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Original Research

Design And Implementation of a Persistence of Vision Display System using Light Emitting Diode (LED)

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Abstract

This study is aimed at designing and implementing a light emitting diode (LED) rotating information display system which can display any character sent to it via Bluetooth devices. The system is used for displaying information in a rotating manner. The light emitting diodes are arranged vertically on the mother board and it is controlled with the use of a microcontroller, which is programmed with a C-programming language and a G5 programmer will be used to compile it into a low-level language which the system understands. To enable a character to be sent to the display system, a user interface (Bluetooth module) will be used. In order to achieve persistence of vision (POV), a very high speed is required and, in this study, a brushless D.C. generator (which can achieve speeds of 1500 RPM and more) was used to achieve this speed. The system, upon completion, was discovered to operate satisfactorily. It rotated at a speed of 3600 RPM and displayed characters sent to it via the Bluetooth module using an android phone.

Key Words: LED, G5 Programmer, Bluetooth Module, POV, DC Generator.

1. INTRODUCTION

Display systems play a very important role in everyday activities in life. They are regarded as information dissemination devices. There usage may also contribute to the beauty of the environment through the display of various colours of light using LEDs (Gurski and Quach, 2005). They act as an medium between systems' software and hardware and viewers. They also form important parameter determining machines effectiveness subject to the review of the users thus creating an interface between the user and the machine (Patel et al, 2015). Electronic display systems make use of different principles. The most common of them makes use of light emitting diodes (LEDs) arranged strategically on the display board (7 segment display). These types of display systems are normally large in size and as such, occupy large spaces and also, consume a lot of energy because of the large number of LEDs being used. The

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rotating display system which makes use of the persistence of vision (POV) technology has the advantage of consuming lesser amount of energy (because of fewer numbers of LEDs) and also, they are smaller in size when compared with the conventional display system mentioned earlier.

In the POV approach, the human mind adds a stream of images into one motion picture as an illusion (Kolsu et al, 2014). The human eye can retain an image for 1/16th of a second. However, if these images are showed at a faster rate than what the eye can retain, then, the eye captures all the images as one moving object (Patel et al, 2015). POV display creates a perception of an image; occupying a spatial portion in rapid succession (Gitika and Mukul, 2015). A POV display has merit over LEDs and the likes which includes power savings, simplicity, aesthetics, and easy configuration (Khamer and Sandhya, 2019).

The purpose of Persistence of Vision (POV) display system is to have a small apparatus that will create a visual using only a small number of LEDs as it spins in a circle. When the LEDs rotate several times around a point in less than a second, the human eye reaches its limit of motion perception and creates an illusion of a continued image. Therefore, the POV display demonstrates the phenomenon by creating a visual as the LEDs spin rapidly in a circle and the person watching will see one continuous image. This phenomenon makes one feel fast moving/changing objects to appear continuous. A television is a common example; in which image is re-scanned every 25 times, thereby appearing continuous.

As stated earlier, the D.C. electric motor is a very important component of the rotating display system. It brings about the high speed of rotation (3600 RPM in this case) needed to achieve persistence of vision. Brushless DC motors are powered by via DC source using an switching power supply that produces an AC electrical signal to drive the motor. AC (alternating current), in this context does not imply a sinusoidal waveform, rather a bi-directional current with no restriction on waveform (Aspen, 2016). A study by (Titus,2009) asserted that the rotor part of a brushless motor can also be a switched reluctance motor or induction motor. Brushless motors may be described as stepper motors; however, the term “stepper motor” tends to be used for motors that are designed specifically to be operated in a mode where they are frequently stopped with the rotor in a precised angular position.

In terms of works previously done in this area of study, Henk, (2008) designed a propeller clock, that made use of LEDs which turn on and off, very rapidly one after the other.

