# DESIGN AND CONSTRUCTION OF AN AUTOMATIC EMERGENCY LIGHTING SYSTEM

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A Thesis Submitted To The Department of Electrical and Computer Engineering, Federal University of Technology Minna. In partial fulfilment of the requirement for the award of B.Eng. of the Federal University of Technology Minna.

NOVEMBER, 2007

# DEDICATION

To God Almighty the most Gracious and merciful

# DECLARATION

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

.................................................... 04/12/07 ....................................................

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# ABSTRACT

Light is a very important form of energy. The power outage in the country(Nigeria) has lead to the design and construction of ' an automatic emergency lighting system. It is a device that provides illumination in dark sensitive areas like hospital theatres, corridors, bank vault, exits etc where normal services are needed during power outage. The device is powered by mains power supply, which charges the stand – by battery. It is fully automatic, turning ON few seconds after the interruption of the mains supply source and turns OFF immediately the supply is restored or the emergency stand – by duration elapses. Fluorescent tube is used for the lighting.

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# CHAPTER ONE

## 1.1 INTRODUCTION

An Automatic emergency rechargeable lighting system can be described as an alternative supply of light whenever there is power failure from the main power supply. In countries like Nigeria where there is incessant power failure, it is extremely important to have an Emergency lighting system to illuminate the areas or places of source sensitivity and danger when main supply is off. Such premises are, operation theatre is Hospitals, libraries, Bank vault, Stadium, generation station, public corridors, exits e.t.c. it may be used ON – LINE between the commercial power and sensitive load to provide transient free well – regulated power, or OFF – LINE and switched only when commercial power fails. It operates whenever there's mains power failure.

## 1.2 Mode at which emergency lighting system works

Normal electrical lights are powered by the 240 volt AC consumer main's. at the failure of the mains supply, back – up battery power supplies, or are connected to activated. The supply is rectified and connected to an automatic switching device called "Relay" with a rechargeable battery connected to it. The automatic switching device (relay) disconnects the emergency lighting system from the mains supply as it was connected to the battery automatically without being touched.

## 1.3 Aims and Objectives

The aim and objective of this project is to design and construct emergency lighting system for sensitive places, like Hospital operating theatres, bibraus, ships, stadium, public corridors exits etc. state other features of the system that also make it unique. Simple and easy method of providing emergency lighting, reduce the amount of energy to provide emergency lighting and increase battery life.

## 1.4 Methodology

The method employed in this work is to carryout the design of individual sub-circuit units which are then synchronized into a system to satisfy the overall objective of the project.

The sub – circuit are:

(i) The power supply unit

(ii) A battery charger circuit.

(iii) The Royer inverter

(iv) Change over circuit

The design methodology follows the block diagram as shown in appendix I. The design also considers the availability of suitable components at reasonable cost.

## 1.5 Scope of the Project

The design and construction of Emergency lighting system has been carried out to serve as a backup lighting system in case there is an emergency power failure. It is dedicated and specifically designed to serve as lighting system for some sensitive areas for some considerable amount of time to remove the danger of instant blackout at emergence of power failure. This system should not be put into use as an alternative for power failure for a very long time; for this does not fit into its design and use. Operating this device beyond this specification will this device affect the life span of this device and may lead to low reliability and efficiency.

## 1.6 Project Layout

Chapter one of this project discuses the general introduction of the topic, automatic emergency lighting system, the aims and objectives of the project.

More so, chapter two contains the literature review of the project. The types of emergency lighting system used in the past ones in use presently are reviewed. Chapter three deals with the design and the analyses. Chapter four deals with the construction, testing and results.

Lastly chapter five forms the conclusion of the project. Recommendations are discussed here.

# CHAPTER TWO

## 2.1 LITERATURE REVIEW

In the history of mankind, lighting has become the most valuable and most needed energy for creating direct visual sensation. Light energy has evolved from the primitive form to the sophisticated form in the present time. Naturally, the lighting systems consists of moonlight, sun and fire[1] from the first place, sun is the heavenly body producing light energy to the earth. The moon reflects light from the sun and illuminates the Earth. Fire which is another form of light energy was produced by burning wood, paper, oil, coal or candles. The early man first produced light by striking two stones together.

In the other hand, the advent of electricity seemed to be the end of the quest for the source of light energy. It is efficient, portable and reliable. This artificial method of producing light energy involves raising the temperature of a solid body or vapour to incandesces by applying heat to it.[4]

Moreso, as the source of the light energy (i.e. electricity) is becoming less reliable most especially in less developed countries, then the quest for providing alternative illumination to some sensitive areas / environment in case of emergency gained momentum. It was this quest that lead to the advent of emergency lighting system. It is of interest to mention here that emergency lighting system had also evolved from differed forms till now.[5] Most of those are:

- Stand – by power source.
- Solid state system
- Maintained emergency lighting system

- Non – maintained system
- Spit fires
- Rotary power source
- Fluorescent lights and combined electronic Ballast and emergency module.

These are explained below:

- STAND – BY POWER SOURCE: The stand – by power source is one of the emergency lighting system that consists of a battery and a DC to AC inverter. The batter is connected to DC to AC inverter. The battery charger is to keep the battery on full charge. The inverter provides AC power for the sensitive load through a switch. Normally, the load operates directly from the mains power line. The sensitive load draws it's power from the AC generator and it is operated through the outage. [6]

