Design and Construction of an Automatic LED Emergency Lighting System

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DEDICATION

I dedicate this work to God Almighty for the grace and to my loving parents Mr. & Mrs. Samuel Akinwale Oyadiran for their continued support.

Declaration

I, Oyadiran 'Tunmise Folasade, declare that this work was done by me and has never been presented elsewhere for the award of a degree. I also relinquish the copyright to the Federal University of Technology, Minna.

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(Jan 11 2011)	1/12/10
Signature and date	Signature and date

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Sincerely, all my colleagues and friends who have helped me so much, though they are too many for me to list by name, I could not have had a very successful completion of project without them.

ABSTRACT

Automatic Emergency Lighting Systems are utilized in organization for important meetings and conferences organized in a big hall in order to illuminate the hall and even in homes when the power supply from the grid system is cut-off. Automatic Emergency Lighting System are also be used in exit routes to illuminates exit routes and open areas in case of emergency such as fire outbreak, disaster etc.

This system operates automatically when a lighting circuit losés the mains power supply from the national grid. Its works with the battery and the mains supply charges the battery when the main supply is available.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 EXPOSITION

In our present day, the rate of constant power interruption and seizure in both industrialized and non-industrialized areas is continually on the increase. Even the availability of generating sets and plant machines is becoming worrisome because of the high cost and incessant scarcity of Premium Motor Spirit (petrol and diesel). Emergency lights can be used to alleviate some of the challenges of frequent power outage.

Emergency lighting operates automatically when a lighting circuit loses the mains power supply. They are commonly used in organizations and homes in the event of a power outage. The use of emergency lights cannot be over emphasized in industrial and non industrial areas such as Board room or hospital theaters and even in some homes. Such type of automatic emergency light can be said to be a requirement in our country today where load shedding has become a part of life due to imbalance in demand and supply of electricity.

Automatic Emergency Light is also useful for important meetings and conferences organized in a big hall in order to illuminate the hall when the power supply from the grid system is cut-off. The emergency light, which can be placed in fixed positions in strategic areas, is connected to the mains supply. Whenever the mains supply is triggered off, the light automatically glows and there will be no hindrance to any work. However, generators and inverters have some drawbacks compared to emergency light such as high cost and the need for more space. Hence, it becomes more advantageous to have an emergency light in order to provide the immediate lighting power whenever mains supply goes off. The illumination power of the lamp depends upon the Voltage and Ampere rating made available at the output [1].

The Automatic Emergency Lights can also be deployed on the roads and highways as street lights. This ensures that roads are constantly and continuously lit at all times.

Emergency lighting falls into two categories:

Escape lighting

This illuminates exit routes and open areas. Exit routes must be clearly lit and signed to ensure people can evacuate the building safely and open area lighting, designed to reduce confusion and panic, whilst ensuring visibility of the nearest exit route. Escape lighting also enables employees to shut down sensitive or potentially dangerous processes before evacuating the building.

Standby lighting

Standby lighting allows normal activities to continue if the main lighting fails for any reason. An application such as an operating theatre or an air traffic control centre would require standby lighting. This Lightning system works via charging of its built-in power source (battery) by mains power supply which remains illuminated after the power supply has been cut-off.

1.2 OBJECTIVE OF THE PROJECT

The objectives of this project are:

i. To design and construct a laboratory model of an Automatic LED Emergency Light that can detect mains supply failure and comes into operation using a rechargeable battery backup.

ii. To construct an Automatic LED Emergency Light that turns on when the mains supply is not available.

1.3 METHODOLOGY

The methodology used in this project entails paper design initially, after which a simulation would be done using Electronic Workbench software. The designed circuit will then put on a bread board to allow for placement adjustments, and then on the actual soldering unto a Vero board.

1.4 THESIS OUTLINE

In this project chapter 1 contains the introduction, exposition, objectives, methodology, scope of work and definition of terms used in this project. Chapter 2 reviews the existing works done in relation to automatic led emergency lighting system which includes the theoretical background, history and development, modern development and technology tomorrow. Chapter 3 focuses on the principles of operation. Chapter 4 shows the tests, results and discussion achieved during the project and Chapter 5 tells about the conclusion and recommendation of the project.

1.5 SOURCES OF MATERIALS

Materials on this project were gotten from various sources such as textbooks, journals, lecture notes, web pages (via internet), consultation with technologists and supervisor.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 INTRODUCTION

This chapter reviews existing works on the topic: Automatic Emergency LED. Such works have relevance to this study as they provide useful guide and theoretical frame work on which this project is built. Towards this, the chapter is divided into the following: theoretical background, history and development, modern development and technology tomorrow and related works.

2.2 THEORETICAL BACKGROUND

Automatic lights were developed from original candle lights to commonly used incandescent lights. In recent years, new-type HID (High Intensity Discharge) and LED lights have also emerged. The LED luminous efficiency can reach 80%-90% [2]. New-type and intelligent LED lights, which are called the fourth-generation automatic light source, have become an outstanding member among global automatic electronic products and will be the new development orientation of auto lamps [3]. Compared with traditional lights, LED lights have much longer service life. Its service life is 50,000 hours in theory and 20,000 hours in practice [4]. The start time for LED lights is only dozens of nanoseconds, much shorter than that of incandescent lights. Its drive current is only 1/4 of that of incandescent lights. Automatic LED lights converted from halogen lights have much stronger night visibility, rich colors and fashionable styles. The energy-saving and environmental-friendly automatic LED light technology will usher in a new development period. It is forecast that the automatic LED lighting will achieve outstanding growth in the LED lighting market in the following years [5].

An emergency light is a battery-backed lighting device that comes on automatically when a building experiences a power outage. Emergency lights are standard in new commercial and high occupancy residential buildings, such as college dormitories. Most building codes require that they be installed in older buildings as well.