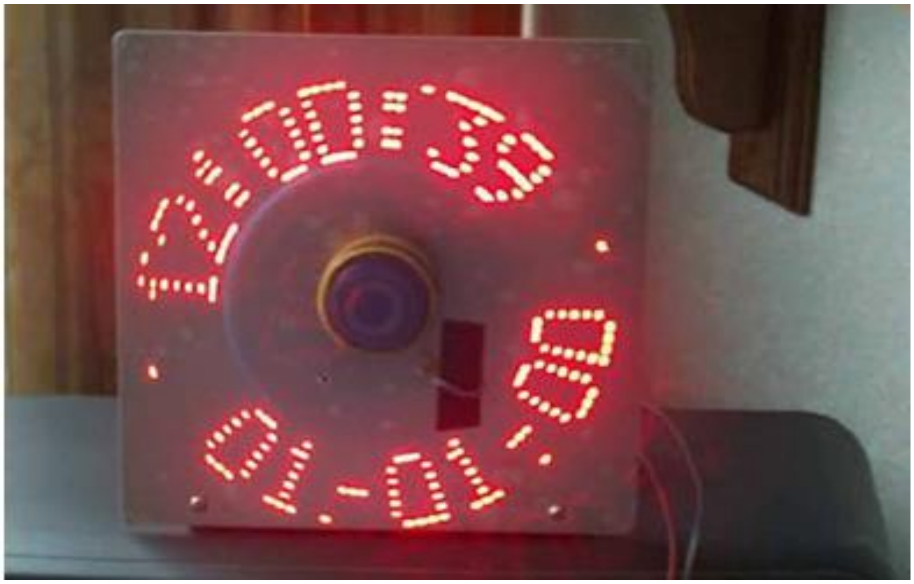

Figure 1: Henk Propeller Clock Image (Source: Henk, 2008)

Blick, (2008) designed a propeller clock that spins on a piece of perfboard. The power is provided from the spinning armature of a plain DC motor. In order to run the wires out of the motor, the bearing is removed from one end of the motor, leaving a big hole. The author used perfboard (Vero board) and hand-wired the circuit together. 18-pin socket for the 16C84 was used because it needed to be programmed before putting it in the circuit. For the 7 current-limit resistors a DIP resistor array was used, because it made it easy to experiment with LED brightness. Seven regular resistors also can be used, because 120 ohms works fine, though it puts the peak current right at the limit for the 16C84. To keep the clock running after turning it off, a 47000uf capacitor was used, so the time can be set while the LEDs get their power separate from this circuit. However, the following limitations were observed from the design;

they use two separate source of power, the design was made to display clock and date and lastly, the use of an infrared which might limit the range of transmission.

This paper therefore is set to address these limitations by achieving the following objectives; making the propeller to display characters, removing the use of infrared as the user interface and replacing it with a Bluetooth module to increase the range/ distance of sending data to the design and lastly, using just a source of power supply as this will help in reducing the weight, complications involving in the entire design process.

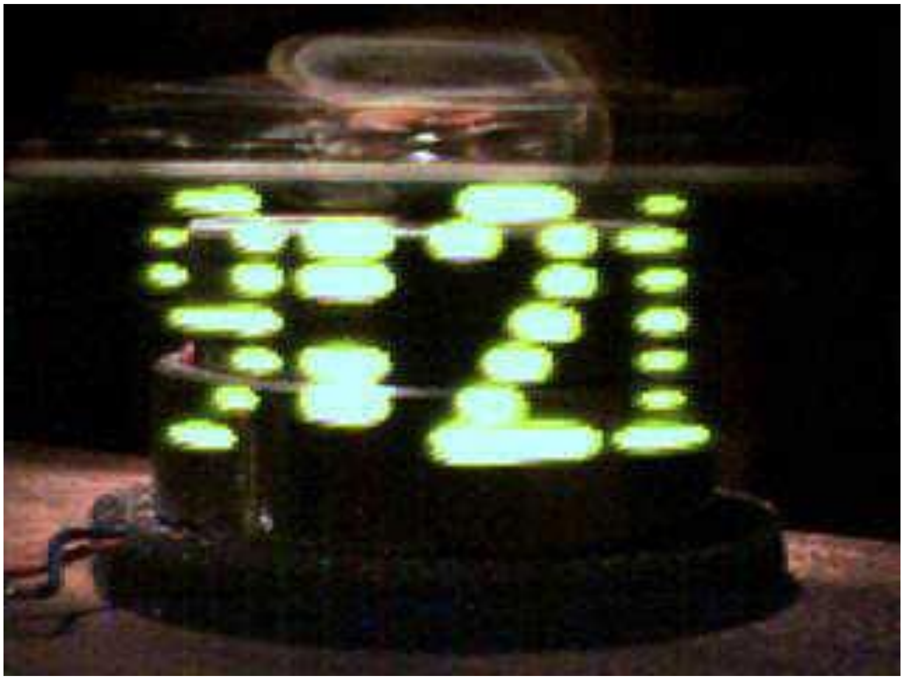

Figure 2: Propeller Clock Image (Source: Blick,2008)