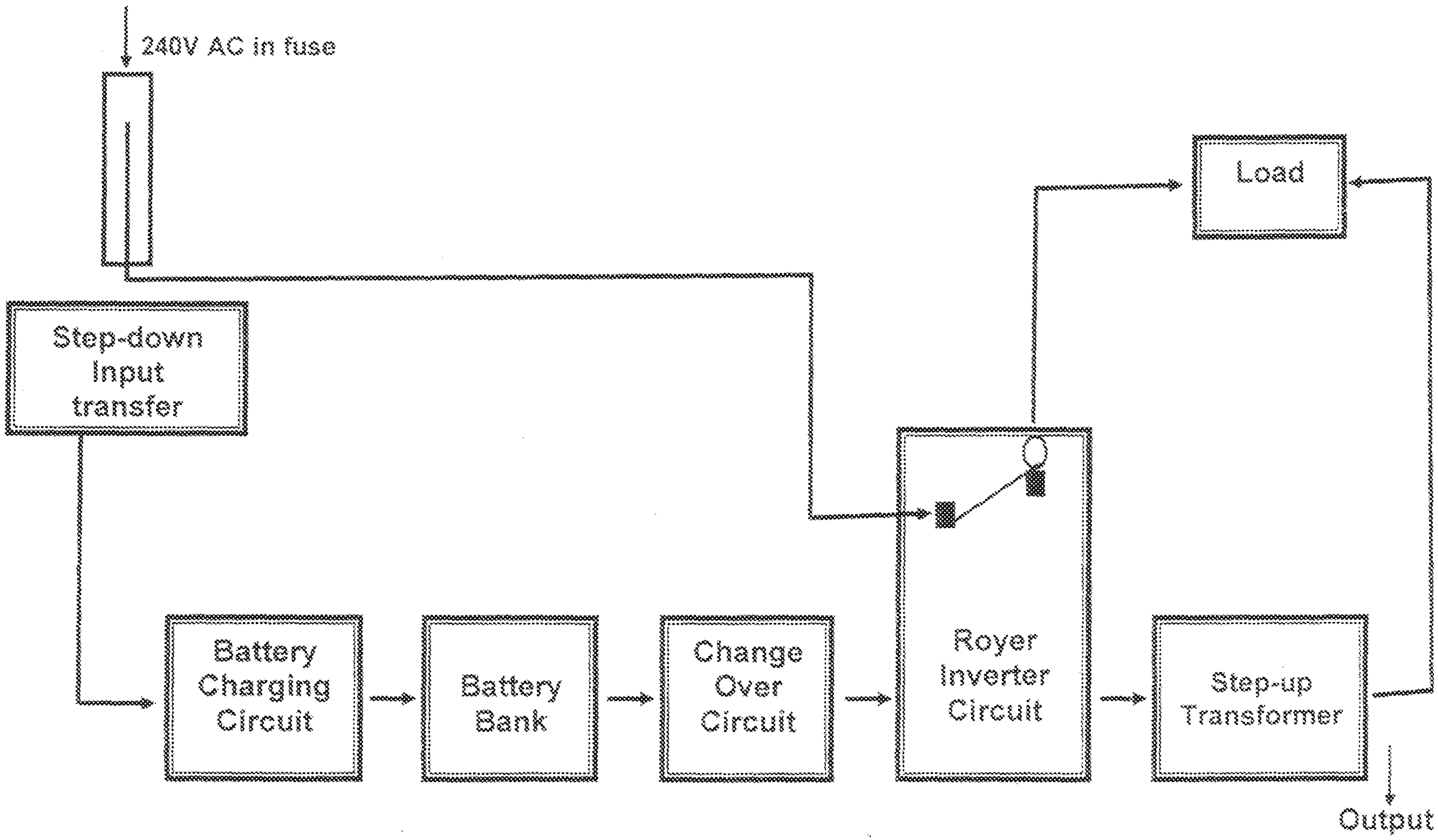
The present invention which is the topic of this project makes use of ROYER DC – AC CONVERTER. This is a low power high – frequency inverter used for this project work (i.e automatic emergency lighting system). It also makes use of a stand – by battery power in order that the same system may be used to provide emergency lighting at a lower level to conserve batery life in the event of power failure. The purpose of the battery charger is to charge the battery when the mains power is present. The battery provide power to the inverter anytime the mains power fails, automatically through the change over circuit. The low – power, high – frequency Royer converter changes the DC voltage from the battery bank to an AC voltage is to power the load. A high voltage is necessary. The battery charger also features a cut – off of mains supply when the battery is fully charged. The inverter determines the quality of the power used to drive the load.

If the inverter fails, the system is out of operation. The emergency lighting system of this project is OFF – LINE [8] which means it switches on only when mains power fails.

Some modificational features in this invention are:

- Simple and easy, method to provide emergency utilization only for a single gas discharge lighting device.
- The amount of energy used to provide emergency lighting over the required period for normal lighting is reduced.
- The battery life is increased through the modification of cutting out supply automatically when the battery is fully charged and reduced ON time for average emergency operation.[9]
- To provide a system that will operate from either alternating or direct current power.
- Have about 45 minutes of emergency duration.
- Has reduced weight and dimensional, thus making it more portable.[5]
- It also has the modification of discharge battery protection.
- An optional control switch for discontinuing the device for long non – operational periods.
- And lastly, it provides adequate – illumination.

## BLOCK DIAGRAM OF AUTOMATIC EMERGENCY LIGHTING SYSTEM



# CHAPTER THREE

## 3.1 The Project Design and Implementation

The design and construction of automatics emergency lighting system is based on four main blocks or units, so this part of the report describers in details at the components level the system make up.[10 ]

The main sub-units are under listed below:

i) power supply unit,

ii) Lead –acid battery charger sub-system,

iii) The change –over units.

iv) Low power high –frequency royer inverter

## 2 The power supply units

All electronic circuits need/require energy to work. The power supply unit provides this electrical energy. In this vain, a suitable, regulated power supply that provides this project work with the suitable energy is used and described below.

The power supply comprises of two power sources.

i) The local ac mains supply.

ii) The DC back up supply.

### 3.2.1 The local ac mains supply.

The local ac mains was needed to charge the incorporated 6V, 4.5 AH lead acid secondary cell.

The suitable power supply was achieved through.

i) stepping-down the AC mains to 12V

ii) Full wave rectification.

iii) Filtering and regulation of the rectified out put.

### 3.2.2. The stepping-down:

The stepping-down of the local AC supply was achieved by the use of a 12V 0.5A step-down transformer.

Fig 3.1 below shows the diagram of an ideal transformer.

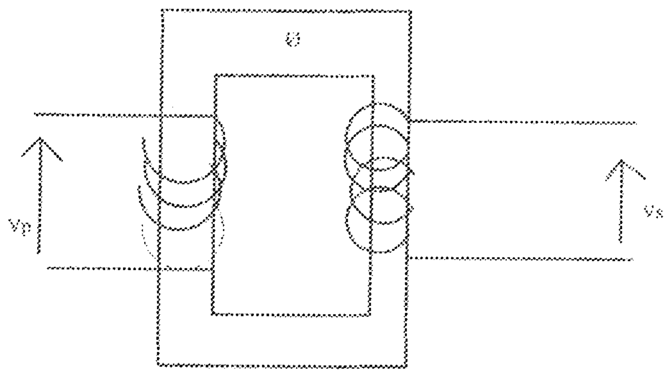



Fig 3.1 Ideal Transformer

ϕ is the flux in the care

Vp is the primary voltage

Vs is the secondary voltage

Ep is the primary e.m.f and

Es is the secondary e.m.f

Let $N_1$ and $N_2$ represent the number of the turns of the primary coils and the secondary coils respectively.

