# Development of Piezoelectric Braille Cell Control System Using Microcontroller Unit (MCU)

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*Abstract:* - This paper describes about designing and developing a system for controlling piezoelectric Braille cell by using Programmable Interface Controller (PIC) microcontroller. For this purpose, PIC microcontroller is used as a controller to the system for controlling the piezoelectric Braille cell. Piezoelectric Braille cells are used in many refreshable Braille display applications. The Braille displays using piezoelectric Braille cell are able to refresh the Braille character that are read by the visually impaired by touching the dots at Braille cell. Each piezoelectric Braille cell consisting of six or eight movable pins or dots in rectangular array. The height of pins or dots in Braille cell is controlled by a piezoelectric bimorph. This will cause the pins or dots at piezoelectric Braille cell to rise or fall and therefore, create the Braille character or alphabet. Throughout the paper, the pin or dots at piezoelectric Braille cell which represent a certain Braille character is also presented. The architecture and operation of the system is discussed in detail, considering both the hardware and software elements involved. The software for programming the PIC microcontroller was written with CCS C program language. The system is developed and tested successfully. This system can be applied in the Braille Display which uses the piezoelectric Braille cell to display some of Braille characters.

*Key-Words:* - Piezoelectric Braille cell; PIC Microcontroller; CCS C program language

## 1 Introduction

A Braille display is an electronic device, typically attachable to a computer that allows the visually impaired to read the contents of a display one text line at a time in the form of a line of Braille characters. It is also called a tactile device that consisting a row of several Braille cells. One Braille cell has either six or eight dots in a rectangular array depending on the model of Braille displays. Some of Braille displays uses Braille cell that has eight dots. Dot number one until six are used to produce 64 different Braille alphabets while dot 7 and 8 to show the position of the cursor in the text. The six or eight pins of each Braille cell can rise up and down depending on the electrical signals they receive. This simulates the effect of the raised dots of Braille impressed on paper. There are usually 40, 65, or 80 arrays (characters) per line of text, depending on how many Braille cell attached at one Braille display. Less expensive Braille display devices, fewer Braille characters that can be display per line[1].

A Braille display operates on either electromagnetic or piezoelectric principles. When currents or voltages are applied to points in each six or eight pins array, various combinations of elevated and retracted pins produce the effect of raised dots or dot-absences in Braille on paper. In the electromagnetic Braille display, each pin is surrounded by a cylindrical casing that contains a coil. The pin is attached to a spring, and also to an iron rod passing through the casing. This forms a miniature solenoid. When a current passes through the coil, the pin is pulled inward. Thus when there is no current, the pin is elevated, corresponding to a raised dot in Braille when there is current in the coil, the pin retracts, corresponding to the absence of a dot. In the piezoelectric display, each pin is mounted above a piezoelectric crystal with metal attached to one side. If a sufficient voltage is applied to the crystal, it becomes slightly shorter. This causes the metal to bow upwards, raising the pin. Thus when there is no voltage, the pin is retracted, corresponding to the absence of a dot in Braille when there is voltage across the crystal, the pin is elevated, corresponding to a dot. At the moment, the piezoelectric Braille cell is being most common in most Braille displays [2] and commercially available because it is relatively light weight, of small size and has direct-electrical control [3]. Braille display is designed for some of electronic media in the Braille format such as email, SMS, blog or website on internet.

This provides access the blind users to read or check the electronic media by touching the Braille display.

In this study, the piezoelectric Braille cell will be integrated and controlled by PIC microcontroller. PIC microcontroller will control whether the pins or dots at Braille cell will rise or fall by sending an electrical signal to the piezoelectric Braille cell. On the other hand, microcontroller will communicate with the computer through serial RS232 or COM serial port to receive a data input from the user. The data input that is mentioned here is an input data from several computer keyboards' keys that will be explained on the next chapter. This application can be used for designing and developing a Braille display panel as a teaching aid.

## 2 Systems Involved

There are four systems involved in order to control the height of pins or dots at piezoelectric Braille cells. Those systems are piezoelectric Braille cell, shift register, DC to DC converter and microcontroller system. Fig. 1 shows the block diagram of the system. Microcontroller is used to control all operation of the system including data input from computer and data output to the piezoelectric Braille cell. The input data is received by microcontroller via RS232 serial port connection and that data will be send to shift register system. Then, shift register system will spread the data to piezoelectric Braille cell to display some of Braille characters or alphabets. This system can be applied in the designing and development of Braille display that uses piezoelectric Braille.

