FUDMA Journal of Sciences (FJS)
ISSN online: 2616-1370
ISSN print: 2645 - 2944
Vol. 7 No. 2, April, 2023, pp 246 - 255
DOI: https://doi.org/10.33003/fjs-2023-0702-863

CONSTRUCTION, IMPLEMENTATION AND PERFORMANCE EVALUATION OF A DOT MATRIX DISPLAY DEVICE

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ABSTRACT

The technology of displaying message is an important part of communication and advertisement. The work aimed at the construction, implementation and performance evaluation of a micro-controller based scrolling display system with Bluetooth interface. The work used the micro-controller (ATmega 328p) as the control component in the construction of the device which making the design of the device simple due to the addition of the input/output port on the microcontroller. A Bluetooth module was incorporated in the design which functions as the receiver of the message sent via Bluetooth. The LED display device mainly consisted of a Bluetooth Module and Microcontroller which receives the message, checks validity and displays the received information after necessary code conversion. Hospitals, banks, sport, stadium, airports, railway stations, education sectors and stock markets find this device a useful tool by prompting them to reflect many times on the scrolling lights, automatically displaying either messages of advertisement, place description or greetings at any time of the day. The constructed device was meant to describe Physics Department by displaying the message "WELCOME TO PHYSICS DEPARTMENT" It could be used for both indoor and outdoor purposes. In fact it is the most alluring, unique, captivating and attractive means of information dissemination.

Keywords: Construction, Dot Matrix Device, ATmega 328P, LED display

INTRODUCTION

Solid state materials have helped man to show that they truly exist by doing wonders in gadgets world. One of the huge improvements made conceivable by the enormous advances in solid state innovation is the "computerized transformation". Hardware is intended to actualize the essential computerized rationale capacities major to every single advanced framework. Computerized gadgets, in this way, delineate the structure, assemble and utilize circuits for preparing data in advanced structure with schools being on the cutting edge of Information and Communication Technology (ICT) upset since mid1990s (Obiechine and Okpala, 2013).

The recognized technique for showing data utilizing notice sheets, bulletins, sign sheets and so forth must be improved utilizing electronic data board which has been made conceivable through the advancement in data technology. These new advances of the computerized age have made programmable and reprogrammable hardware show conceivable to proffer answers for the issue of static method of sign presentation, for example, flags, flyers and so on. These electronic gadgets could be found in numerous spots and are being utilized for various purposes. It is utilized to show enthusiasm for banks indicating exchange rates, to show menu and costs at inns and bars, and to show accessible merchandise in markets among others.

A speck framework show is a variety of light producing diodes (LEDs) masterminded in a rectangular structure that is utilized to show a customized information/data. It is a presentation gadget used to show data on machines, timekeepers, railroad flight pointers and numerous different gadgets requiring a basic showcase gadget of constrained goals. The undertaking configuration centers on moving message also known as computerized speck network show, with a little alteration, an exceptional greeting to branch of material science message. The presentation comprises of a spot grid of lights or mechanical markers orchestrated in a rectangular design (different shapes are likewise conceivable) with the end goal that by turning on or off chosen lights, content or illustrations can be shown. A spot framework controller changes over directions from a processor into signals which turns on or off lights in the network with the goal that the necessary presentation is created.

The customary electronic moving message shows the substance spared in the processor. The need to change the substance to be shown requires reinventing the chip which later uses PC interface to change the substance without reconstructing the chip. The cutting edge configuration utilizes GSM innovation to change the substance by means of sms which needs to spend in any event N10 to change the substance of the showcase. The reason for the task is to alter the current plan by adding Bluetooth innovation to change the substance utilizing android based cell phone.

Many researchers have worked on similar devices using different controllers and electronic components to display different messages. Rahul and Abrol (2013) structured and built up a GSM based various LED show sheets utilizing AT89S52 microcontroller, GSM module, LCD and a few moving LED shows. Obiechine and Okpala (2013) chipped away at Design and development of a spot lattice data show based on AT89C52 microcontroller, 74374 lock, and LED grid show together with different segments. Adamu *et al.* (2014) took a shot at Design and Implementation of GSM-based Scrolling Message Display Board to show the data on the network show by utilizing GSM through AT89C52 microcontroller. Hakani (2014) constructed a GSM Based Alphanumeric Scrolling Display System utilizing PIC 16F877A microcontroller interface with GSM modem through MAX232 level convertor. Mayul *et al.* (2014) likewise chipped away at a similar task with little adjustment of changing the language in which the microcontroller was coded with Embedded C and Kiel while the PC was coded with Visual Basic. Gowrishankar *et al.* (2014) proposed advancement of GSM Based computerized see board. Revanth et al (2016) did Zigbee and PC Controlled Scrolling LED Message Display. The gadget worked by showing attractive substance by workstation or PC through Zigbee correspondence. Ganiyu and Umah (2017) took a shot at Design and Implementation of an Alphanumeric

Microcontroller Based GSM Scrolling Display System. The principal hardware was based on PIC 16F877A microcontroller as the control segment combined with other fringe parts. Nagendra *et al.* (2019) built a Wireless Based LED Dot Matrix Message Display.