Then, $\frac{Vp}{Vs} = \frac{N_1}{N_2}$ [ 2 ]

Thus $Vs = \frac{Vp \times N2}{N_1}$

In this project, a standard 12v transformer is used.

### 3.2.3 Rectification.

Rectification is the convertion of alternating current to direct current i.e. DC. In this project work, a full wave bridge system of rectification was adopted. With this method, there is no need for a center tapped power transformer. The output is twice that of center-tap circuit for the same secondary voltage.

The arrangement is shown in fig 3.2 below .it contains four diodes D1, D2, D3, and D4 connected to form bridge. During the positive input half-cicy, terminal p of the secondary is positive and Q is negative. Diodes D1 and D2 become forward biased (i.e. ON) whereas D2 and D4 are reverse-biased (OFF). During the negative input-half-cycle, secondary terminal Q becomes positive and p negative [2]

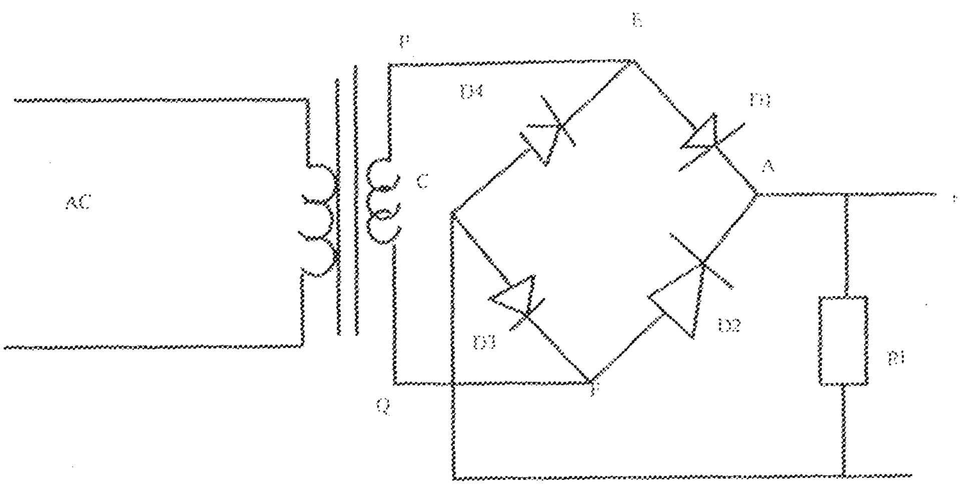



Fig 3.2 full wave bridge rectifier circuit

The waveform of the secondary voltage to the bridge rectifier is AC input.

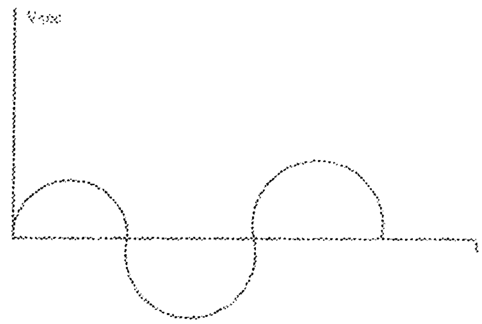



Fig 3.3 Input waveform of AC supply

The output voltage is a DC output. The waveform is as shown below in fig. 3.4.

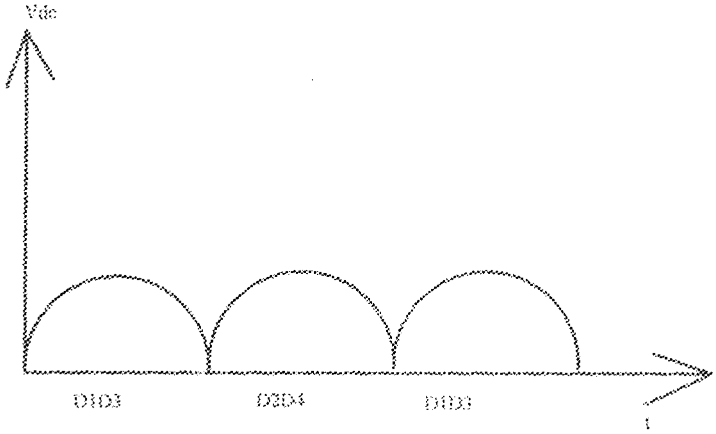



Fig. 3.4 The rectified output waveform

The full wave rectification efficiency can be calculated using

$$\eta = \frac{0.812\ Rl}{r_D + Rl} \qquad [16]$$

Where Rl = load resistance and

$r_D$ = diode resistance.

After full wave rectification, the relation below gives the DC voltage with the peak amplitude.

$V_{DC} = (V_{rms}\sqrt{2} - 1.4)\ V$ [16]

For 12V rms input, the peak DC voltage is therefore:

$V_{DC} = (12\sqrt{2}-1.4) = 15.6V$

$V_{DC} \cong 16.0V$

### 3.2.4. Filtering

The output waveform of fig 3.2 comprises of both AC and DC components.

The AC component in a DC power supply, which is caslled a ripple voltage, is removed through filtering or smoothering.

In this project work, the DC voltage was smoothened by a 25V 2200µf capacitor and fed in to the charger circuit.

The complete power supply unit is show in fig 3.5 below.

