Interfacing LED Dot Matrix Display with PIC16F887 Microcontroller

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***Abstract*—This research work is to design and implement six English letters, which stand for the name of our Degree College, Nationalities Youth Resource Development Degree College, NYRDDC. The letters are made up of acrylic sheets, PVC sheets and aluminum foils. Each letter box is 35 inches tall, 24 inches high and 4 inches deep. The ratio of the front surface area of each letter is A4 size ratio and letter font is Arial Black. The front surface is made holes though which LEDs are put into. In each letter, LEDs are arranged into a matrix of 24 rows and 16 columns. LEDs in each row is connected in parallel. All anode terminals from 24 rows are connected together as a common anode. So, the design of each letter is 24 rows and 1 column. Since there are six letters on the display board, the design of the whole system is [24 × 6] LED-dot-matrix. The length of the diameter of each LED is 9 mm and power dissipation for each is 0.12. W (12 V × 10 mA). There are 1361 LEDs in the display system. The maximum number of LEDs lighting on at a time is 100. The power of the constant current source is 12 V- 30 A. The sourcing driver IC for anode side is TD62783APG and the sinking driver is ULN2803APG. The two drivers are from Toshiba's products. The control device is PIC16F887 microcontroller. LEDs display is controlled with microcontroller and scanned by rows and columns. The programming language is PIC Assembly Language. In each operation, eight rows of the matrix are first set HIGH and then one column is set HIGH. After 1 millisecond (ms), that column is set LOW and successive next column is set HIGH again and again. For a complete cycle of the whole display system, number of processing is 18 and LED-ON-time is also 18 ms. So, the scanning rate is 55 Hz. The result is acceptable with the Persistence of Vision.**

Keywords—LEDs lighting, PIC16F887 microcontroller, TD62783APG, ULN2803APG, LED dot-matrix display.

I. INTRODUCTION

We can see what we can see or vice versa. It is interesting. When an object is viewed, it may be seen or not depending on two roots. The first one depends on the viewer and the second one does on the object which is viewed. If the eyesight is normal, visible objects can be seen. But every visible thing cannot be always seen. It depends on the seeing count in a second. Today's motion pictures flash images on the screen at 24 frames per second [1]. If the seeing count is less than 24 in a second, it becomes invisible.

At night, if an electric switch is turned off just after turning on, there is a light left. The faster you can do so, the longer the lighting time. If you can do at least 24 times within a second, night becomes day. If not, there will be dimmer. This is because the switching time is not fast enough. In digital electronics, microcontroller can do so fast. Switching time for PIC16F887 is just 0.2 µs [2].

Microcontroller has many control pins. Each I/O pin can directly control an LED to turn on or off. But there are many LEDs on a display board. So, multiplexing LED dot matrices are used to reduce the number of control pins.

Another interesting point is the brightness of an LED which is dependent on the current flowing through it within a limited range. The output current depends on the type of power supply. Suppose, 20 mA current is required for an LED, to turn on 100 LEDs at the same time, 2 A current is needed. For more numbers of LEDs, higher current will be needed. In a LED display system, a good constant source is required.

For microcontroller-based LED display system, its output current is not sufficient enough to display. So amplifying ICs have to use. Transistors can amplify the current many times. For high current applications, the use of transistors become okay but for digital display system, there is a problem of long switching time. Because of this effect, shading appears on the display panel. To solve this, LED driver ICs containing Darlington transistor arrays become useful. Their switch-OFF time is also faster and power dissipation is less. So, sinking and sourcing drivers such as TD62783 and ULN2803 become useful.

For LED dot-matrix display, there are three sorts of scanning approaches namely row scan, column scan, and dot-by-dot [3]. To design a large LED dot-matrix display, we need to deal with flickering and lower luminous intensity issues. As the size of display becomes larger, to reduce perception of flickering, frame rate and refresh rate need to be increased in both horizontal and vertical directions [4].

However, in spite of using fast digital controller, the effects of delays, inductance and capacitance restrict to the number of LED dot-matrix modules and refresh rate. As luminous intensity of LEDs is directly counted on the current flowing through the LEDs, lower frame rate (with same switch-on time) reduces overall luminous intensity [3].

