# DESIGN AND CONSTRUCTION OF A MOVING MESSAGE DISPLAY USING THE PIC16F648A MICROCONTROLLER

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## ABSTRACT

This work describes the implementation of an LED dot matrix moving message display system using a PIC16F648A microcontroller. The microcontroller, programmed with assembly language using MPLAB version 5.7 software and a PIC programmer, controls the LEDs to display a seven-character message. The 5x7 dot matrix display comprises 392 low-power LEDs. The LEDs are connected such that the cathodes of all LEDs in a column and the anodes in a row share connection. This configuration allows each row and column to be powered by separate lines. Limiting resistors are used for the eight output lines from the microcontroller to the LEDs. The system employs a dynamic display scheme where LEDs are sequentially lit using “vertical strobe” or “horizontal strobe” modes. In vertical strobe mode, rows are selected one at a time, and in horizontal strobe mode, columns are selected. This approach improves display brightness and reduces energy consumption.

**Keywords:** Decade-counter, Flow-chat, Dot-Matrix, Microcontroller, PIC

## 1. Introduction

Moving Message Display (MMD) notice boards are rapidly replacing conventional methods, such as fliers, wall displays, and painted wooden panels. The increasing intricacy of advertising and announcements fuels this shift. MMDs, also known as electronic notice boards, are electronic devices capable of showcasing alphanumeric characters, symbols, and various visual representations using arrays of light-emitting diodes (LEDs) (Titus, Godwin, Adekunle, & Ajani, 2022). MMD displays are widely used in banks to display exchange rates, stock exchanges for share prices, and airports for flight information. Their growing popularity is a result of their ability to convey information to large audiences quickly and efficiently (Bakare & Odeyemi, 2015).

When creating publicity, how a message is conveyed is crucial. The versatility of LED displays has contributed significantly to their appeal in a wide range of applications (Madandola, Sakariyay, & Oyelowo, 2022). An additional advantage of employing this type of display is that LEDs are an exceptionally efficient type of illumination with incredibly bright and eye-catching colours and waste less energy than incandescent lighting, (Twaha & Zhang, 2014). The numerous advantages offered by this form of message display make them a better method of relaying information either for advertisement or communication than the conventional approach such as (Murtala, Gbenga, Ochi, & Taidi, 2014).

This work, therefore, aims to build and implement a moving message display system using an LED dot matrix display and a microcontroller with the following features:

a) Creating and implementing the moving message display panel.
b) Inputting, storing, controlling, and displaying the message character data on a dot matrix using a PIC microcontroller.

The schematic of a moving message display system building blocks is shown in Figure 1 below.

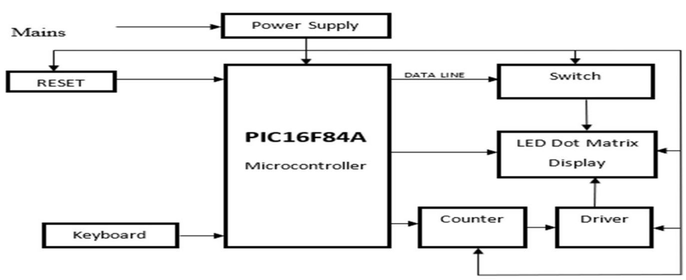


**Figure 1: Block diagram of an electronic notice board**

The important requirements of the project are:

a) Power supply
b) Voltage regulators
c) Switch
d) Microcontroller
e) LED dot matrix display
f) Counters
g) Drivers
h) AND gates

## 2. Materials and Method

Certain logical procedures were taken into consideration in the implementation of this work in order to determine the hardware components. These actions followed the design model. Additional components of support that were required were determined. The comprehensive circuit diagram is displayed in figures 2 and 3 below.

