DESIGN AND CONSTRUCTION OF A RECHARGEABLE LAMP

BY

ABOLARIN FREDERICK GBENGA

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DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

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A THESIS SUBMITTED TO THE
DEPARTMENT OF ELECTRICAL AND
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MINNA

OCTOBER 2006

DEDICATION

This project is dedicated to the maker of heaven and earth, who, when men said no gave me a yes that it may come to pass fulfillment of an answered prayer "Catobarlabrazo".

DECLARATION

I, ABOLARIN FREDERICK GBENGA 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.

ABOLARIN F. GBENGA	DR. Y. A. ADEDIRAN
Student	Supervisor
12/10/06	
....	....
Signature and Date	Signature and Date
DR M. D. ABDULLAHI	....
H.O.D.	External Examiner
....	....
Signature and Date	Signature and Date

ACKNOLWLEDGEMENT

I announce my sincere acknowledgement toward the Almighty God for making every turbulent water about this project, still!

I appreciate my supervisor, Dr.Y A. Adediran for his enormous attention towards this project.

I thank God for my parents Chief J.M. Abolarin, Late Queen D.W. Abolarin, and Mrs. F. Abolarin, who were not tired of my apology,

I would not be done without my angel, Onipede Christie Olaronke, whom her consistencies, a word is not strong enough to describe.

I would also sincerely acknowledge my sisters, Ms. Ayo Abolarin, Mrs. Ronke Adigun, Mrs. Oluwasheun Omolewa and their families. May their oil not go dry and also Mrs. C. A. Onipede, for accepting me from the very beginning, may she live to enjoy the fruit of her labour.

I commend all my friends and folks, who have contributed immensely towards my life, may our dreams all come true in JESUS MIGHTY NAME, AMEN

ABSTRACT

The project titled "Rechargeable Lamp" is designed as an alternative to lighting a 5watt compact tube from a battery which is rechargeable. A step-down transformer is used to give about 9 volts AC which is later rectified to a 8.8 volt DC and then stored by a Suncan RB640CS 4.5Ah battery for about a maximum of 12 hours. To use the lamp, the switch is simply turned on and the stored voltage is allowed to be inverted. A 4060B IC provides the ripple frequency, using the two high current MOSFET 1RF244 connected in series through to a step-up transformer. A 220volt AC, which lights the 5watt compact tube, is obtained

TABLE OF CONTENTS

CHAPTER ONE

INTRODUCTION

The project involves a rechargeable lamp. Its design is quite simple and economical. The lamp holds a 5 watts compact tube, which is lit with a Suncan RB640CS 4.5Ah rechargeable 6 volt battery. The lighting requires a much higher voltage from the battery which is derived through a step-up transformer.

The lamp is made as simple as possible by the use of limited number of components. The design allows the battery to light the involved 5 watt compact tube for roughly four hours. The lamp is suitable for reading, searching and other uses. The importance of the project is evident with the deteriorating electric power supply in the country.

1.1 AIMS AND OBJECTIVES

The project is aimed at the design and construction of a simple rechargeable lamp. It is designed with a 5watts compact tube and 6 volt rechargeable battery.

1.2 METHODOLOGY

As earlier stated, the design involves the lighting of a 5 watts compact tube that requires 220V AC power supply with a 6 volt rechargeable battery. A fact is clear about the design, an inverter allows the conversion of the relatively low DC voltage to a reasonably high AC voltage required for lighting the lamp. The inverter consists of an oscillator that provides the required 51Hz frequency for the resulting AC output.

A battery charger is incorporated into the circuit to restore the used voltage back into the battery. A discouraging feature of the battery charger is its non-automatic switching-off whenever the battery is fully charged. But the charger is compensated by a tickling charging effect that prevents the battery from damage through continuous charging.

1.3 SCOPE OF THE PROJECT

The project involves the lighting of a 5Watt compact tube with a 6V rechargeable lamp. The project is aimed for simplicity. Full automatic charging is not involved in the project but tickling made which allows continuous charging on the battery with little effect.

1.4 LIMITATION AND PROBLEMS ASSOCIATED WITH THE PROJECT

The design of the circuit was quite tiresome due to a quest for its simplicity. Moreover, the acquisition of the related component was quite a task. Ample information was required for getting the correct choice of components. In fact, the information of all components involved resulted to the whole design.

CHAPTER TWO

LITERATURE REVIEW

2.1 HISTORY AND DEVELOPMENT OF LAMPS

Generally, potable electric lamps use fluorescent tubes. The earliest ancestor of the fluorescent lamp is probably the device by Heinrich Geissler who obtained in 1856 a bluish glow from a gas sealed in a tube, excited with an induction coil. Though he is remembered as a physicist, Geissler was educated as a glassblower.

In 1894, D. McFarlane Moore created the Moore lamp, a commercial gas discharge lamp meant to compete with the incandescent light bulb of his former boss Thomas Edison. The gases used were nitrogen and carbon dioxide emitting respectively pink and white light, and had moderate success.

In 1901, Peter Cooper Hewitt demonstrated the mercury-vapour lamp, which emitted light of a blue-green colour, and thus was unfit for most practical purposes. It was, however, very close to the modern design. This lamp had some applications in photography where colour was not yet an issue, thanks to its much higher efficiency than incandescent lamps.

Edmund Germer and co-workers proposed in 1926 to increase the operating pressure within the tube and to coat the tube with fluorescent powder which converts ultraviolet light emitted by a rare gas into more uniformly white-colour light. Germer's is today recognized as the inventor of fluorescent lamp.

General Electric later bought Germer's patent and under the direction of George Inman brought the fluorescent lamp to wide commercial use in 1938.

2.2 THEORETICAL BACKGROUND

2.2.1 How a typical rechargeable lamp works:

Lamps, that are battery powered, consist of a battery charger and voltage inverter that convert the DC supply from the battery into higher AC voltage capable of switching a lamp. The load (the lamp) is usually fluorescent lamps due to their low power consumption which saves battery's life. Even low- wattage tubes are used for rechargeable lamp applications.