In the present system, microcontroller drive and control the LED display panel via the LED drivers. The rest of this paper is organized as follow. Section 2 describes the research methodology and background information of this system. Step by step procedures and experiments are explained in section 3. The results are analyzed and evaluated in section 4. Section 5 concludes the system.

II. RESEARCH METHODOLOGY

A. Functional study of the PIC16F887 Microcontroller

PIC16F887 is a popular, powerful and easy to program device. It is a 40-pin package. It is one of the midrange-PIC microcontrollers from Microchip Technology. It features all the components which upgraded microcontrollers normally have. For its low price, wide range of application, high quality and easy availability, it is an ideal solution in applications such as: control of different processes in industry, machine control and measuring the different values, etc.

B. Memory Organizations

Memory is part of the microcontroller used for data storage. Every memory location corresponds to its memory address. Each memory has its own bus so that concurrent access can occur. There are two memory blocks in the PIC16F887. These are Program Memory and Data Memory.

The PIC16F887 has a 13-bit program counter capable of addressing an 8k × 14 program memory space and 8k × 14 words of flash program memory. Accessing a location above these boundaries will cause a wraparound within the first 8k x 14 space. The Reset vector is at 0000h and the interrupt vector is at 0004h.

The data memory is partitioned into four banks. Each bank contains the General Purpose Registers (GPR) and the Special Function Registers (SFR). The SFRs are located in the first 32 locations and the GPRs are in the last 96 locations of each bank. The register file is organized as 368 × 8 in PIC16F887. Each register is accessed, either directly or indirectly, through the File Select Register (FSR). The SFRs are registers used by the CPU and peripheral functions for controlling the desire operation of the device. These registers are static RAM. Two bits of STATUS register, RP1 (STATUS<6>) and RP0 (STATUS<5>), are bank selecting bits and expressed in Table 1.

Table 1 Selecting bank using RP1 and RP0

RP1	RP0	Bank
0	0	0
0	1	1
1	0	2
1	1	3

C. Input or Output Ports

One of the most important features of the microcontroller is it has many peripherals. In this microcontroller, there are thirty-five general purpose I/O pins. All of them are grouped into five called ports denoted by PORTA, PORTB, PORTC, PORTD and PORTE. All of them have special features. In general, when a peripheral is enabled, that pin may not be used as a general I/O pin. Every port has its corresponding TRIS register. By clearing some bit of the TRIS register (bit=0), the corresponding port pin is configured as output. Similarly, by setting some bit of the TRIS register (bit=1), the corresponding port pin is configured as input.

D. PORTA and the TRISA Register

PORTA is an 8-bit wide, bidirectional port. The corresponding data direction register is TRISA. Setting a TRISA bit (= 1) will make the corresponding PORTA pin an input (i.e., disable the output driver). Clearing a TRISA bit (= 0) will make the corresponding PORTA pin an output (i.e., enables output driver and puts the contents of the output latch on the selected pin). Reading the PORTA register reads the status of the pins, whereas writing to it will write to the PORT latch. All write operations are read-modify-write operations. Therefore, a write to a port implies that the port pins are read, this value is modified and then written to the PORT data latch. All PORTA pins act as digital inputs/outputs. Besides, five of them can also be analog inputs (denoted as AN).

PORTB is an 8-bit wide, bidirectional port. Bits of the TRISB register determine the function of its pins. Similar to PORTA, a logic one (1) in the TRISB register configures the appropriate port pin as input and vice versa. Each PORTB pin has an additional function related to some of built in peripheral units and all the port pins have built in pull-up resistor.

PORTC and PORTD are 8-bit wide bidirectional ports. Bits of the TRIS registers determine the functions of its pins. Similar to other ports, a logic one (1) in the TRIS registers configure the appropriate port pin as input.

PORTE is a 4-bit wide, bidirectional port. The TRISE register's bits determine the function of its pins. Similar to other ports, a logic one (1) in the TRISE register configures the appropriate port pin as input. The exception is RE3 which is input only and its TRIS bit is always read as '1'.

E. Oscillator Types

The Oscillator module has a wide variety of clock sources. Clock sources can be configured from external and internal oscillators. There are eight clock modes in PIC16F887 microcontroller. These modes can be configured by FOSC<2:0> bits in the Configuration Word Register 1 (CONFIG1).