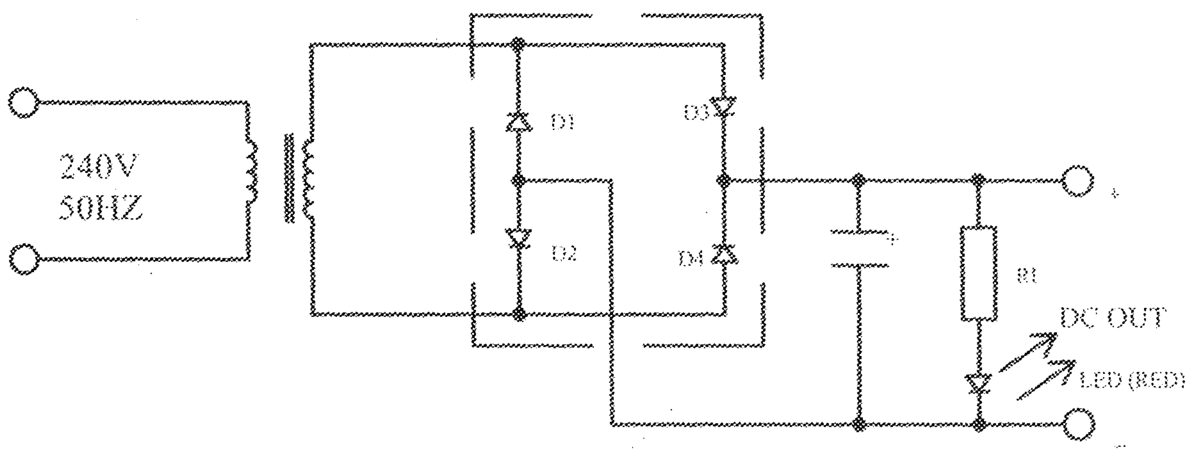



Fig 3.5 Power supply unit

An LED (red), power indicator was provided across the DC out put to reflect the presence/absence of the local mains.

A current limiting resistor (RI) was wired in series with the LED, the value of which was evaluated using

$$RI = \frac{V_{DS}-V_{LED}}{I_{LED}} \quad [2]$$

$V_{DS}$ = 16v, $V_{LED}$=1.7V, $I_{LED}$ =10mA

Thus ;

$$Rl = \frac{16-1.7}{0.01} = \frac{14.3}{0.01}$$

$$= 1430\Omega = 1.43k\Omega$$

To account for line voltage variation of typically ± 10%, a 3.3 k resistor was used.

The output wave form that is been filtered through a smoothening capacitor is shown below in fig .3.6.

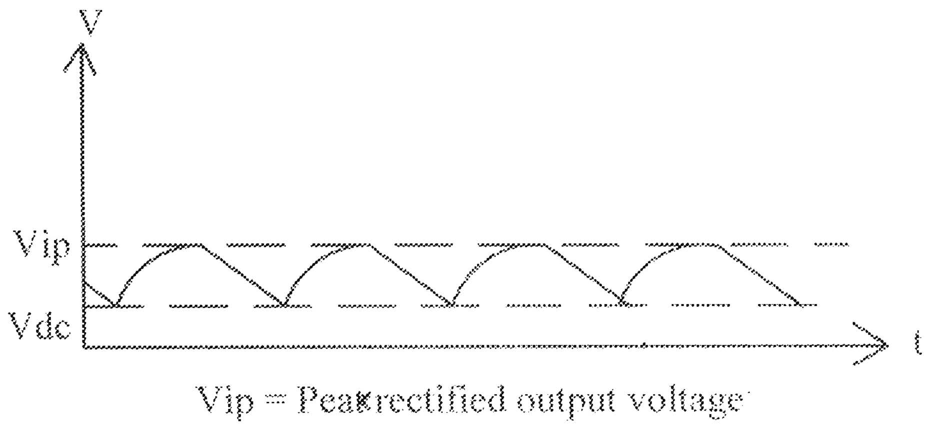



Fig 3.6 Filtered output waveform

## 3.3 The change-over switch

### 3.3.1Relay

Relay is an electromechanical device or switch to keep electronic circuits electrically isolated from the ac power line Also use to switch from the one power sources to another [ 1,18 ] in this project work 12v relay was used for switching. the fig3.7 below shows a typical relay.

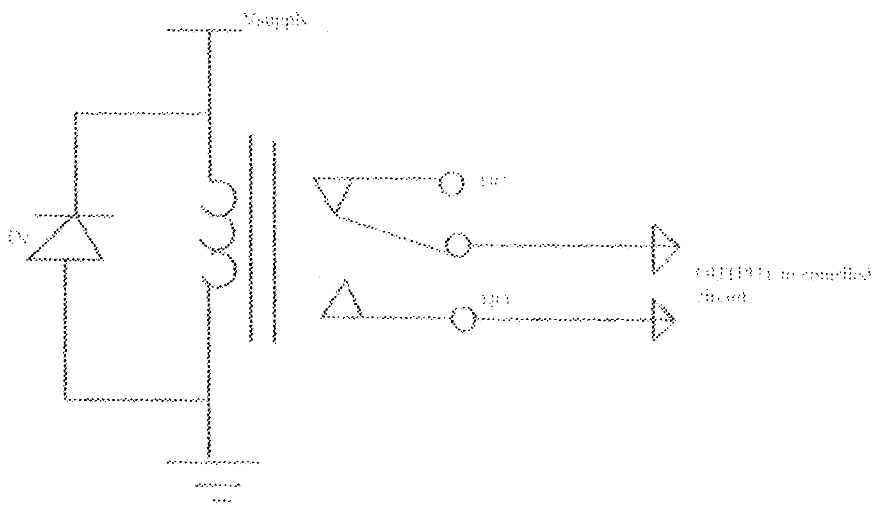



Fig 3.7 Symbol of Electromechanical Relay

N.C means normally closed contact and

N.0 means normolly open contact

Dc is the clamp diode which prevent voltage spikes indulged in then

The 12v Dc electromechanically relay was used to effect battery power transfer between the charger and the inverter stage. The DC relay was energized by the rectified DC voltage, connecting the battery to the charge output as shown in fig 3.8below.[19]

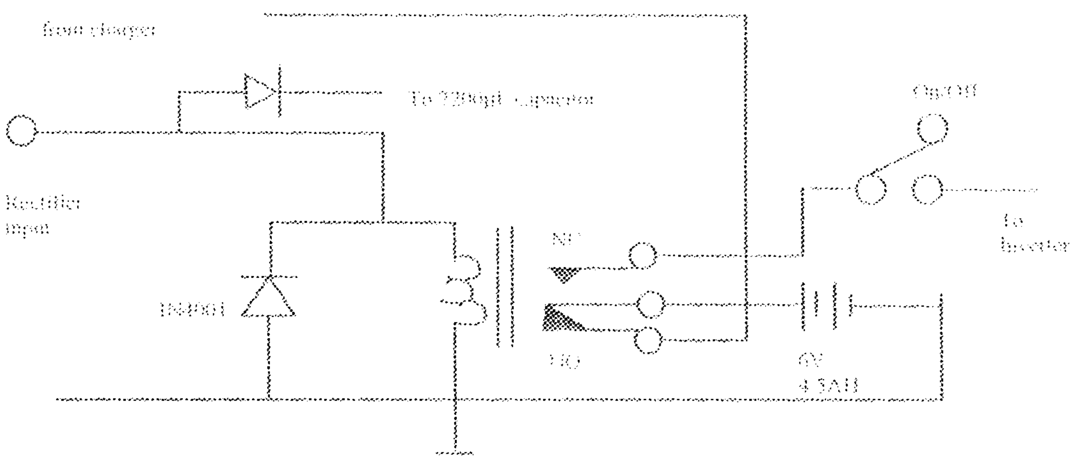



Fig 3.8 Change Over Unit

With local mains present the relay is energized and the contacts change over to connect the battery to the chargers output where it is charged. When local AC fails the battery connected to the standard by ON/OFF switch as indicated in fig.3.8 above.