2. METHODOLOGY

A light emitted object if rotated at fast speed circularly will show a continuous circle. Using this approach, LEDs can be rotated circularly to show concentric circles. But when switched off at some duration, a display pattern which is steady is revealed. Therefore, LED is used for showing each pixel as they continue to rotate. The amount of the LED count can be reduced through the usage of a propeller type display. The POV used in this study includes a total of nine color LEDs that are stacked vertically and rotate in a circle on the horizontal plane. The pictures generated by the spinning LEDs are coordinated by a microcontroller and programmed using C programming language. A diode is placed in the forward biased mode of the input of the rectifier which helps to serve as level detector to the microcontroller. The microcontroller can receive a reference point from the diode, each time it sees a signal (sign wave) it should start outputting the visual during each rotation. The LED board and the microcontroller were placed on a single 2x8 inch platform mounted to the top of a small 12VDC motor. The motor was plugged into the wall socket and placed firmly on a flat surface for the POV display to function properly. The block diagram of the rotating display system is shown in figure 3. In achieving the aim of this study, the speed of the DC motor, the design of the rectification and generating unit, the filter circuit, the timing step and the design of the LED display are presented using equations (1) to (11).

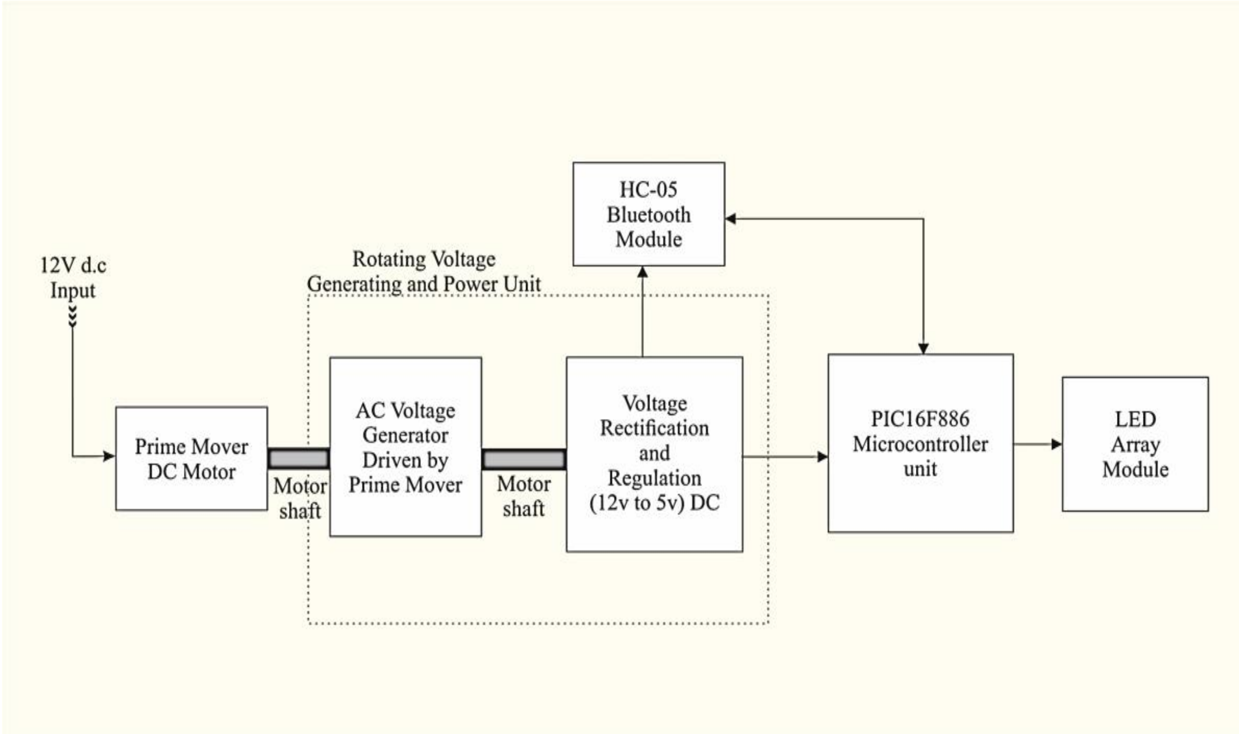

Figure 3: Block Diagram of Rotating Led Display

Required Speed for the DC Motor calculation

ON / OFF time for LED (T) = 25.4ms
Time for one oscillation = 25.4ms
Required RPM :
1 revolution = 25.4ms
X revolutions = 1s

Therefore , X = 39.37 revolutions per second
Revolution per minute = 2362.2 RPM
The cabinet Cooling fan had about 3600 RPMs and produces a perfectly balanced rotation. In Table 1, the data used for the prime mover is presented.