The design technology has found its usefulness in educational system as well, as illustrated by the works of Adedoyin et al., (2023) who designed and implemented the Online Learning System using JavaScript (Vue), PHP (server-side programming Language) and NoSQL as the database. The developed system was evaluated by potential users and found to meet predefined user requirements.

In this research therefore, we set out to construct and implement a scrolling Dot Matrix device using ATmega 328p micro-controller as the control component and for the purpose of describing Physics Department by displaying the message "WELCOME TO PHYSICS DEPARTMENT" which could be used for both indoor and outdoor purposes. The display could be alluring, unique, captivating and attractive.

MATERIALS AND METHODS

The materials used in the implementation of this work include: LED Dot Matrix Display, Microcontrollers, Bluetooth Module, Voltage Regulator, Shift Registers, Developer, transistors, capacitors, resistors and diodes. Other materials used were: Soldering iron, Soldering Lead, Drilling machine, Screw driver, Multimeter, Plier and cutter, Aluminum, Transparent glass, Strawboard, Vero board, Dunlop, Perspex, Proteus 7 Professional, AVR Studio, Fly Pro and Virtual Terminal

The Circuit Board

In designing automatic system circuits, different approaches could be applied such as the use of Arduino Uno board, Development kit or self-design circuit board. Arduino Uno (Fig 1) is an open source microcontroller board, equipped with sets of digital and analog input/output pins that may be interfaced to various expansion boards and other circuits. The board has 14 digital pins and 6 analog pin which makes it non-usable in complex digital works. It can be powered by USB cable or external 9volt battery, though it accepts voltages between 7 and 20volts.

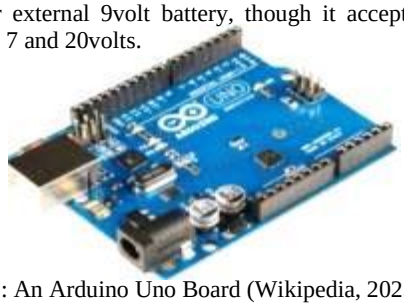

Figure 1: An Arduino Uno Board (Wikipedia, 2023)

A self-designed control board (Fig 2) could either be constructed on breadboard, vero board or PCB. A self-design circuit board allows the builder to solder each and every component one after the other unlike Arduino which already has every component fabricated.

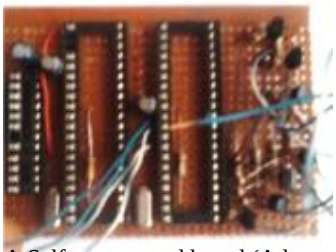

Figure 2: A Self-constructed board (Adamu, 2014)

The Display Section

Foreign LED Dot matrix display (Fig 3) is an already made display board which the user only needs to purchase when in need. It helps in simplicity and faster work.

Figure 3: A Multiplexed Dot Matrix Display (Wikipedia, 2023)

To understand the working principle of foreign Dot matrix boards, people fabricate own board on Perspex board with desired numbers of LEDs. In fabricating this board, holes are drilled on a Perspex in rectangular array which the LED are inserted (Figure 4).

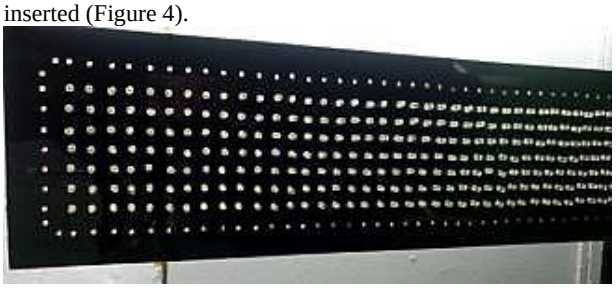

Figure 4: A Hand-made Dot Matrix board (Captured)

The construction of self-made matrix simplify the process of multiplexing. With few limitations, a self-made matrix board works accurately with no difference with the foreign board. Any of the methods can be employed depending on the interest of the constructor, one can choose to use the foreign designed matrix board with self-constructed circuit board and vice versa.