### 3.4 The battery charger unit.

An integrated circuit LM317T, three-terminal adjustable regulator was used to effect charging of the integral secondary cell. It is available in several packages such as TO – 220, TO3 etc. fig 3.9 below shows a typical one of them.

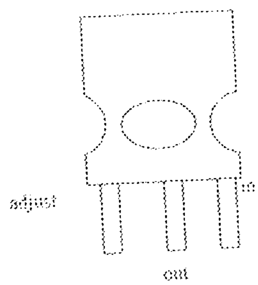



Fig. 3.9 LM317T Voltage Regulator

The devices can provide regulated voltages V minimum of 1.2V to V maximum of 37V, with a nominal output current of 1.5A at package dissipation less that 20W.[ 20 ]. It has no ground terminal; instead, it adjusts $V_{OUT}$ to maintain a constant 1.25 volts (band gap) from the output terminal to the adjustment terminal LM317T is wired as shown in the fig.3.10 below.

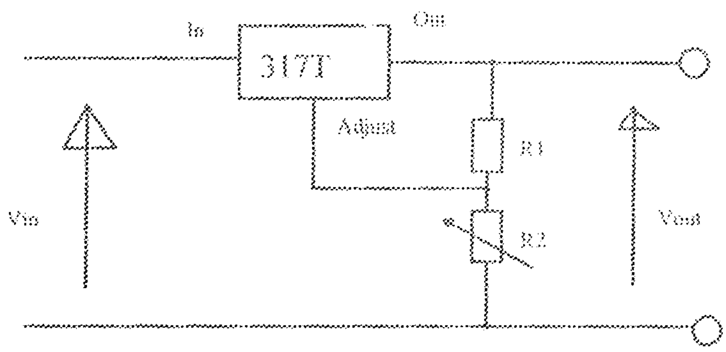



Fig. 3.10 LM317T Voltage Regulator

The output voltage is given by the relation:

$V_{OUT} = (1.25(1+R2/R1))V$.[3 ]

Where;

1.25 = internal reference voltage,

R1 = 220Ω (from the manufacturer's recommended value.)

R2 = Voltage setting resistance

Note that R2 is normally adjustable only over a narrow range.

The device also functions as a current regulator [ 3 ] when wired as shown in fig.3.11 below.

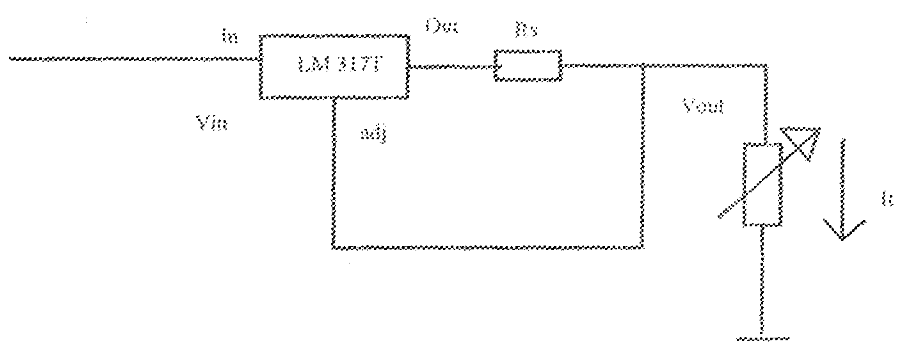



Fig. 3.11 LM317T Current Regulator

When operated as a current regulator, the output load current is given by

$$I_{OUT} = \frac{1.25}{Rs}$$

Where Rs = resistance between the output and the adjust pin.

A constant –current constant-voltage charging scheme was used in which the battery was initially charged at a constant current at the commencement of the charging system, switching over to the constant voltage mode once the battery attains full charge. The charger circuit is show in fig. 3.12 below

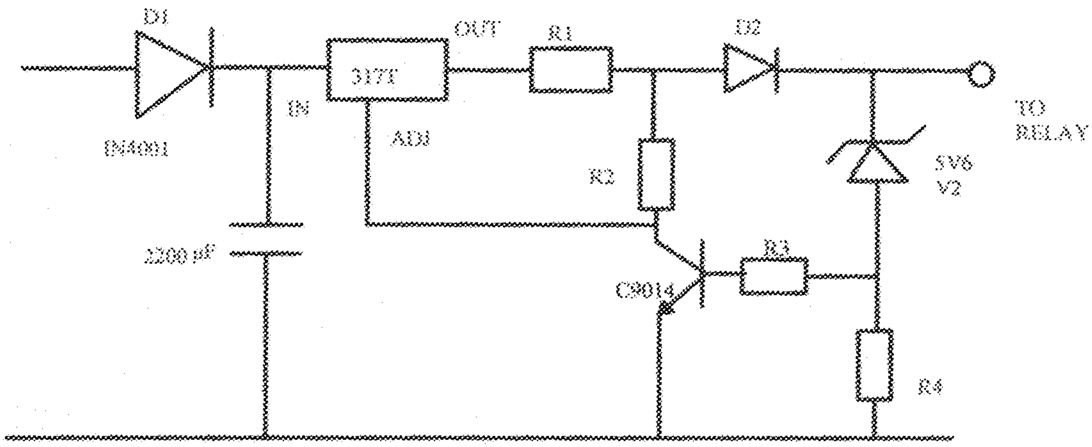



Fig. 3.12 Battery Charger

R1=Rs was made a 2.7Ω resistance to supply a maximum charging current of

$I_{OUT} = 1.25 \div 2.7$

$=0.46A$

Diode D2 prevents back discharge of the battery when the input charging voltage is removed.