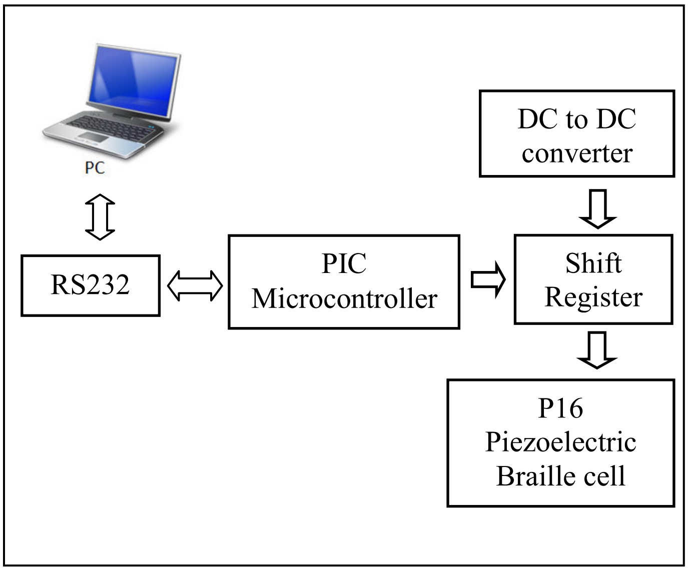
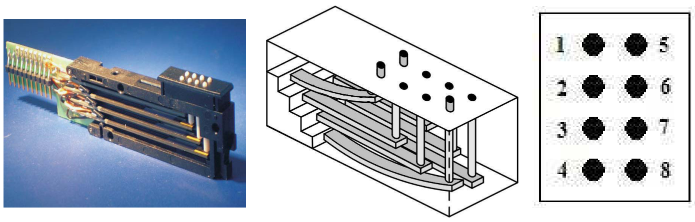



Fig.1 A system for controlling the piezoelectric Braille cells.

### 2.1 Piezoelectric Braille Cell

Piezoelectric Braille cell represents a single unit of a Braille character that can be displayed and refreshes itself to any Braille character depending on a command input. It consists of a structural base, piezoelectric bimorphs, a printed circuit board (PCB), a cap and pins or white dots. Each cell has eight dots in a rectangular array 4x2 and is controlled by piezoelectric bimorph [1]. This piezoelectric bimorph is located inside piezoelectric Braille cell and attached to every single dot. Those dots will represent a Braille character or alphabet. Piezoelectric bimorph will bend up or down depending on the value of voltage applied. In normal position, the bimorph is a straight beam when there is no electrical excitation. If there is a voltage that causing the bimorph to bend up, the white dots will raised up. On the other hand, if there is voltage that causing the bimorph to bend down, the dot will fall down under the reference surface. P16 piezoelectric Braille cell module from Metec Company as illustrated in Fig. 2 has been used as a Braille actuator in this study.




(a) (b) (c)

Fig.2 (a) P16 piezoelectric Braille cell module [3], (b) Piezoelectric bimorph inside Braille cell [4], (c) The position of the pins in columns and rows of in the Braille cell.

Voltage applied for this module is around 200V. There are 10 pins at PCB board on each P16 Braille cell. Pin 1 is connected to positive supply 200V and pin 2 is shorted to ground. The other pins represent each dot at piezoelectric Braille cell [3] as shown in Fig. 3. When the voltage 200VDC is applied to each pin that attached with the dots of Braille cell, piezoelectric bimorphs inside Braille cell will bend down and make the dot fall. If voltage 0V is applied, the situation is reversed. Some of Braille characters can be formed by applying these two voltages.

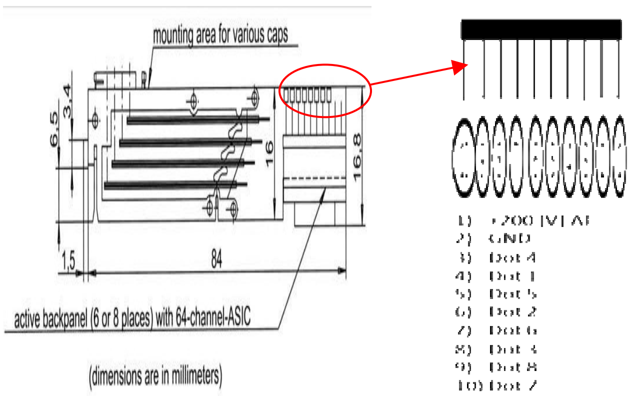



Fig.3 Braille cell pins configuration [3].

## 2.2 Shift Register

Shift register is a type of sequential logic circuit, mainly used for storage of digital data. It is a group of flip-flops connected by a chain so that the output from one flip-flop becomes the input of the next flip-flop. All the flip-flops are driven by a common clock, and all are set or reset simultaneously. One of the most common uses of a shift register is to convert between serial to parallel data interfaces.

For this study, shift register is used to convert the serial data from microcontroller to parallel data which can be spread to every single dot at Braille cell. As we know, each Braille cell has eight pins that representing each dot for one Braille cell. As illustrated in Fig. 3, all pins need to be triggered by some voltage value whether 200V to rise up the dots or 0V to fall the dots under reference surface. HV507PG chip has been used as a shift register for this system. The HV507PG chip is a low voltage serial to high voltage parallel converter integrated circuits (ICs) with 64 push-pull outputs. By combining high voltage and low voltage devices in one IC, it replaces a large number of discrete components including multiple high voltage N-channel and Pchannel MOSFETs in applications such as driving piezoelectric transducers and flat panel displays in push-pull mode. The HV507PG can be used in any application that requiring multiple output, high voltage, low current sourcing and sinking capabilities [5]. The input voltage for this shift register is around 0.5V to 6.0V and it can produce output voltage on each pin up to 300V.