The Components

Microcontroller

A microcontroller is a solitary chip PC control framework. It involves numerous electronic circuits which can interpret composed directions and convert them into electronic sign. The microcontroller additionally ventures forward by experiencing directions and executing them consistently (Ganiyu and Umah, 2017).

The microcontroller is a solitary incorporated circuit made out of some pertinent highlights. These highlights incorporate the Bi-directional I/O pins permitting control and discovery of rationale state. Focal preparing unit ranges from 4 piece processor to 34 or 64 piece processors. It has unstable RAM, ROM, and EEPROM for putting away information just as blaze memory for putting away preparing parameters. It has peripherals like counter, clock, clock generator, ADC, DAC, PWM generator and furthermore investigating help. It additionally devours low power.

The fundamental microcontroller framework consists of input unit, control unit and output unit.

The input unit consists of components that feed signals into the system through digital devices such as switches, push buttons, keypads and radio receivers; it also consists of analogue sensors such as light dependent resistors, thermistors, gas sensors and pressure sensors.

The control unit processes the inputs and as a result of the program written into it, turns output ON and OFF. The microcontroller stores the program in its memory and executes the instructions under the control of the clock circuit. The output unit outputs the processed data through output devices such as light emitting diodes, buzzers, motors, alphanumeric displays, radio transmitters, 7-segment displays and liquid crystal displays.

Bluetooth Module

Bluetooth basically works by the working standard of sending and accepting information as radio waves. Each Bluetooth empowered gadget has a card-like connection known as the Bluetooth connector. It is these Bluetooth connectors that send and get information. A Bluetooth module (figure 5) has specific scope of association. One electronic connector can see another Bluetooth gadget if the subsequent gadget is available inside the scope of the primary gadget. At the point they are inside the range, they can strike up an association among themselves and pair.

Figure 5: JDY-31 Bluetooth Module (Bluetooth module Datasheet)

The module has on board chip receiving wire to discuss straightforwardly with different Bluetooth dongles and cell phone with new AT direction support. The AT order is a language like code that the Bluetooth framework gets.

The Voltage Regulator

A voltage controller is a framework intended to naturally keep up a consistent voltage. They are found in control supply segment of an electronic circuit where they balance out the DC voltages utilized by the processor and different parts (Donald and Wyne, 1978). It is for the most part used to manage at least one AC or DC voltage. A LM7805 Voltage Regulator is shown in Figure 6.

Figure 6: LM7805 voltage regulator (Wikipedia, 2023)

Shift Registers

A shift register is a circuit which uses flip-flops associated in line with the goal that each piece which is put away at the Q yield is moved to the following flip-flop in line at each clock beat. Move registers structure is a significant class of segments in a wide range of computerized circuits on the grounds that the flip-flop yield is changed uniquely by a clock beat after the info has been changed. The expulsion of clock beats, leaving just the stock voltage leaves the yield of the flip-flop unaltered for whatever length of time that these conditions are kept. There are numerous sorts of move register ICs however; the CD4017 move register shown in Figure 7 was utilized.

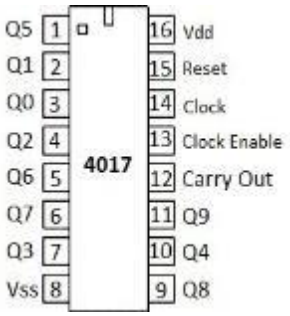

Figure 7: Pin configuration of CD4017 Shift Register (Shift Register Datasheet)

The CD4017 is a rapid 8-piece Serial-In Parallel-Out Shift Register. Sequential information is entered through a 2-info AND entryway synchronous with the LOW to HIGH change of the clock. The gadget includes an offbeat Master Reset which clears the register, setting all yields LOW autonomous of the clock (Shift Register, 2023)

Developer

In gadgets, particularly in microcontrollers, developer is utilized as a loader. It interfaces between the PC and the microcontroller. Developers are utilized to get the codes of directions from programming of a PC and keep in touch with them on the microcontroller's memory for a microcontroller to work autonomously from the PC, execute and run the records stacked. It is a circuit uncommonly intended to be utilized in stacking the codes from the PC to the microcontroller. Figure 8 is an image of a widespread developer. It also has a transmission line and a sequential connection towards the CPU of the register so as to interface the microcontroller to the PC. Distinctive microcontrollers have various software engineers relying upon its sort and its producer.

