DESIGN AND ANALYSIS OF A CIRCULAR DIGITAL DISPLAY USING A LINEAR LED ARRAY

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ABSTRACT

This paper presents a rotating LED display design where a 3000rpm motor is used to rotate an array of 8 LEDs in order to display a set of words. The design presented in this paper was selected mainly due to its simplicity. The major challenges were to get the correct LEDs blinking at the right time and to balance the rotating part. For this we had to measure the speeds, RPMs and time delays. The methods of measuring the speeds, RPMs and time delays are being presented together with their calculations. At the end a motion performance of the rotating LED display prototype is being presented.

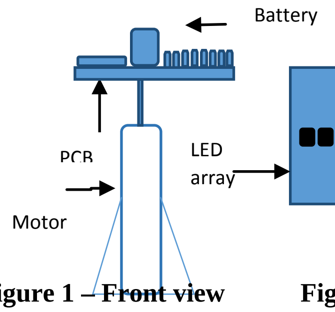
1. INTRODUCTION

There are various methods of communications in the universe and one of the widely used methods of communication has been visual communication. Starting off with paintings and sketches we have created a world in which we even produce 3-D images to communicate, for instance, the hologram where we could examine a particular image in three dimensional details.

Next was the creation of a motion picture. A set of images taken at very low time intervals between consecutive picture frames were displayed at fairly high speeds to create an episode of a real world incident. This concept of a motion picture was a great leap for mankind in terms of visually aided communication. Videos and video related concepts are a result of the motion picture idea.

A similar methodology is used in this project. In the rotating LED display we rotate an array of 8 LEDs but instead of rotating a set of picture frames we blink the LEDs in such a way that the blinking is not visible to the naked eye. This project is based largely on the persistence of vision theory which states that the human eye can only detect a change which occurs for more than $1/10^{th}$ of a second and nothing less. With these fundamentals we carry out the experiment to produce a set of words like in any LED display. But the specialty of our project is that we only use a single array of LEDs that rotate and blink unlike the LED displays where 10 – 25 LED arrays are used and certain LEDs are lit up to get a particular letter or a shape.

To get the correct LEDs blink at the right time the solution we found was to calculate the delay using a set of calculations which we call the [6]delay calculations and to balance the rotating part we used the battery which acts as the supply to microcontroller. These solutions are elaborated in the methodology. There have been many rotating displays done. There's even a clock made out of a rotating LED array and one which displays cartoon videos. There are a lot of prototypes of the rotating LED display but the challenge was creating it with an engineering control which makes this design perfect by using perfect delays in blinking the LEDs.



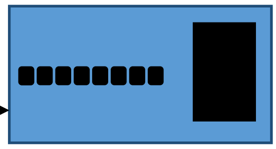


Figure 1 – Front view **Figure 2 – Top view**

Shown above is a simple labeled diagram of our prototype. The difference with this project from the rest of them is that we try to make the LEDs adapt to the speed variations that causes distorted images using an optical sensor.

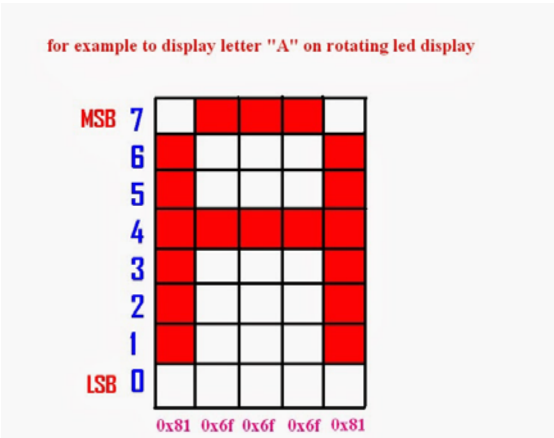
2. METHODOLOGY

Basically the concept is the LED array is rotated at calculated RPMs and the blinking is also done at delays corresponding to the calculated RPM. Hence we can continuously see a dot at the same position even though the LED is rotating. To implement this concept we conducted the following tests.

- Time period measuring of the motor using an optical sensor.
- ON / OFF time measuring of the LED using a function generator and an oscilloscope.

First of all we measure the minimum ON time for an LED. This is done by connecting an LED through a resistor to the function generator where a pulse is given and also to an oscilloscope where we observe the pulse. We change the frequency to a certain value until we don't see the LED blinking even though it is actually blinking extremely fast. Then we adjust the duty ratio to acquire our desired brightness after which we measure the time for the LED to switch ON, switch OFF and switch ON again which was found to be 25.4ms. Using this reading we calculated the RPM required to actually seeing the LED switched ON while the array oscillates. Next we have to measure the RPM of the motor. This was done again by using an optical sensor where the optical sensor was connected to a DC supply and an oscilloscope. The rotating part of the motor was covered in black tape on which a white strip of paper was pasted. Whenever the piece of paper crossed the infrared beam produced by the optical sensor a deflection in the waveform in the oscilloscope was produced. This oscillation was found to be periodic. When we measured the period of the waveform we obtained a value of 19.4ms. Using this reading we did necessary calculations to acquire the RPM of the motor. The calculations are presented.