HV507PG chip consists of a 64-bit shift register, 64 latches, and several control logic pins such as direction (DIR) pin, Latch Enable (LE) pin, blanking (BL) and polarity (POL). This device also has two control data pins named DIOA and DIOB and both pins are controlled by DIR pin. For example, when DIR is grounded, DIOA is Data-In and DIOB is Data-Out; data is shifted from HVOUT64 to HVOUT1. When DIR is at logic high, DIOB is Data-In and DIOA is Data-Out: data is then shifted from HVOUT1 to HVOUT64. Data is shifted through the shift register on the low to high transition of the clock. Transfer of data from the shift register to the latch occurs when the LE is high [5]. The data in the latch is stored during LE transition from high to low. The HV507PG can be controlled by some peripheral in PIC microcontroller called serial peripheral interface (SPI). SPI is a serial bus standard established by Motorola and supported in silicon products from various manufacturers. SPI specifies four signals that are clock (SCLK),master data output or slave data input (MOSI), master data input or slave data output (MISO) and slave select (CSS).

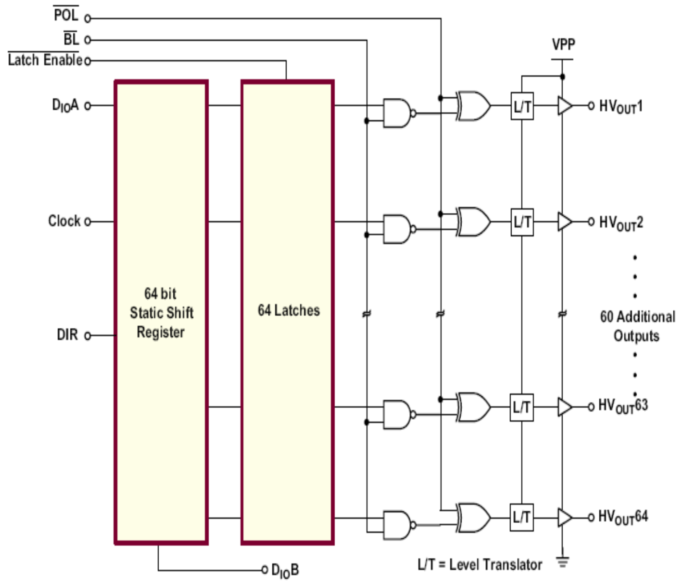



Fig.4 Functional block diagram for HV507PG shift register [5].

## 2.3 DC to DC Converter

DC to DC converter is an electronic circuit which converts a source of direct current (DC) from one voltage level to another. It stores the input energy temporarily and then releases that energy to the output at a different voltage. The storage may be in either magnetic field storage components (inductors, transformers) or electric field storage components (capacitors). Many of DC to DC converters are designed to move power in only one direction, from the input to the output. It is has been used in many devices application that required higher voltage but lower current consumption such as in portable electronic device like cellular phones and laptop computer. DC to DC converter that has been used for this system is one direction, from 12V input voltage to 200V output voltage. This output voltage will be applied at each pin of P16 Braille cell. The maximum output power for this DC to DC converter is 1.5Watt [6].

## 2.4 PIC Microcontroller

Microcontrollers are one of the most important devices implementing communication and electronic control systems. A microcontroller is a type of microprocessor furnished in a single integrated circuit and needs a minimum of support chips. The microcontroller is capable of storing and running programs. It contains a CPU (central processing unit), RAM (random-access memory, ROM (read- only memory), I/O (input-output) lines, serial, parallel and Ethernet ports, Serial communication pheripheral, sometimes other built-in peripheral such as A/D (analog to digital) and D/A (digital to analog) converter[7]. PIC stands for programmable interface controller. It is a family of harvard architecture microcontroller made by Microchip technology. It is a special kind of microcomputers integrated on a single chip, which in addition to the central processing unit and a memory consist of numerous applications with some peripheral like timers, analog to digital converter and communication modules [8]. PICs families' microcontrollers are so popular among developers due to their low cost, wide availability, large user base and also extensive collection of application notes[9][10]. It can also reduce the number of external elements or circuits as well as the cost [11] and most of them are available in small packages of dimensions [12]. PIC microcontrollers can be found in many application devices such as manufacturing equipment, instrumentation and monitoring, data acquisition, power conditioning, environmental monitoring, telecom and consumer audio/video applications.

PIC18F452 will be used as a controller for the system. It used to control every single dot at each Braille cell depending on input data from computer. This integrated circuit(IC) contains some peripherals such as eight channels of 10-bit Analog-to-Digital (A/D) converter, the synchronous serial port can be configured as either 3-wire Serial Peripheral Interface (SPI) and Universal Asynchronous Receiver Transmitter (USART) [13]. PIC18F452 has 44 pins and five ports; Port A, B, C, D, and E which can configure as input or output port. The microcontroller does not incorporate an internal oscillator and needs therefore of an external system of oscillation to be connected to generate the clock. In this case, a crystal oscillator has been used in order to generate the clock pulse for microcontroller.

