International Journal of Physical Research, 12 (2) (2024) 90-96

International Journal of Physical Research

Website: www.sciencepubco.com/index.php/IJPR

Research paper

Analytical design and implementation of a sequential display signboard

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Abstract

This study is aimed at the analytical design of a lighting system called a sequential display signboard to create a special illumination effect, which can be used in cock tail, disco halls, offices door, theatre and signboards using relevant mathematical equations and physics relations. The sequential display signboard consists of power supply unit connected to an arrangement of oscillator and switching circuits that triggered the light emitting diodes (LED) to display the words which are written inform of a message display. The system consists of 555 timers which functions as an Astable Multivibrator to generate pulses and transistors acting as switches thereby aiding the display of the message. With an input pulse from the 555 timer, the 4017 IC will cycle through its ten count sequence, lighting up each LED one at a time and recycling back to the first LED which results in a visual pleasing sequence of flashing lights in form of a message display.

Keywords: *Signboard; Switching Circuit; Multivibrator and Oscillator.*

1. Introduction

A signboard is a board carrying a sign or notice, usually used for advertisement of products, events, sale or let of houses, cautionary or educative purposes [1-2]. In 1393, King Richard II of England compelled landlords to erect signs outsides their premises. The legislation started "whoever shall sell in the town with the intention of selling it must hang out a sign; otherwise he shall forfeit his sales". This was in order to make them easily visible to passing inspectors of the quality of the sales item they provided. Another important factor was that, during the Middle Ages, a large percentage of the population would have been illiterate and so, pictures were more useful than the words as a means of identification of public houses. For this reason, there was often no reason to write the establishment's name on the sign board and Inns opened without a formal written name being defined on the public house's sign. In this sense, a public sign can be thought of as early example of visual branding [3]. The ancient Egyptians are known to have used trade signboards. In Rome, signboards were usually made from stone or terracocca. Although the history of when the use of signboards, sign post, bill-board began cannot be easily traced but one can conclude that at any point in time, man has use signboard to transfer message. But in modern times, the use of Light Emitting Diode started through the discovery of semiconductor materials. As improvement continued in semiconductor physics, the reliability of LED increases, because of very low current consumption, higher switching speed, and multiplicity of colors [4-6].
Nowadays, the electronic display commonly known as sequential display signboard is one of the fastest growing in multimedia technology. Sequential display signboard was mainly designed for the purpose of public information transfer and notification. It is a tool for communication, but it is a passive communication media since the other party at receiving end cannot exchange information in return [7]. The Block Diagram of the Sequential Display Signboard (SDS) is shown in Fig 1.

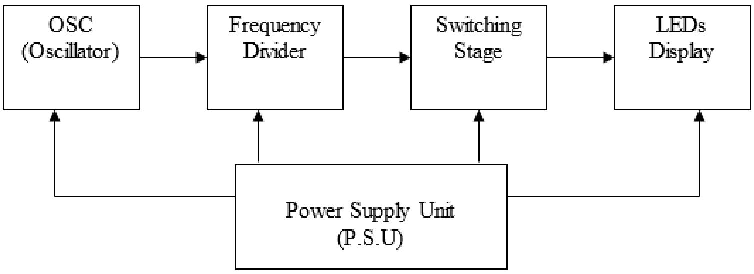

Fig. 1: Block Diagram of a Sequential Display Signboard.

The oscillator is built around the world most popular IC-NE555 and is used specifically for timing applications, Step-down transformer is primarily used to step-down incoming AC 220v input to a safer value level required by the circuit, The A.C input from the step-down transformer cannot be used directly for the operation of the system even though it has been step-down to a safe level, therefore it must be rectified to direct current voltage suitable for the operation of the circuit. The frequency divider majorly consists of a CMOS chip known as decade counter which on receiving input clock pulse determines the counting sequence of the display. The switching stage consist of a Transistor which is employed to perform the function of turning 'ON and 'OFF' of the load via the help of a relay as an intermediary. The LEDs creates an attractive display of characters with just very minimal current consumption at no heat dissipation to the surrounding. Durability of the device depends greatly on the choice of material used to construct the signboard. Majority of the researchers who had reported similar phenomenon had made use of woods, metal sheets, rods e.t.c which are subject to rusting, corrosion and decay [4-6]. However, an aluminum frame was employed in this research since it is proved to be free from corrosion, it's portability due to its lightness, possession of a shiny appearance with good attractive surface and its durability. The aim of this research is to design and construct a sequential display electronic signboard which uses light emitting diode to display the sentence "Welcome To Electrical And Electronics Engineering Department" such that certain characters' pops up at the same time and goes off followed by the next set of characters and so on. The format is thus:

WELCOME TO
ELECTRICAL AND
ELECTRONICS
ENGINEERING
DEPARTMENT

This study is built around the principles of generating signal (oscillation) and how to transfer this signal or information generated to the output terminal for display. It employs simple design concept devoid of complex programming for cost effectiveness, ease of reproducibility and application of design concepts to other display characters of interest.

2. Materials and method

The general mathematical theories and methodology used to achieve this project is described here which are in relation to the propounded theories and laws of Physics as stated by Daniel et al. [8]. The method employ involve the design of individual units as described in the block diagram, integration of the various units into a system, design implementation and testing of the workability of the device. The design specifications/Materials (electronic components) used includes the following:

Step-down transformer rating 15V, 2A with input A.C 220V, 50Hz.
LED with a maximum current of 30mA each.
Voltage regulator of specification 7012 to maintain 12Vd.c output.
PIV of bridge diode = $\sqrt{2}$ Vm = $\sqrt{2}$ x 12 = 16.9 V
Frequency (F) = 2 x 50Hz = 100Hz for full wave and bridge.
For transistor (BC108), V_{CE} = 5V, V_{BE} = 0.7V
For transformer wattage (P); Power factor, cos A = 1; But power (in watt) = IV cos A
P = 2 x 15 = 30W

The project requires a direct current (DC) power supply unit which consists of a step-down transformer, a bridge rectifier, a capacitive filter circuit and a regulator to maintain constant output supply to switching circuit. The block diagram is shown in Fig 2.

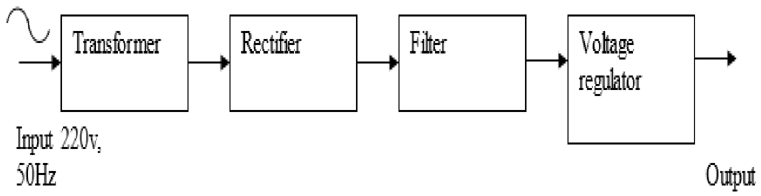

Fig. 2: Block Diagram of a Power Supply Unit.

A step-down transformer (fig 3) was used with transformer wattage rated at 30W as calculated above. The essential factors considering the parameters are as follows:

Primary e. m. f, E_1 = 220V_{AC}; Secondary e.m.f E_2 = 15V
Number of primary turns N_1 = 500t; Number of secondary turns N_2=?

From transformation ratio given by equation 1:

$$\frac{E_1}{E_2} = \frac{N_1}{N_2} \quad (1)$$

$$N_2 = \frac{15 \times 500}{220} = 34\text{turns}$$

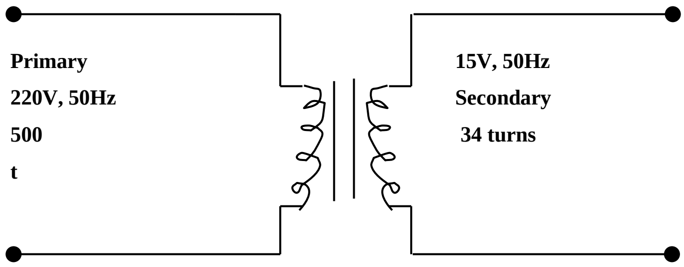

Fig. 3: A Step-Down Transformer.

The current (I) consumption of the primary side of the transformer is given by equation 2:

$$P = 1V \times \text{power factor} \tag{2}$$

30 = I x 220 x COS 0°; 30 = I x 220 x 1

I=30/220=0.136A

Then, the winding ratio of the transformer will be
$N_1/N_2= \frac{500}{34} = 14.7$; Such that the secondary current supply of the transformer becomes, 14.7 x 0.136 = 2.005 = 2 Ampere
The A.C rectification stage was built with 4 diodes as full wave rectifier. This is shown in Fig 4.