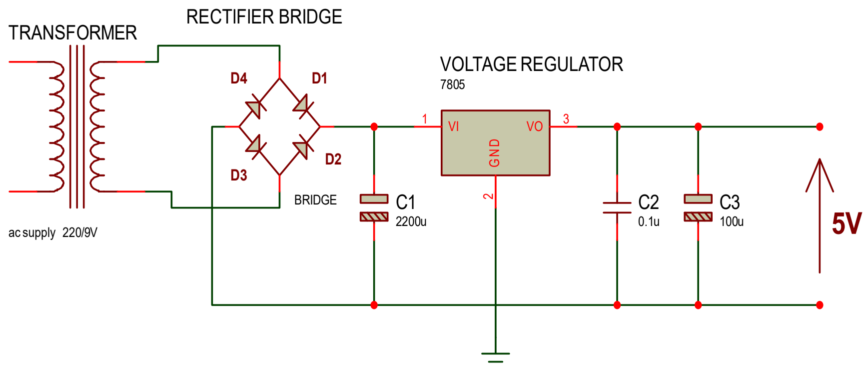


**Figure 2: Power supply Single phase full wave Rectifier Bridge**

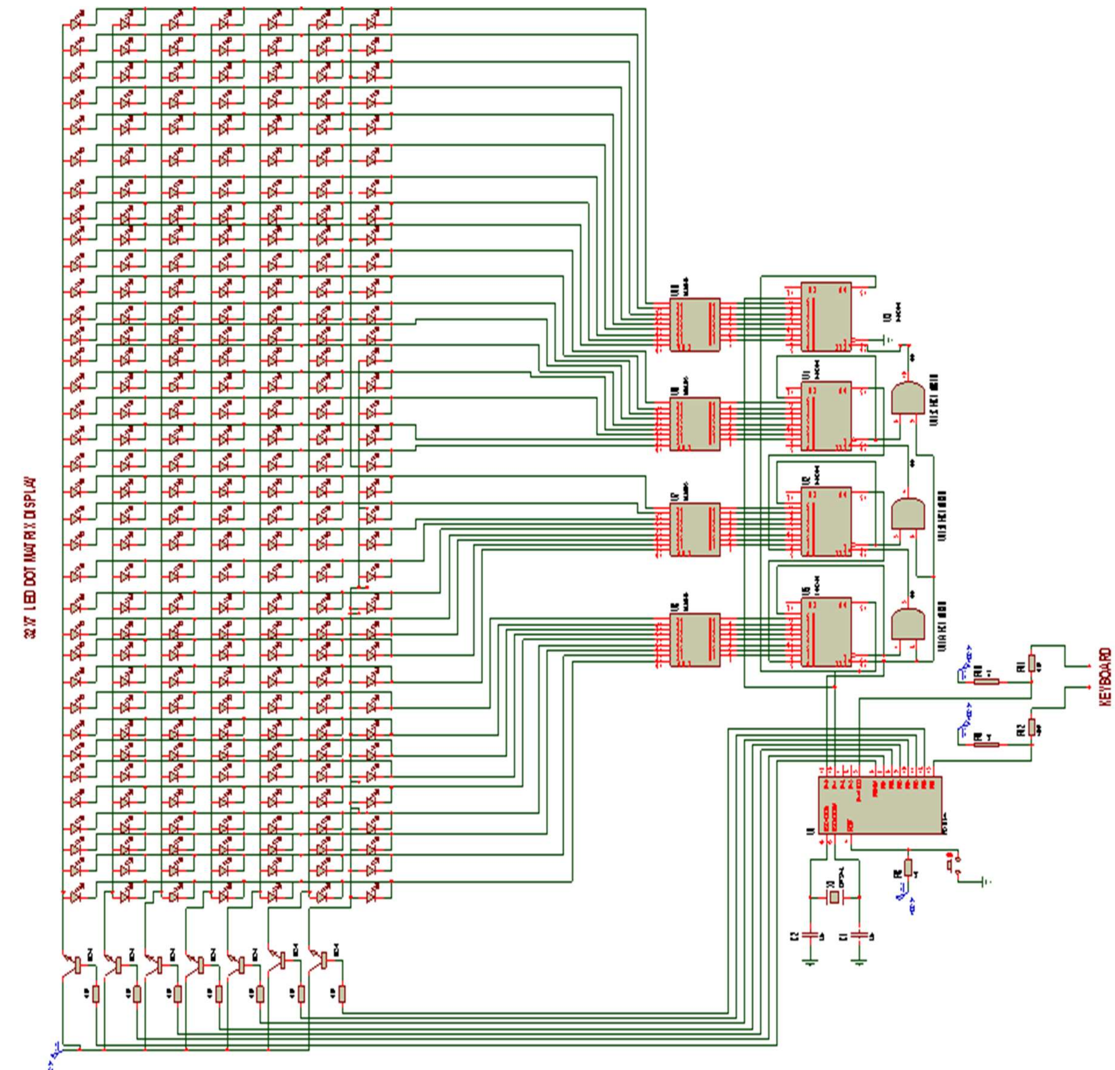


**Figure 3: Circuit Diagram of an electronic notice board**

**2.1 Microcontroller Unit**

The work requires a PIC controller with more than 16 input and output ports to accommodate the following:

i. Two input ports for crystal oscillator
ii. Seven output ports for the display
iii. Two output ports for the counter
iv. Two input ports for the keyboard
v. Control enable input port
vi. Control enable output port