The PIC18F452 microcontroller will communicate with the computer through USART peripheral modules, also known as a Serial Communications Interface (SCI). These peripheral modules will be connected to a serial COM port that is located at the computer and following the RS232 communication protocol. The advantage of using USART is it can be configured as a full-dull-duplex asynchronous system that can communicate with peripheral devices such as CRT terminals and personal computer. It also can be configured as a half-duplex synchronous system that can communicate with other peripheral devices such as EEPROM and A/D converter integrated circuit (IC) [14].

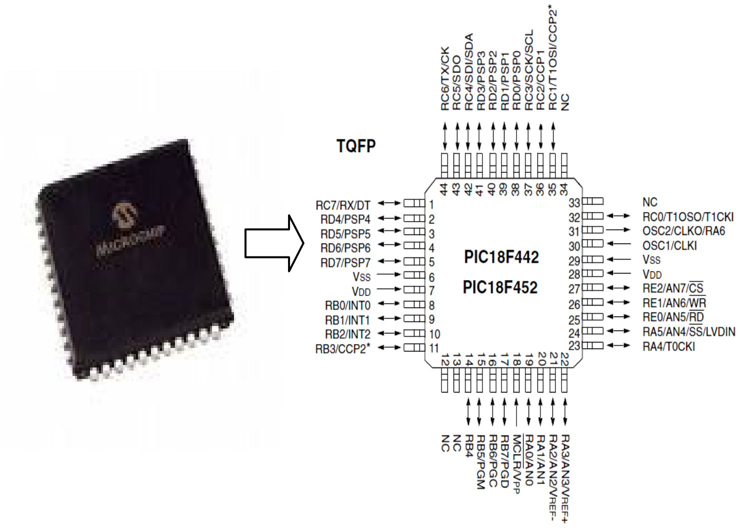



Fig. 5 PIC18F452 microcontroller unit [13].

# 3 Design of Schematic Circuit

Fig. 5 below shows the schematic diagram of the system. The power of the circuit was constituted by one voltage regulator, IC L7805. This L7805 will generate positive voltage 5V from a direct supplied voltage 12V. By referring to the Fig. 5, a 20MHZ quartz oscillator is connected to port OSC1 and OSC2 of the PIC (pin 30 and 31). The PIC MCLR port is connected to the reset button which is attached to the pull up resistor 10K ohm. The reset button is used to restart the PIC to initial state of program and also can be used to load a new program on the PIC. There is another button that was connected to the ports RB5 (pin 15). This button is configured as an input pins for execute or run the program.

In order to communicate between PIC18F452 with computer through COM port, MAX232 chip needs to be used. MAX232 is produced by Maxim. It is an integrated circuit that provides the adequate voltage levels in order to interface with the computer [15]. MAX232 is connected between DB9 connector and line RC6 and RC7 of PIC18F452. It will convert the serial line voltage (0-12V) to the voltage value that can be accepted by PIC microcontroller in range voltage (0-5V). Max232 has two channels for bidirectional RS232 communication and it requires only positive 5V for RS232 transmission standard. SPI pins that are SCL (pin 37), SDA (pin 42) and SDO (pin 43) are connected to the IDC socket 10 ways pins which is attached to the shift register and piezoelectric Braille cell.

On the hand, voltage 200V generated by DC to DC converter is also connected to this IDC socket. The voltage is used as the supplied voltage for piezoelectric Braille cell to rise up or down the white dots.