Table 1: Data Sheet of Brushless DC Motor

Input voltage	**12vdc**
Input current (nom/max)	**0.12/0.16**
Rating	**1.44/1.92**
Speed(rpm)	**3600 rpm**
Weight	**65grams**

Brushless DC motor has a torque which is given as

$$K_T = \frac{ke}{0.00684} \quad (1)$$

(Source: Pittman, et al ,2016)

$K_T = \frac{11.4}{0.00684x}$ = 1666.67 ib-in/amp

= 1666.67 X 0.12 = 200.00 ib-in

Hence the motor torque = current (I) X K_T

= 1666.67 X 0.12 = 200.00 ib-in

= 22.6Nm

Rotating Voltage and power generating unit

In Figure 4, the generating and rectification unit is presented. The alternator has a 3 phase connected winding, but just a single phase winding is needed for the purpose of this study such that Vout = 11.4VAC line-line = phase voltage.

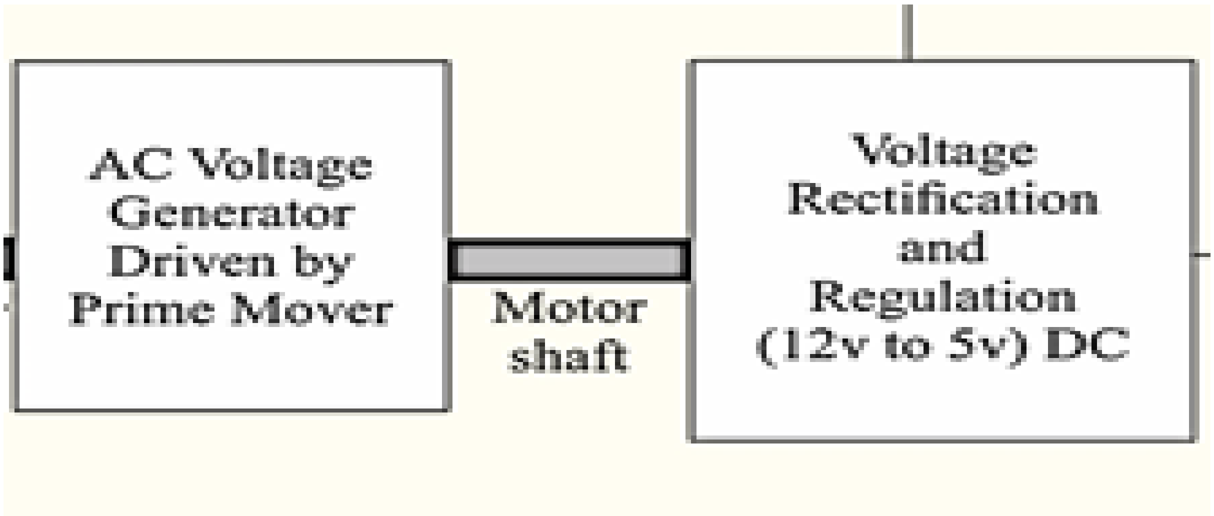

Figure 4: Generating and Rectification Unit

Rectifier Circuit

V_P= (V_{RMS} × 1.414)- 1.4V =(11.4 × 1.414)- 1.4V

$$V_p = 14.72V \quad (2)$$

$$V_{DC} = \frac{2Vp}{\pi} = \frac{2\times14.72}{(3.142)} = 9.37V \quad (3)$$

Filter Circuit

To obtain a ripple factor of 1% (99% DC, 1% A.C)