Figure 8: Universal Programmer (Wikipedia, 2023)

The Transistor

A transistor (Figure 9) is a gadget made out of a semiconductor material with three terminals for association with an electronic circuit. A current or voltage applied to one set of the transistor terminal changes the motion through another pair of terminals. The transistor is the central structure square of present day electronic gadgets, and is pervasive in current electronic frameworks (Mohammed, 2014)

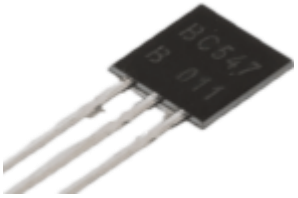

Figure 9: BC547 Transistor (Wikipedia, 2023)

Capacitors
A capacitor is an uninvolved electronic gadget that stores vitality in electrostatic field. A capacitor comprises two directing plates isolated by a protecting material called the dielectric. The capacitance is conversely corresponding to the division between the plates and straightforwardly relative to the surface regions of the plates (Muhammad, 2014).

Resistors
A resistor is an uninvolved two-terminal electrical segment that executes electrical obstruction as a circuit component. In electronic circuits, resistors are utilized to predisposition dynamic components, decrease current stream, to isolate voltages and modify signal levels among different employments.

Diodes
A diode is an electronic part of two terminals that predominantly lead flows a single way. In one heading, it has low obstruction and high opposition in the other. Most diodes are made with semiconductor material, or selenium. Diodes can be at low weight, voltage controllers, signal limiters, signal modulators or switches. Diodes exist in various sorts, for example, zener diodes, LEDs, PIN diodes and passage diodes.

Design Procedure
The design of any circuit determines the function and capability of the system. Here, the design factors were looked at and presented in an analytical form to achieve a functional circuit. During the design, the following were employed:

i. Design of the control unit
ii. Design of the power supply unit
iii. Design of the display board
iv. Design of the casing

Device Block Diagram

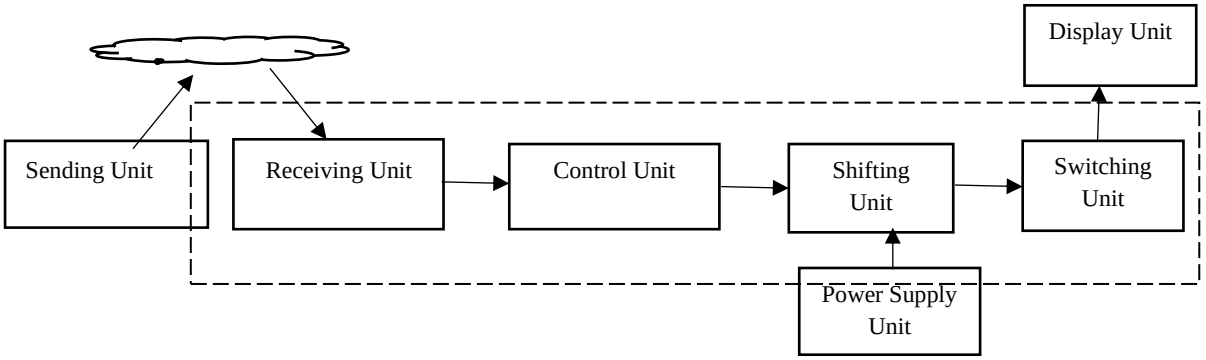

Figure 10: Block Diagram of matrix display operation

Figure 10 shows the different units and their positions in the display process. The sending unit sends message to the system through Bluetooth device, the receiving unit on the system receives the message and the process steps further by forwarding the message to the control unit which saves the received message in its memory thereby triggering the shifting unit which in turn powers the switching unit, and hence the display unit displays the sent message. The entire system operates only when power is supplied to the system. Figure 11 shows the different units and their interconnectivity within the system.

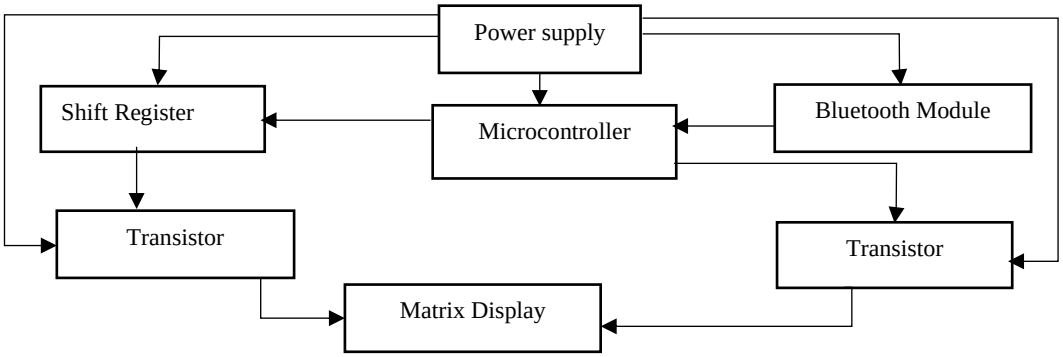

Figure 11: Block Diagram of the interconnectivity within the display system

Design of Power Supply Unit
The power supply provides power to various units of the device. This unit consists of a power adapter, voltage regulator, capacitors and resistors. The specification of the power adapter chosen is decided by the summation of all the fixed values of voltages and currents specified by each component manufacturer. Table 1 shows the rating of the power supply components.