2.2.2 Principle of operation of Fluorescent lamps

The main principle of fluorescent tube operation is based around inelastic scattering of electrons. An incident electron (emitted from the coils of wire forming the cathode electrode) collides with an atom in the gas (such as mercury, argon or krypton) used as the ultraviolet emitter. This causes an electron in the atom to temporarily jump up to a higher energy level to absorb some, or all, of the kinetic energy delivered by the colliding electron. This is why the collision is called 'inelastic' as some of the energy is absorbed. This higher energy state is unstable, and the atom will emit a photon (a "packet of light energy") to allow the atom's electron to revert to a lower, more stable, energy level. The photons that are released from the chosen gas mixtures tend to have a wavelength in the ultra-violet part of the spectrum. This is not visible to the human eye, so must be converted into visible light. This is done by making use of fluorescence. This fluorescent conversion occurs in the phosphor coating on the inner surface of the fluorescent tube, where the ultra-violet photons are absorbed by electrons in the phosphor's atoms, causing a similar energy jump, then drop, with emission of a further photon. The photon that is emitted from this, second, interaction has a lower energy than the one that caused it, and the chemicals that make up the phosphor are specially chosen so that these emitted photons are at wavelengths visible to the human eye. The difference in energy between the absorbed ultra-violet photon and the emitted visible light photon goes to heat up the phosphor coating.

2.2.3 Advantages of fluorescent tubes over incandescent lamps

Fluorescent lamps are much more efficient than incandescent light bulbs of an equivalent brightness. This is because more of the consumed energy is converted to usable light and less is converted to heat, (allowing fluorescent lamps to run cooler). An incandescent lamp may convert only 10% of its power input to visible light. A fluorescent lamp producing as much useful visible light energy may require only 1/3 to 1/4 as much electricity input. Typically a fluorescent lamp will last between 10 and 20 times as long as an equivalent incandescent lamp.

The higher first cost of a fluorescent lamp may be offset by lower energy consumption over its life. The longer life may also reduce lamp replacement costs, providing additional saving especially where labour is costly.

2.2.4 Disadvantages of fluorescent lamps

Fluorescent lamps do not give out a steady light, instead they flicker (fluctuate greatly in intensity) at a rate that depends on the frequency of the driving voltage. Whilst this is not easily discerned by the human eye, it can cause a strobe effect posing a safety hazard in a workshop for example, where something spinning at just the right speed may appear stationary if illuminated solely by a fluorescent lamp. It also causes problems for video recording as there can be a 'beat effect' between the periodic reading of a camera's sensor and the fluctuations in intensity of the fluorescent lamp. Incandescent lamps, due to the thermal inertia of their element, fluctuate less in their intensity, although the effect is measurable with instruments.

Fluorescent lights cannot be connected to a standard dimmer switch used for incandescent lamps. Four-pin fluorescent lamps and compatible controllers are required for successful fluorescent dimming.

2.2.3 Tube designations fluorescent tubes

Bulbs are typically identified by a code such as F##T##, where F is for fluorescent, the first number indicates the power in watts (or strangely, length in inches in very long bulbs), the T indicates that the shape of the lamp is tubular, and the last number is diameter in eighths of an inch. Typical diameters are T12 (1½" or 38 mm) for residential bulbs with old magnetic ballasts, T8 (1 in or 25 mm) for commercial energy-saving bulbs with electronic ballasts, and T5 (5⁄8" or 16 mm) for very small bulbs which may even operate from a battery-powered device.

High-output bulbs are brighter and draw more electrical current, have different ends on the pins so they cannot be used in the wrong fixture or with the wrong bulb, and are labeled F##T12HO, or F##T12VHO for very high output. Since about the early to mid 1950's to today, General Electric developed and improved the Power Groove(R) lamp with the label F##PG17. These lamps are recognizable by their large diameter, grooved tubes.

U-shaped tubes are FB##T##, with the B meaning "bent". Most commonly, these have the same designations as linear tubes. Circular bulbs are FC##T#, with the diameter of the circle (not circumference or watts) being the first number, and the second number usually being 9 (29mm) for standard fixtures.

Color is usually indicated by WW for warm white, EW for enhanced (neutral) white, CW for cool white (the most common), and DW for the bluish daylight white. BL is often used for backlight (commonly used in bug zappers), and BLB for the common backlight-blue bulbs which are dark purple. Other non-standard designations apply for plant lights or grow lights.

CHAPTER THREE

DESIGN ANALYSIS

3.1 BLOCK DIAGRAM FLOW

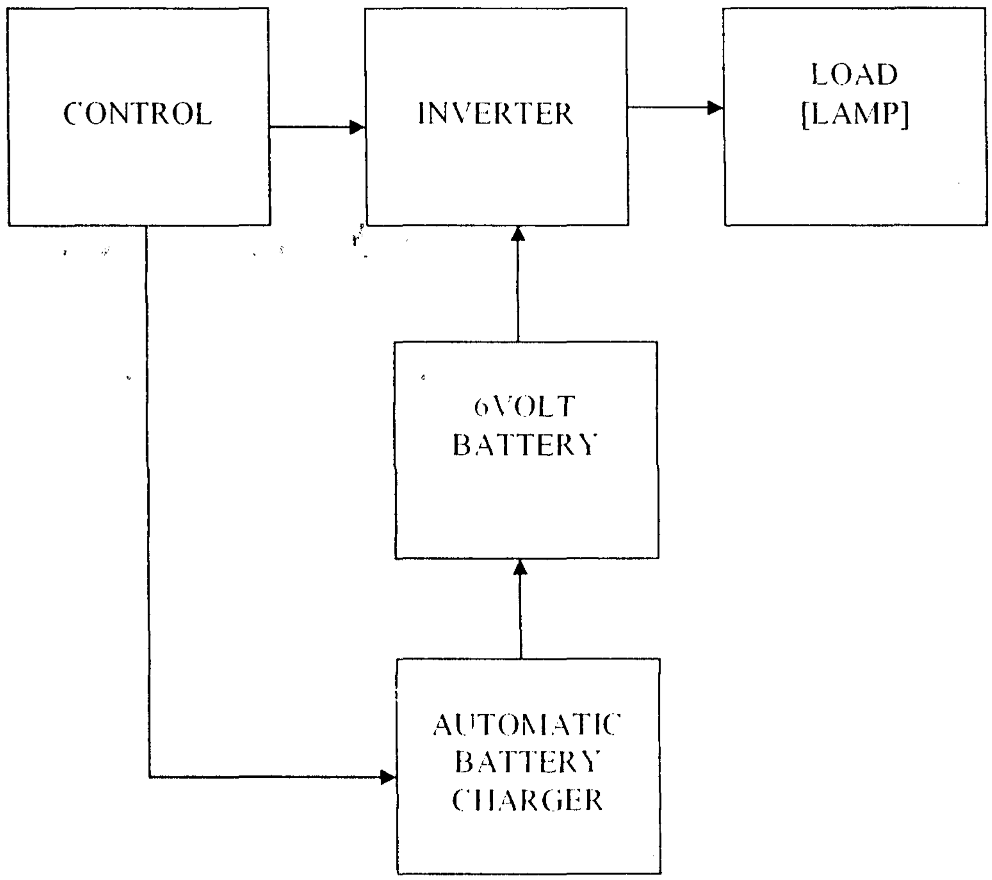


Fig 3.0 Block Diagram of a Rechargeable lamp

The block diagram in Fig 3.0. Includes the control unit, Inverter units, 6volt battery, automatic battery charger and the output unit. The control unit allows full control of operation of the whole circuit. It involves switching off, and on of the output unit which can be done in two ways. The 6volt battery is connected to a small inverter that invert the 6volt D.C from the battery into 220 volt AC. The inverter unit holds an oscillator that operates at about a frequency of 51Hz which is used in energizing the step-up transformer. An automatic battery charger is incorporated into the design to prevent over-charging the involved battery. The charger simply automatically switches off, the moment the battery is fully charges and this helps the life's span of the battery. The output must consist of a 5 watt compact bulb.