Y = Ripple Factor

$$Y = \frac{1}{(2\times\sqrt{3} \times f \text{ x c x RL})} \quad (4)$$

(Theraja & Theraja, 2008)

$$0.01 = \frac{1}{(2x\sqrt{3} \text{ x } 50 \text{ x } 577.35 \text{ x C})}$$

C= 1000x10^{-6}f

Output voltage across the filter capacitor

$$V_{DC} = \frac{Vp}{(1 + (\frac{1}{2 X 50 X C X RL})}$$

V_{DC} = 9.21 V

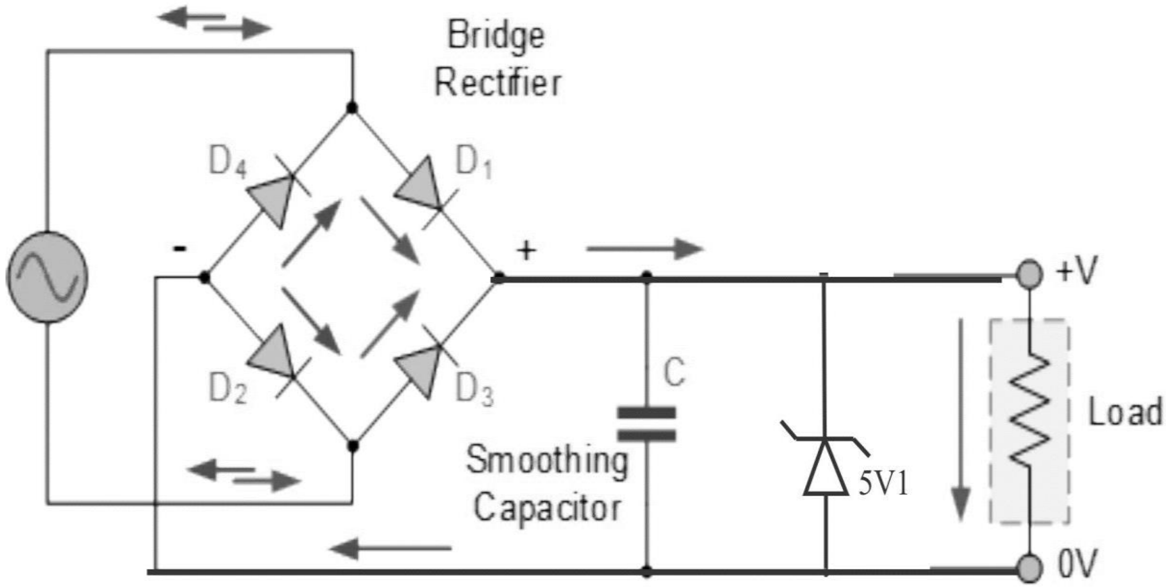

Figure 5: Voltage Generator Rectification and Regulation

In order to get an output at the same location consistently as is required to create the POV 'optical illusion', a near perfect timing is envisaged. The PIC 18F886 with the aid of the signal from the zero-crossing detection was therefore utilized for this purpose.

Calculating Each Timing Step

In equations (6) – (8), the minimum time with which the microcontroller has to react with the POV are presented.

Where,

r = radius of the LED display arm

C = Circumference of arm

f = frequency

$$f = 25Hz\ (25\ frames\ in\ a\ second)$$

(Standard value for POV to occur in chromatic flickers)

$r = 5.3cm$

C = 2 x π x r (6)

C= 2 x π x 5.3

= 2X 3.142X 5.3 = 33.305 cm

$C = 0.333m$

DLED = 2mm (Vertical distance between the LED's)

In order that a character be displayed, the horizontal and vertical distance from pixel to pixel or LED to LED should be the same. We calculate the number of displayable pixels on the horizontal axis.

$$\text{Pixel per count horizontal} = \frac{C}{Dled} \quad (7)$$

$$\text{Pixel per count horizontal} = \frac{C}{Dled}$$

$$= \frac{0.333m}{0.002m} \approx 166.5$$

Max character to be displaced =

$$\frac{Pixel\ per\ count\ Horizontal}{\max led\ count\ horizontal} = \frac{166.5}{6} = 27.75$$

The most speed of the microcontroller is needed when a LED is toggled every time. This corresponds to a bit pattern of 101010101... The microcontroller must be fast enough to toggle the LED's 166 times in a second. With 25 frames in a second:

Reaction freq = frequency x pixel per count horizontal (8)

Reaction freq $= 25Hz\ x$ 166.5 = 4162Hz

To be able to See the LED ON, there must be a delay of;

$T = \frac{1}{f}$ (9)

$$Delay\ ON = \frac{1}{4162} = 240.2\mu S\ Delay$$

LED Display

In Figure 6, the LED arrangement for the rotating display is presented.

