Vol. 19, No. 1, 2022, ISSN 15965538, pp 11 -17

Journal of Civil and Environmental Systems Engineering

Department of Civil Engineering, University of Benin, Nigeria

Journal homepage: https://j-cese.com/

Design and Construction of an Electronic Scrolling LED Matrix Display

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Research Article

Abstract

A scrolling light-emitting diode (LED) display system is essential in any establishment or association to convey data among the partners. In the modern age, the traditional analogue display of information is tedious and not accommodating for brisk data sharing. This study explores the design of scrolling dot matrix display systems using PIC18F46260 microcontroller, UDN2981A driver and shift registers. The display is acquired on a 7×35 *dot matrix display board, orchestrated on a Perspex material about 1mm thick. The brilliant design allows an instant message to be sent from a computer through the MAX232 IC to the display board which is all basic, quick and financially savvy therefore providing a solution to the laid-back paper-based notification system.*

Keywords

Dot-matrix, PIC18F46260, UDN2981A, LED matrix display, persistence of vision, POV

Article History

Received: January, 2021
Reviewed: February, 2022
Accepted: February, 2022
Published: March, 2022

1. Introduction

From scrolling marquees to streetlights, light-emitting diodes (LEDs) have affected the world with their aesthetics. Even power-consuming LEDs are cost-effective design alternatives compared to the light bulb in many applications such as billboards, street signs, multi-purpose displays etc. LED matrix display is a system electronically designed and constructed to display different information to the audience. The message displayed could be diagrams, symbols, letters, colours, numbers, codes etc., depending on the particular place and time. LED matrix display operates on what is known as persistence of vision (POV) (Edward, 1990; Vintage Technology Association, 2017). When the LED matrix display operates, only one of the LEDs is lit at a time however, it is lit at high scan speeds that the audience's eye merges the lit LEDs to get the picture. This technique is called POV and occurs at a scan rate of no lower than about 10 scans per second. However, the display might flicker at a rate of approximately 20 - 30 scans per second. Analogue display of information has long been in use in various forms as seen in signposts for showing direction or caution signs, billboards for displaying prices and exchanging rates, scoreboards for displaying scores in a game or even large boards for advertisement purposes. The major drawback of the approach is that there is no flexibility. Digitization allows flexibility, therefore, the replacement of the analogue format of display with an automated electronic display system would allow flexibility. Viewers get the information displayed in good and attractive colours. Also, the height advertisement has attained in Nigeria will be maintained if its operations are digitized. Substantially, it will also maintain a good relationship between the company and its numerous customers.

In this paper, we present the design and construction of a programmable electronic 7×35 LED matrix display capable of displaying different characters (letters, numbers and symbols) which could be changed at any time. Section 2 discusses the construction of the LED matrix display on a material, the design, simulation using the Proteus software and the PCB fabrication. Finally, it presented the coupling and testing of the desired encoded scrolling text message and the serial communication interface between the computer and the system. Section 3 is the results and discussion of the observations and research findings. Lastly, section 4 is the conclusion of the study.

A scrolling text message on an 8×16 LED dot matrix design was carried out in R-B, (2011). The circuit used a PIC18F2550 microcontroller that ran a program with the hardcoded text message. There was no means to change the text message that was displayed. The dot-matrix system was interfaced with two shift registers and a decade counter connected to minimize the number of microcontroller pins required to drive the columns and rows of the dot-matrix. A sink driver was connected between the decade counter and the rows of the dot-matrix to limit the current through each LED. Similarly, a design utilizing a monochrome LED dot matrix display used for displaying the characters and symbols was proposed by Kksjunior (2017). The project achieved the display of a scrolling text message on a 48×8 LED dot matrix using Arduino Uno through hardcoded data. To minimize the required number of pins for the 48 columns and 8 rows, 6 shift registers and 1 shift register respectively where the 6 shift registers used the daisy-chaining technique. Arijaje et al. (2018) presented the design and construction of a programmable scrolling matrix display that scrolls the message "WELCOME TO PHYSICS DEPARTMENT". The 28-character text was programmed in a PIC18F4620 microcontroller to control a 7 × 140 LED matrix display. The complete work was designed, simulated and routed with Proteus. Their work states that the programmable text was achieved through a serial communication between the host computer and the microcontroller, however, the means of accomplishing it was not discussed. In this study, we implement a similar design with a 7×35 LED dot-matrix display constructed on a Perspex material with a C# graphics user interface (GUI) application designed in the Windows operating system to control the speed of the scrolling text and the text displayed.