3.2 POWER UNIT

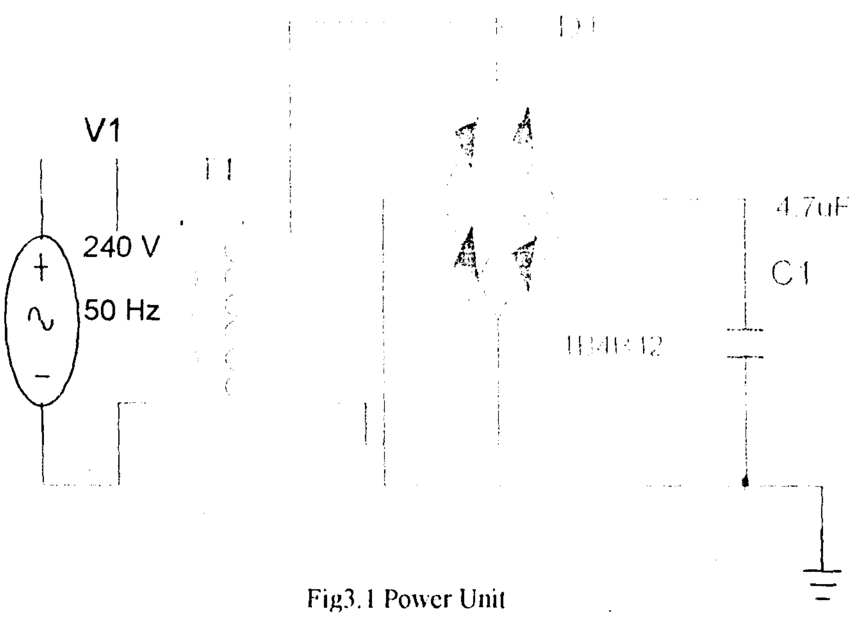


Fig3.1 Power Unit

Almost all electronic devices and circuits require a DC source for their operation. Subsequently the concept of this project implies that an AC power supply be stored and later be called for use when the need arises.

AC supply could only be stored in form of a DC, having passed through the circuit in Fig 3.1 which can be further subdivided into the following:

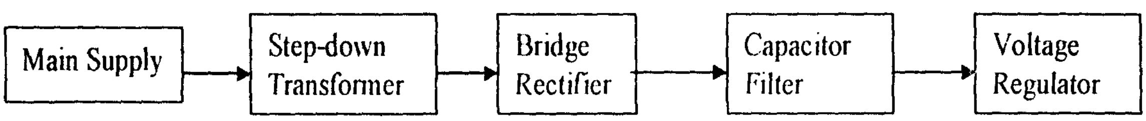


Fig. 3.2 Block diagram of the power supply

TRANSFORMER: its function is either to step up or mostly step down the AC supply voltage to suit the requirement of the solid state electronic devices and circuits fed by the DC power supply. It also provides isolation from the supply line, an important safety consideration.

RECTIFIER: it is a circuit which employs one or more diode to convert ac voltage into pulsation dc voltage.

FILTER: the function of this circuit element is to remove the fluctuation or pulsation (ripples) from the output voltage supplied by the rectifier.

VOLTAGE REGULATOR: its main function is just to keep the terminal voltage of the dc supply constant even when

1. Ac input voltage to the transformer fluctuates
2. The load varies

VOLTAGE DIVIDER: its function is to provide different dc voltages needed by different electronics.

Basically all that is really required for conversion from ac to dc is a transformer, a rectifier and a filter, since the aim of the power supply in this project is to charge a battery.

TRANSFORMER:

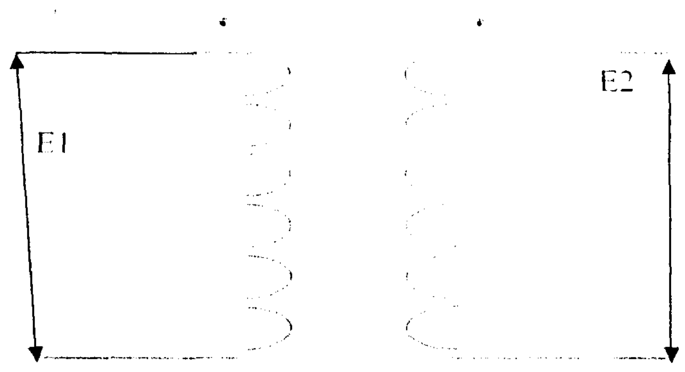


Fig 3.3 Transformer

However we can deduce from fig 3.3 that

$$\frac{E_2}{E_1} = \frac{N_2}{N_1} = K \text{.....................eq (1)}$$

where

N_1 = Number of turns for the Primary

N_2 = Number of turns of the Secondary

$E_1 = V_1$ = Voltage in Primary

$E_2 = V_2$ = Voltage in Secondary

K = Voltage transformation ratio

$$V_1I_1 = V_2I_2 = 1/K \text{ .... eq (2)}$$

From eq (2)

Given: output power of the bulb = 5 Watts

Input voltage of the transformer = 6 Volts

The input current from the battery

I = 5/6

= 0.833A

The operation time of the battery

T= 4.5/0.833

= 5.4 Hours

This is the theoretical operation time of the battery, although in practice it is roughly 4 hours.