F. Programming the PIC microcontroller

Microcontroller and humans communicate through a programming language called Assembly language. In order the microcontroller can understand a program written in assembly language, it must be compiled into a "machine code". The machine code is represented by a 14-bit array of zeros and ones which microcontrollers understand. A compiler generates data file called "executive file, .hex file". After being generated, data file is loaded and stored into the microcontroller using programmer. It is shown in Fig. 1.

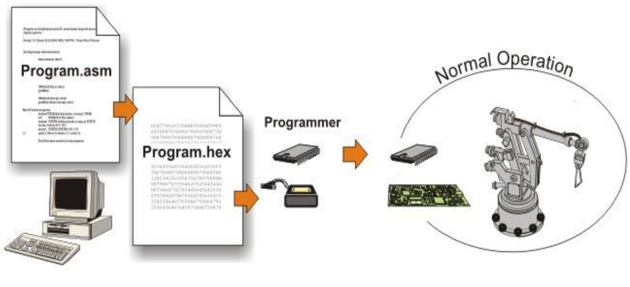

Fig. 1 Procedures for programming the microcontroller

In order to write a program on PC, the MPLAB software is used. It is a Windows program package which enables easy program writing as well as easy program development. Assembly program is written and compiled on Text Editor in it. To enable "hex code" transmission to the microcontroller, it is necessary to provide a cable for serial communication and a special device called programmer. The programmer used in this project is PIC Kit2.

G. FUNCTIONAL STUDY OF LED DRIVERS

Although digital outputs are fine and dandy, embedded systems usually need to control actuators with digital ICs. The limited current available from CMOS device is not enough to drive high current. The usual expectations for implementing high current outputs are bipolar junction transistors (BJTs), Darlington pairs.

Bipolar Junction Transistors (BJTs) are one of the most cost-effective ways to implement a “high current driver.” When a BJT is saturated, $V_{CE\ (sat)}$ will be finite and nonzero. The power dissipated in a transistor due to the collector current will be $V_{CE\ (sat)} \times I_C$. The base current will also contribute $V_{BE} \times I_B$ watts to the total power dissipated. Fig. 2 shows the simplest single transistor low-side driver, also called a sinking driver. To keep the transistor in saturation, the base current is required. CMOS devices specify a maximum IC that may be pulled from V_{CC} or sunk into GND.

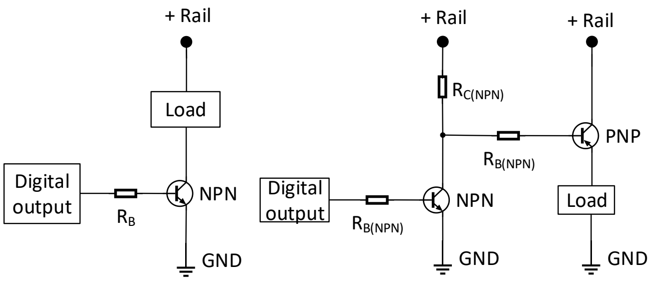

Fig. 2 The simplest single transistor low side driver and two-stage source driver

Building drivers capable of sourcing or sinking many amperes will usually require multiple stages of current amplification. Heating in the PNP’s base resistor is a key design consideration. For high rail voltages, the V^2/R heating in the PNP’s base resistor can be very high.

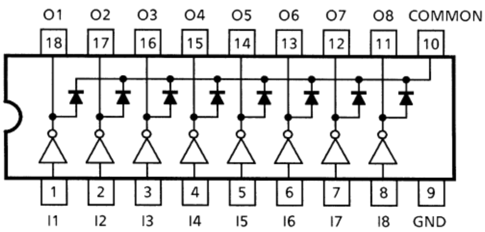

FIG. 3 (A) PIN DIAGRAM OF ULN2803

For applications requiring many high-current drivers, there are ICs available containing eight channels of Darlington drivers. Fig. 3 (a) and 3(b) show the pin diagrams and schematic diagrams of each driver of ULN2803 and TD62783 respectively. The ULN2803 is a sinking driver and the TD62783 is a sourcing driver. Both of these devices may be driven from CMOS outputs.