2.3 HISTORY AND DEVELOPMENT

The earliest lamps were used by Greek and Roman civilizations, where light primarily served the purpose of security, both to protect the wanderer from tripping over something on the path as well as keeping the potential robbers at bay. At that time oil lamps were used predominantly as they provided a long-lasting and moderate flame. The Romans had a word 'laternarius', which was a term for a slave responsible for lighting up the oil lamps in front of their villas. This task continued to be kept for a special person as far as up to Middle Ages where the so-called 'link boys' escorted people from one place to another through the murky winding streets of medieval towns.

Before incandescent lamps, gas lighting was employed in cities. The earliest lamps required that a lamplighter tour the town at dusk, lighting each of the lamps, but later designs employed ignition devices that would automatically strike the flame when the gas supply was activated. The earliest of such lamps were built in the Arab Empire especially in Córdoba, Spain [6].

By the nature of the device, an emergency light is designed to come on when the power goes out. Every model, therefore, requires some sort of a battery or generator system that could provide electricity to the lights during a blackout. The earliest models were incandescent light bulbs which could dimly light an area during a blackout and perhaps provide enough light to solve the power problem or evacuate the building. It was quickly realized, however, that a more focused, brighter, and longer-lasting light was needed. The modern emergency floodlight provides a high-lumen, wide-coverage light that can illuminate an area quite well. Some lights are halogen, and provide a light source and intensity similar to that of an automobile headlight.

Early battery backup systems were huge, dwarfing the size of the lights for which they provided power. The systems normally used lead acid batteries to store a full 120-volt charge. For comparison, an automobile uses a single lead acid battery as part of the ignition system. Simple transistors or relay technology was used to switch on the lights and battery supply in the event of a power failure. The size of these units, as well as the weight and cost, made them relatively rare installations. As technology developed further, the voltage requirements for lights dropped, and subsequently the size of the batteries was reduced as well. Modern lights are only as large as the bulbs themselves - the battery fits quite well in the base of the fixture. Light-emitting diodes are small, completely solid state, very power-efficient, long-lasting (as they have no filaments to burn out) and can be seen very easily even at great distance. LED-based light bars can be made very thin, reducing wind resistance by around 8-10 percent [7].

2.3.1 MODERN DEVELOPMENTS

Modern emergency lighting is installed in virtually every commercial and high occupancy residential building. The lights consist of one or more incandescent bulbs or one or more clusters of high-intensity Light Emitting Diodes (LED). The emergency lighting heads are usually either PAR 36 sealed beams or wedge base lamps. All units have some sort of a reflector to focus and intensify the light they produce. This can either be in the form of a plastic cover over the fixture, or a reflector placed behind the light source [8]. Most individual light sources can be rotated and aimed for where light is needed most in an emergency, such as towards fire exits. Modern fixtures usually have a test button of some sort which temporarily overrides the unit and causes it to switch on the lights and operate from battery power even if the main power is still on. Modern systems are operated with relatively low voltage, usually from 6-12 volts [9]. This both reduces the size of the batteries required and reduces the load on the circuit to which the emergency light is wired. Modern fixtures include a small transformer in the base of the fixture which steps-down the voltage from main current to the low power required by the lights. Batteries are commonly made of lead-calcium, and can last for 10 years or more on continuous charge. U.S. fire safety codes require a minimum of 90 minutes on battery power during a power outage along the path of egress [10, 11].

As a method of signaling a power outage, some models of emergency lights must be shut off manually after they have been activated. This is true even if the main building power comes back on. The system will stay lit until the reset button on the side of the unit is pressed.

Emergency lighting is often referred to as egress lighting. Emergency lights are used in commercial buildings as a safety precaution to power outages, so that people will be able to find their way out of a building. Exit signs are often used in conjunction with emergency lighting [12].

As there are strict requirements to provide an average of one foot candle of light along the path of egress, emergency lighting should be selected carefully to ensure codes are met.

2.3.2 TECHNOLOGY TOMORROW

Technology Tomorrow is based on research work. It appears that the developed nations of the world are in the fore front of this research work. For example, in Belgium, LumiLed, a joint venture between Philips and Agilent are developing ultra high brightness LED's. In Japan, Nichia continues to push the brightness – cost ratio [13]. In England, Cambridge Display Technology succeeded in producing the World's first blue light emitting polymer (LEP) and have now gone on to produce a white organic LED (OLED). Currently all development in this field is aimed at producing technology that can be used in colour display screens. In the USA, The Massachusetts Institute of Technology (Nano Structures Lab) is working on a device called a Photonic Band Gap LED. Initially the research is aimed at improving the efficiency of single colour LED's. Extensions of this research could lead to a LED where both colour and intensity can be set electronically. The potential for effects lighting are staggering [14]. In England, Artistic License is pioneering new techniques for electronic control of LED intensity [15]. Recent developments include a system called Frequency Modulation. Frequency Modulation provides a number of benefits compared to the older Pulse Width Modulation technique [16]. The most notable of which is the ability to produce higher resolution control over the low intensity range. This is of particular interest in colour mixing applications. This research work continues and it is hoped that soonest the world would witness the result of great minds.

2.4 RELATED WORKS

Before the use of Led in emergency lighting systems, incandescent light bulbs, arc light, photoelectric control were in use.

Arc lights had two major disadvantages. Firstly, they emit an intense and harsh light which, although useful at industrial sites like dockyards, was discomforting in ordinary city streets. Secondly, they are maintenance-intensive, as carbon electrodes burn away swiftly. With the development of cheap, reliable and bright incandescent light bulbs at the end of the 19th century, arc lights passed out of use for street lighting, but remained in industrial use longer [17].