RECTIFICATION:

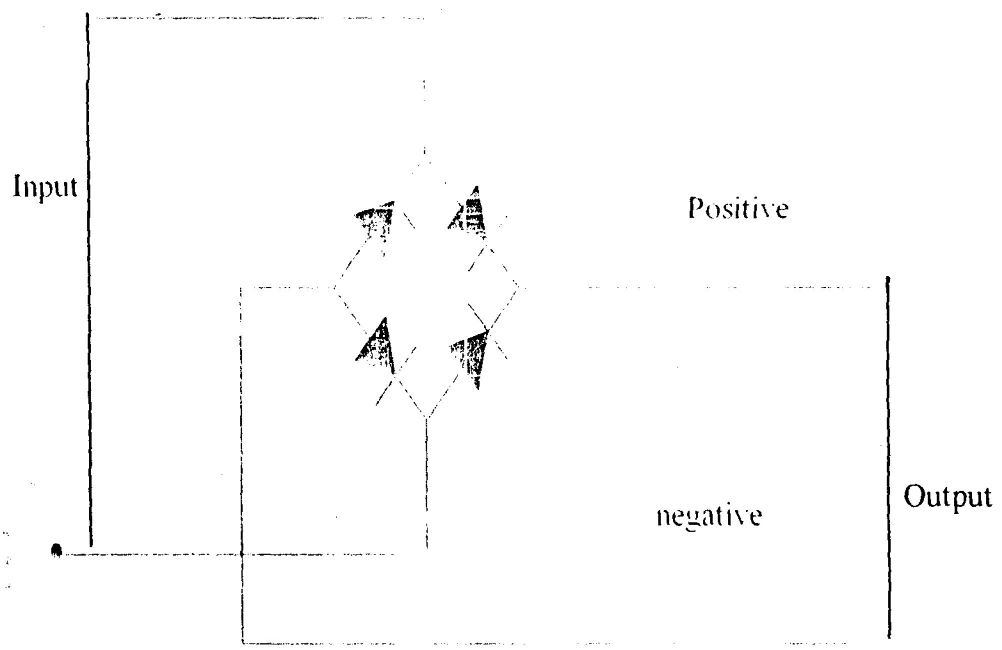


Fig 3.4 Rectifier

Fig 3.4 is a full wave bridge rectifier; this circuit is used in changing an alternating voltage to a pulsating dc voltage by eliminating the negative half cycle of the alternating voltage

From Fig 3.4

The threshold frequency of each diode = 0.7volt peak primary voltage = 220 x √3

= 381 Volt

Peak secondary Voltage

= 381 – 1

25

= 15.2

Peak full wave rectified voltage at the filter input

Vip = 15.2 – 2 x 0.7

= 13.8V

The load ripple voltage

$$\gamma = \frac{1}{4\sqrt{3}FCRL} \quad \ldots\ldots\ldots\ldots \text{ eq (3)}$$

$$= \frac{1000000}{4 \times \sqrt{3} \times 50 \times 47 \times [4.44 + 15000]}$$

= 0.004

DC voltage output for the filter bridge rectifier

$$Vdc = \frac{Vip}{1 - \gamma}$$

$$= \frac{13.8}{1 - 0.004}$$

= 13.85V

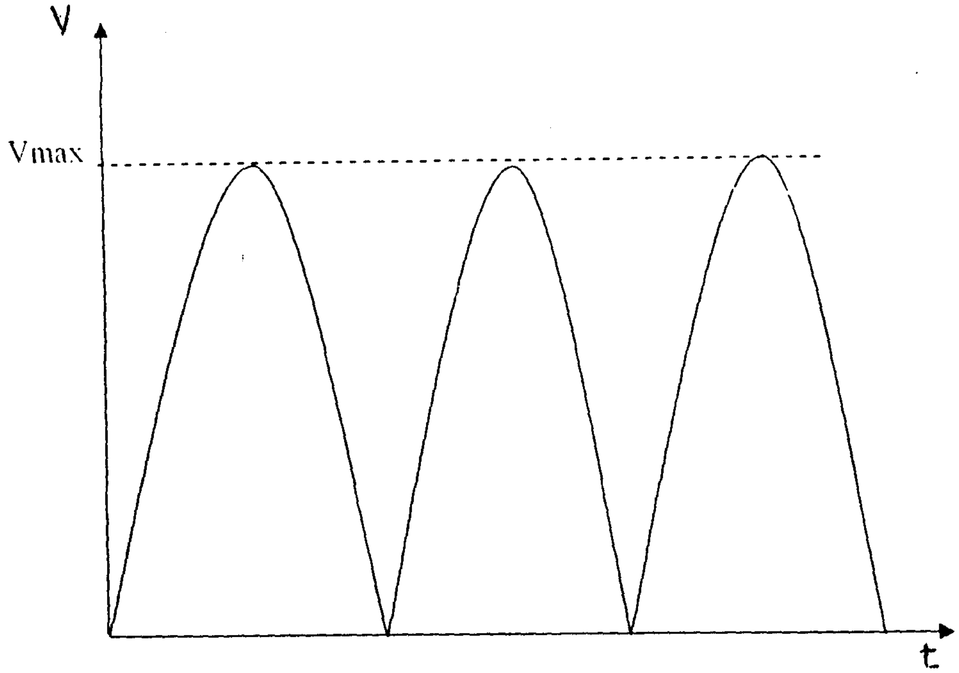


Fig 3.5 The desired rectified output

Filtering:

The main function of a filter is to minimize the ripple content of the bridge rectifier output. At the output of the rectifier, the voltage is unidirectional, that is either positive or negative with respect to earth. Depending on which way the diodes are connected, but it's by no means constant. It contains high ripple content at 50Hz for half wave or 100Hz for full wave and harmonics of these frequencies, the ripple can be largely filtered out, leaving a substantially smooth dc voltage.

We have two basic types of filters:

1. Capacitor Filter
2. Choke Filter

But for the purpose of this project we shall only discuss capacitor filter.

Capacitor Filter (Shunt)

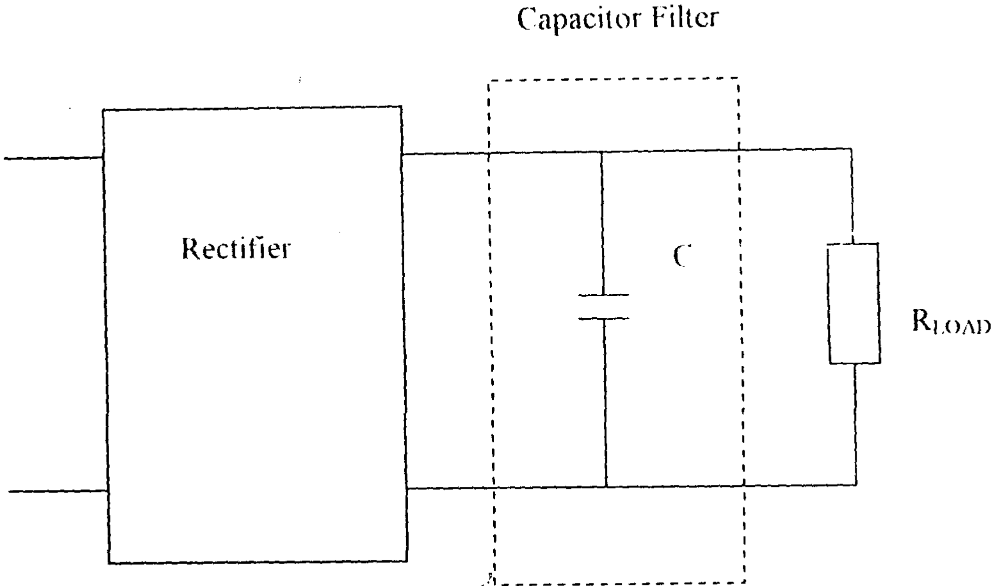


Fig 3.6 Shunt capacitor

One prominent property of a capacitor is that "it resist change of voltage across it" and hence provides the desired smoothing action. The smoothing capacitor is charged from the rectified voltage.