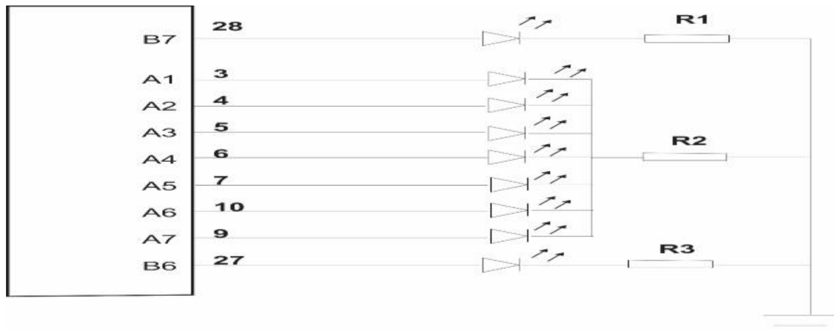

Figure 6: Led Arrangement for the Rotating Display

$R_{BLU} = \frac{V_{supply} - V_{AK} - V_{CE}}{I_{LED}} - R_{DS\ (on)}$ (10)

(Source : Renesas,2008)

$R_{BLU} = \frac{5V - 3.6V - 0.6}{20mA} - 0.8\Omega = 39.2\Omega = R2$

$R_{RD} = \frac{V_{supply} - V_{AK} - V_{CE}}{I_{LED}} - RDS\ (on)$ (11)

$R_{RD} = \frac{5V - 1.75V - 0.6}{20mA} - 0.8\Omega = 124\ \Omega = R3 = R1$

Where

R_{BLU} = Resistance of Blue diode,

R_{RD} = Resistance of Red diode,

V_{AK} = Anode to Cathode voltage.

Known Values

FET RDS (on) = 0.8Ω,

V_{CE} (Sat) @ 20mA = 0.6V,

LED Green V_{AK} = 3.5V,

LED Blue V_{AK} = 3.6V,

LED Red

V_{AK} = 1.75V,

All LED's I_{LED}(Max) = 20mA

Microcontroller Processing

Figure 7: Pic16f886 Pin Specifications (Source: Microchip Technology Inc, 2016)

Table 2: Data sheet of the pic16f886 microcontroller

Input Voltage	**2.0 – 5.0VDC**
Operating Speed	D,C – 20MHz oscillator / clock input
Memory Size	256MB
Programmable Code Protect	1000,000 wrie EEPROM endurance, Flash / Data EEPROM retention > 40 years
Peripheral	28/ 35/ I/O pins with individual direction. 8 bits timer / counter

Remote Communication (Bluetooth)

The HC-05 Bluetooth module is a low cost device designed for wireless data connections. It has six labelled pins:

1. KEY: Used for change between operation modes (configuration, communication).
2. VCC: Used for power supply (turn on the module).
3. GND: Ground pin.
4. TXD and RXD: Used for communication mode (receive and send data).
5. STATE: State pin (shows the current operation mode).

The module was interfaced directly to the microcontroller as shown in Figure 8. The microcontroller was programmed using C language while the flow chart is shown in Figure 9.