2. Materials and Method

The tools used for the construction of the 7 by 35 dot matrix display are the soldering iron, soldering lead, drilling machine, pliers, masking tape, measuring tape, solder sucker, wire cutter, sandpaper, and Multimeter.

The construction of the LED dot matrix requires layering, marking and soldering, therefore, to achieve a high-quality design, the best industry practices for soldering were considered. Soldering is a method of joining metal parts using an alloy of low melting point filler material (solder). In a soldering process, heat is applied to the metal parts, and the alloy metal is then pressed against the joint. The pressed alloy metal melts and is drawn into the joint by capillary action and around the materials to be joined by 'wetting action'. After the metal cools, the resulting joints are not as strong as the base metal but have adequate strength, electrical conductivity, and water-tightness for many uses (Greenfield, 1999; Kesparis, 2003).

The circuit model of the design is present in Figure 1. It is sectionalized as the microcontroller, the row driver and the column driver.

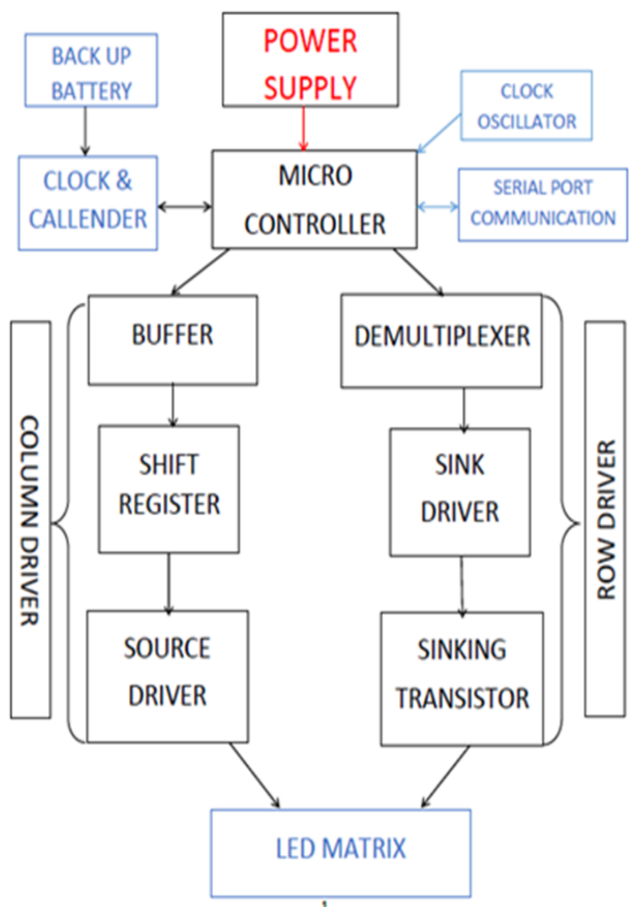


Figure 1 Block diagram of the circuit

In the design of the hardware, the microcontroller is the centre of control and instruction (the main controller) for the entire circuitry. The microcontroller has peripheral accessories that will ensure flexibility to a great extent (Archer, 2000; Starveren & Roermond, 2000). The system requires a real-time/date value to be displayed alongside the text. This is shown by the clock and calendar block which is powered by the power unit, however, a backup CMOS battery serves to keep the time/date counting during a power outage. The row driver consists of the decoder/demultiplexer, sink driver and the sinking transistor. The decoder minimizes the required number of pins of the microcontroller for the rows of the display, the current through the rows (cathode) of the matrix display is sunk by the driver as it is higher than the rated maximum current of the microcontroller and finally, the sinking transistor also abstracts the microcontroller from the matrix display. Similarly, the column driver is designed to drive the column LEDs. It is achieved through the shift registers, 3-state buffer (octal buffer) and source drivers. The instruction from the microcontroller is buffered by the octal buffer which is fed to the shift register cascaded in parallel and then to the source drivers which light up the LEDs as instructed by the microcontroller (Electronics Projects, 2014).

Display Unit

For a 7×35 dimension LED matrix display, 245 LEDs were used where a character was displayed in a 7×5 LED dot-matrix. The dimension could contain 7 characters; the rows of the display were the cathode of the LEDs whereas, the columns were the anode of the LEDs. Practically, a voltage (V_{DD}) = 2volts can considerably bias an LED to be driven in the forward direction and the typical current value is 20mA.

