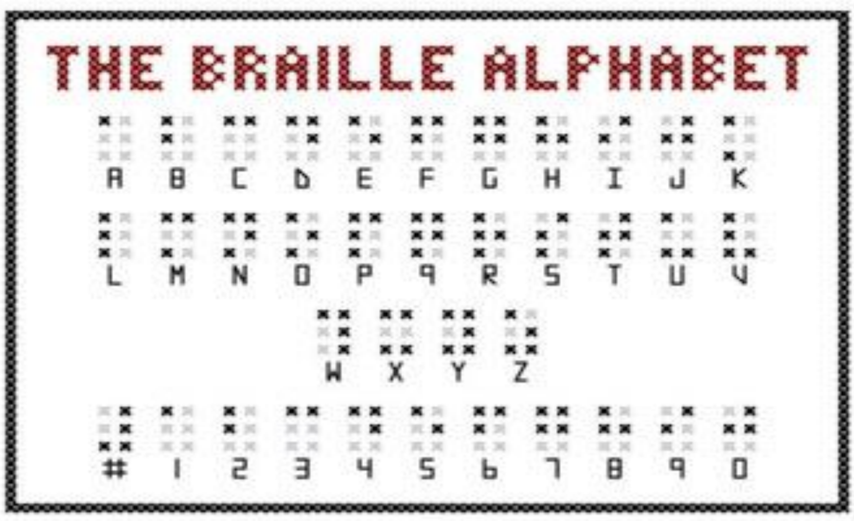

Figure 4: Braille alphabet

2.4 Number of Braille cell

This project needs 18 refreshable Braille cells because 18 alphabets are enough to show the name of the road. For example, the words "JALAN MAHAMERU" only need 14 alphabets including the space between words.

2.5 Circuit Design

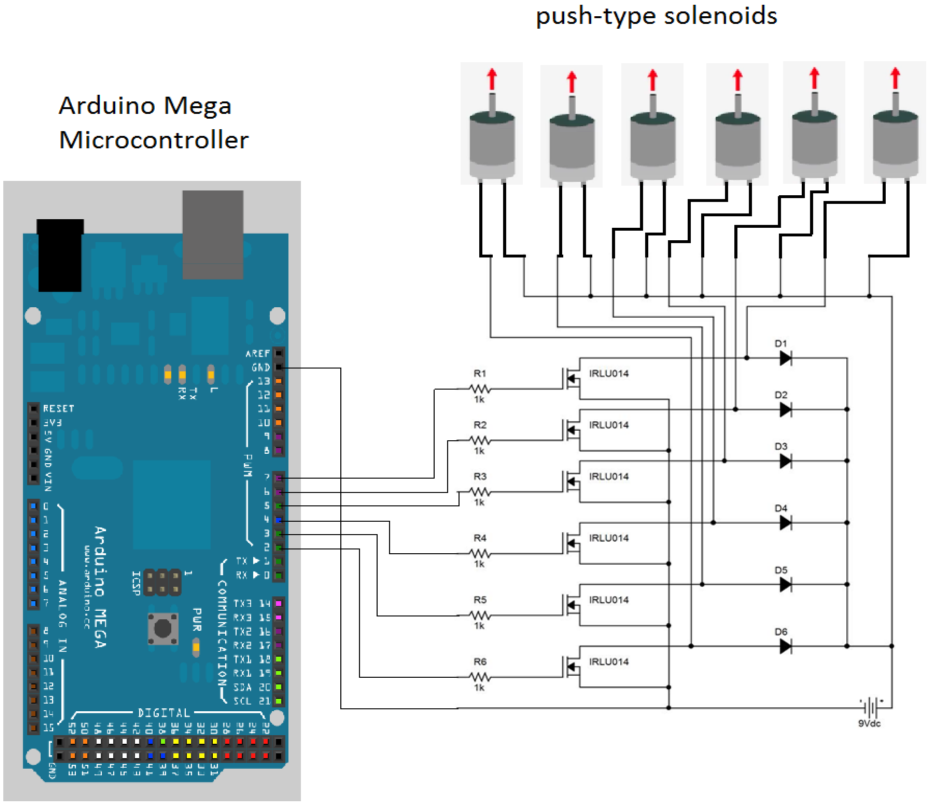

Figure 5: Schematic circuit design and connection

The schematic above in Figure 5 shows the circuit design and connection between the Arduino microcontroller and push-type solenoids to the circuit. For this circuit design, there are a few components that are needed. The first one is an IRLU014 n-type MOSFET transistor, which consists of four terminals, which are the body, gate, drain, and source. This type of transistor can act as a voltage-controlled switch and also logic gates from an MOS switch.

A silicone diode of 1N4004 (1A, 400v) is needed to allow current to move in one direction only. As compared to the Germanium diode, the Silicone diode is much better in terms of high voltage application and high current application and withstands a high temperature also. Apart from that, 1kΩ (ohm) resistors are needed in each connection to the microcontroller to reduce current flow and lower voltage within the circuit. It is important so that the circuit is safe and efficient in the long term.

A DC voltage supply that is needed for the solenoids to move upward ranges from 3v-12v. A single 9V alkaline battery is sufficient enough for the whole system to operate and push the solenoids upward. To sum up, A 9V alkaline battery is economical and convenient in terms of price and size as it comes with dimensions of height of 48.5 mm, length of 26.5 mm, and width of 17.5 mm (or 1.9"x1.0"x0.68"). The 9V battery snap (connector) is easy to find in most electrical or electronic stores.