The entire system requires 12V DC to work. The required current was reduced to 5A to avoid damage of module and microcontroller since a 12V, 5A power supply will perfectly work with the device. Other factors considered were the unavailability of a 12V , 12A power supply and if available would require a current step down transformer which would result in very high cost.

A power adapter of the following specifications was therefore chosen: Model number – LZ1250; Input – 100-200V; Frequency – 50-60Hz; Output – 12V, 5A

Table 1: Rating of power supply parts

Component	Operating voltage(V)	Current(mA)	Quantity	Total Current required (mA)	Total Voltage required (V)
Microcontroller	1.8-5.5	3.3	2	6.6	1.8
White-red LED	1.8-2.5	20	378	7560	1.8
White-yellow LED	1.9-2.0	20	130	2600	1.9
Shift register	3-5	20	9	180	3
Bluetooth module	3-5	30	1	30	3
Total				10.4	11.5

The 12V output was further stepped down to 5V supply to components and modules that require not more than 5V. The voltage step down was done with LM7805 voltage regulator, capacitor, current limiting resistor and a LED as indicator. Figure 12 shows the circuit diagram of the stepped down voltage from 12V to 5V.

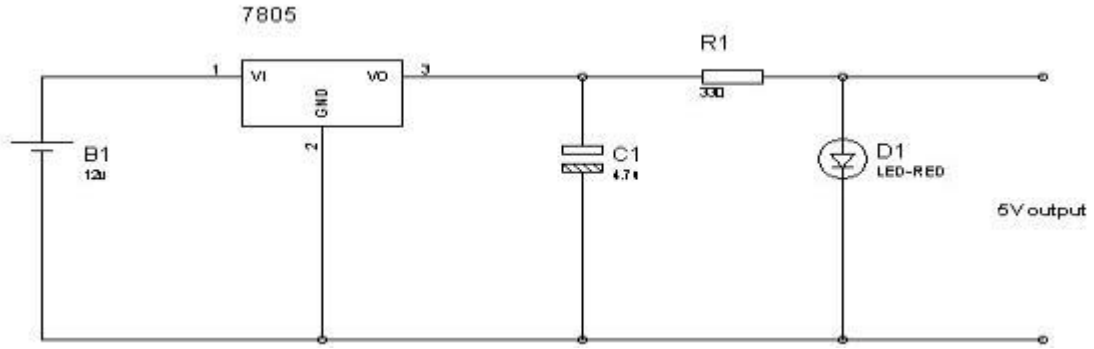

Figure 12: 5V regulated voltage (Proteus Simulation)

Determination of LED current limiting resistor

The LED current limiting resistor serves as to limit current flowing through LED's. It is expressed as:

$R_{LED} = \frac{V_{CC} - V_{LED}}{I_{LED}}$

where ;

R_{LED} = LED current limiter resistor

V_{CC} = Supply voltage

V_{LED} = LED forward voltage

I_{LED} = LED forward current

For V_{CC} = 12V, V_{LED} = 2V and $I_{LED} = 10mA = 0.01A$

$R_{LED} = \frac{12-2}{0.01} = 1k\Omega$

Therefore, resistor of 1kΩ was applied across all LEDs to limit the current flowing through them.

Serial Communication with Bluetooth Module

There are various ways to communicate between the microcontroller and PC or an Android phone but in this work, serial communication was employed. The serial USART (Universal Synchronous Asynchronous Receive Transmit) was used for full duplex (two way) communication between a receiver and a transmitter. This was accomplished by equipping the ATmega328 with independent hardware for the transmitter and the receiver. The USART is typically used for asynchronous communication (i.e, there is no common clock between the transmitter and receiver to keep them synchronized with one another).

In the case of this design, the transmit pin of the Bluetooth was connected to the microcontroller receive pin while the receive pin was connected to the microcontroller's transmit pin. This gives room for asynchronous communication. Fig 13 shows the connection between the microcontroller and Bluetooth.