Incandescent lamps were primarily used for emergency lighting system until the advent of high-intensity discharge lamps. They were often operated at high-voltage series circuit. Series circuits were popular since the higher voltage in these circuits produced more light per watt consumed [18]. Incandescent lamp produces heat and blackens the bulb. Furthermore, before the invention of photoelectric controls, a single switch or clock could control all the lights in an entire system.

To avoid having the entire system go dark if a single lamp burned out, each lamp was equipped with a device that ensured that the circuit would remain intact. Early lamps were equipped with isolation transformers [19] that would allow current to pass across the transformer whether the bulb worked or not. Later the film cutout was invented. The film cutout was a small disk of insulating film that separated two contacts connected to the two wires leading to the lamp. If the lamp failed (an open circuit), the current through the string became zero, causing the voltage of the circuit (thousands of volts) to be imposed across the insulating film, penetrating it (see Ohm's law) [20]. In this way, the failed lamp was bypassed and power restored to the rest of the system. The emergency light circuit contained an automatic voltage regulator, preventing the current from increasing as lamps burned out, preserving the life of the remaining lamps. When the failed lamp was replaced, a new piece of film was installed, once again separating the contacts in the cutout. This system was recognizable by the large porcelain insulator separating the lamp and reflector from the mounting arm. This was necessary because the two contacts in the lamp's base may have operated at several thousand volts above ground.

Based on all these shortcomings, led were introduced. Led have no ultra violet output, they consume less power and they long life span compared to incandescent light, they produce very little heat at the output, white led are very bright and they have high illumination power.

CHAPTER THREE

3.0 DESIGN AND IMPLEMENTATION

3.1 PRINCIPLES OF OPERATION

Automatic LED Emergency Light is a lighting system that works when the main supply is not available. Its works with the battery and the mains supply charges the battery. The block diagram of the project is showed in fig. 3.1.

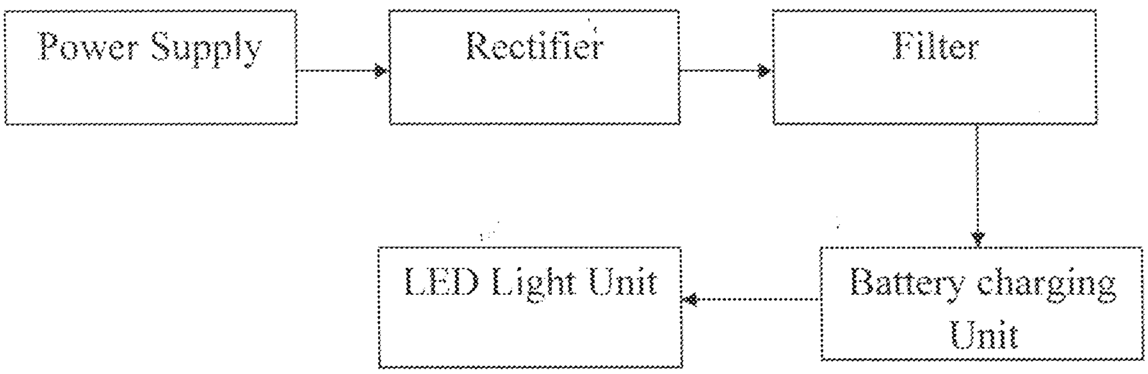

Fig.3.1: Generalized Block Diagram

3.2 POWER SUPPLY

The power supply comprise of a step down transformer. Transformer, electrical device consisting of one coil of wire placed in close proximity to one or more other coils, used to couple two or more alternating-current (AC) circuits together by employing the induction between the coils. The coil connected to the power source is called the primary coil, and the other coils are known as secondary coil. A transformer in which the secondary voltage is less than the primary, the device is known as a step-down transformer. The product of current and voltage is constant in each set of coils, so that in a step-down transformer, the voltage decrease in the secondary is accompanied by a corresponding increase in the current. In this project the step down transformer rating is 230V 0-9V, 500mA. This means that the primary session is 230V and the secondary session is 0-9V, 500mA.

3.3 RECTIFIER

A rectifier is a circuit that employs one or more diodes to convert ac voltage into pulsating dc voltage. Automatic LED Emergency light uses a full wave bridge rectifier which uses four diodes with a transformer and has a maximum voltage of V_{sm} which is 9V as shown in the fig.3.2.

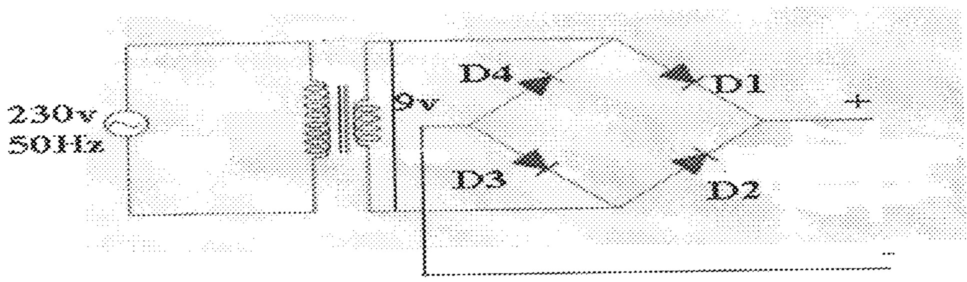

Fig.3.2: Bridge Rectifying Circuit

The full-wave bridge rectifier is available in three distinct physical forms shown [21]:

1. Four discrete diodes
2. One devices inside a four-terminal case
3. As part of an array of diodes in an IC.

Fig.3.3 shows the distinct physical forms:

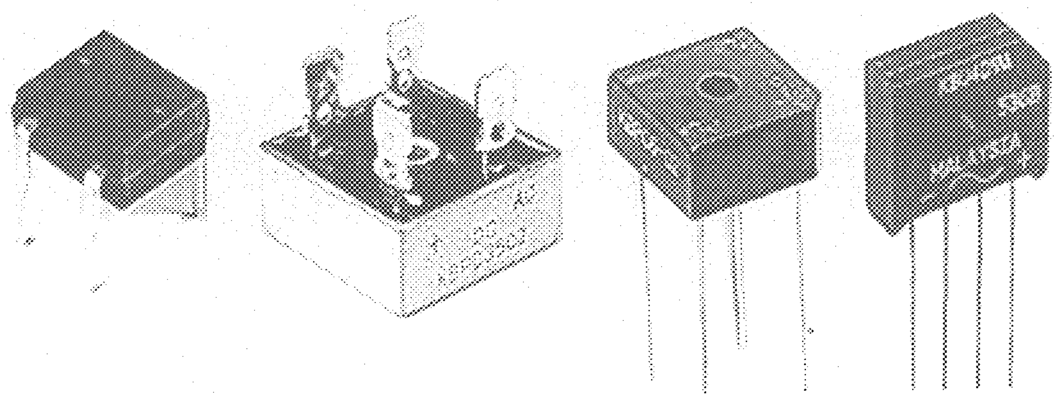

Fig 3.3: Distinct forms of a bridge rectifier

A diode is a semiconductor device which allows current to flow through it in only one direction. Current flows from the anode side to its cathode side. A junction diode can be biased in two regions; forward biased region and reverse bias region.

3.4 FILTER

The main function of a filter is to minimize the ripple content in the rectifier output. Outputs of some rectifier circuits pulsate. It has some dc value and some ac components called RIPPLES. These circuits require a very steady dc output that approaches the smoothness of a battery`s output. Fig 3.3 is a graphical representation of the output of a filtered dc.

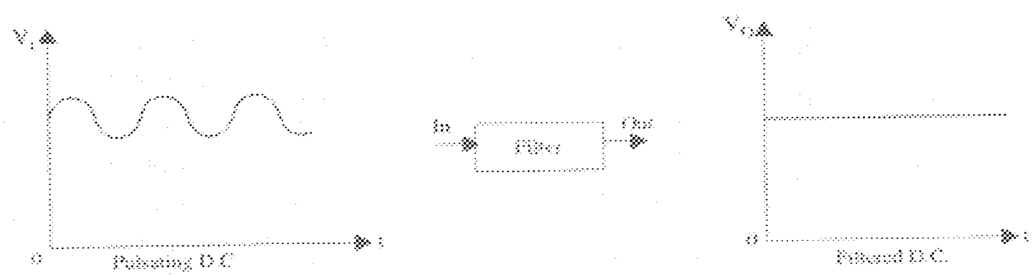

Fig. 3.4: Pulsating dc being filtered

Capacitor, device for storing an electrical charge, sometimes called a condenser. In its simplest form a capacitor consists of two metal plates separated by a non-conducting layer called the dielectric. The dielectric may be air, plastic, waxed paper, or another substance such as the mineral mica. When one plate of a capacitor is charged using a battery or other source of direct current, the other plate becomes charged with the opposite sign; that is, positive if the original charge is negative, and negative if the original charge is positive.

The electrical size of a capacitor is its capacitance, which is the amount of electric charge it can hold per unit potential difference across its plate

$$C = \frac{Q}{V} \qquad [1]$$

A bigger capacitor should be used in order to:

1. reduce the magnitude of ripple voltage;
2. increase the peak current in the diode;
3. increase the peak current in the diode.
4. The formula to calculate the ripple factor is as follow:

For half wave rectifier:

$$\gamma = \frac{1}{2\sqrt{3}fCR_L} = \frac{I_{dc}}{4\sqrt{3}fC}\left[\frac{1}{V_{ip}} - \frac{1}{V_{dc}}\right] \qquad [2]$$

For full wave rectifier:

$$\gamma = \frac{1}{4\sqrt{3}fCR_L} = \frac{I_{dc}}{4\sqrt{3}fCV_{ip}} \qquad [3]$$

Where V_{ip} = peak output voltage

I_{dc}=load current

f=frequency

C=capacitor

Peak primary voltage = 230 × √3

=325 V

Peak secondary voltage =9 × √3

= 15.6 V

Peak full wave rectified voltage at the filter input

V_{ip} = 15.6 - 2×0.

=12.9 V

$$\gamma = \frac{500\times10^{-3}}{4\sqrt{3}\times50\times1000\times10^{-6}\times12.9}$$

= 0.011 (1.1%)

3.5 BATTERY CHARGING CIRCUIT

The battery charging circuit comprises of two sessions: The Voltage Regulator and the charging of the Battery.

3.5.1 VOLTAGE REGULATOR

The voltage regulator used here is the LM 317 whose output can be adjusted over a wide range. It can be adjusted from 1.2V to 37V. It is a three terminal IC regulator. Fig 3.5 shows the LM 317 connected to the external resistors R_1 and R_2 to produce an adjustable output voltage.

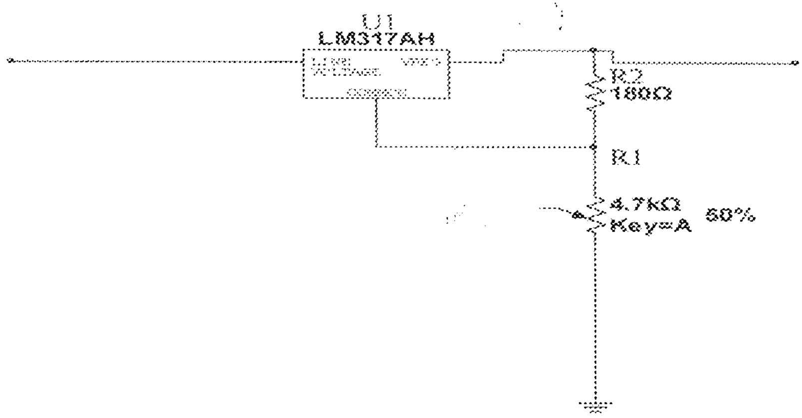

Fig. 3.5: LM 317 connected to external resistors

The LM 317 develops a constant 1.25V reference voltage (V_{ref}) between the output and the adjustment terminal which produces a constant current (I_{ref}) through R_1. The value of the I_{ADJ} is around 100µA.