The controller PIC16F84A meets the requirement of the design as it is programmable

It consists of (RAM/ROM) storage memory, 16 input/output ports and the wide operating voltage between 2.0 to 5.5V with a sink and source current of 25mA. Below is the pin function of the microcontroller:

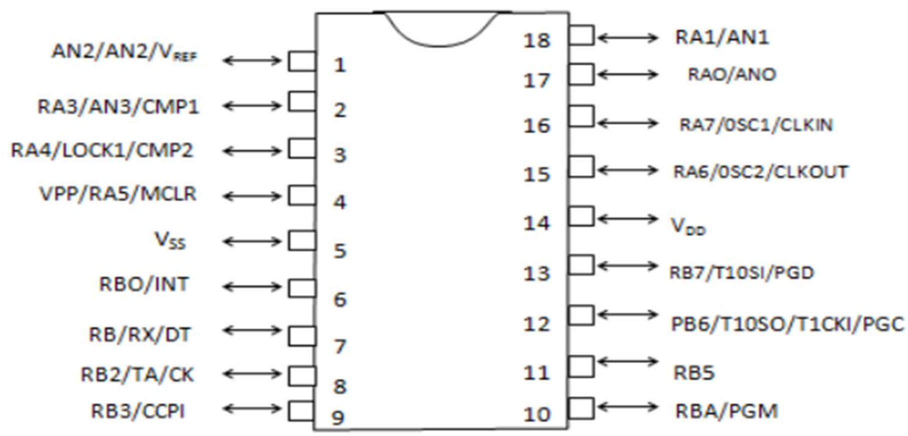


**Figure 4: Pin Configuration of PIC16F648A**

A crystal oscillator is connected to pins 15 and 16 of the microcontroller. The oscillator determines the execution speed of the microcontroller as it clocks it and emits pulse at fixed frequency. Without the crystal oscillator (clock) the system will not work. The frequency of crystal oscillator is used to provide a stable clock signal for digital integrated circuit and stabilize frequencies for radio transmitters or microcontroller chip. The crystal oscillator is rated in MHz, the one used in this work is 4MHz.

**2.2 Counter Circuit Analysis**

This setup is designed to sequentially illuminate each column of LEDs. Utilizing a 5-stage Johnson decade counter (HCT4017), the design achieves this. The counter features ten outputs, each activating sequentially. Given the counter's limit to count from 0 to 9, additional HCT4017s are cascaded to extend the count from 0 to 34, sufficient to drive the 35 columns of the 5X7 LED matrix display. These counters share a common clock line. The 10th output of the first counter connects to the enable pin of the second counter. An AND gate monitors the enable pin's status alongside the 10th output of the first HCT4017 and the clock signal. When both signals are high, triggering the gate, it advances the counter to the subsequent stage.

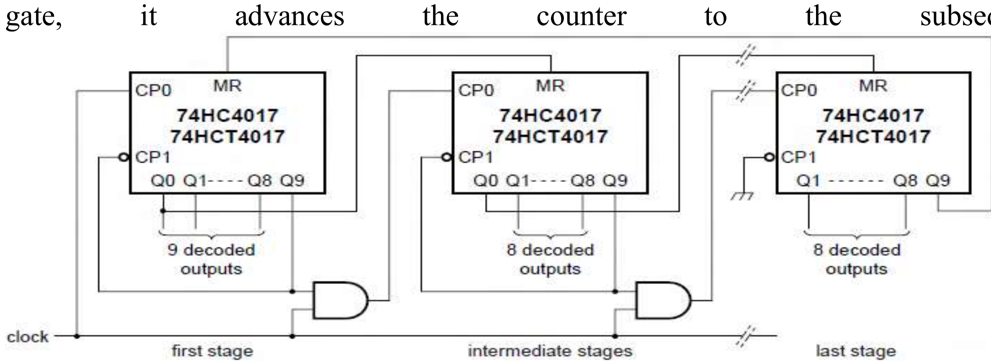


**Figure 5: Counter Expansion**

**2.3 Display Unit**

This is a LED array arranged using the dot matrix technique, featuring a dimension of 42 columns by 7 rows, totaling 42x7 LEDs. It's designed to display seven characters across the matrices, comprising the display section. The matrix layout, utilizing a 5x7 dot matrix: configuration, is depicted below