Table 1 Technical data for LEDs (Electronic Club, 2021)

Type	Colour	I_f max.	V_f type	V_f max.	V_r max	Luminous Intensity	Wavelength
Standard	Red	30mA	1.7V	2.1V	5V	5mcd @ 10mA	660nm
Standard	Bright Red	30mA	2.0V	2.5V	5V	80mcd @ 10mA	625nm
Standard	Yellow	30mA	2.1V	2.5V	5V	32mcd @ 10mA	590nm
Standard	Green	25mA	2.5V	2.5V	5V	32mcd @ 10mA	565nm
High Intensity	Blue	30mA	4.5V	5.5V	5V	60mcd @ 20mA	430nm
Super Bright	Red	30mA	1.85V	2.5V	5V	500mcd @ 20mA	660nm
Low Current	Red	30mA	1.7V	2.0V	5V	5mcd @ 2mA	

I_F max.	Maximum forward current, forward just means with the LED connected correctly.
V_F typ.	Typical forward voltage in the LED resistor calculation. This is about 2V, except for blue and white LEDs for which it is about 4V.
V_F max.	Maximum Forward voltage.
V_R max.	Maximum reverse voltage
Luminous Intensity	The brightness of the LED at the given current, mcd=Milicandela
Wavelength	The peak wavelength of the light emitted; determines the colour of the LED.

An LED must have a resistor connected in series to limit the current through it; otherwise, it will burn out almost instantly. In this study, we made a block of the LED to consist of four LEDs (two parallel connections and two series connections) such that the resulting block is terminated to act as a single unit.

For the series LEDs,

$$V_{DD} = 2 \times 2V = 4volts \quad (1)$$

For the parallel LEDs,

$$I_{DD} = 20mA \times 2 = 40mA \quad (2)$$

In the circuit, driving voltage Vs = 12volts is applied to the line driving the LEDs. This is too high for the LEDs and hence, the current limiting resistors are needed whose value is calculated as

$$R = \frac{12-4}{40mA} = \frac{12-4}{0.04} = 200\ \Omega \quad (3)$$

Considering safety, it is advisable to use a resistor with a higher value for each LED block to reduce the current driving them. The closest resistor value of 220Ω was chosen as the current limiting resistor for each block of the LEDs. Hence, the current that will drive the LED block from this current limiting resistor will be;

$$\frac{12-4}{220} = 36.4mA \quad (4)$$

Therefore, 36.4mA is a reasonable current value to drive a block of four (4) super-bright LEDs requiring a maximum current of 40mA current.

Power Unit

The power unit used for the LED matrix display supplied a rating of 12V 2A DC supply. The rated values met the requirement of the microcontroller, clock and calendar, octal buffer, decoder, MOSFET, source or sink drivers, dual transmitter/receiver and the LED matrix. In the design, row scanning was used to a maximum of 35 LED dots would light at once which are connected in parallel. Thus, the maximum current rating of the LED matrix display can be calculated as follows;

Each LED dot consumes a maximum current of 40.

Hence, a total of 35 LED dots will consume a total of $35 \times 0.04 = 1.4A$. (5)

The voltage and current rating of the ICs are given in Table 2.

Table 2 Power rating of the ICs used

IC	Description	Rating
PCF8583	Clock and calendar	2.5 V to 6 V at 50μA
74HC541	Octal buffer	750mW
PIC18F460	Microcontroller	5V
CD74HC4514	Decoder/Demultiplexer	2V to 6V at 160μA
IRF3808	MOSFET	75V, 140A
74HC595	Shift register	8mA, 4.5V
UDN2981A	Source driver	-500mA 50V
MAX232	Dual Transmitter/Receiver	5V
LM2576	Voltage regulator	7-40V, 3.5A

Control unit

The row scanning operates at a rate higher than 100 scans per second and the eye sees the display as “steady”. The control unit consists of the microcontroller, PIC18F4260, five shift registers, 74HC595, decoder, CD74HC4514 and buffer, 74HC541. The desired scrolling text displayed in the study was “WELCOME TO THE DEPARTMENT OF COMPUTER ENGINEERING” which was the default text message. The program code used for the PIC18F4620 microcontroller was written in C with the MikroC application. The circuit diagram designed in Proteus software is shown in Figures 2—4.