To calculate the output voltage,

$$V_{out}=V_{ref}\,[1+R_2/R_1]+I_{ADJ}\,R_2 \qquad [4]$$

R_2= 4.7kΩ

R_1=180Ω

V_{out}= 1.25[1+ 4.7k / 180] + 1000×10^-6×4.7×10^3

= 34.35V

V_{out}=1.25[1+ 4.7× 10^3 /0] +1000×10^-6×0

=1.25V

The maximum and minimum output voltages are 1.25V and 34.35V. For this project the output required is 7V to charge the battery. The adjusted pin of the LM 317 is adjusted to give the desired output which is 7V.

3.5.2 CHARGING UNIT

The output from the voltage regulator provides charging current through diode D5 and limiting resistor R16. By adjusting preset VR1, the output voltage can be adjusted to deliver the required charging current. When the battery gets charged to between 5.1V and 6.2V, zener diodes ZD_1 and ZD_2 conducts and charging current from regulator IC1 finds a path through transistor T_1 and T_2 to ground and it stops charging of the battery to avoid damage of the battery or over charging of the battery. The voltage that charges the battery is 6.20V. Fig 3.6 is the circuit showing the charging unit of the battery.

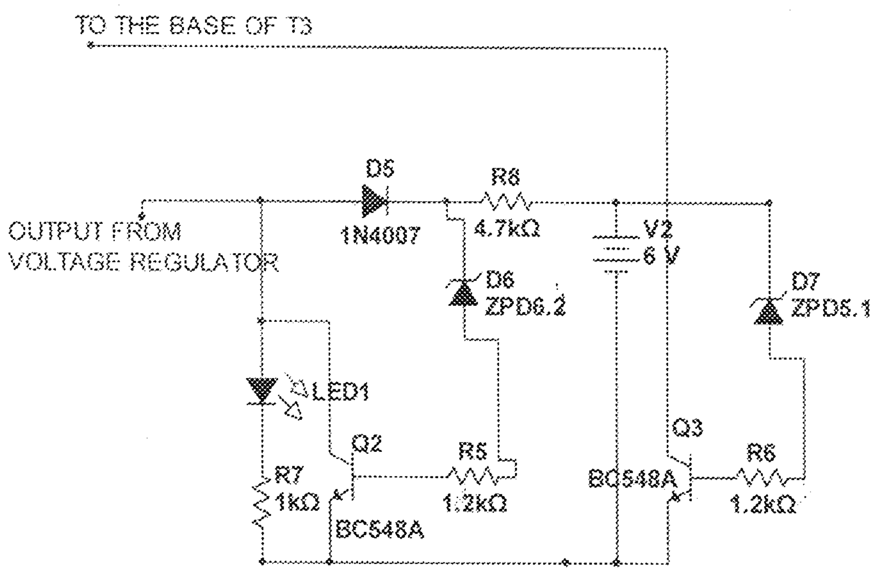

Fig 3.6: Circuit showing the charging of the battery and LED indicator

3.6 LED DRIVER SESSION

The LED driver session consist of the relay which acts as a switch and the LED circuit.

3.6.1 RELAY

A relay is an electrically operated switch. Current flowing through the coil of the relay creates a magnetic field which attracts a lever and changes the switch contacts. The coil current can be on or off so relays have two switch positions and they are double throw (changeover) switches.

Relays allow one circuit to switch a second circuit which can be completely separate from the first. For example a low voltage battery circuit can use a relay to switch a 230V AC mains circuit. There is no electrical connection inside the relay between the two circuits; the link is magnetic and mechanical. The relay's switch connections are usually labeled COM, NC and NO:

• COM = Common, always connect to this; it is the moving part of the switch.

• NC = Normally Closed, COM is connected to this when the relay coil is off.

• NO = Normally Open, COM is connected to this when the relay coil is on.

3.6.2 LED LIGHT CIRCUIT

All the LEDs are connected in series with a 100Ω resistor in series with each. The common-anode junction of all the twelve LEDs is connected to the collector of pnp transistor T3 and the emitter of transistor T3 is directly connected to the common of the relay and then the normal opened to the positive terminal of 6V battery. The unregulated DC voltage, produced at the cathode junction of diodes D1 and D3, is fed to the base of transistor T3 through a 390Ω and 560Ω resistor. When mains supply is available, the base of transistor T3 remains high and T3 does not conduct. The relay acts as a switch so that when the mains supply is on the LED don't glow. On the other hand, when mains fails, the base of transistor T3 becomes low and it conducts then the normal open makes a contact with the normal closed.

This makes all the LEDs (LED1 through LED12) glow. The mains power supply, when available, charges the battery and keeps the LEDs off as transistor T3 remains cut-off. During mains failure, the charging section stops working and the battery supply makes the LEDs glow. Driver transistor T3 can deliver up to 1.5A. Fig 3.7 shows the LED driving circuit.