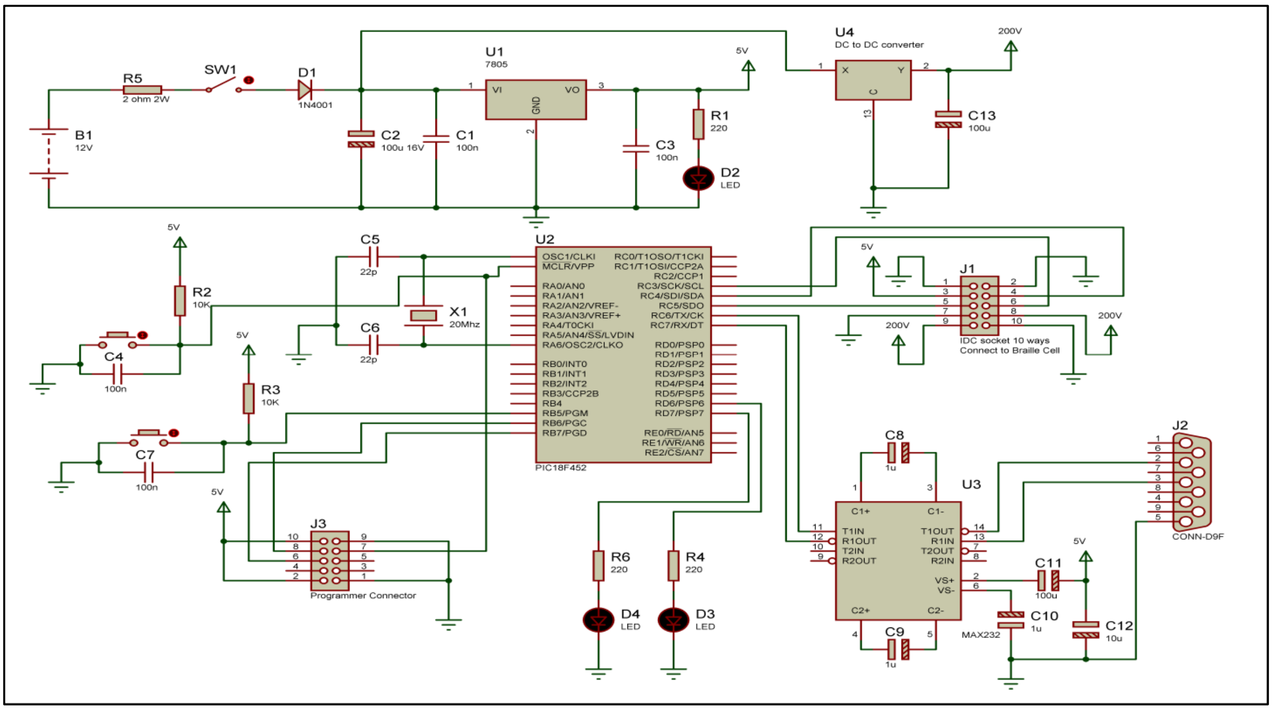



Fig.6 Schematic diagram of the system.

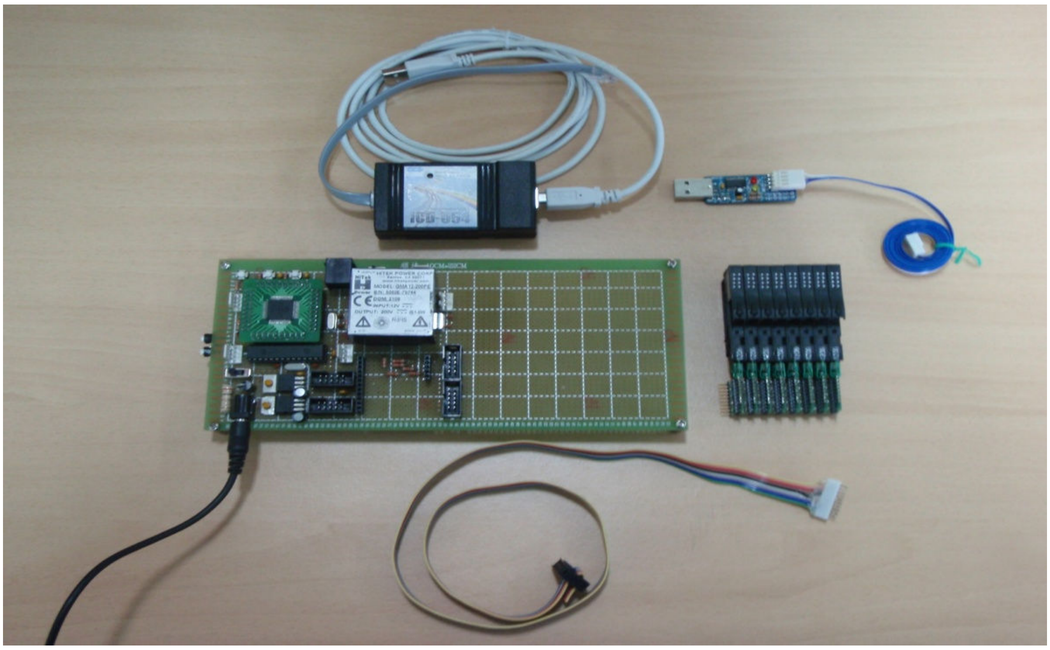


Fig.7 Photo of overall hardware circuit's system.

# 3 Design Considerations for Software Implementation

In the software implementation process, initialization processing, data input processing from PC and data output to P16 Braille cell modules processing are considered. All of the software programs are written by using CCS C compiler software.

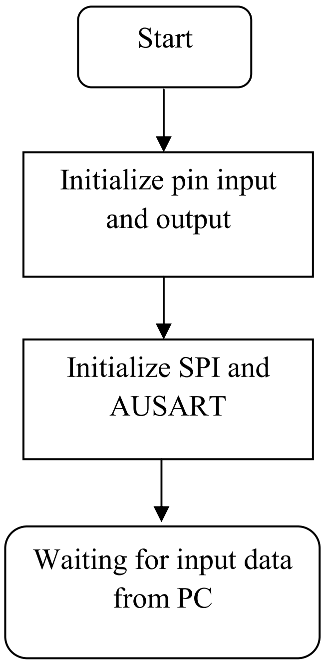



Fig.8 Flow chart of initialization process.

First, the required mode is initialized. In this process, pin RB5 at port B is defined as an input or play button. This button will execute the program after all initialization has been made. Serial Peripheral Interface (SPI) and Universal Synchronous Asynchronous Receiver Transmitter (USART) are also being configured and initialized in this process. The SPI is used to communicate between PIC18F452 microcontrollers with HV507PG shift register. The size of the data transferred by SPI is eight bit serial data. Eight bit serial data will be converted to eight bit parallel data by shift register. One bit represents one dot at Braille cell. USART is used to communicate between PIC18F452 with PC through hyper Terminal using RS232 serial communication protocol.