R3 and R4 are biasing element for Q1(C9014) .Q1 provides a shutdown of the 317T at maximum battery terminal voltage.

Q1 switches on when $V_{be} > 0.7v$.

The maximum battery terminal voltage was evaluated using the relation.

$0.7 = V_{batt} - Vz$

$V\ batt. = 0.7 + Vz$

0.7 = V be forward-voltage drop in the C9014 NPN silicon transistors

Vz = zener voltage =5.6V.

From the given values the battery chargers to a maximum of ( 5.6 + 0.7) v = 6.3v.

At 6.3v, the regulator is forced into the power down mode, occussionally waking up to charge the battery if its terminal voltage falls bellows 6.3v.

The current through the 2.2k resistor at full-charge is

$$= \frac{V_{batt.} - Vz}{R4}$$

$$= \frac{6.3-5.6}{2200}$$

$= 0.7 \div 2200$

$= 0.3mA$

The 0.7V turns ON Q1 pulling its collector to 0V, shutting down the regulator.

### 3.4.1 The battery

A battery is a device ideally capable of providing a constant voltage independent of current flowing through it .6v lead acid battery was used in this project work.

The circuit symbol of a battery is shown in fig 3.13 below.

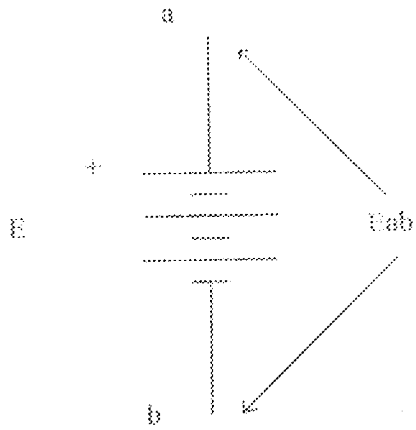



Fig .3.13 Circuit Symbol of a Battery.

Its terminal voltage, decrease linearly under current load as show in fig 3.14 below.

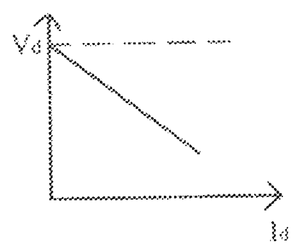



Fig. 3.14A

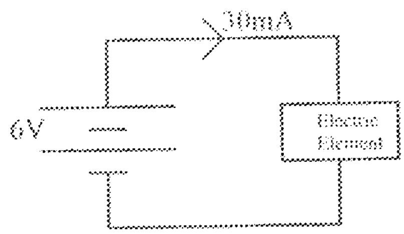



Fig. 3.14B

Thus $V_d = I_d R_s$

Where Rs =load resistance

Id =load current

$V_d$ =load voltage.

## 3.5 Low power royer dc-ac inverter

The DC-AC inveter used in the design work is illustrated in fig.3.15 below. It comprises of two NPN transistors, a high- frequency ferrite transformer and a biasing network composed of there resistors.

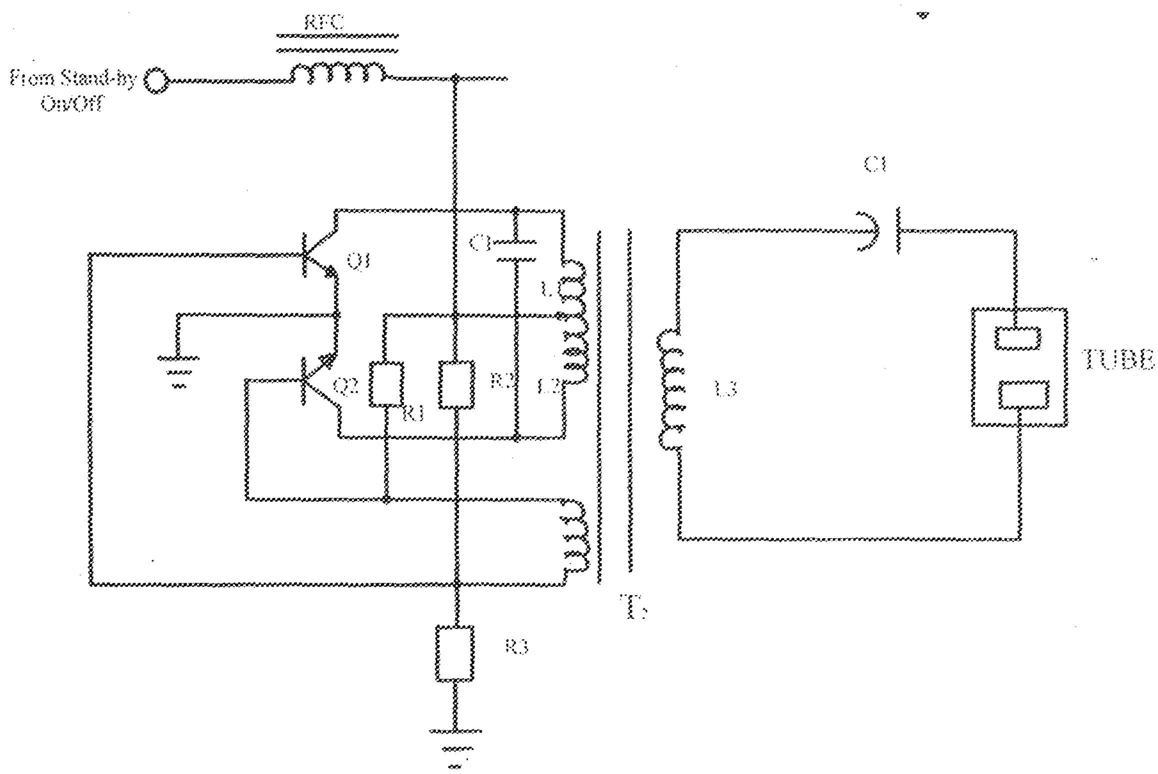



Fig. 3.15 Low Power Royer DC—AC Inverter

The RFC in the fig 3.15 means radio frequency choke, it is to protect the transistors from burning.

Q2 and Q3 are high frequency medium power NPN silicon transistor (D882) they are wired as push pull sinusoidal oscillator working into an LC turned stage of frequency []

$F = (1/2\pi\sqrt{L_1C})$ Hz

The resonant frequency is always above 20 kHz (to prevent auditory discomfort in humans).[ ]

The inductance of $L_1$ was measured using a digital RLC meter and found to be 400 μH.