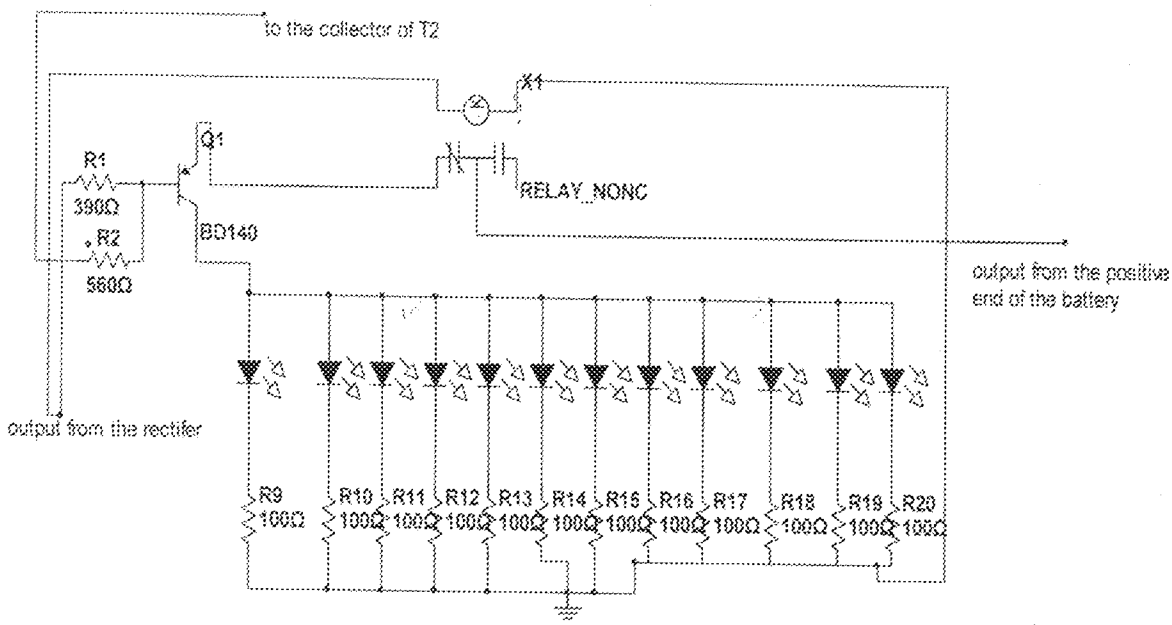

Fig 3.7: Circuit showing the LED driver.

3.6.3 RESISTOR

Resistors determine the flow of current in an electrical circuit. Where there is high resistance then the flow of current is small, where the resistance is low the flow of current is large. Resistance, voltage and current are connected in an electrical circuit by Ohm`s Law.

The color code: Some resistors have color bands that indicate their values and tolerances. Fig 3.8 five bands around carbon-composition resistors:

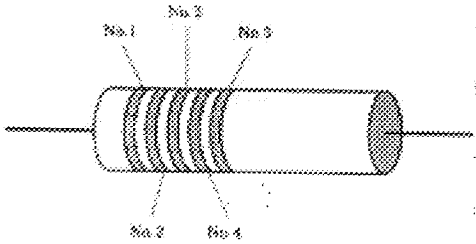

Fig. 3.8: Resistor showing five bands of colors.

3.7 CONSTRUCTION

Design and Construction of an Automatic Emergency Lighting system includes the components used in the design and the choice of casing used.

3.7.1 COMPONENTS SPECIFICATION

The specifications of components used in constructing this project are as follows:

1. Transformer 230 – 9 V, 50Hz
2. Diodes (6) - 1N4007
3. LM 317
4. Capacitor - 1000µf, 25 V
5. Variable resistor - 4.7kΩ
6. Resistors - 100Ω, 180Ω, 390Ω, 560Ω, 1kΩ, 1,2kΩ, 4.7kΩ
7. Transistors - BC 548. BD 140
8. Zener diode - 5.1V, 6.2V
9. Relay 6V
10. Battery 6V
11. LEDs (12)

12. Connecting wires

The circuit was first constructed on a bread board to ensure that it worked perfectly well before it was transferred into a Vero board permanently. The components were placed on the line Vero board and neatly soldered. Plate 3.1 shows the arrangement of components on the vero board.