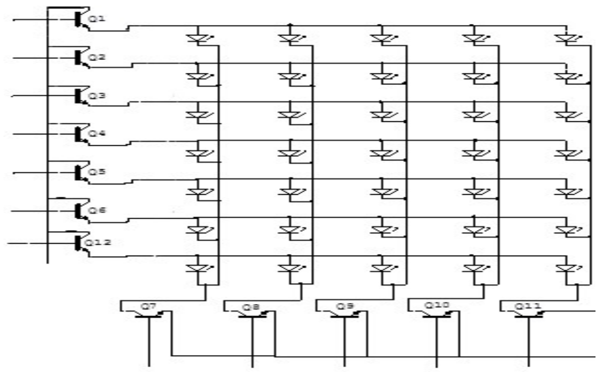


**Figure 6: 5X7 LED Matrix**

All LEDs share identical ratings and are connected in parallel. Consequently, only one current-limiting resistor per row is necessary. The value of the current-limiting resistor was determined as follows:

$$= \frac{V_s - V_d}{I_d}$$

$$R = \frac{5V - 2.5V}{5mA} = 500\Omega$$

From the above a standard resistor value of approximately 1kΩ was used. Hence, all resistors R1 to R7 are identical, each set to 1kΩ.

**2.4 Switching Circuit Analysis**

Below is a typical transistor switching circuit:

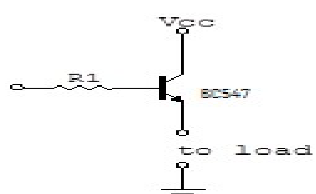


**Figure 7: Typical Transistor Switch**

This subsection addresses the circuit design responsible for toggling the column of LEDs on or off.

$\mathrm{V_{CC}} = 5\mathrm{V}\mathrm{V_{CE}} = 250\mathrm{mV}\mathrm{V_{BE}} = 770\mathrm{mV}\mathrm{I_B} = 5\mathrm{mA}\mathrm{V_B} = 2.5\mathrm{V}\beta = 110 \quad \mathrm{V_E}, \mathrm{R_B} = ?$

At cut-off $V_B < V_{BE}$To operate as switch

$R_B = \frac{V_B}{I_B} = \frac{2.5V}{5mA} = 500\Omega$

$\mathrm{V_{CC}} = \mathrm{V_{CE}} + \mathrm{V_E}$

$V_E = V_{CC} - V_{CE}$

$V_E = 5 - 0.25 = 4.75V$

**2.5 Column Switch Analysis**

This section employs ULN2803 octal peripheral driver arrays, comprising NPN Darlington transistors that connect the anodes of the LEDs to a 0V output. Each transistor within the ULN2803 is individually activated (one at a time) by the outputs of the HCT4017 counter chip. For the switch to output a LOW signal, corresponding to the 0V voltage rail, a HIGH logic level is required at its input. Essentially, the transistor switch operates in an active LOW mode, acting as an inverting buffer. When any output of the counter goes high, the associated transistor sends a LOW signal to the cathodes of the connected LEDs. As all row switches are identical, the design for one applies to all.