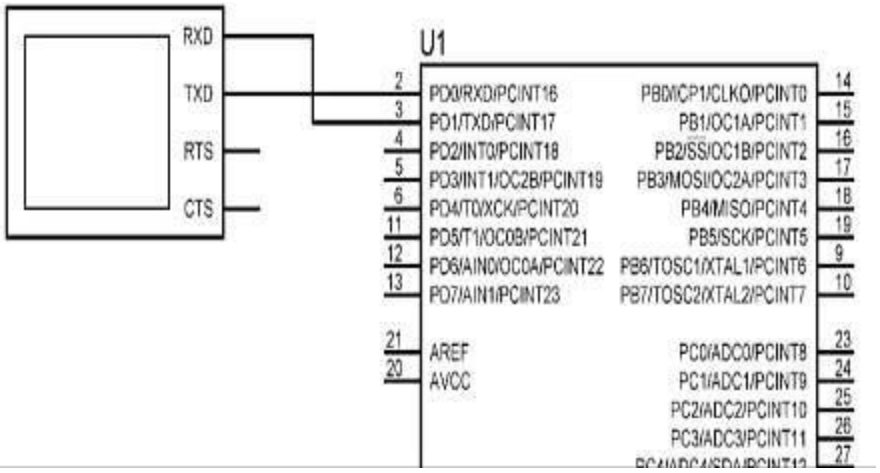

Figure 13: Bluetooth Connection with Microcontroller

Single Column Array

In the single column array shown in figure 14, the cathode of 7 LEDs are connected together to have a common ground with each anode unconnected as output. Combination of several columns of this type makes up a complete Dot Matrix Display.

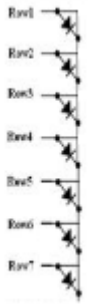

Figure 14: Single Column Array

7x9 LED Matrix

The 7x9 LED matrix is made by multiplexing 9 column array together. In this case, we connect the anode of each column to the next and continue in that way. A 7x9 LED array is shown in Figure 15. In the case of this work, nine 7x9 matrix was used which results in 7 rows, 54 columns LEDs.

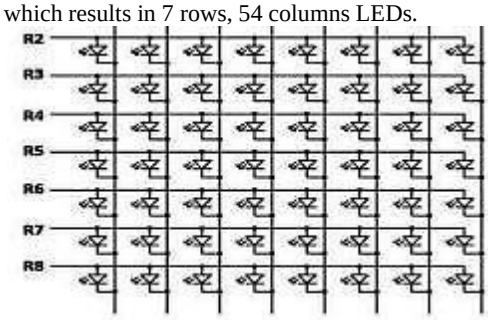

Figure 15: A 7x9 LED Matrix Display

Device Circuit Diagram

Figure 16 shows the various units, components and the interconnection of two set of 7x9 as the device schematic diagram.