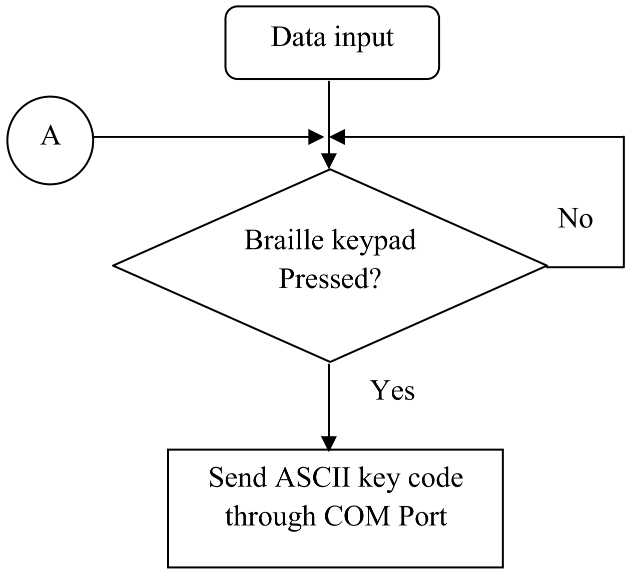



Fig.9 Flowchart of data input processing

In data input processing, the program will wait until some of Braille keypad is pressed. The Braille keypads mentioned here is computer keyboard keys that are “f”,”d”,”s”,”j”, ”k” and ”l” . Those keys represent the six key of Perkins Brailler. The Perkins Brailler is a typewriter to write Braille character or alphabet. The Perkins Brailler has several keys corresponding to each of the six dots of the Braille code. By simultaneously pressing different combinations of the six keys, users can create any of the characters in Braille code [16]. Fig. 7 shows the Braille alphabet or character that can be formed by using all six key that mentioned above.

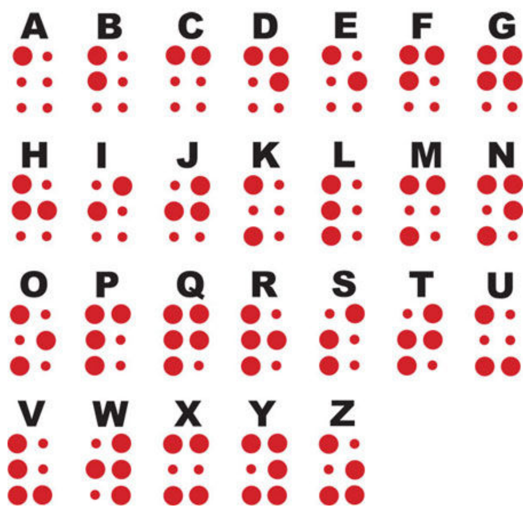



Fig.10 Braille Alphabets [17]

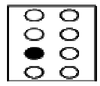
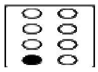
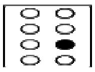
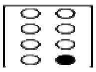
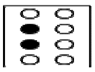
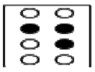
| Computer Keyboard Key | ASCII Code | Braille Code | Dots Braille |
|---|---|---|---|
| “ f ” | 0x66 | 0x40 |  |
| “ d ” | 0x64 | 0x20 |  |
| “ s ” | 0x73 | 0x10 |  |
| “ j ” | 0x6A | 0x04 |  |
| “ k ” | 0x6B | 0x02 |  |
| “ l “ | 0x6C | 0x01 |  |
| “f” & “d” | 0x66 & 0x64 | 0x60 |  |
| “f” & “j” &”k” | 0x66 & 0x6A & 0x6B | 0x46 |  |

Table 1

ASCII Code and Braille Code for combination of six keys

In this study, six keys on computer keyboard that are “f”,”d”,”s”,”j”,”k” and “l” will be input data for the system. These six keys will control every single dot at Braille cell. For example, “f” key will control dot 2 to rise if this key is pressed. This entire function key is shown at Table I. In order to show “A” Braille alphabet at Braille cell, we need to raise dot number two which refer to “f” key. For case “B” Braille alphabet, we need to raise dot 2 and 3. To achieve this, the “f” and “d” keys are pressed simultaneously. By combining some of these six keys, we can write the Braille alphabet from “A” to “Z”.

After one of Braille keypad has been pressed, an ASCII code for that key will be send by computer using Hyper Terminal through the COM port and this will be received by PIC18F452 microcontroller via USART. Computer will send ASCII code only but not Braille code. For example, if “f” key (without caps lock) has been pressed, ASCII code “0x66” in hexadecimal is send through Hyper Terminal. This value needs to be converted by microcontroller to Braille code value such as “0x40” for “f” key to raise the dot number 2 at Braille cell.

In data output processing, the program will check at USART buffer whether the data has been received or not. If the data are not received via USART, the program will not execute to next step and it will wait until a data has received. When PIC18F452 has received data via USART, that data will be converted to Braille code first before sending it to shift register. Then, that Braille code will be send to HV507PG shift register. Shift register will spread the data to every single Braille cell to perform a character of Braille. All of three processes will continue until the reset button is pressed.