For a 25 kHz circuit operation, C was calculated to be

$C = (1/(2\pi F)^2 L)$

$$= \frac{1}{2\pi x25x103)2x400x10\text{-}6}$$

= 0.1 μf

art up current is provided by two 330Ω resistors and 220Ω resistor.

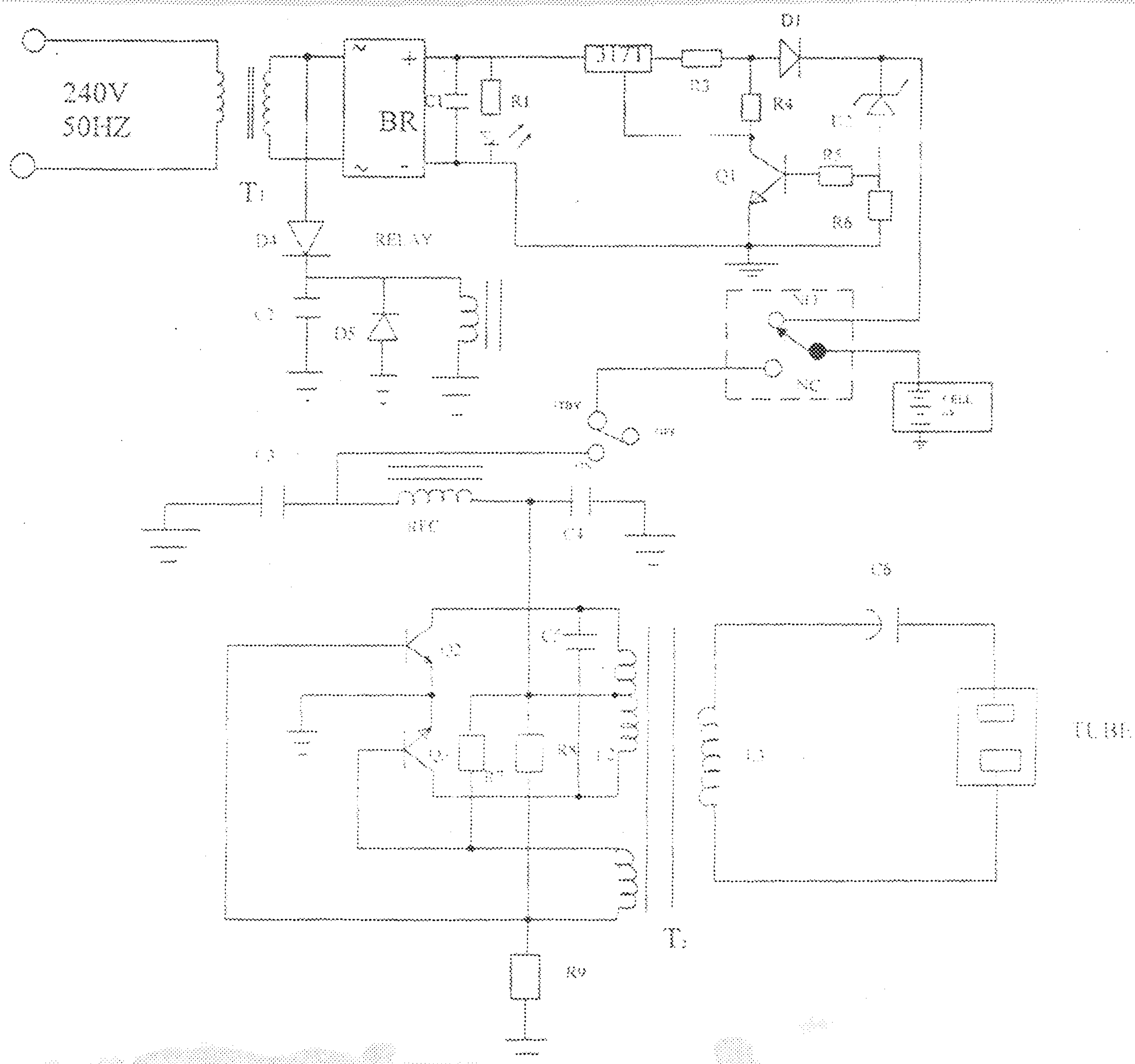
scillation is guaranteed by the inherent imbalance in transistor specification.

if both transistors are exactly alike, then the circuit might not oscillate. The imbalance in specifications causes one of the transistors to turn ON faster.

Assuming Q2 has a higher gain than Q3 it turns on first at power application and holds Q3. load current and transformer magnetizing current them flows in the upper half of $L_1$ winding. Auto- transformation supplies the base drive until Q2 saturates. With Q2 saturated, it loses its base drive and turns OFF. The transformer voltages reverse turning Q3 ON and repeating the cycle.

A sinusoidal AC out put voltage is observed across $L_3$ whose values are given by $L_1 : L_3$ winding ratio.

The high- voltage AC out put is fed into the tube via a 1000 pf capacitor.




COMPLETE CIRCUIT DIAGRAM OF AUTOMATIC EMERGENCY LIGHTING SYSTEM

# CHAPTER FOUR

## 4.1 Test, Results, and Discussion

### 4.1.1 Testing

The testing started right from the beginning of this project work. Each of the components used for the construction of the automatic emergency lighting system was tested. The circuit was first constructed on the bread board and simulated to ensure its workability. The circuit was proved working after testing before soldering it on the verroboard. Partial contact of pins and possible short circuit were avoided. All connections are carefully controlled the system device was plug to the main AC power supply, the GREEN LED came ON which indicate the presence of the main and battery charging operation.

The battery-terminal voltage was tested and measured using multi-metre connected across the positive and negative terminals of the battery emergency lighting system was tested by putting it under various degrees of loading. The output voltage of the inverter circuit was also measured and the tested. While testing, the operation of the battery, the RED LED came On indicating the emergency lighting. Thus, tee aim of the project termed automatic lighting system is them successfully achieved.