2.6 Solenoid Braille System Design

There are a few systems involved in order to control the heights of pins or dots at push-type solenoid Braille cells. The systems are n-type MOSFET transistors, push-type solenoids, and Arduino microcontrollers. Based on Figure 6 below, the Arduino microcontroller is used to control all operations

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of the system, including data input from the computer or keypad and data output to the solenoid Braille cell.

The data processed by the Arduino microcontroller will be sent into an n-type MOSFET transistor that acts as a logic gate. Then transistor will spread the data to the solenoid Braille cell to display some of Braille characters or alphabets. The 9V alkaline battery is used to give sufficient voltage for the solenoid pins to rise and act as a Braille character.

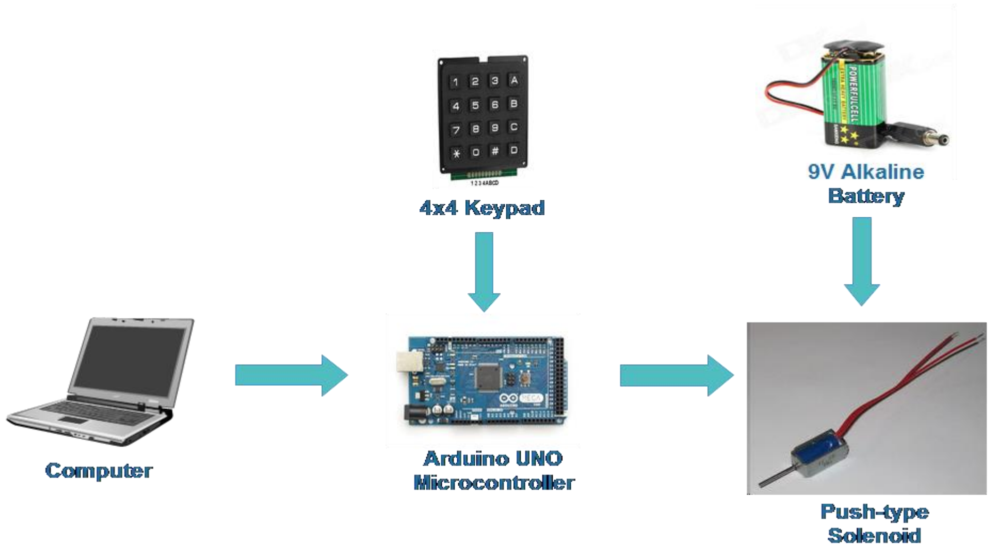

Figure 6: Components integration of input and output system

3.0 RESULTS AND DISCUSSION

This section will discuss the results obtained from the test that was done in this project. The result will be discussed on what has been achieved through the test of the prototype itself. Basically, the prototype is a system where each Braille character is made of six push-type solenoids that are arranged in 3x2 matrices. An Arduino microcontroller with input from the keypad 4x4 will control the Braille character. Arduino coding language plays an important role in completing the project successfully. A simple wide container is used to put all the components and arrange all the solenoid Braille cells.

3.1 9V DC Open-Loop Solenoid Test

This test is conducted to analyze the functionality of the push-type solenoid after they are connected to the circuit and supplied to the DC voltage. This open loop test is to ensure the entire solenoid Braille pin will rise when a direct 9V DC voltage is supplied.

Before the 9V alkaline battery is supplied, all the solenoid Braille pins remain at the initial position, as shown in Figure 7. An alkaline battery of 9V is connected then to the solenoid, and all the six solenoid Braille pins are raised, as shown below in Figure 8. The Braille pins rise immediately after the 9V is supplied. Delay can be implemented later using Arduino coding and also different Braille output from the user input keypad.

Figure 7: Braille pins are at initial position

Figure 8: All Braille pins rise up after the voltage is supplied

3.2 Cost Analysis for Material Used

In the production of the solenoid-based refreshable Braille cell, technological innovation plays a pivotal role, particularly in material selection and integration. The development process involves meticulous material choices to ensure durability, tactility, and efficient functionality. Advanced polymers or composite materials are often explored to create the structural base, providing a sturdy yet lightweight foundation for the Braille cell. These materials undergo precision molding techniques, ensuring the intricate design accommodates the 3x2 rectangular array required for the six-dot Braille characters.

Table 2: Cost for Solenoid-based Refreshable Braille Cell

Items	Price (RM)	Unit	Total Price (RM)
Arduino Mega with accessories	90.00	1	90.00
IRLU014 Transistor	6.00	18	108.00

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9V Alkaline battery	8.00	3	24.00
Keypad 4x4	17.00	1	7.00
Push-type solenoids	25.00	18	450.00
Electrical Parts	40.00	1	40.00
		Total	719.00

Moreover, the technological breakthrough lies in the solenoid system integration. Innovative engineering techniques are employed to fabricate push-type solenoids capable of delicately controlling the rise and fall of individual pins corresponding to Braille dots. These solenoids, engineered for low-voltage operation, align with the user-friendly command input system, ensuring a seamless user experience. The incorporation of Arduino microcontrollers enhances adaptability and programmability, allowing for precise control of the solenoids, thereby dictating the display of Braille characters. This amalgamation of materials and cutting-edge solenoid technology, shown in Table 2, represents a significant stride in producing a refreshable Braille cell, catering specifically to the needs of visually impaired individuals.

4.0 CONCLUSION

In this project, push-up solenoids were used to engineer a specialized Braille display tailored explicitly for individuals with visual impairments. Based on the results of the study, all the solenoid pins were successfully raised when voltage was supplied, indicating the objective is achieved, which is to enhance accessibility by enabling visually impaired individuals to interpret Braille characters easily across various devices. This initiative symbolizes a potential technological advancement akin to an 'Electronic Eye,' envisaged to significantly improve the quality of life for those with visual impairments.

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