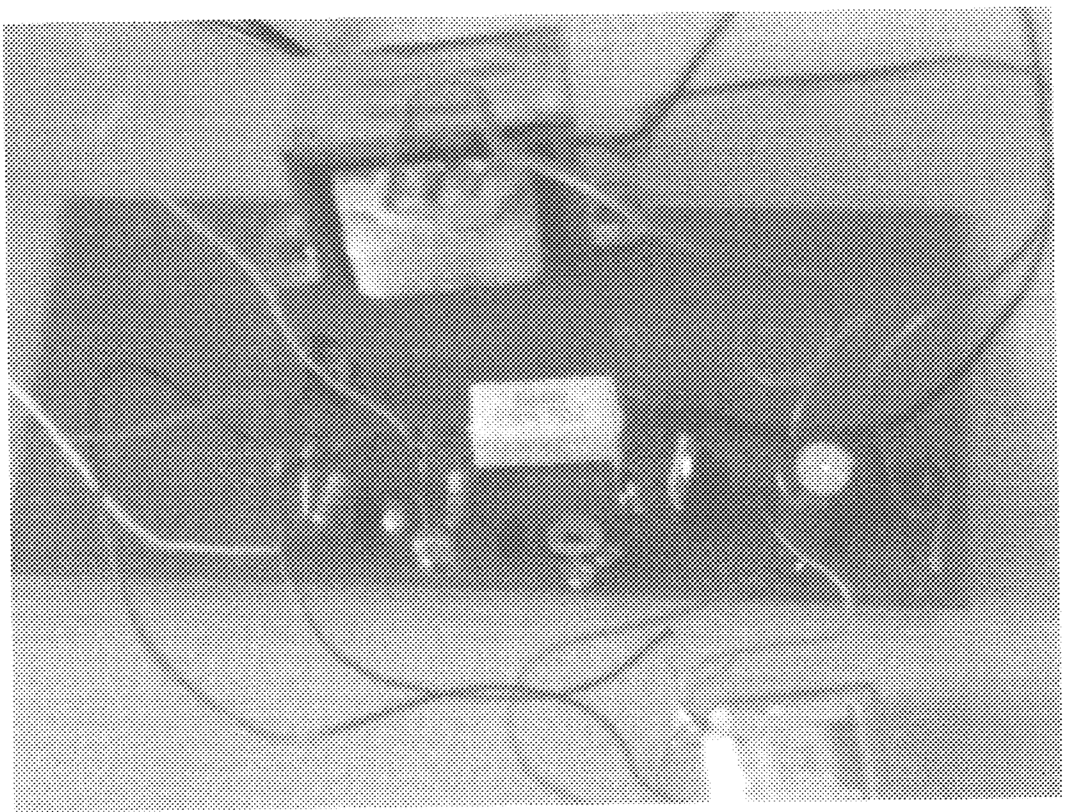

PLATE 3.1: Components on vero board

3.7.2 CASING

For an automatic LED emergency the casing can either be wood or plastic depending on the rating of the transformer. Plate 3.2 shows the wooden casing of an Automatic Emergency Lighting system and fig 3.9 shows the comprehensive circuit diagram of an Automatic Emergency LED lighting system.