### 4.1.2 Results

The maximum battery terminal voltage

i.e $^{V}$batt. = 6.290 volt

$\cong$ 6.30 volt

The inverter-output voltage to the fluorescent

$V_{out} = 589.5$ volt

$\cong 600$ volt

The RMS output voltage is plot against the load (in ohms) and it is shown in fig. 3.15 below

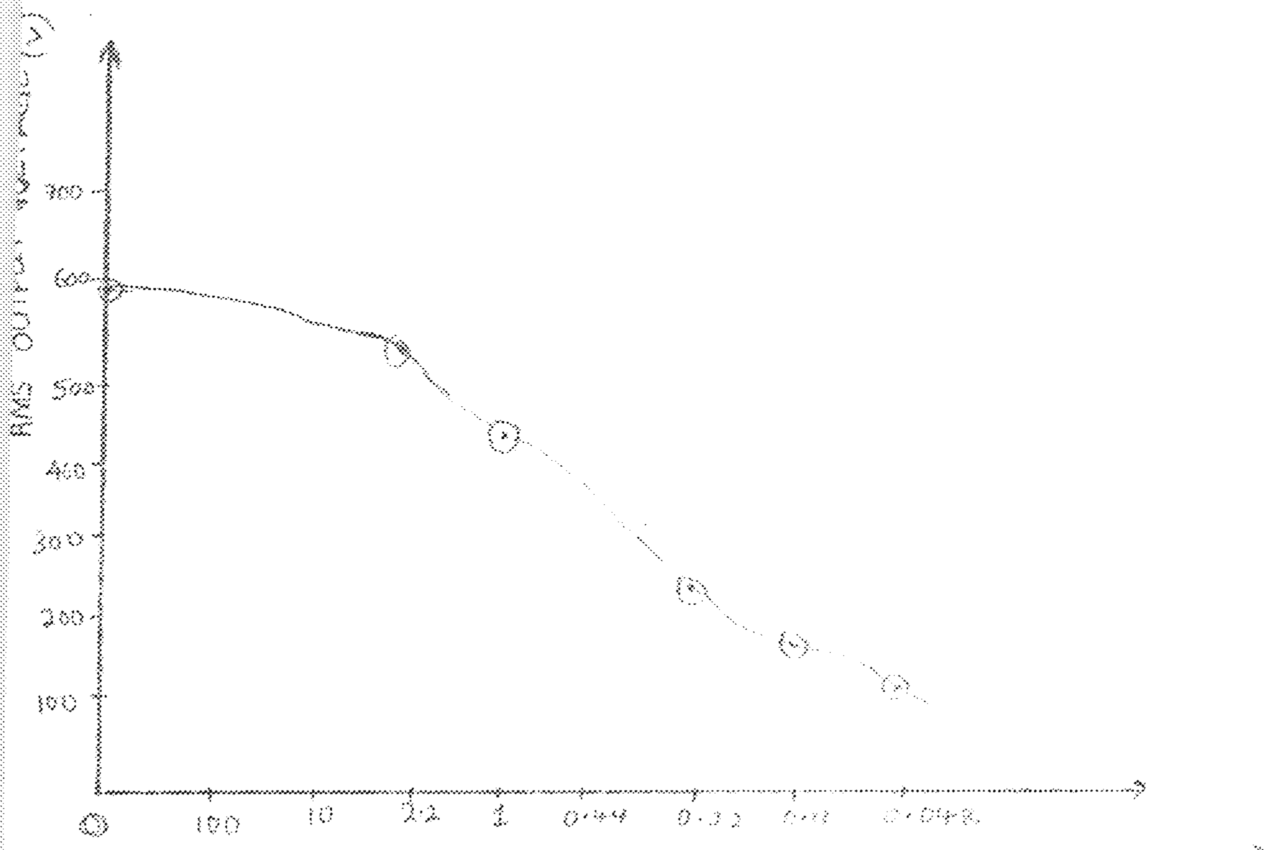



Fig. 4.1 Graph of output voltage against Load

## 4.12. Discussion of Results

From the graph of fig. 2.15, the Rms output voltage decreases from low loading to high load situation. This means the more load connected against the inverter output, the less the rms voltage value. Also, the Vout of approximately 600volts provided the potential difference which is able to cause the glowing of the gas discharge fluorescent tube of power rating 20W.

The resulting lighting of the tube when the power from the mains is OFF, indicates the successful result of the project and the circuit function fine throughout the duration of testing.

# CHAPTER FIVE

# CONCLUSION AND RECOMMENDATION

## 5.1 Conclusion

Automatic emergency lighting system's design and construction follows the steps of the basic principle of electronics. It is a principles basically from analogue to digital electronics.

The components used during the design and construction were very common and inexpensive. This project is useful is the are when the power outage is very common.

The automatic emergency lighting system has two main parts, the battery charger circuit and the inverter circuit. The battery supply the power to the inverter circuit through the automatic switch (relay). It should be of greater advantage if and only if it's use incase of power outage.

## 5.2 Recommendation

The following recommendations are made on the project "automatic emergency lighting system" for further improvement son the project.

i. The inverter could be improved upon. to power high power devices like halogen lamp for outdoor illumination.

ii. Thyristor could be used in the inverter circuit instead of the transistors to enhance the power handling.

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# APPENDIX III

## RESISTORS

| LABEL | VALUE |
|---|---|
| $R_4$, $R_5$ | 1KΩ |
| $R_3$ | 2.7Ω |
| $R_6$ | 2.2KΩ |
| $R_7$, $R_8$ | 330Ω |
| $R_9$ | 220Ω |
| $R_1$ | 2.3KΩ |

## CAPACITORS

| LABEL | VALUE | VOLTAGE |
|---|---|---|
| $C_1$ | 2200μF | 25V |
| $C_2$, $C_3$ | 1000μF | 16V |
| $C_4$, $C_5$ | 0.1μF | - |
| $C_6$ | 1000μF | Electrical Capacitor |

## TRANSISTORS

| LABEL | VALUE | TYPE |
|---|---|---|
| $Q_1$ | C9014 | NPN |
| $Q_2$, $Q_3$ | D882 | NPN |

TRANSFORMER

| LABEL | VALUE | VOLTAGE |
|---|---|---|
| $T_1$ | 12V | Step – down |
| $T_2$ | $24V_{CT}$ | Step – Up Ferrite Transformer |

DIODES

| LABEL | VALUE |
|---|---|
| $D_1$, $D_4$, $D_5$ | IN4001 |
| $D_2$ | 5V6, V2 (Zener ) |
| $D_3$ | LED (RED) |

RELAY

| LABEL | VALUE | TYPE |
|---|---|---|
| RI | 12V | Single pole double contact |

BATTERY

| LABEL | VALUE | TYPE |
|---|---|---|
| $B_1$ | $6V_{DC}$ | Physical Battery |

TUBE

20W Fluorescent

INDUCTANCE

$L_1 = 400\mu H$