When the diode is reversed biased, the capacitor discharges into the load. The input and output waveform of the filter circuit is shown as follows.

The electrolytic capacitor depends on its operation; the property of the device is to charge-up during the conducting half cycle and discharges during the non conducting half cycle.

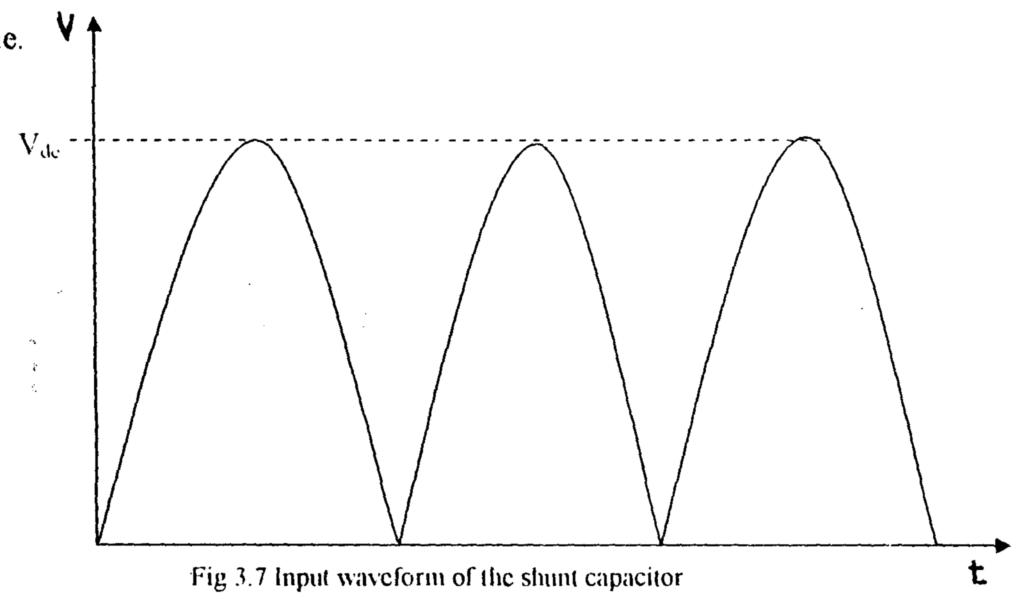


Fig 3.7 Input waveform of the shunt capacitor

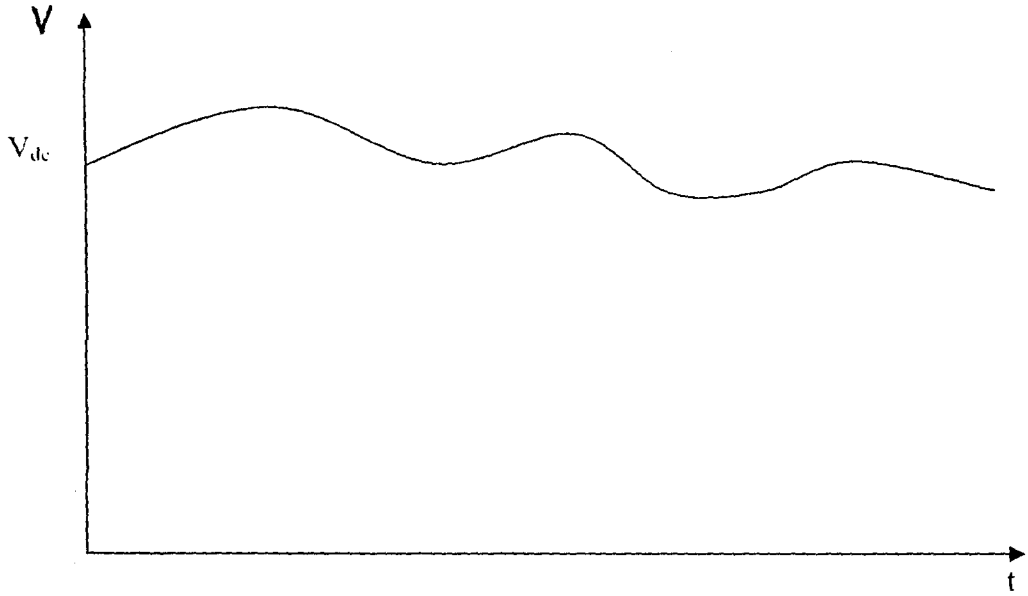


Fig 3.8 Output Waveform at the Shunt Capacitor

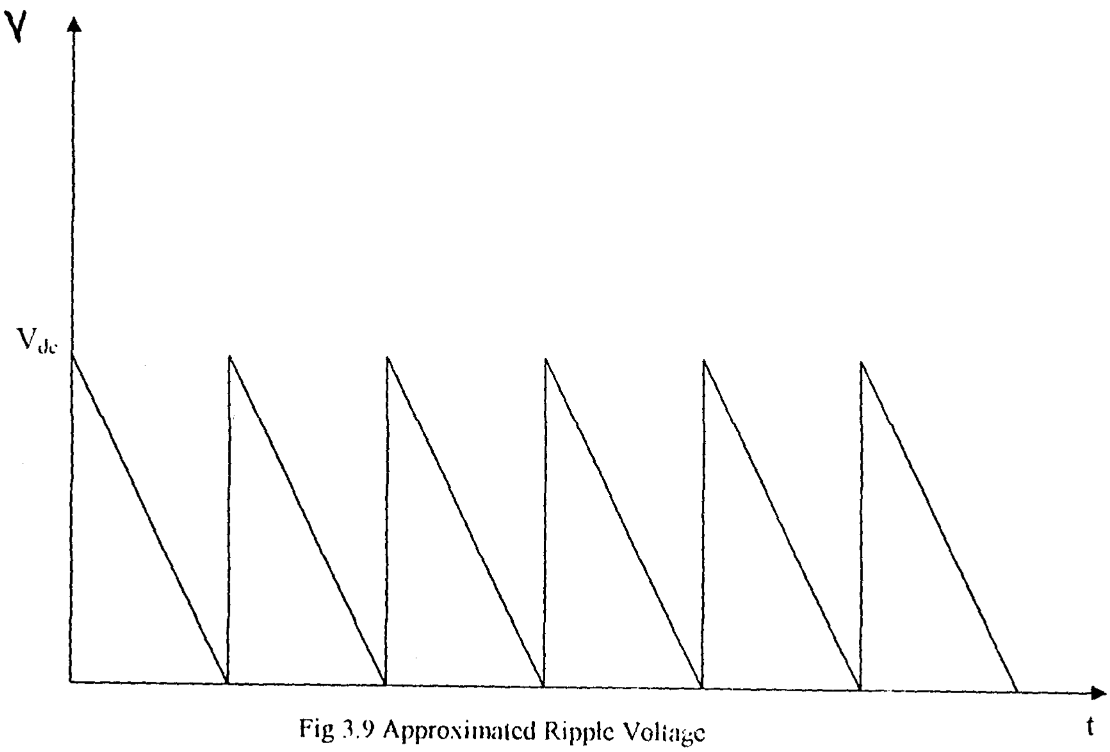


Fig 3.9 Approximated Ripple Voltage

Fig 3.9 indicates approximated ripple voltage by a triangular waveform that has a peak-to-peak ripple voltage, V_r (P-P), and a period T.

3.1 OSCILLATOR

An electronic oscillator may be defined as an electronic source of alternating current or voltage having sine, square or saw-tooth or pulse shape.