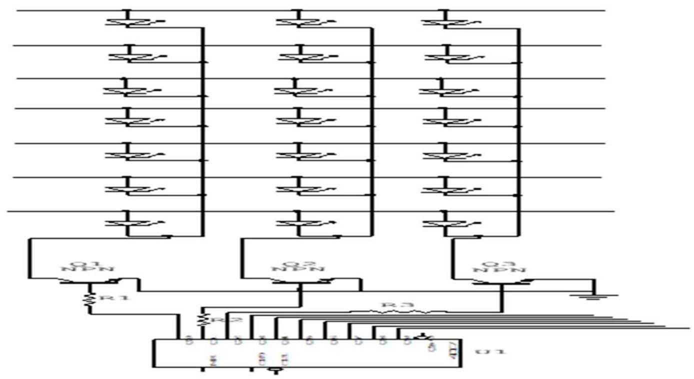

**Figure 8: Column Switch with LED and Counter**

Transistors Q1, Q2, and Q3 serve to draw current from the cathodes of the LEDs within each row, completing the circuit and enabling a specific LED to illuminate. Table 1 below illustrates the lighting conditions for RB7 to RB0 from the controller when a letter such as "L" is scanned on the first column RB6, designated as PIN0 and controlled by the decoder via the RA port of the PIC. Initially, a bit pattern corresponding to '11111111' is transmitted via the RB ports of the PIC. Subsequently, the next column, PIN2, is selected by the PIC, and the corresponding bit pattern '00000001' is dispatched through the RB ports. This process repeats for the remaining levels, executed at a high speed to create the illusion that all LEDs are simultaneously illuminated to the human eye.

**Table 1 : Lighting Patterns of LEDs**

| | PIN1 | PIN2 | PIN3 | PIN4 | PIN5 |
|---|---|---|---|---|---|
| RB0 | ● | | | | |
| RB1 | ● | | | | |
| RB2 | ● | | | | |
| RB3 | ● | | | | |
| RB4 | ● | | | | |
| RB5 | ● | | | | |
| RB6 | ● | ● | ● | ● | ● |

### 2.6 Power Supply Unit Analysis

The system is engineered to function on 240V AC sourced from the mains and 5V DC from the power supply unit. The determination of component values for the power supply unit is as follows: The specifications of the control transformer are:

i. Rated VA = 4.5VA
ii. Input voltage $V_P$ = 240V
iii. Output voltage $V_S$ = 9V (since a regulator is used to get 5V

The Volt-Ampere rating of the transformer is determined by estimating the load currents of different sections of the project as follows:

(a) The controller rated current = 60mA

(b) Transistor rated current = 10mA

(c) The LED rated current = 5mA

(d) The counter rated current = 50mA

(e) The driver rated current = 500uA

(f) The AND gates rated current = 20mA

The total sum is equal 235.5mA, which was approximated to 250mA to accommodate for additional loads and circuit losses. Therefore, Is = 250mA

Thus, based on the power supply circuit shown in Figure 1 above and the value of Is, the power rating of the transformer is determined. S = VA = 9 × 250mA = 2.25VA. During the positive half cycle of the voltage, power is supplied to the load through diodes D1 and D3; similarly, diodes D2 and D4 conduct during the negative half cycle of the supply voltage. The rectified DC voltage is given by:

$$Vdc = \left(\frac{2}{T}\right)\int_0^{\frac{T}{2}} V\,m \sin\theta \, d\theta$$

$$Vdc = \left(\frac{1}{\pi}\right)\int_0^{\pi} Vm \sin\theta \, d\theta = \frac{2Vm}{\pi} - 2\,Vd\,(diodevoltagedropof\ 2\ diodes)$$

$$= 2\sqrt{2}\times\frac{Vs}{\pi} - (2\times 0.7) = 2\sqrt{2}\times\frac{9}{\pi} - 1.4 = 6.7028V$$

The rms value of the ac component in the output voltage is given as:

$$Vac = \sqrt{[Vs^2 - Vdc^2]}$$

$$= \sqrt{9^2 - 6.7028^2} = 6.006V$$

The ripple voltage, $V_r$, is calculated from the relation:

$$V_r = 0.308V_m = 0.308\times\sqrt{2}\times 9 = 3.9202V$$

$$= \frac{I_{dc}}{4\sqrt{3}fC}$$

Therefore, the value of the filtering capacitor is

$$C = \frac{250\times10^{-3}}{8\sqrt{3}\times50\times3.9202} = 92.047\mu F$$

While the voltage rating is: $V_c = 2V_m = 2 \times \sqrt{2} \times 9 = 25.456V$

Therefore, the standard capacitor of $100\mu F$, 16V is sufficient for filtering.

A stable 5V DC is essential to power the microcontroller and its associated input/output channels. To ensure a consistent DC supply output despite variations in load, current, input voltage, or temperature, a regulator circuit is incorporated into the DC output. This regulator maintains the output voltage constant, a process known as "Regulation".

The 7805-voltage regulator is employed for this purpose, capable of handling a maximum input voltage of 30V while reliably providing regulated, non-fluctuating 5V at its output terminal. It features three terminals. Below is a basic diagram illustrating the voltage regulator with its pin configuration.