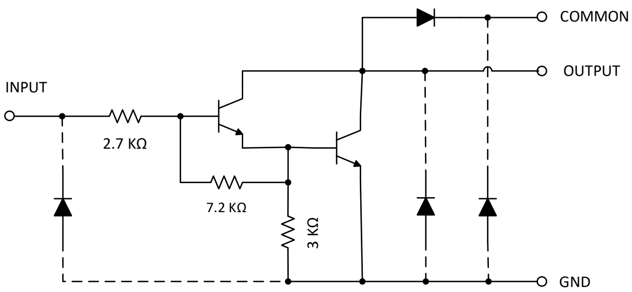

Fig. 3 (b) The schematic diagram of each pin of ULN2803

III. EXPERIMENT

This work is to display six English letters for the name of our Degree College, Nationalities Youth Resource Development Degree College. The letters are made up of acrylic sheets, PVC sheets and aluminum foils. PIC Assembly Language is used to implement this system.

A. Designing Letters

The horizontal arrangement of the letters on the display board is shown in the following Fig. 4

Fig. 4 The horizontal arrangement of the letters on the board

Every letter is designed to be a letter box in the ratio of A4 paper size (1: √2). Letter font is Arial Black. It is 35 inches high, 24 inches wide and 4 inches deep. All letters are equal in height and in depth but the widths need to be adjusted according to the font size.

The front part of the letters is covered with acrylic sheets which are 3 mm thick and in light blue color. It is enclosed with 8 mm white PVC sheets in the back of the letters. To wrap the lateral sides around the letters, golden yellow aluminum foil is used.

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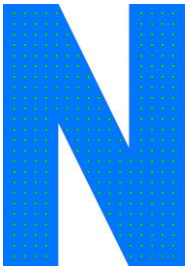

Fig. 5 The diagram of the letter N

The front surface area of each letter is equally divided into a matrix form of 24 rows and 16 columns. An opening or a hole has to make at every junction point where a horizontal line and a vertical line meet. The diameter of a hole is 9 mm. There are 272 holes for the letter N. There are 1361, (272 + 163 +170 + 276 +276 + 204), holes for all of six letters. The diagram of the letter N is shown in Fig. 5.

B. Wiring Each Letter

There are 24 rows and 16 columns for each letter. Since LED are simply connected in parallel in a row, there is an electrode for cathode combination and there is another one for anode combination. So, there will be 24 cathodes and 24 anodes for all row in a letter. Actually, there are only 24 rows and 1 column for each letter because all of 24 anode terminals are joined together to be single one. The wiring diagram of each letter is shown in Fig. 6.

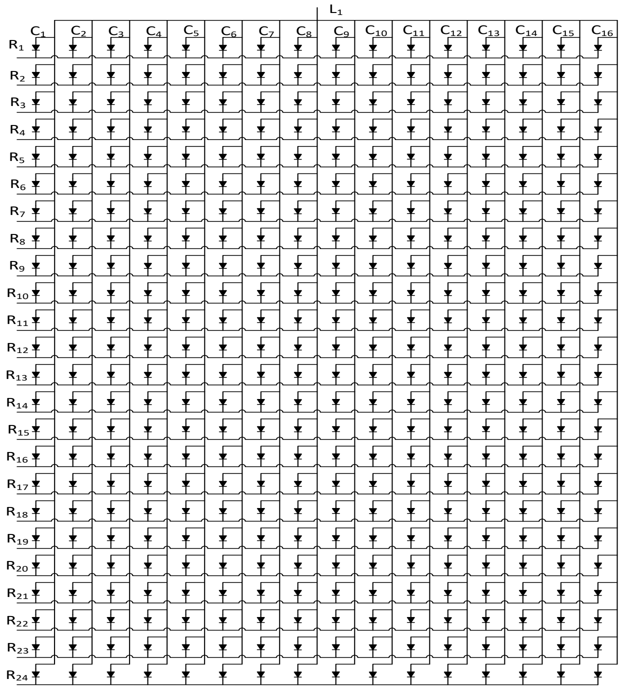

Fig. 6 The wiring diagram of each letter

According to the connection in the Fig. 6, all LEDs in the first row will emit light when R_1 and first letter (L_1) are HIGH. When both R_2 and L_1 are HIGH, all LEDs in second row will do so. Accordingly, when all rows and L_1 are HIGH, all LEDs in a letter will give light. Alternatively, to switch on and off the light of a whole letter, the main control electrode is common anode L_1.