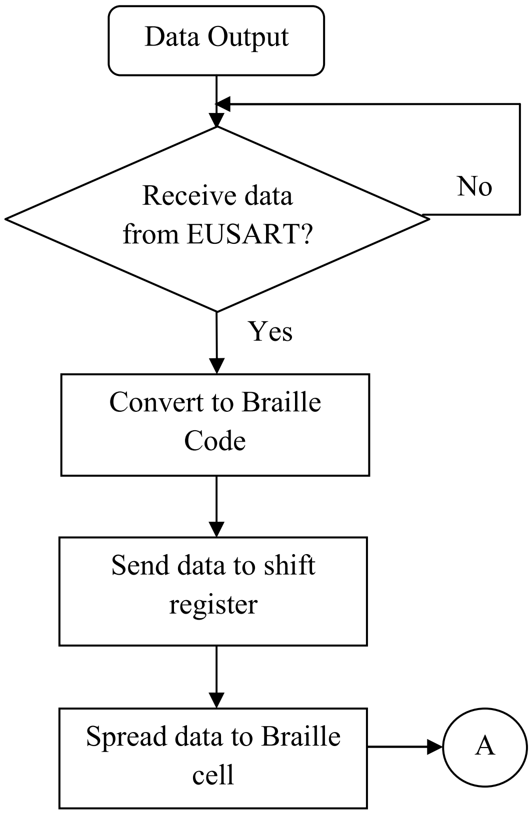



Fig.11 Flowchart of data output processing

## 4 Software Programming Tools

There are many software programming tools with full functionality freely available on the internet for programming the PIC microcontroller family. Most of them have a compiler that can support several higher-level languages such as C, C++, Pascal and Basic language. Some compilers provide an extensive set of common and microcontroller specific libraries that can help the user in writing and developing a source code for programming the PIC microcontroller. There is software providing by Microchip Technologies named MPLAB Integrated Development Environment (IDE). MPLAB IDE is a Windows Operating System (OS) software program that runs on a PC to develop applications for Microchip microcontrollers and digital signal controllers. It is called IDE, because it provides a single integrated "environment" to develop code for embedded microcontrollers [7].This software offers a full range of development tools for programming its PIC microcontroller family. It is also has several programming tools, simulator product guide, assembler tool and C compiler for the C language programming. This MPLAB is normally support only the Microchip's propriety hardware [17].

Besides Microchip's software tools, there are other software tools that can be chosen but in different manufactures. For example, HI-TECH PICC, IAR Embedded Workbench, CCS C Compiler, and mikroC compiler [18]. This all software tools can be used to develop the code for 8-bit microcontrollers (PIC10, PIC12, PIC14, PIC16 and PIC18 families) and 16-bit microcontrollers (dsPIC and PIC24 families).

Some of the tools are more user friendly to the consumers who use it. It is because it provides more library functions and tutorials for those who are new in programming the PICs. For this research, CCS C compiler has been chosen as software tools for programming the PIC microcontroller. CCS C compiler provides a complete, integrated tool suite for developing and debugging embedded applications running on PIC microcontroller family. Development tools offered by CCS include an optimized C compiler, in-circuit programmers/debuggers,production programmers and complete development kits that contain all hardware, software and accessories needed for programming the PIC. On the other hand, CCS C compiler provided a lot of optimization function library such as UART function library for RS232 communication and SPI function library for communication between PIC microcontroller with external device like shift register. CCS also offer the customer a programmer or debugger tools for debugging the code and downloaded the firmware into PIC microcontroller. It support all target of PIC families that have debug mode when used in conjunction with CCS IDE compilers.

## 5 Finding/Result

In this study, results were obtained from entering the input data by pressing some of Braille keypad key's that are "f","d","s","j", "k" and "l" keyboard key. All of this input data will represent a Braille character or alphabet at piezoelectric Braille cell. Before running the program at PIC18F452 microcontroller, the Hyper Terminal at computer needs to be setting first. Both transmitter/sender and receiver between PIC and Hyper Terminal must be set up to use the same communication parameter. For example, computer COM 3 port is set at 9600b/s communication speed (see Fig. 12). Microcontroller SPBRG register is responsible for the USART communication speed, according to the relation: Baud Rate = FOSC/ (16(*SPBRG value (decimal)* +1)) [80]. Taking into account the 20Mhz oscillator crystal (see schematic diagram in Fig. 6) . So, SPBRG will be loaded with decimal value 12 in order to have the same 9600 baud rate as the PC serial port.