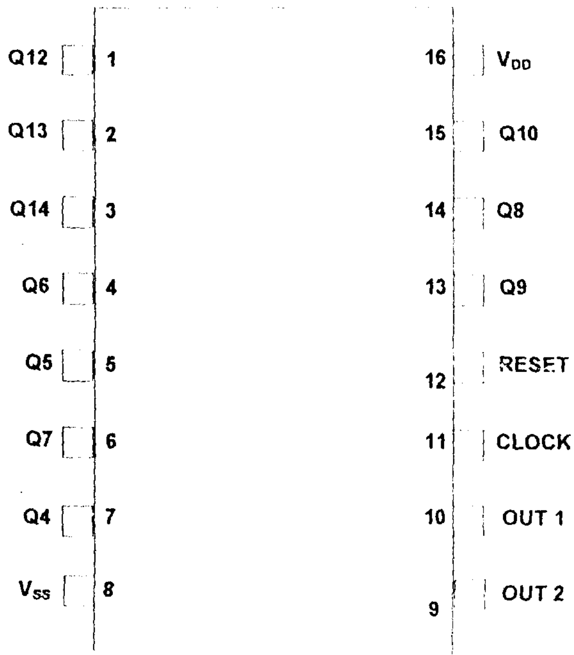


Fig. 3.10 4060 IC

However as it related to this project the 4060B IC indicated in Fig 3.10 is necessary to produce the require oscillation.

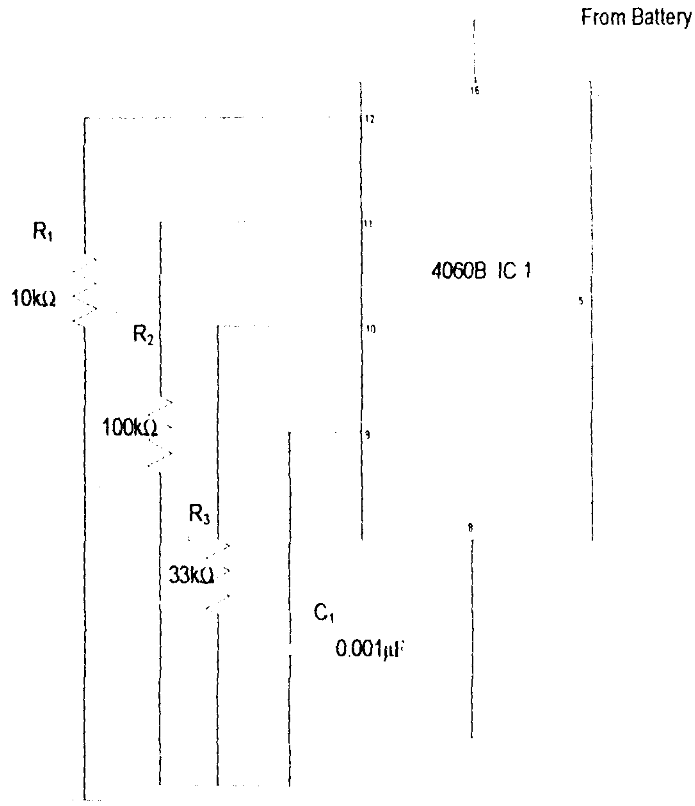


Fig 3.11Oscillator

From fig 3.11 to obtain the frequency of oscillation, the formula indicated below is fundamental after several experiments.

$$F = 1/2.3R_TC_1 \qquad \text{eq (4)}$$

where

F = Frequency of oscillation

R_T =Total Resistance

C_1 = Capacitor

R_T = 100K + 33K

C_1 = 0.001μF

F = 1/ 2.3 (133K) x 0.001μF

= 1000000/ (2.3 x 133K)

= 3,269Hz

Hence the output frequency

$F_{q6} = F/2^6$

$= 3,269/64$

$=51Hz$

The 4060B IC is then able to produce the desired AC output frequency, which is used in energizing a step-up transformer in the inverter unit.