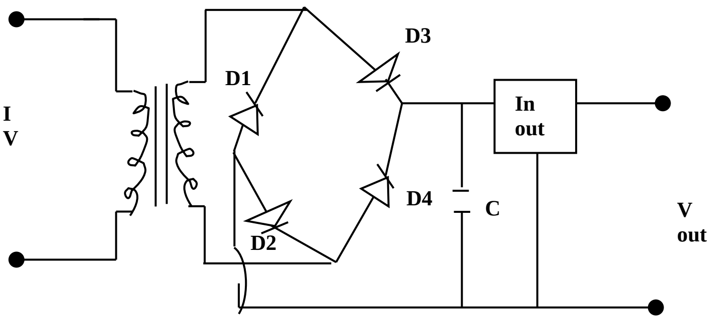

Fig. 4: Complete Power Supply Indicating the 4 Bridge Diode Rectification Stage, Capacitive Filter Stage and Voltage Regulator Connection.

For a circuit with rating of high current, a rectifier diode such as 1N4001 cannot be applied since it is only suitable for circuits with current rating less than 1A. Hence, 1N5007 was used and connected in bridge form.
The peak value of the 220v, 50Hz input is given by equation 3:

$$V_{rms} = \frac{Vm}{\sqrt{2}} \tag{3}$$

Therefore, Vm = √2 Vrms; Vm = √2 x 220 = 311V
The capacitive filter is used for the filter stage. Capacitor is used to suppress ripple current after rectification and allows pure dc voltage drop across the circuit section [9]. Other important parameters of the D.C filter circuit that was considered includes the peak to peak ripples, the filter output of this power supply fluctuates between 20V and 30V and therefore, the ripple peak to peak value is about 15V – 25V which is equal to 10Vp–p difference.
Hence, peak of the ripple = ½ of peak to peak value

= ½ x 10Vp–p = 5Vp–p value.

The ripple R.M.S value is √2 Vp–p

= 0.707 x 5= 3.54V.

Therefore, ripple percentage of ripple factor is expressed by equation 4 as:

$$\frac{V_{rms}}{V_{av}} \times 100\% \tag{4}$$

= 3.5 x 100%
15
= 23%

Ripple voltage (which is the voltage across the capacitor) =Voltage output of diode – voltage across the regulator.

= (14.3 – 2.3) V
= 12V
But q = CV = It

C = It/V
T= 1/f

Where C is capacitance, V is voltage, t is time, T is period and f is the frequency. For bridge rectification;

T= $^1/_{2f}$ = $^1/_{2x50}$ =$^1/_{100}$ = 0.01 sec

Therefore $C = \frac{1.6\times 0.01}{12} = 1333\mu F$

Standard capacitor available is close to 1000µF. As such a choice of 1000µF,16V Capacitor was made.
The Oscillator was build using IC (NE555) with it pin configuration shown in fig 5.

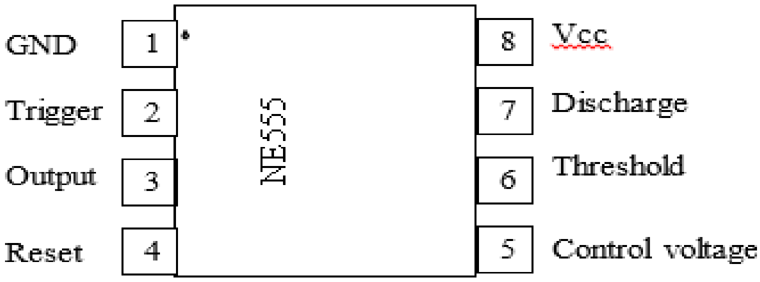

Fig. 5: Pin Out Configuration of NE555IC.

The Circuit Diagram of the Oscillator is as shown fig 6.