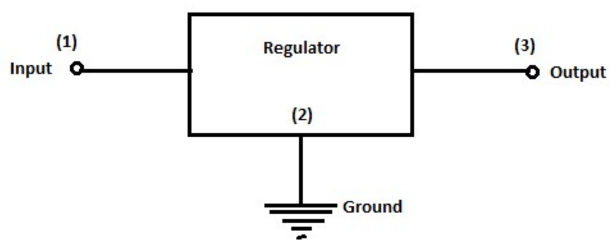


**Figure 9: Simple voltage regulator circuit**

### 2.7 Assembler

The assembler employed for this project is MPLAB version 5.7, obtained from the Microchip website. MPLAB is a Windows-based integrated development environment (IDE) software providing support for PIC and other microcontrollers. It offers a comprehensive set of features, including a full-featured editor, three operating modes (editor, emulator, simulator), a project manager, customizable toolbar and key mapping, and a status bar displaying project information.
MPLAB facilitates editing of source files, whether in assembly language or 'C'. Additionally, it supports debugging using source files and absolute listing files.

### 2.8 PIC Programmer

This device is utilized to program hex files into the PIC. It offers functionality to program PIC16F series microcontrollers, erase EEPROM, and verify existing programs for errors.

The entire hardware setup hinges on a program written for the PIC16F84A. The 5x7 Video Screen can display scrolling messages. Although the display can only show seven letters at once, the words remain readable.

For the RUNNING SIGN Routine, data is loaded into 35 Ghost locations (11h-33h), which are then displayed on the screen. One byte is transferred at a time from the table and loaded into the Ghost section. Subsequently, a routine outputs the thirty-five locations to the screen. The data in the Ghost section is shifted one place to the left, and a new byte is loaded into the 35th location (33h). This creates the effect of a message scrolling across the screen, from right to left. The program continues this process, detecting "FF" to repeat the message.

## 3. Implementation and Result

The implemented project, as depicted in the complete circuit diagram in Figure 2, underwent testing using a multimeter. After successful testing, it was constructed on a breadboard and verified to be functional. Subsequently, the components were soldered onto the Vero board, where their functionality was again confirmed.

The circuit operates as follows: when any letter or number is pressed on the keyboard, the controller registers the input and sends it to the counter, where it is then displayed on the LED display unit. The ULN2803 acts as a driver, facilitating the movement of the message from right to left across the display unit. This continuous display and movement persist until the system is reset or powered off.

### 3.1 Flow Chart

Figure 10 below illustrates the scroll display control flow chart

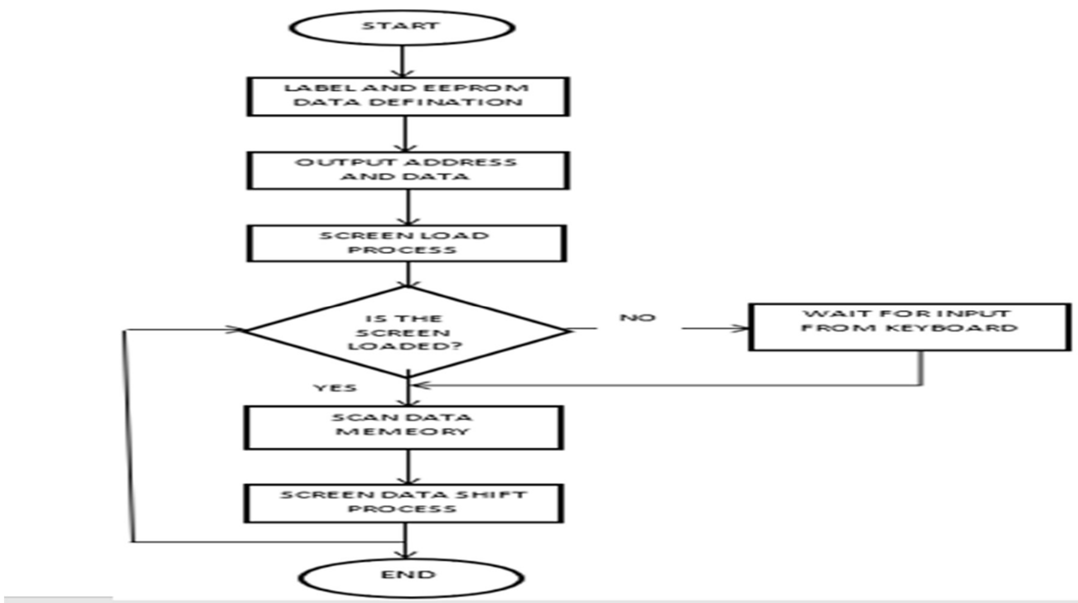


**Figure 10: Scroll display flow chart**

### 3.2 Result

The results of this work encompass both hardware and software aspects for successful operation. The software, comprising the source code, is utilized to program the microcontroller, enabling logical decision-making and control of scroll display operations. Additionally, this software facilitates monitoring of system operations as programmed.