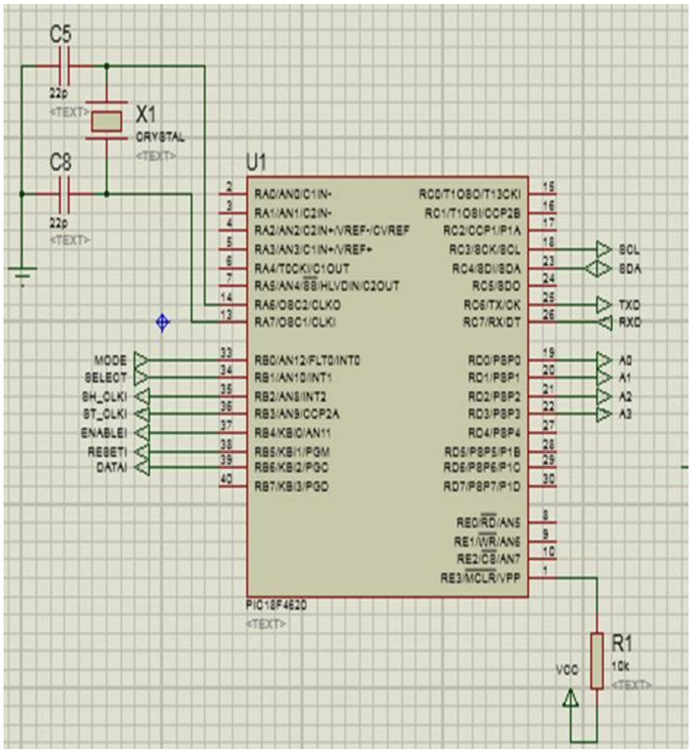


Figure 2 Schematic for Microcontroller

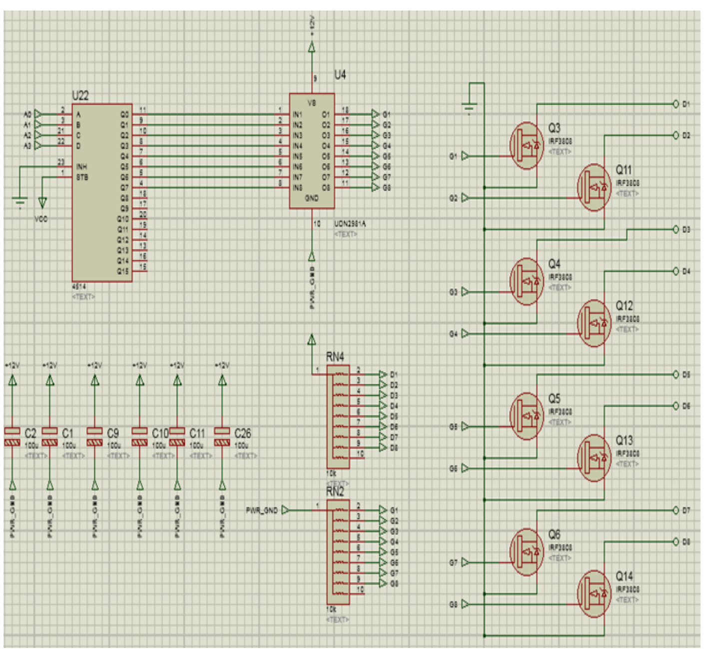
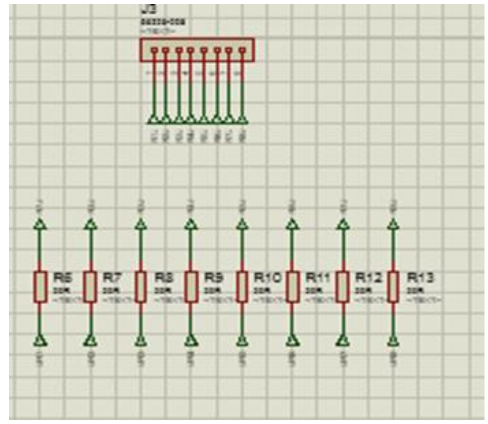