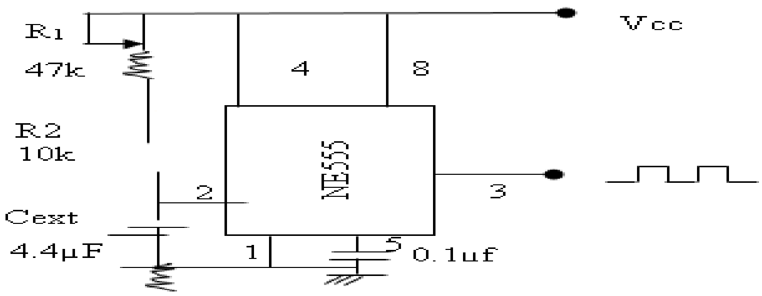

Fig. 6: NE555 Connection to Operate As An Astable Multivibrator.

As shown above, the values of R_1, R_2 and Cext determine the frequency of oscillation. Generally, for Astable Multivitbrator,

$PRF = \frac{1.44}{(R1+2R2)Cext}$(Hz) [10] (5)

$PRF = \frac{1}{0.69(R1+2R2)Cext}$

Hence, the value of each parameter used is substituted to obtain the frequency at which the NE555 timer generates pulses.

Therefore $PRF = \frac{1.44}{[10K+2\times 10K]4.4\times 10^{-6}}$

PRF =$\frac{1.44}{1.32} = 1.09$

PRF = 1Hz

But period of oscillation = $^1/_{PRF}$ = $^1/_1$ = 1 second.
The frequency divider is a CMOSIC called CD4017 or the Johnson counter Nicknamed after the inventor. It's called decade counter because it can count an incoming pulse up to 10 times before it restarts again. The physical appearance is shown in fig 7.

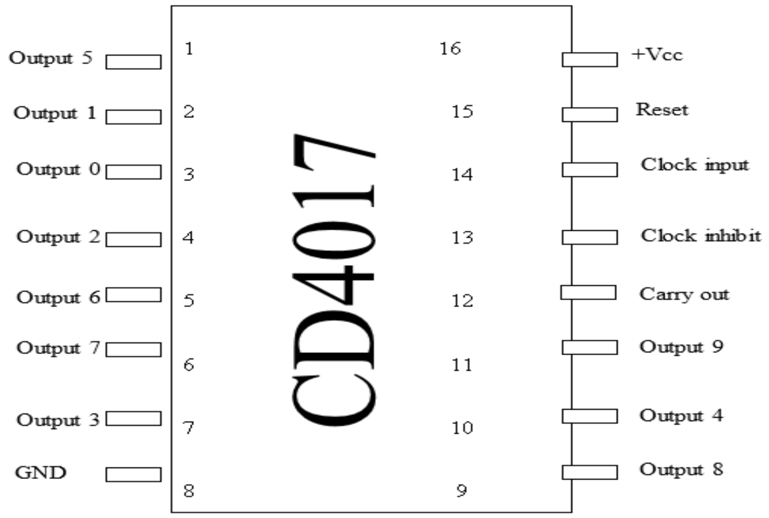

Fig. 7: CD4017 Physical Appearance.

The circuit diagram demonstrating the operation of the counter is shown in Fig 8. When high input clock pulse is fed to the pin 14 of the CD4017, it starts counting the input pulses from O to 9 and recycles again. Since the clock pulse frequency is very high, the human eye cannot distinguish between the flashes of the LEDs outputs except at very low frequency.

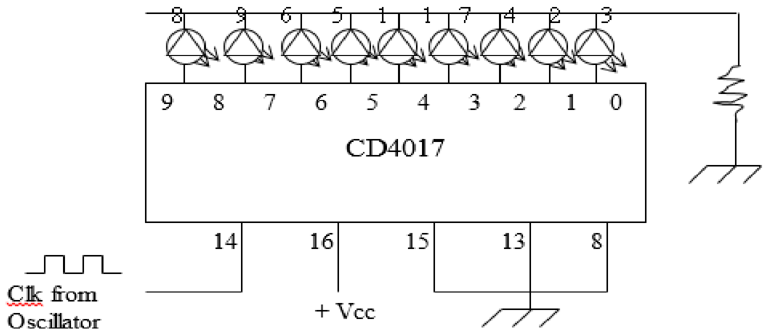

Fig. 8: Circuit Connection to Demonstrate Operation of A Decade Counter.