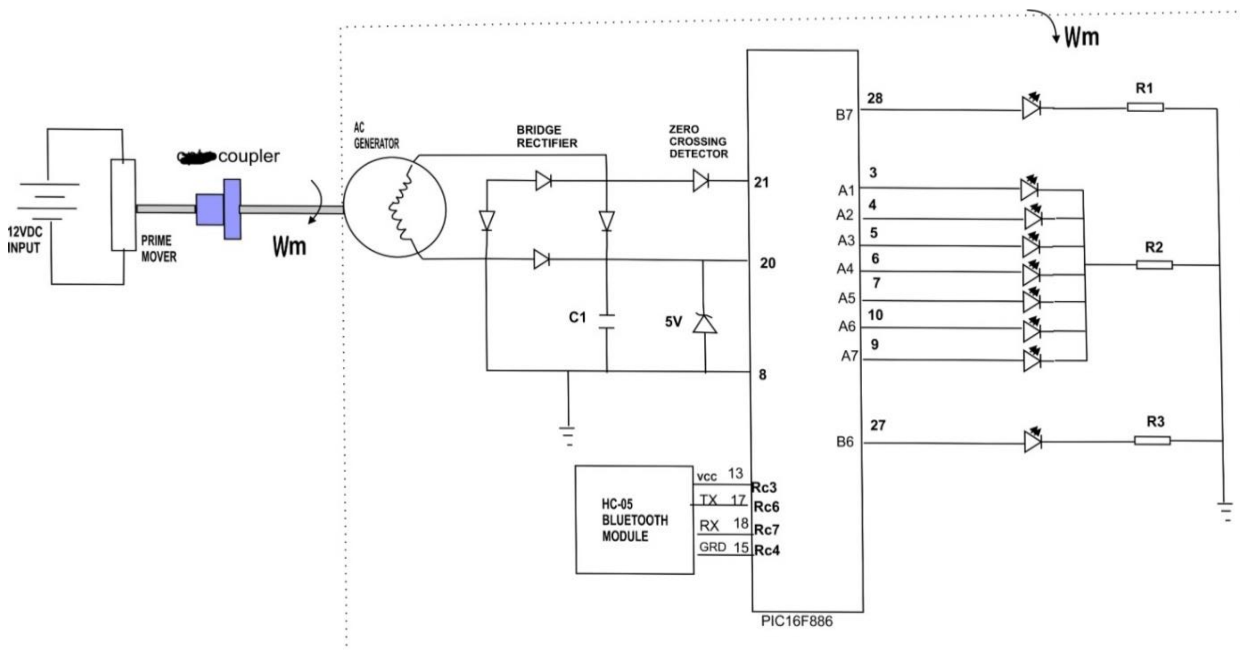

Figure 8: Complete Circuit Diagram for the Rotating Led Display

The complete circuit diagram is shown in Figure 8. A 12VDC is supplied to the brushless d.c motor, which spins at 3600rpm; the motor shaft was connected across the rotor of the synchronous generator and the mother board. The generator produces a 11.4VAC (due to losses) “N:B: Mini AC Generator used is a single phase” which was rectified by the rectifier circuit, the output of the rectifier is a pulsating dc, the ripples are then been filtered by a filter capacitor. Since the microcontroller and the Bluetooth module needs 5VDC, a voltage regulator was placed at the output of the filter capacitor which helps in giving out a constant 5VDC which was connected to the inputs of the microcontroller and the Bluetooth module. The Bluetooth module which has a transmitting and a receiving terminal, the transmitting terminal was connected to the microcontroller, which helped to transfer characters sent through any Bluetooth device to the microcontroller, since it was designed to send information in form of binary code to the microcontroller. The LEDs which are connected individually to a pin in the microcontroller, the microntroller lights up the LEDs as programmed. As the motor spins the mother board, the microcontroller lights up the Light emitting Diode (LED) at different position and time, due to the high rate of rotation and the speed of which the microcontroller switches the LEDs, the human tends to reach its limit of perception.