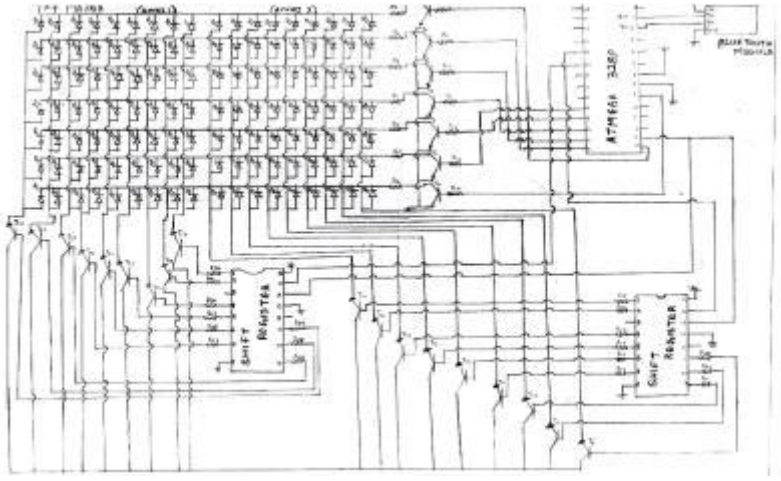

Figure 16: Device Circuit Diagram

The Flowchart
The flowchart of the whole device is shown in Figure 17

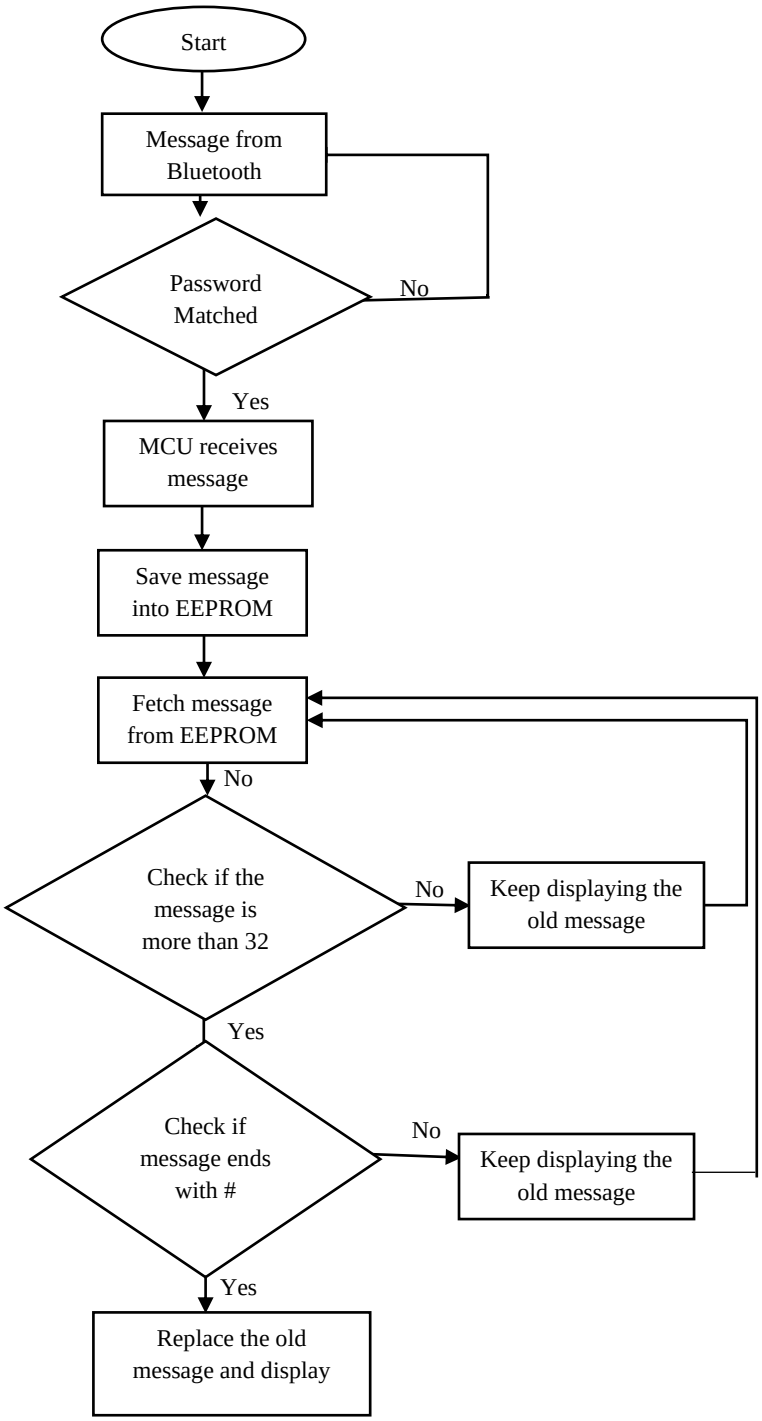

Figure 17: Flowchart of the device scrolling message display board

Device Assembly
This device came to actualization from interconnecting various modules and components together using appropriate equipment and tools. Fig 18 shows the image of the completed device.

Figure 18: Completed device

RESULTS AND DISCUSSION

The Bluetooth scrolling message display board device, upon completion, functioned as desired. The rate at which new messages were analyzed and presented was faster than those in previous works of Mala (2016) and Nangia (2017) because of the two ATmega328 used. The display board was only able to display a maximum of 32 characters due to the size of the EEPROM used, which was 1024 bytes. The message was seen to be updated without physical connections (i.e. only via wireless connection) and the problem of manual programming of the Microcontrollers was completely eliminated.

Components and Device Testing

All the components were checked individually using Multimeter to ascertain their functionality before the device was put to use.

After the construction was completed, various tests were carried out to ensure that the circuit construction and the whole device were functioning properly according to specifications and objectives. The tests employed for this work includes the Static test and dynamic test.

Static test

Static test was carried out when the circuit was not powered. This was done to ensure that the connections on the board were properly made to avoid damage. All the components were checked individually even after they were mounted on the Vero board to ensure that they were functioning properly. After soldering, another continuity test was carried out for the entire components with the help of multimeter to ensure that there was no bridging in the circuit soldered. The terminals soldered together gave out result with a sound which implies the soldering was well done without bridging or breaking.

Dynamic test

This test, also known as signal test, was conducted when the electronic circuits or components were powered. This form of test was carried out from the power supply. A voltmeter was used to test the power supply up to the appropriate point on the circuit board and the voltage at every point according to specifications. Dynamic test comprises voltage and current test. After the whole test was done, the device was powered and the device displayed "WELCOME TO PHYSICS DEPARTMENT". Figure 19 (a), (b) and (c) show the output of the device when testing its functionality.