3.2 Inverter Unit

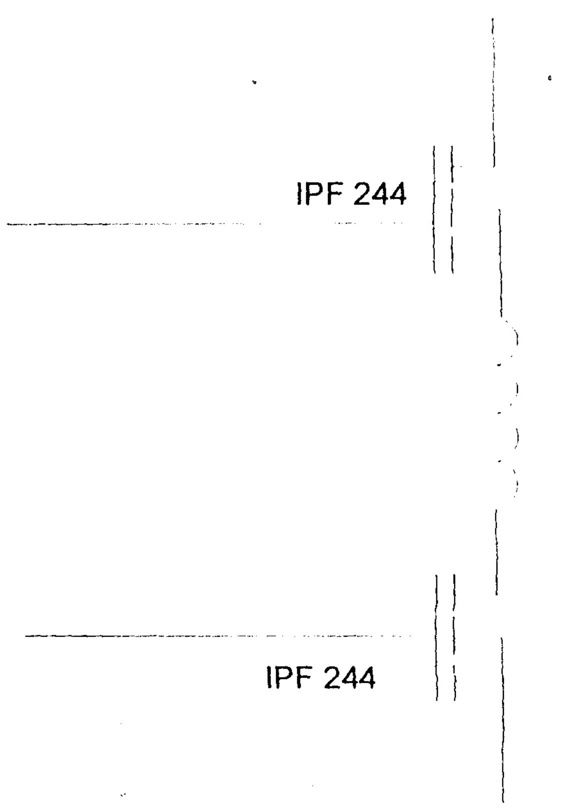


Fig. 3.12 Inverter

The two high current MOSFET devices are connected to the primary end of the transformer; the voltage from the oscillator is then energized, before a step-up is achieved at the secondary end of the transformer.

From Fig 3.12

$I_D = K[V_{GS} - V_{GS}(_{Th})]^2$ .... Eq (5)

where I_D = Drain current

K = constant, depending on MOSFET

$V_{GS} = V_{DS}$ = Gate-source voltage

$V_{GS}(_{Th})$ = Threshold gate-source voltage

Given

I_D = 0.833 Amp

V_{GS} = 6 volt

$V_{GS}(_{Th})$ = 3 volt

MOSFET constant

$$K = \frac{0.833}{(6-3)^2}$$

$= 0.093\ A/V^2$

Differentiating equation (5) with respect to VGS, gives

$$\frac{dI_D}{dV_{GS}} = gm = 2K\,[V_{GS} - V_{GS}(_{Th})] \quad \text{..........} \quad \text{eq (6)}$$

From equation (6)

The voltage gain

Gm = 2 (0.093) (6v – 3v)

= 2(0.093) (3v)

= 0.186 x 3v

= 0.558S

3.3 OUTPUT CONTROL

The output control is achieved in two ways, one way is through a switch which is in two states .The on-state, is to put on the bulb while, the off-state, is to put off the bulb. The Second is the solid state Bipolar junction transistor switch, a BJT can also be used to turn ON and OFF the bulb, the output signal from the oscillator is enough to provide the base drive to switch the transistor ON and OFF and hence providing a switch for the load, this could be achieved by making the transistor operate in two modes, with one mode being in the active region, and the other in saturation region (Short Circuit).

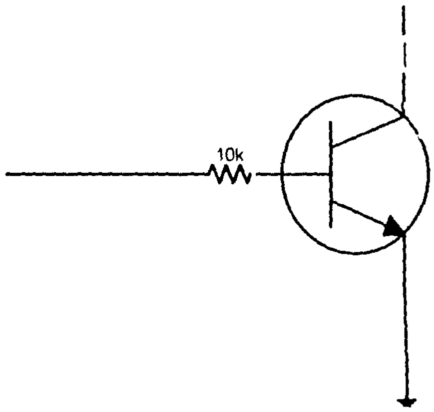


Fig. 3.13 Transistor (NPN)

= Forward Current transfer ration between Ic and IB

A = Forward Current transfer ratio between Ic and IE

Given $\alpha = 0.98$

$$B = \frac{0.98}{1 - 0.98}$$

= 49

$B = Ic/I_B$ ……………………eq (7)

Battery collector current

I_{CB} = 49 x 0.6mAmp

= 0.0294 Amp

Mains collector current

Icm = 49 x 0.9mAmp

= 0.0441Amp

$V_{CC} = I_C R_C + V_{CE} + I_E R_E$ .... eq (8)

Where $V_{CE} = 0$, at saturation

$I_E R_E = 0$
$V_{CC} = I_C R_C$

For Battery

$R_{CB} = 6 / 0.0294$

$= 204.1$

For mains

$$R_{CM} = \frac{9}{0.0441}$$

$=204.1$

$0 < RC < 204.1\Omega$ is the range within which the transistor will remain in active region, if the two sources were allowed to operate at the same time then the transmitters will go into saturation and the load will be cut off then charging will commence.

CHAPTER FOUR

CONSTRUCTION, TESTING AND DISCUSSION OF RESULT

4.1 CIRCUIT CONSTRUCTION

Before construction, the manufacturer's data sheet of the involving components was studied to know the proper pin configuration of 4060B IC and the polarity of other components. The construction could be divided into three stages, with the first stage being the arrangement of the components on the bread board according to their circuit diagram. While this lasted, attention was given to sensitive components like diodes, transistors, and MOSFETs

The second stage involves the transferring of the component from the breadboard directly to the Vero board according to the way they were arranged with reference to the block diagram in units. The third stage was the soldering. Soldering was performed with due regard to safety. It was carried out using a low voltage soldering iron, after having ensured that the soldering iron was well cleansed. In soldering, the soldering iron was ensure to be well placed on the portion where the joining was to take place and the soldering lead was brought to the iron to make a proper joining.

4.2 CASING CONSTRUCTION

The casing could also be divided into three stages, the first is, measurement. The casing was made from acrylic (Perspex) material which was measured with proper allowance for adequate maintenance and the cutting follows immediately into different bits.

The second stage is the joining together by an adhesive of a low heat, which allows proper setting and steady drying. Subsequently the casing was well ventilated to allow proper air exchange with the surrounding in terms of proper maintainability culture.

The last stage is the fixing of the various modules of the whole circuit by the help of a screw driver.

4.3 TESTING

After the work was well cased, routine test was carried out on the project by connecting the input plug to the mains ac supply. It was allowed to charge for some twelve (12) hours after which the 5 watt bulb was fixed at the output unit and the lamp lit by the help of the switch. However the testing reveals that the lamp could not be used when charging

4.4 DISCUSSION OF RESULT

The result was overwhelming due to the fact that the lamp lasted for about four hours after which the light started blinking and it was then switched off.