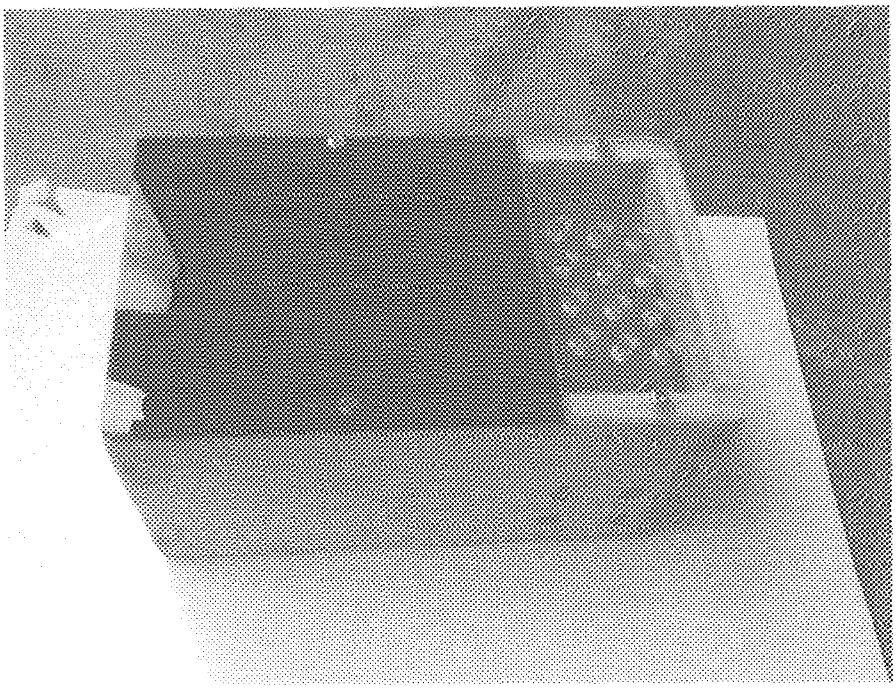

PLATE 3.2: Automatic Emergency Lighting System

3.8 COMPREHENSIVE CIRCUIT DIAGRAM

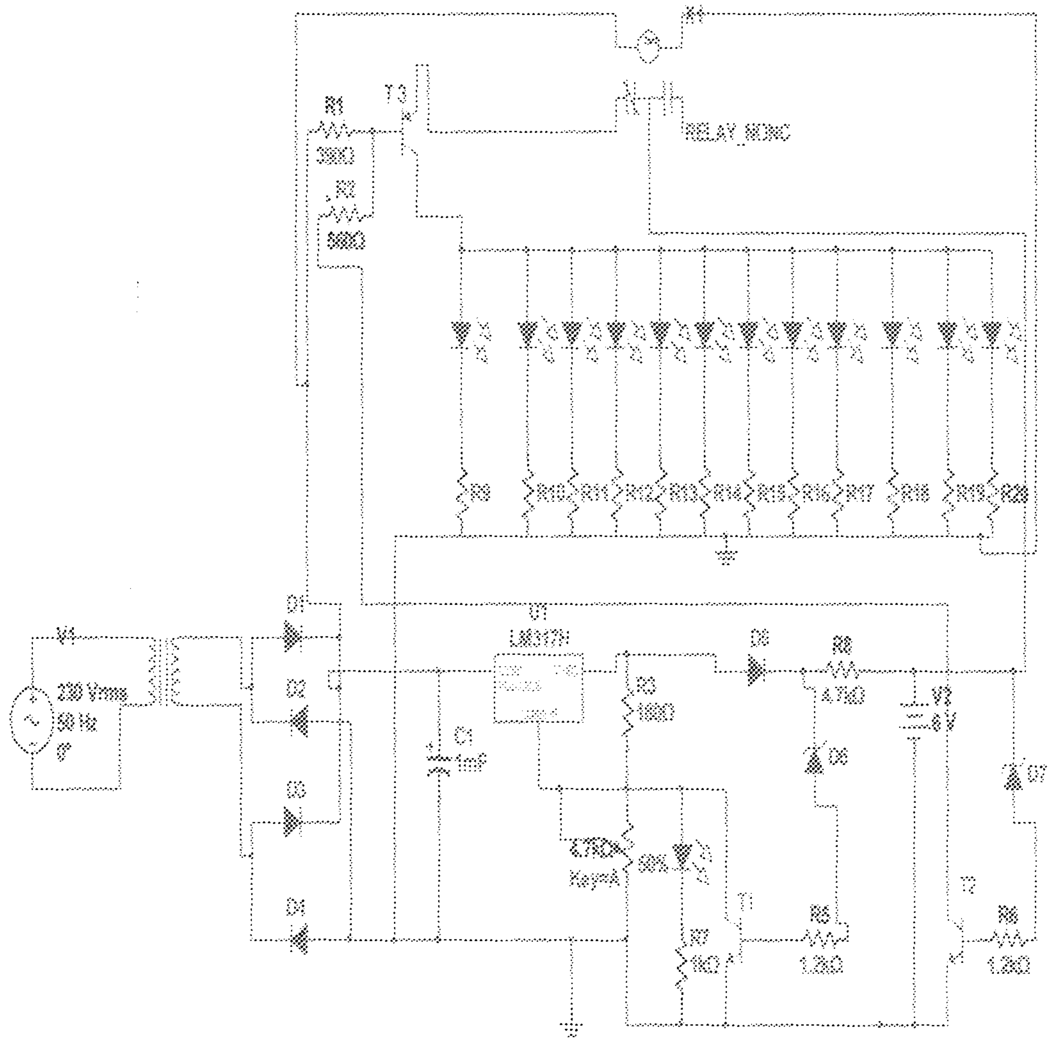

Fig. 3.9: Comprehensive circuit diagram

CHAPTER FOUR

4.0 TEST, RESULT AND DISCUSSION

4.1 TEST AND RESULT

After the device was coupled together, the battery was found to be fully charged after five (5) hours when the battery is empty. The charging voltage was found to 6.2 volts because the voltage that charges 6 volts battery must be more than the current voltage rating of the battery. Plate 4.1 shows the Vero board connection of an automatic LED emergency light.

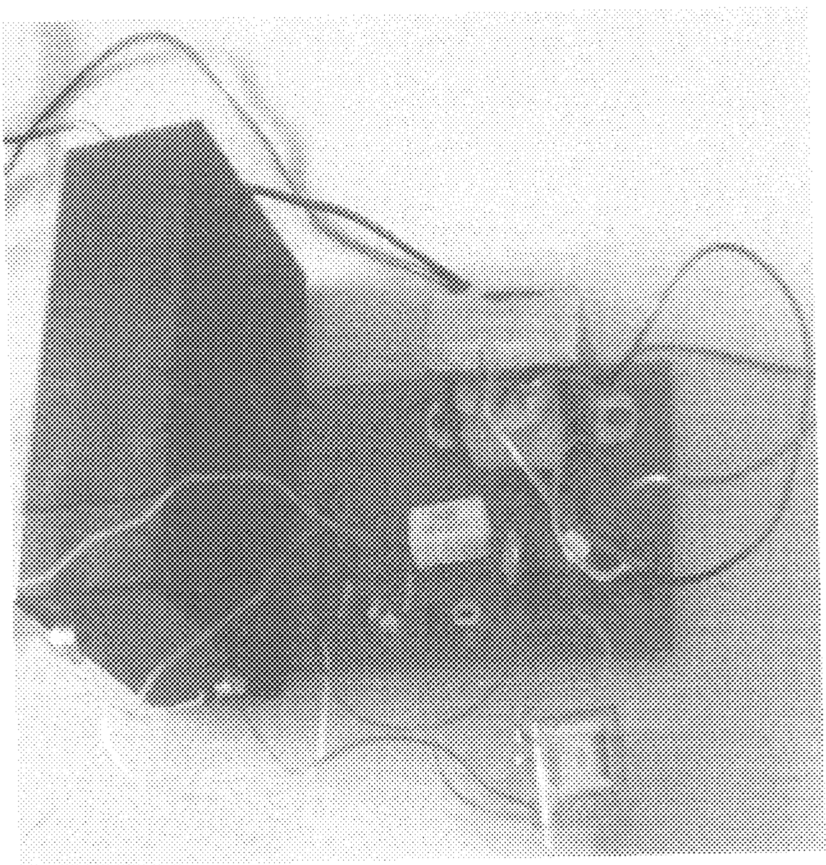

PLATE 4.1: Vero board connection of the circuit

4.2 DISCUSSION OF RESULT

The LEDs would also be bright for twelve hours so far the battery is fully charged. The voltage that is supplied to the LED driving session is 6 volts. For the LEDs to illuminate well, the LEDs are attached to a reflector that helps in illuminating the light. A switch was connected across the LED to control when the LEDs come on so that the battery life could be extended.

4.3 TROUBLESHOOTING

During the course of testing the device, it was found out that when the supply voltage is not up to 220 volts, the voltage entering the regulator will be less than 9 volts and the voltage that charges the battery would not be up to 6.20 volts but the variable resistor could increased to produce a voltage higher than 6 volts.

4.4 LIMIATATION

The limitation of this device is the inability to use more LEDs though the circuit could be modified to use more LEDs.

4.5 PRECAUTIONS

1. The components were measured with a multimeter to check polarity before carefully placed on a lined vero board.

2. The components were soldered carefully and sufficient heat was used to melt the lead.

3. Amount of soldering lead used was minimal to avoid bridging of components.

4. After each soldering, the soldering iron was cleaned to avoid excess melting of the lead.

CHAPTER FIVE

5.0 CONCLUSION

5.1 PROBLEMS ENCOUNTERED

The problems encountered during the execution of this project were mainly burning of some components due to excessive voltage. Also, during the assembling on a Vero board, some pins of the components broke. The battery used (as source of power) was continually weakened when powered on without appropriate recharge because the charging voltage was very low due to low voltage supply from PHCN.

5.2 RECOMMENDATIONS

After the completion of this project work, I would recommend that Automatic Emergency lights be used in lectures halls, offices, homes and even as street lights in the event of power outage.

5.3 CONCLUSION

After the successful testing of this device, I would categorically say in the advent of the set out objectives of this project, the project was successful.

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