Thus, all LEDs from other letters can be lit by doing so. For the first letter, 24 rows and L_1 are needed to be HIGH. For the second letter, 24 rows and L_2 are similarly needed. For the letters from third to sixth, 24 rows and L_3, L_4, L_5 and L_6 are particularly needed.

To sum up, LEDs in each letter are wired as a common anode and can be controlled by L_1, L_2, L_3, L_4, L_5 and L_6.

C. Wiring All Letters for LED Dot Matrix

To control the operation of a row or a column, it has to use an I/O pin from a PORT of the microcontroller. For switching a letter ***ON*** or ***OFF***, the required number of I/O pins is 25. 24 pins are for rows (cathodes) and 1 pin is for column (anode). For all six letters of display system, more numbers of pins (150 pins) will be needed. But the PIC16F887 microcontroller contains only 35 I/O pins. Therefore, all rows of all letters must be respectively connected in series as shown in Fig. 7. By connecting each row so, the number of pins required for all letters are reduced to [24 × 6] matrix. In the present matrix each column represents each letter.

There are six pins for the anode side labelled columns as L_1, L_2, L_3, L_4, L_5 and L_6. These pins are connected from the outputs of anode driver, TD62783. For the cathode side, the inputs of first eight rows is connected from the output of the first cathode driver, ULN2803. The second eight rows are connected from the outputs of the second sinking driver. The last eight rows are done so from the last ULN2803.

The inputs of these drivers are connected from the outputs of microcontroller. Three output pins from PORTE and three output pins from PORTA of the microcontroller are fed to the six inputs of anode driver. Again, eight output pins from PORTB, is fed to the eight inputs of the first cathode driver. The rest two sixteen pins are similarly fed, from PORTC and PORTD to the last two cathode drivers. Complete wiring design of the six letters is shown in Fig. 8.

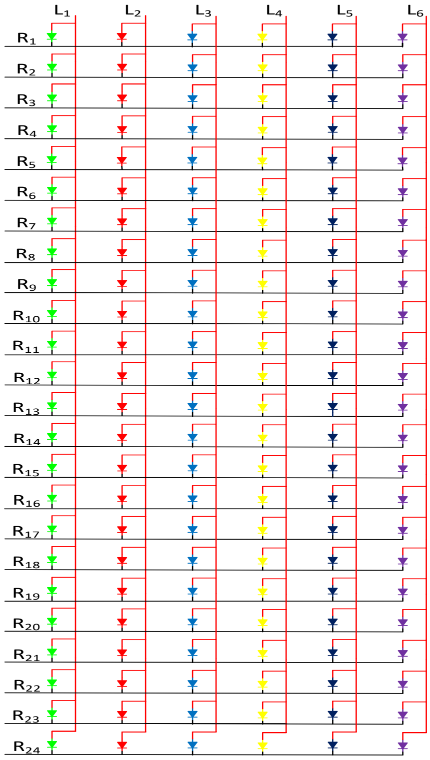

Fig. 7 Wiring diagram of [24 × 6] matrix

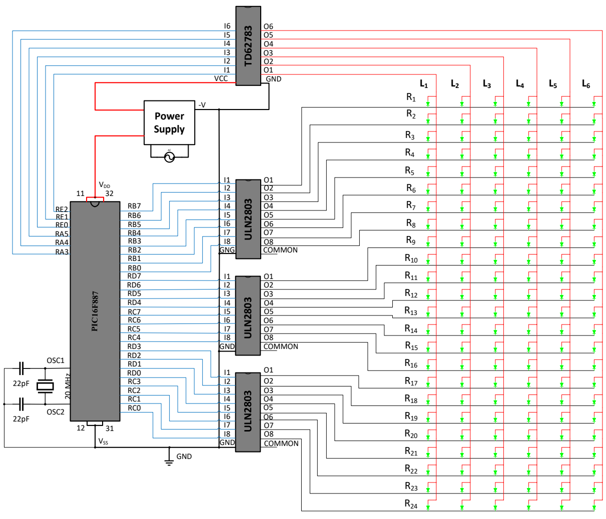

Fig. 8 Complete wiring design of the six letters

The power of an LED used in the present system is 0.12 W (12 V × 10 mA). The power supply is 12V-30 A. It is shown in Fig. 9. The positive voltage from the power source is supplied to the V_{CC} of anode driver and the negative voltage is supplied to the GND of cathode and anode drivers. For microcontroller's V_{CC}, the supplied voltage is reduced using a 7805 regulator.