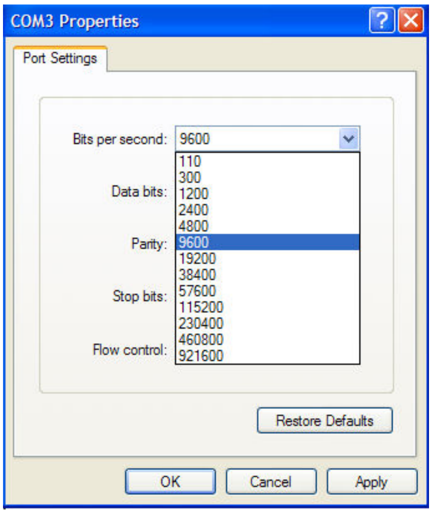



Fig .12 Port setting at Hyper Terminal

The program at PIC microcontroller is running when the button at pin RB5 port B is pressed. During starting program, the PIC will send several ASCII's word to the Hyper Terminal display to acknowledge the user that the system is now waiting for input data from Braille keypad. It can be seen in Fig.13. When the user presses one of the Braille keypad such 'f' keyboard's key, an ASCII code of that key's will be transfer to the microcontroller through RS232 communication line. That ASCII code can be referring to the Table 1 in this paper. The PIC18F452 microcontroller who is received the ASCII code, again will send another word in ASCII format to Hyper Terminal display to mention about the key's that the user have pressed. After that, PIC18F452 microcontroller will convert the ASCII code to the

Braille code and will send it to shift register system. This shift register system will spread the data to piezoelectric Braille cell to perform Braille characters or alphabets. This result is shown on Table 2 below. Once a Braille character is displayed at Braille cell, PIC will send the ASCII word and asked the input data again from the user. This process will continue repeating itself until the reset button is pressed.

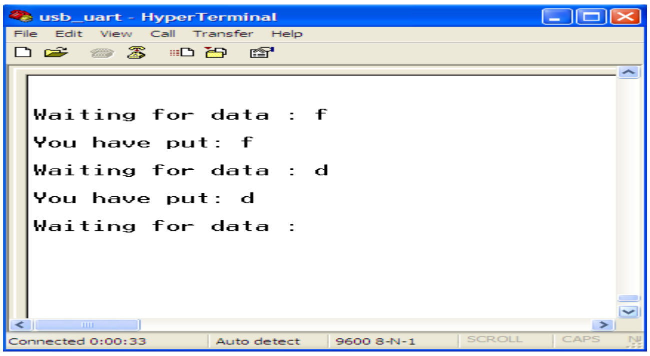



Fig.13 Input data from Hyper Terminal

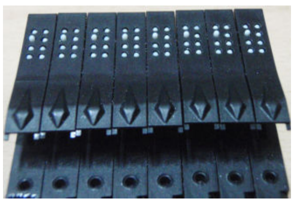
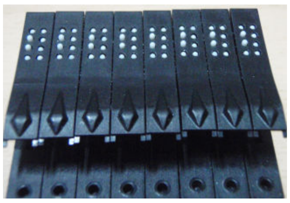
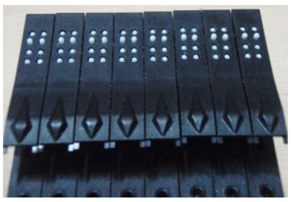
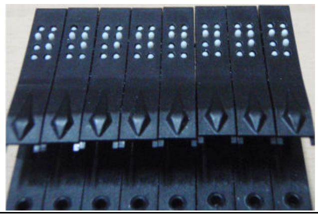
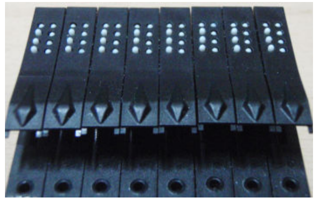
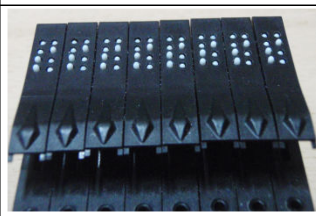
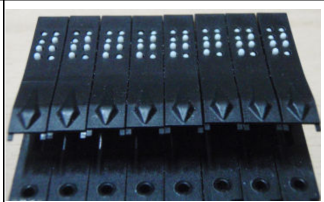
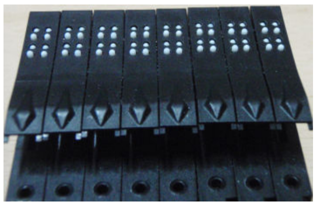
| Computer Keyboard key | Result Display at Braille Cell | Braille Alphabets |
|---|---|---|
| " f " |  | A |
| " f " & " d " |  | B |
| " f " & " j " |  | C |
| " f " & " j " & " k " |  | D |
| " f " & " d " & " s " |  | L |
| " f " & " d " & " j " & " k " |  | N |
| " d " & " s " & " j " |  | S |
| " d " & " s " & " j " & " k " |  | T |
| " f " & " s " & " j " & " k " |  | X |
| " f " & " s " & " j " & " k" & " l " |  | Y |

Table 2
Braille Character Appeared at Eight P16 Piezoelectric Braille Cell.

# 6 Conclusion

This paper has introduced and presented a system for controlling the piezoelectric Braille cell by using PIC microcontroller. By pressing the Braille keypad, a certain character or word can be displayed at piezoelectric Braille cell. The Table 2 proved that the system can successfully display the character or alphabet of Braille appeared at piezoelectric Braille cell after Braille keypad has been pressed. This system can be applied in designing and development of Braille display that used piezoelectric Braille as Braille actuator.

# 7 Acknowledgment

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