To verify the proper functionality of the message board, various tests were conducted, and their outcomes were as follows: each component underwent meticulous testing, encompassing hardware troubleshooting and software debugging. Upon typing the word "TEST" from the keyboard, it appeared on the display unit, and the message began moving from right to left as expected. A stopwatch was employed to measure the duration it took for the message to disappear and reappear. The following equipment was used:

i. Digital multi-meter
ii. Bread board
iii. Stop Watch
iv. Logic probe
v. Light emitting diodes (LED)
vi. MPLAB simulation software

The results obtained to determine the accuracy of the moving message is tabulated below:

**3.3 Power Supply**

The measured voltages and currents for the electronic circuit and the 4.5VA transformer power supply section of the project are tabulated in Table 2 below:

**Table 2: Power supply test results**

| *Input* | | *Output* | |
|---|---|---|---|
| *Voltage (V)* | *Current (A)* | *Voltage (V)* | *Current (mA)* |
| 226 ac | 2.19 | 8.8 dc | 39.32 |

**3.4 Timing**

Below is the table detailing the response time for messages to reappear according to both the program and the project design.

**Table 3: Delay time results**

| S/No | Designed Time for Message to Re-Appear at Display (Secs) | Time Message Re-Appear on Display (Secs) | % Error |
|---|---|---|---|
| 1 | 1 | 0.94 | 6 |
| 2 | 1 | 0.92 | 8 |
| 3 | 1 | 0.91 | 9 |
| 4 | 1 | 0.93 | 7 |
| 5 | 1 | 0.95 | 5 |

The % Error is determined from the values obtain in the above tables:

$$\%\ Error = \frac{1 - 0.94}{1} \times 100\%$$

$$= 6\%$$

$$\%Error = \frac{1 - 0.92}{1} \times 100\%$$

$$= 8\%$$

$$\%Error = \frac{1 - 0.91}{1} \times 100\%$$

$$= 9\%$$

$$\%Error = \frac{1 - 0.93}{1} \times 100\%$$

$$= 7\%$$

$$\%Error = \frac{1-0.95}{1} \times 100\% = 5\%$$

$$Average\ \%Error = \frac{(6+8+9+7+5)\%}{5} = 7\%$$

$$Accuracy = (100-7)\%$$

$$= 93\%$$

**4. Discussions**

Based on the results obtained above, it was noted that there were deviations between the intended time for the moving message to reappear and the actual time it took for the message to reappear in the constructed moving message. The observed delay exceeded the expected duration outlined in the design. This delay could be attributed to the fact that certain components were not obtained with precise values as calculated but rather with estimates or approximations. Consequently, the deviation may be a result of data losses occurring during the transmission from the main control to the display unit.

**5.Conclusion**

In conclusion, the design and implementation of the Moving Message Display using LED Dot Matrix Display proved successful, marking a significant step forward in communication technology. However, to enhance its capabilities and versatility, additional input/output ports are necessary to accommodate larger screen sizes, thereby transforming the moving message display into a more potent tool for disseminating information.

Throughout this endeavor, various skills were employed to overcome challenges inherent in engineering design and construction. Despite practical approximations and deviations from theoretical ideals, it remains imperative to uphold professional standards and ensure deviations remain within acceptable tolerances.

Nonetheless, this research underscores the importance of continued investigation and investment in this field. The evolution of technology, particularly in wireless communication and memory storage, presents opportunities to further refine electronic notice board systems. Remote control input and message storage capabilities offer avenues for enhancing user experience and functionality.

To build upon this work, several suggestions were proposed. Expanding the digital message display beyond seven characters by incorporating additional 5x7 matrices would necessitate additional circuitry but would enable the presentation of longer messages. Additionally, adopting matrix configurations such as 7x9 would result in larger, bolder characters, enhancing message visibility.

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