The maximum current used by each LED of red color is 0.03A [2] since different colored LEDs have different current consumption, the red color LEDs were used because of their brightness and attractive nature. Therefore, with 80 LEDs for a set of alphabets, total current consumption will be = 0.03 x 80= 1.6A Fig 9 is an arrangement of the components connected together to form the complete circuit diagram. The circuit diagram consists of the power supply unit, pulse generator unit, decade counter circuit, switching unit and the LEDs which serve as the load.

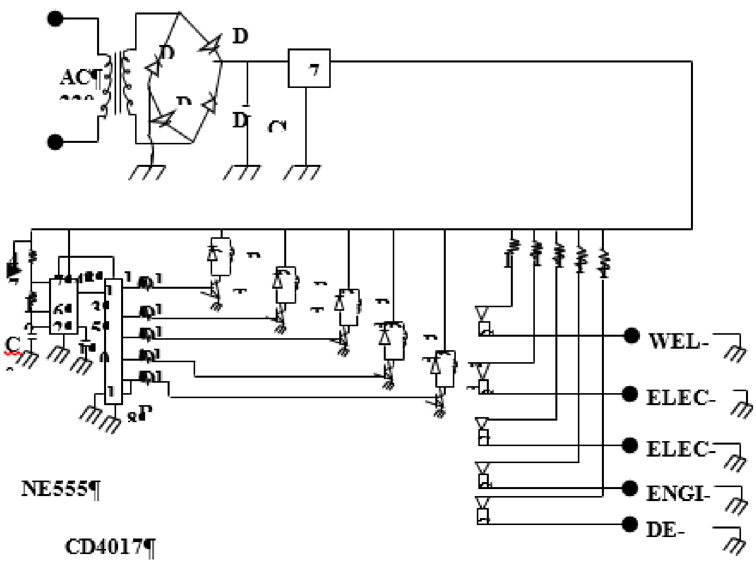

Fig. 9: Complete Circuit Diagram of A Sequential Display Signboard.

The operation of this sequential display signboard is quite simple and straight forward. It comprises primarily of a 555 timer used as an Astable Multivibrator, a decade counter (CD4017IC), a 15Vdc supply from the power supply unit, a switching stage built with transistors (BC108) and the LED (load).

The NE555 timer controls the timing of the system by generating pulses on receiving input DC voltage of 15Vdc from the power supply unit. The sequences of pulses are then fed to the input of the decade counter (pin 14) and the counter (i.e. CD4017IC) in turns determines the operational sequence of the message displayed. The decade counter functions a frequency divider giving one output at time at a frequency of 1Hz.

The NE555 timer generates a signal of 1Hz frequency while the counter is acting as decade counter operating in the ‘ON’ and ‘OFF’ state and counting it output up to 10 before it is reset. It is this property of the decade counter that is used to change the message display sequentially via transistor BC108 which act as a switching device and the transistor collector terminal is connected to a 12Vdc relay of contact current rating 10A which serves as an intermediary between the transistor and the load (LED) so that, the first clock pulse from the 555 timer triggers the counter and turns ‘ON’ the first set of LEDs arranged to display “WELCOME TO’ at 1Hz (i.e. for a period of 1 second) after which the timer changes and send another clock pulse to counter and then to the switching stage to display the next set of LEDs arranged to display “ELECTRICAL AND” and so on until the last set of LEDs are displayed. After a count of 10 by the decade counter, it is reset and start from the beginning again. This process is continuous except there is no power supply to the circuit.

The Vero board was then cleaned with iron brush to remove dirt on its surface after which the circuit components were then assembled and with each component terminals clearly positioned. The components were mounted on the board one after the other and soldered sequentially following the circuit diagram. The ICs were not directly soldered to the board but were connected to it via IC sockets in order to prevent damage from heat and also to make replacement easier, faster and more efficient. Units like the display pad and keys that were not linked directly to the board were connected to it through flexible wires which enhances flexible mounting of the units on the enclosure. During the soldering process, care was taken to ensure that the soldering joints have good mechanical and electrical contacts. The display board consists of a large size strip board on which the LEDs were soldered and the outer board is a slightly transparent plastic. The layout diagram is shown below in fig 10.