Fig. 9 LEDs used in this project

D. *Scanning LED Dot Matrix*

A dot-matrix is comprised of rows and columns where each LED is connected with a specific row and a specific column. Matrix modules with simple x-y addressing of each letter are cascaded to create a large LED display. It can be extended to both horizontal and vertical directions. In order to reduce the number of I/O lines between the controller and dot-matrix display, multiplexing technique is used.

Driving each column **ON** and **OFF** in a quick succession is column scanning. In case of column scanning data are fed to rows and control signal is fed to the selected column. If the column update time is fast enough to scan the frame on and on within brief period of time, all the columns will emit light at the same time. This is due to the illusion of the effect known as Persistence of Vision (POV). To create a steady pattern, scanning rate is generally set to be higher than 50Hz.

In this approach, the eight bits connected to the first eight rows are set HIGH at the same time and a bit connected to L_1 is also set HIGH. After 1 ms, L_1 bit is set LOW. Secondly, the next eight bits for R9 to R16 are simultaneously turned on for 1 ms. After that that bit is set LOW. Thirdly, the last eight rows are done as in the first and second.

After scanning the first letter, L_1, the operations for the second letter, L_2 are similarly done as in L_1. In this case, the control pin is L_2. After that next columns are set as in previous setting. Thus, looping process will be carried on. The flow chart of the control program is shown in Fig. 10.

With 18 processes and 1 ms per process, the time to go back to the foremost process is 18 ms. The refresh rate is about 55 Hz. It is acceptable.

IV. DISCUSSION

It is important to design a practical LED board on which all LEDs have stable light and equal brightness. But it is impossible to switch on all LEDs on the board simultaneously. This is because there is a power loss for each LED when it is in use. To overcome the difficulty, the scanning method is used. It is the most important part in the present work. There are two important sections in a scanning process to get a good LED board. The first one is to choose the required number of scanning stages and the second one is to adjust LED-ON time. the first one is for brightness and the second is to avoid flickering effect.

The scanning process makes the brightness of LEDs lower. The greater the number of scanning stages, the dimmer the brightness. In the present work, there are 24 stages (24 rows × 1 column) for each letter. For all of six letters, there would be 144 stages. If we scan so, the brightness is too dim to use. In order to be better, the number of stages has to be reduced. when the number of stages becomes 3 for each letter and 18 for all letters, the luminous intensity is brighter than the first.