4.5 PROBLEMS ASSOCIATED WITH THE CONSTRUCTION

i. Wrong choice of frequency configuration
ii. Few inferior components
iii. Shocks from a bad soldering iron
iv. Inadequate information about the components
v. Bridge soldering which led to burning of some components

4.6 PRECAUTION DURING CONSTRUCTION

i. The circuit diagram was strictly adhered to while constructing
ii. Proper soldering was ensured
iii. Maintainability was duly observed during construction
iv. The voltage coming from the power supply was measured to be exactly expected voltage stored by the battery.
v. Continuity was used in detection of error.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

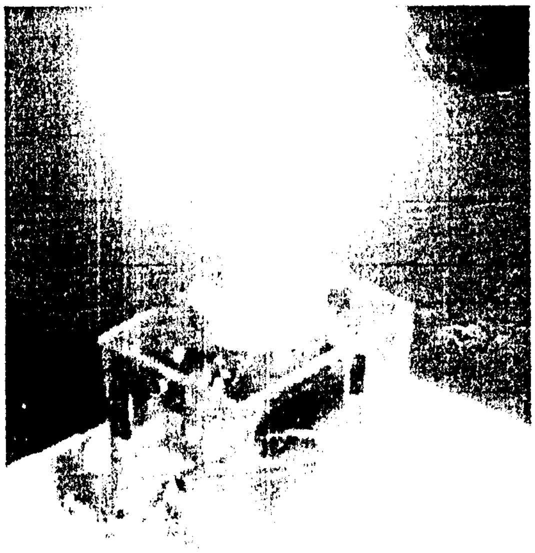
5.1 CONCLUSION

The aim and objective of constructing a simplified circuit for a rechargeable lamp was well achieved, and as cheaply as possible. However, it was difficult to charge the battery continuously for twelve hours because of the erratic nature of the main power supply but a standby generator was used as a substitute and the circuit was tested with a 5Watt compact tube and lasted for about four hours.

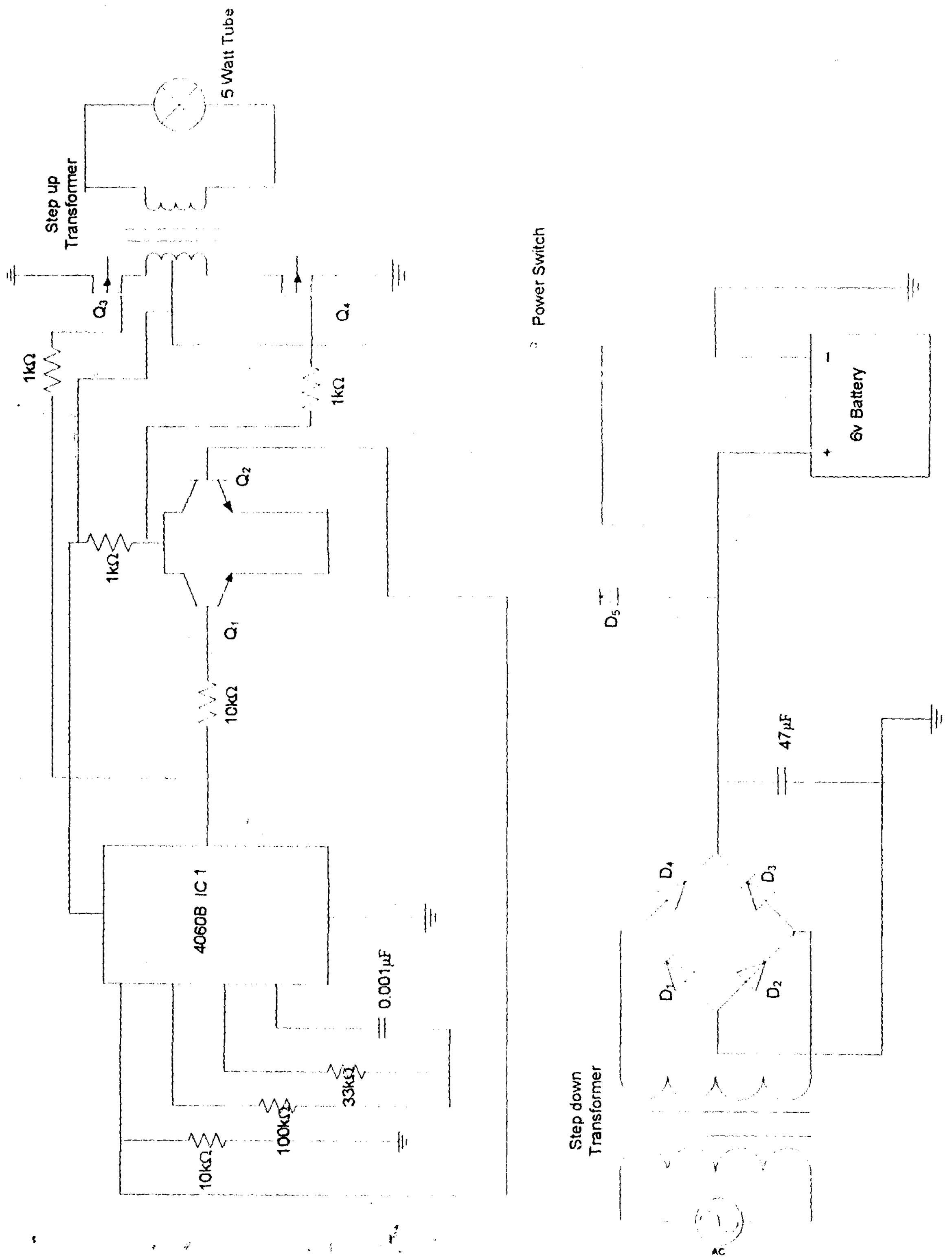
5.2 RECOMMENDATION

1. The circuit could be made simpler and cheaper if a lesser power bulb is to be used.
2. A much longer operation time could be achieved with further research.
3. The circuit could be integrated to lit a much higher power bulb
4. A full automatic overcharged and undercharged indicator could be added to the circuit
5. A sensor could be added to the circuit to serve as an automatic switch.
6. Auxiliary power storage like a rechargeable battery could be used in household appliances
7. The circuit could be further integrated to serve as a power bank for commercial uses.

List of figures



Construction work



The circuit diagram

BILL OF ENGINEERING MATERIAL AND EVALUATION

S/N	DESCRIPTION	QUANTITY	RATE	AMOUNT
1	4060B IC	1	210	120
2	Step-down Transformer	1	120	120
3	Diode [IN4001]	5	5	25
4	Capacitor [47µF 16V]	1	40	40
5	6 Volt Battery	1	450	450
6	Transistor Common emitter			
	2SC945	2	10	20
7	Switch	1	30	30
8	Step-up transformer	1	150	150
9	N Channel, EMOSFET 1RF 244	2	150	300
10	5 Watt Tube	1	100	100
11	Resistor 33KΩ	1	10	10
12	Resistor 10KΩ	3	10	30
13	Resistor 100KΩ	1	10	10
14	Resistor 1KΩ	3	10	10
15	Acrylic	12	450	450
16	Screw	1	2	24
17	LED	1	10	10
18	Lamp Holder	1	50	50
19	Wires	1	20	20
20	Plug	1	30	30
21	Soldering Lead	1	20	20
22	IC Socket	1	20	20
	TOTAL			₦2,039

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