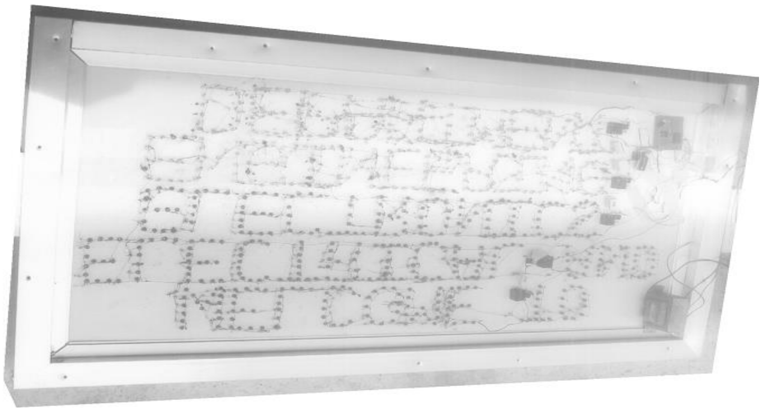

Fig. 10: Layout Diagram.

The packaging is quite simple in that, it doesn’t require metal forging or welding of joints, neither is it made up of heavy material such as wood or metals. The casing is made up of plastic and aluminum frame screwed together with a groove that allows easy placing of the circuit layout. As the circuit layout is inserted, it was then covered with a very light but durable board screed to the aluminum frame. The LEDs on the layout surface were covered with a slightly transparent plastic which gives the package a beautiful and attractive look. The pictorial view of the Sequential Display Signboard is shown below in fig 11.

The testing of the project proved satisfactorily when the power cord was connected to the mains and the power switch toggled ON to check its functionality. Using a Multimeter, the voltage level at various points were taking to ensure that the correct amount of power is reaching all units and each components working accordingly.

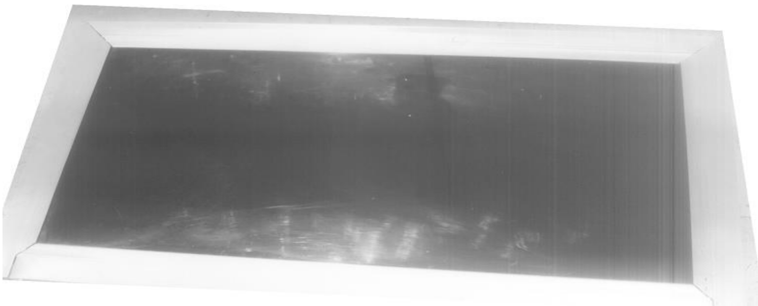

Fig. 11: Pictorial View.

3. Results and discussion

After a successful testing, the results obtained conformed to the expected and calculated values. With the aid of a Multimeter, the results obtained at each test point were as follows:

AC voltage supplied to the transformer input from was found to be 220V, 50Hz.

Voltage drop at the secondary side of the transformer was measured as 15V with a current amplitude value of 2A as stated in the specification.

Voltage drop across each diode that forms the bride rectifier was measure to be 1.4V at the voltage regulator output, the measured voltage drop was 12Vdc constant.

Vcc of all ICs = 12V (measured)

Gnd of all ICs = 0V (measured)

After the voltage and current test at various points gave satisfied results, the power button was deactivated. It is important to note that; constructed project like sequential display signboard plays an important role in educating and informing people. As such, it must look attractive and a brilliant output is required so as to attract attention in order to achieve its purpose. However, LEDs which plays the vital function of displaying the message are of different colors with different illumination intensity. Others appears physically colorless but can radiate different color depending on the voltage drop across them.

4. Conclusion

The electronic Sequential Display Signboard was designed and constructed successfully, but not without problems which are of course, surmounted. In the course of executing this project, tremendous experience was acquired in the area of design and application of 555Ic timer and Decade counters to electronic circuits. The approach adopted was the use of integrated circuit chips and LEDs to enhance efficiency and reliability of the system. The use of LEDs to construct the lighting display as against the use of hand written messages is more attractive, information and educative as relates to advertisement.

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