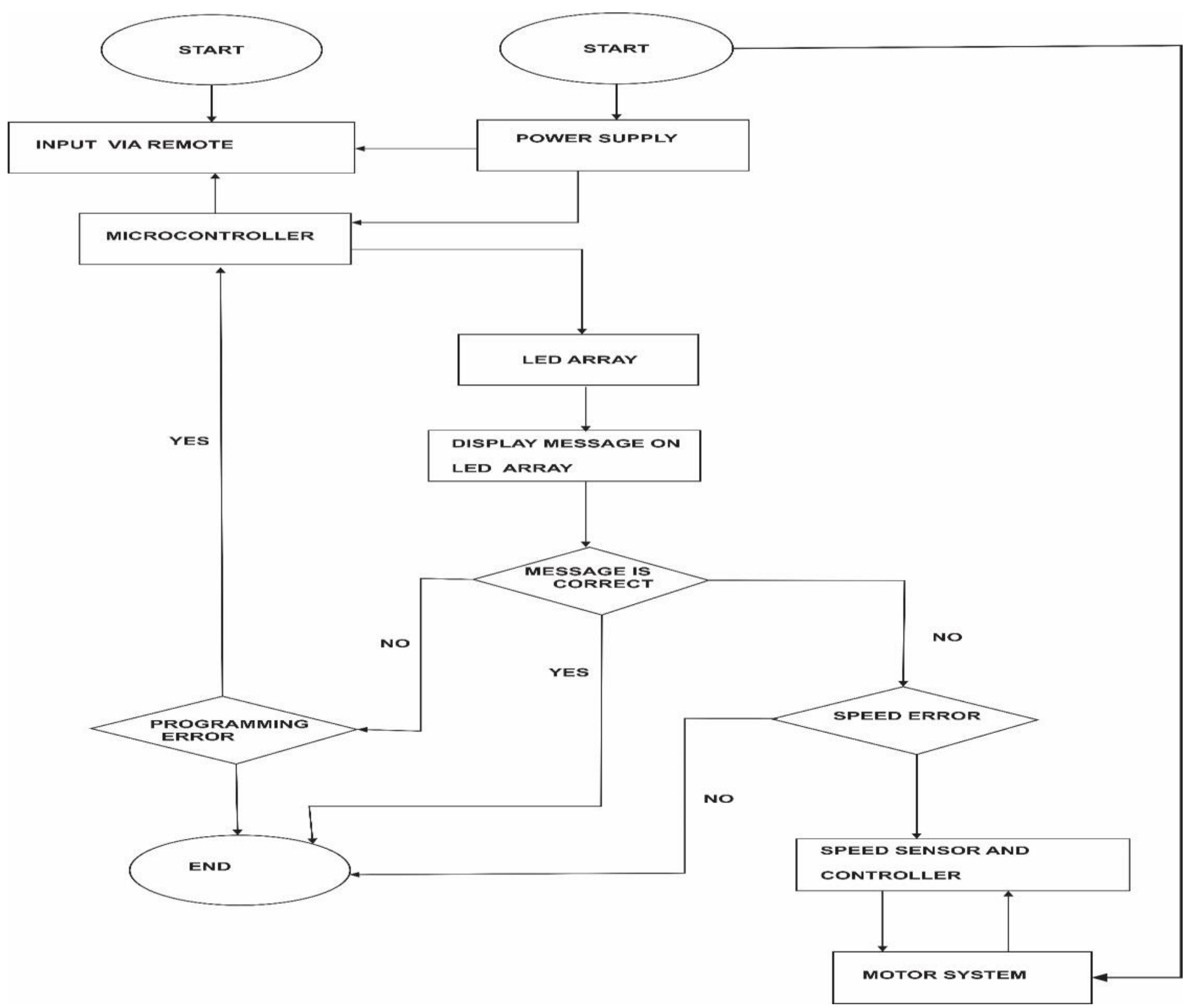

Figure 9: Flow Chart of Program Code for the Rotating led Display

3. TESTING AND RESULTS

Testing the LED Module

Before the display is run on full scale, the need to check that all the LEDs are connected to the Microcontroller is essential. Also, it is necessary to confirm that each of the LEDs displays the desired colour upon the storage of a particular value. Issues may arise when the LEDs are connected to the wrong pins of the microcontroller. This may bring about a pattern totally different from what is expected and may give an impression that the display is out of sync. When the sequence of the pins are not missed , an inverted display or mirror-image may appear as against the expectation of an upright image.

Testing the Motor Speed and Resolution

In order to achieve this task, it was ensured that no wires were entangled to any of the parts that will rotate when the motor is switched on. The potentiometer was kept at slowest speed and checked periodically to ensure that no part was hanging out thereby avoiding to get tangled during operation. Thereafter, the speed was increased gradually via rotating the potentiometer until a satisfied resolution was reached.

Testing the Motor Speed Controller

It might happen that the controller might not be supplying sufficient power to the motor to operate to its full capability. To ensure that the module worked at its full potential, the voltage levels at the module output was checked using a DMM.

Testing the Bluetooth Module

The Bluetooth module was tested to confirm its effectiveness in receiving data sent to it through a corresponding Bluetooth device. A Bluetooth app (Blueterm) was used for this purpose, the characters were typed using this app and at the end, a dollar sign was typed last indicating "send". This was achieved when the device was rotating, each time it starts receiving a character, it turns off display. This happens when a character is been sent to it, at the end of the last digit (dollar sign "$"), the display comes up again. The brushless d.c motor was switched on and it span at the required speed of 3600RPM. As it span, the Bluetooth came up, which blinked a red coloured light indicating it is ready to connect with other Bluetooth devices. Characters were sent to the device via an android phone, which was displayed as typed, indicating that everything worked according to the design.

4. CONCLUSION

An attempt has been made in this paper to present a POV system which may be beneficial from economic and environmental condition standpoint due to its relative cost and friendliness to the environment. The POV also has the advantage in the reduction of the size as well as ease of operation, maintenance and repair by the appropriate persons handling the device. It can be concluded from this study that the prototype was in good working condition and it fully performed its intended function and fully meets design objectives and aims. Also, it meets safety and quality standards and does not show signs of failure or being unsafe to the user.

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