Figure 19 (a): Image of device displaying "WELCOME" 19(b): Image of device displaying "TO PHYSICS"

19(c): Image of device displaying "DEPARTMENT"

Mode of Operation

This device is primarily made up of four main units, the input unit, the processing unit, the output unit and the power unit. For a message to be displayed there must be a stored message in the microcontroller memory (EEPROM). This is achieved by pairing an Android phone Bluetooth and the device Bluetooth using a Bluetooth Android app, Then a message can be sent to the device. The message is received by the device via its Bluetooth and stored in the device memory. For the device to receive the message sent from the Android phone, certain conditions must be met. The conditions include:

i. An @ symbol must be sent first after pairing (this clears the memory of the device to free space)
ii. The desired text to be sent must not be more than 32 characters (this is because of the size of the device memory)
iii. The text to be sent must end with # symbol (this is used to indicate where the message sent terminated)

The following procedures were followed when contents of display needed to change.

i. An Android phone Bluetooth was connected with the device Bluetooth (Device Bluetooth name: JDY- 31-SPP)

ii. An @ symbol was sent for device to erase memory, the device then replied with "ok"
iii. A 32 or less characters text message was composed ending with # symbol and sent to the device.
iv. The device replied with "ok" and started displaying the new text immediately the former text ended. The message kept displaying from left to right until a new @ symbol was introduced.

Once the above conditions and procedures were met, the device would accept the incoming message, store it and display on the display board. In the case of this work, the device displays "WELCOME TO PHYSICS DEPARTMENT" message. The display would continue until it is interrupted by incoming new message. From the device source code, there was a time lag of 1000ms between the storage and display of the new message under crystal oscillator of 16MHz of the microcontroller. At the end, the set objectives were achieved through careful design of hardware section and careful debugging of source code for software section.

Packaging

After the whole testing, the device was packaged showing the final view of how the project as designed. The hardware part was successfully done according to the specification needed. The device was packaged with a 90 by 15cm aluminum covered with a transparent glass for visibility; the back side was covered with thick strawboard tied with bolt and nut to hold it firmly.

Discussion of findings

The device has proved to be very efficient and worked effectively based on the result of the test carried out on each and every component used in the design. The device would work perfectly as other display devices except that it might not be as bright as the already made display devices due to the challenges encountered in the power section. The challenges include voltage regulator heating up and the device showing less brightness in the display, the first challenge was later eliminated and the other was minimized by using another alternative which is powering the device with a power adapter.

The work actually wiped out the primary problems engaged in manually reprogramming the microcontroller which is responsible for showing a new message on the display board. The challenges of reprogramming the microcontroller which is cumbersome and could cause physical harm to the system were therefore eliminated. Comparing to the works done by Rahul and Abrol (2013) and Hakani (2014), this work has proven to be more updated in the display section where LCD used in their work is updated to LED display.

From the result obtained by Obiechine and Okpala (2014), this work, from its implementation, has proven to be more improved in the interface section because their work had no element of interface in which the content of display could be changed.

In the work done by Ganiyu and Umah (2017), they used GSM interface as the means of updating the device contents of display which usually requires charges of 4naira per SMS. The implementation of this work has also eliminated the cost of charges in sending a new text to be displayed and also does not require network to display content to be updated unlike the GSM interfaced ones where the desire of changing contents of display fail if network is unavailable.

This work is fully comparable to work done by Adamu *et al.* (2014) in terms of processing and display of new message because same method was adopted in increasing the processing time which is the use of two microcontroller. The work done by Nagendra *et al.* (2019) has more modification than this design because of both Wi-fi and Bluetooth technology incorporated in their design for message update.

CONCLUSION

The goal of this undertaking was accomplished by constructing and implementing a Dotmatrix Display Device displaying the message "WELCOME TO PHYSICS DEPARTMENT". The structure was actualized through a remote system which disposes of both the superfluous wired associations and the errand of manual reinventing of the microcontroller at whatever point another message must be shown. The plan used the benefit of microcontrollers to decrease the size of the structure and fabricate the whole framework in much progressively minimized and versatile structure. Additionally, the utilization of two ATmeaga 328p during the structure has incredibly expanded the speed of preparing and message show. Likewise, the structure has demonstrated to be financially savvy taking the benefits of economical segments. This examination model can be utilized productively for prompt data move in films, eateries, schools, open vehicle, railroads, air terminals and banks with less blunder and upkeep.

Despite the high reliability of the design, some areas of the design could still be improved upon so as to enhance its performance. Such improvements include:

i. The power supply section should be improved using solar panel or DC battery
ii. Microcontroller of higher rating should be used to increase processing speed and memory for data storage
iii. The display board can be designed to be longer so as to capture long words at once

CONFLICT OF INTEREST

The authors declare no conflict of interest

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