Figure 3 Schematic for Row Driver



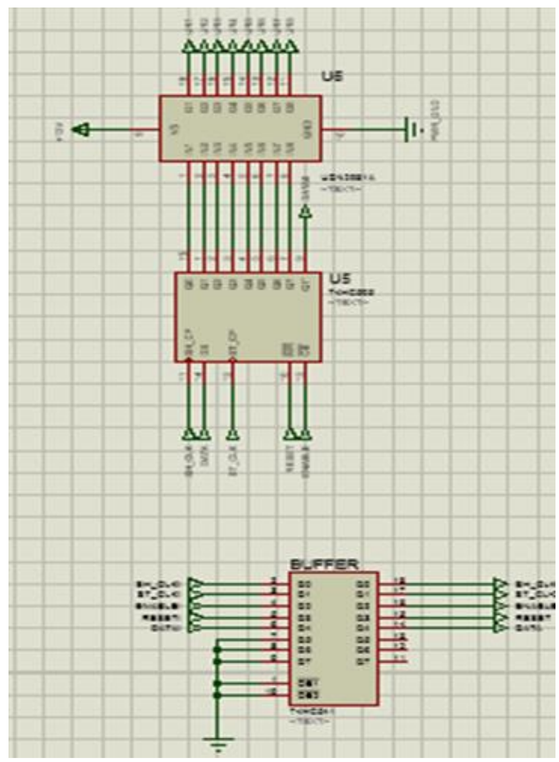


Figure 4 Schematic for Column Driver

Communication Unit

The communication unit allows for the scrolling display text to be programmed from a host computer. The communication interface used MAX232 to create a serial communication between the PIC microcontroller and the host computer. A C# GUI application was designed to enable the user to change the scrolling messages and the speed through a serial port in a Windows operating system.

Construction of matrix display board.

A Perspex board measuring $0.15 \times 0.$375 meters was procured. The points for the placement of LEDs were carefully identified and evenly marked. Holes of 4mm were drilled in the marked points in the Perspex to allow the LED measuring 5mm in diameter to fit tightly into the drilled holes. 245 holes were drilled for 245 LEDs on the Perspex.

Before placing the LEDs in the slots already drilled on the Perspex, each LED was tested to ensure that the LEDs were working properly and the polarities were right. When all the LEDs, transistors, switches, resistors IC sockets and all other components have been fitted, the LED display was tested to make sure all the LEDs were working. The LEDs were tested and the faulty (including those with poor brightness) LEDs were promptly replaced. The LEDs were grouped in four and interconnected to form single lighting. LEDs were wired such that all the cathodes along a row share a common terminal and all the anodes along a column shared a common terminal.

3. Results and Discussion

The Perspex material holding the 7×35 LED components in a dot matrix is shown in Figure 5 where each dot is a combination of serial and parallel connection of four LEDs.

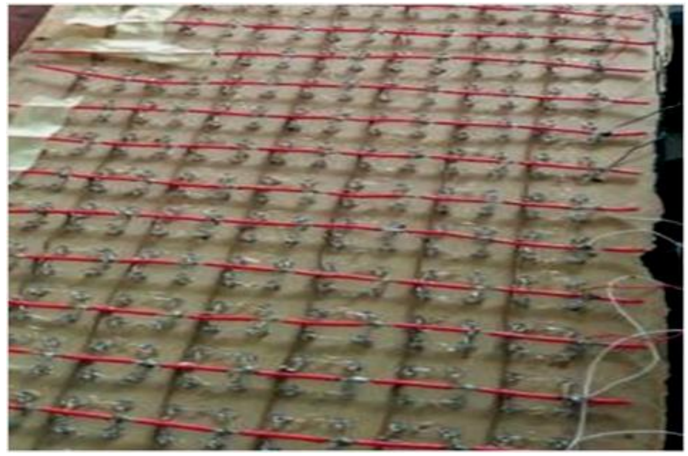


Figure 5 Rows and Columns Termination

The complete project was designed, simulated and routed with Proteus. The circuit worked satisfactorily before the actual components were then assembled on a printed circuit board. All the IC sockets were first soldered on the PCB before all other components were soldered after being tested. The result of the PCB fabrication and the developed circuit is shown in Figure 6.

Figure 6 The Circuit Board

4. Conclusion

The study presented the programmable scrolling text 7×35 LED dot matrix display board system which scrolls the default text “WELCOME TO THE DEPARTMENT OF COMPUTER ENGINEERING”. Such flexibility of design improves the analogue form of information display. Particularly, the implementation of the GUI interface for programming the microcontroller to change the scrolling text allows an excellent user experience. The study explored the POV technique in row scanning of the matrix display and considered the calculations required for a quality design in engineering. It is important to mention conclusively that the LED matrix display is a widely used means to display vital information in a more fancied digital and coloured form as such large companies and corporate organizations have taken over its full advantage.

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