The second step was to set a certain number of columns for a single letter. We decided on 5 columns per letter. Hence, the letter 'A' would be displayed as such:



[7]**Figure 3 – Columns for letter A**

Before fixing the components we carried out a Matlab simulation with the guidance of our professor where we observed how a word could be displayed in a circle using dots. The script and the results of the simulation are shown below.

Using the results of the simulation we did the coding on Mikroc.

After fixing all the components (PCB board, LED array, motor, and battery) properly we run the motor and give power to the microcontroller with the relevant program written in it. We could see the distortion of the letters produces\d which we figured was due to the speed variations. To overcome this we were advised to use an optical sensor to measure the instantaneous speed and then feed that particular reading to the microcontroller as an input so that the delay will be calculated accordingly. This theory is yet to be applied to our prototype and we assume that this is the appropriate solution to our issue at hand.

The mechanical assembly plays a crucial part in the proper functioning of the rotating display. If we do not get the proper balance and the right torque we wouldn't get the desired result. Hence we decided after considering many methods to keep the battery on the PCB board so that the battery becomes a part of the rotating components. The battery would only give power to the microcontroller through a regulator and the power to the motor will be given separately because the motor needs 18V to operate at the required RPM. To minimize the vibrations the motor is held tightly by a frame mounted on rubber bushes.

A basic overview is given using the following block diagrams.

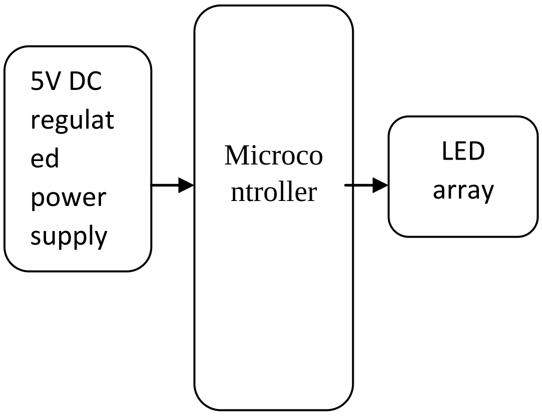


Figure 4 – Flow diagram of display part

3. IMPLEMENTATION

In the prototype we have used the following main components.

Table No. 1: Circuit details

Components	Specifications
Microcontroller	PIC 16F877A
Oscillator	1 - 20MHz
Resistors	32 – 330 ohms 1 – 10k ohms
Capacitors	2 – 22pf 2 – 104pf 2 - 47µf
Motor	19V DC motor
LED	8 red LEDs

The specific bit arrangement for the LED to blink so that the set of words appear correctly is sent to the LEDs as an output. The speed of the motor is taken as an input to the microcontroller so that the delays are set accordingly to get a clear result.

The trigger for the optical sensor is planned to be fixed on the PCB board and the optical sensor clamped at the optimum height so that it sensors the trigger accurately.

4. CALCULATIONS

The RPM and delay calculations are shown below

Required RPM calculation

ON/OFF time for LED (T) = 25.4ms
Time for one oscillation = 25.4ms
Required RPM;
1 revolution = 25.4ms
X revolutions = 1 s
Therefore, X = 39.37 revolutions per second.
Revolutions per minute = 2362.2 RPM

RPM of the motor calculations

Next task was to find the RPM of the motor. For this we used an optical sensor (IR sensor). We pasted a thin strip of paper on the rotating part of the motor and kept the optical sensor which was connected to the oscilloscope in a fixed position and observed the waveform. From the waveform we obtained from the oscilloscope we measure the time period of the wave which we found to be 19.4ms. The calculation for the RPM of the motor is as follows.

Time period (T_2) = 19.4ms
1 revolution = 19.4ms
X revolution = 1 s
X = 51.5 Revolutions per second.
Therefore,
Revolutions per minute = 3092 RPM

Therefore, RPM of the motor is larger than the required RPM. Hence this motor can be used for to rotate the LED array.

[6]Delay calculations

Motor speed = 3092 RPM
Time for one rotation = 19.4ms
Radius = 12cm
Perimeter = 2 x pi x 12 = 75.408 ≈ 76
Width of LED column = 0.5cm
Total number of LED columns = 76 / 0.5 = 152
Therefore,
152 LED columns = 19.4ms
Hence,
One LED column time = 19.4ms / 152 = 127.6µs
Columns for each letter = 5
Time for a letter = 5 x 127.6µs = 638.2µs
Length of a letter = 0.5 x 5 = 2.5cm
Total letters = 152 / 2.5 = 60.8 letters

5. CONCLUSION

This rotating LED display has many advantages. The overall cost is at a very affordable level. Also, maintenance and repairing of this project is very easy that anyone with a very little knowledge about electronic could fix it. Made from scrap it can be used anywhere and everywhere and the result is a crystal clear display.

This paper introduces the mechanisms and the basic principles to be followed in order to build a rotating LED display. The motion analysis is discussed along with its controllability using the optical sensor. It is also proved that the unevenness of the rotating part of the display could have an effect on the image produced.

6. REFERENCES

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