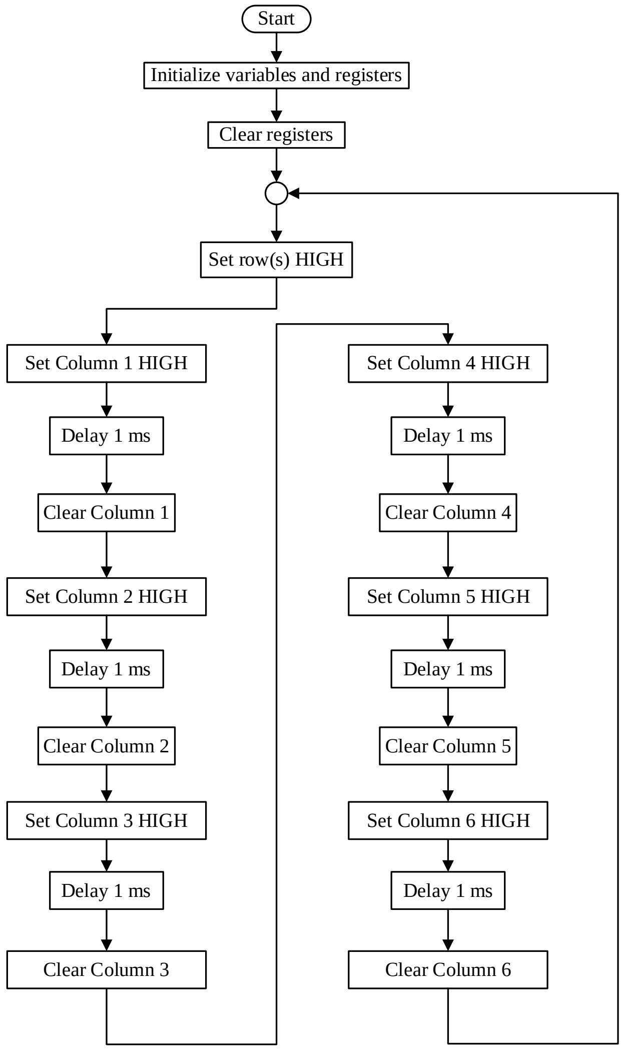

Fig. 10 The flow chart of control program

Afterwards the control program is tested by increasing the value of LED-ON time from a minimum value to the most acceptable value. LED-On time is also called execution time and it is a time taken to turn all LED on once. The minimum value is 14.6 µs. This time value is increased up to 100 ms as the test. There is a stable lighting patterns at the time values between the minimum value and 25 ms. However, flickering effect starts to shake just after the time value is over 25 ms. This effect becomes distinct at higher time values. Accordingly, the critical value for flickering effect can be regarded as 25 ms.

The experimental results can be again expressed in terms of frequency. The frequency range of the present system is from 68 kHz to 10 Hz. The stable lighting patterns can be found at the frequencies which is greater than 40 Hz. At the frequencies which is less than 40 Hz, the flickering effect will be found. The key point to the experimental critical frequency is 40 Hz.

The LEDs used in this work are low power LEDs. The power rating is less and intensity is better. The current flowing an LED is about 10 mA at 12 V.

According to the procedures in the control program, the maximum number of LEDs running on at a time is at most 100. The maximum current is not greater than 1 A. The power supply generating the constant current is 12 V-30 A.

The scanning process is software selectable. This action is done by the microcontroller. It can precisely control the operations we ask to do. And time control used in the program is also precise. The total scanning time for a complete cycle is measured with a stopwatch. Its execution time is 18 ms as shown in Fig. 11. Based on the present result, we can express that LEDs in an operation emit light for 1 ms per cycle, these LEDs do so 55 times a second and therefore light emitting time is 55 ms. This result is within the POV range.

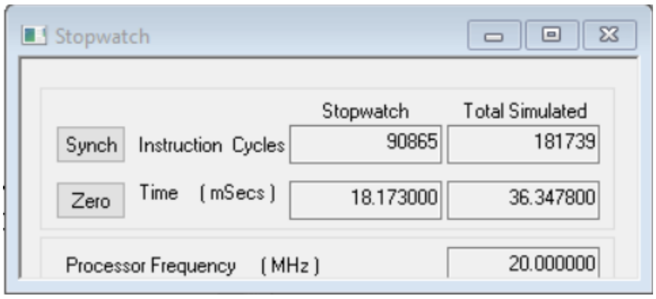

Fig. 11 The screenshot for scanning time

In each operation, eight rows of the matrix are first set HIGH and then one column is set HIGH. After 1 ms, that column is set LOW and successive next column is set HIGH again and again. For a complete cycle of the whole display system, number of processing is 18 and LED-ON-time is also 18 ms. So, the scanning rate is 55 Hz. The result is acceptable with the Persistence of Vision.

V. Conclusion

The result of the work is good at designing the display board and shaping the letters. Moreover, the brightness is good. The two main reasons why LEDs fade away are due to the large number of modules and LED-ON-time. These two reasons are also corresponding to each other. Brightness effect may be due to the controller's scanning rate and actual power rating of the power supply. Moreover, it is impossible to neglect the OFF-time rating of driver ICs. In this work, an attempt has been made to design a display system, which is of low cost, portable, very low power and self-contained. It is an efficient display system controlled by microcontroller. The lighting effect is also changeable. According to the study and analysis of various parts of the system, the design has been implemented and tested for various modes of operation. After implementation of the system, it is found that the whole system works very well in different modes of operation.

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